American Journal of
Preventive Medicine

RESEARCH ARTICLE

Cannabis Vaping, Smoking, and Dual Use and the Onset of Respiratory Symptoms Among U.S. Young Adults

Ruoyan Sun, PhD,[1] Neal L. Benowitz, MD,[2] David Hammond, PhD,[3] David Mendez, PhD,[4] Kenneth E. Warner, PhD[4]

Introduction: Many young adults vape and smoke cannabis, but it remains unclear whether dual use increases the risk of respiratory problems.

Methods: This study analyzed the national longitudinal Population Assessment of Tobacco and Health Study. The sample included 5,211 young adults (aged 18−24 years) without prior respiratory or pulmonary conditions at Wave 6 who completed Wave 7. Multivariable logistic regressions examined longitudinal associations between baseline cannabis vaping and smoking and functionally important respiratory symptoms at follow-up, controlling for sociodemographics, other substance use, health conditions, obesity, and cannabis use frequency. Data were collected between 2021 and 2023 and analyzed in 2025.

Results: At baseline, 18.8% of young adults reported past 30-day cannabis vaping or smoking: 2.1% vaped only, 11.3% smoked only, and 5.3% both vaped and smoked. Overall, 2.3% reported the onset of respiratory symptoms at follow-up. Compared with no cannabis vaping or smoking, cannabis vaping only was not associated with respiratory symptoms (AOR=0.93, 95% CI=0.20, 4.43), whereas cannabis smoking only (AOR=3.04, 95% CI=1.64, 5.64) and dual vaping and smoking (AOR=4.36, 95% CI=2.12, 8.96) were associated with increased odds. Excluding young adults who used tobacco products at baseline, only dual vaping and smoking were associated with increased odds (AOR=4.20, 95% CI=2.03, 8.70).

Conclusions: Young adults who smoke cannabis, particularly those who smoke and vape, have higher odds of developing functionally important respiratory symptoms. However, these findings must be considered preliminary. More detailed data on cannabis use patterns, products, and co-use with tobacco are needed to better understand these associations.

Am J Prev Med 2026;71(4):108421.

INTRODUCTION

Many U.S. states have legalized cannabis (or marijuana) in the past 2 decades. By the end of 2024, 24 states had legalized cannabis for recreational purposes, and 39 states had legalized it for medical purposes.[1,2] This wave of legalization, combined with decreasing perceptions of health risks and increasing social acceptance, has contributed to the popularity and rapid growth in cannabis use, especially among young adults.[3,4] In 2024, among adults aged 19−30 years, 41.4% reported using cannabis in the past 12 months,

From the [1]Department of Health Policy and Organization, School of Public Health, University of Alabama at Birmingham, Birmingham, Alabama; [2]Department of Medicine, University of California San Francisco, San Francisco, California; [3]School of Public Health Sciences, University of Waterloo, Waterloo, Canada; and [4]Department of Health Management and Policy, School of Public Health, University of Michigan, Ann Arbor, Michigan

Address correspondence to: Ruoyan Sun, PhD, Department of Health Policy and Organization, School of Public Health, University of Alabama at Birmingham, 310C Ryals Public Health Building, 1665 University Boulevard, Birmingham AL 35294. E-mail: rysun@uab.edu.

0749-3797/$36.00
https://doi.org/10.1016/j.amepre.2026.108421

29.0% reported using it in the past month, and 10.8% reported using it daily. These rates were 30.3%, 18.5%, and 7.1%, respectively, 10 years earlier in 2014.[5]

Although smoking is still the most popular administration route for cannabis, the prevalence of cannabis vaping has grown.[6,7] Vaping involves inhaling aerosolized liquid from an electronic heating device to deliver substances such as cannabis. Vaped cannabis products usually contain delta 9-tetrahydrocannabinol (THC) and/or cannabidiol. Lifetime cannabis vaping prevalence increased from 14.4% in 2017 to 34.6% in 2020 among young adults.[8] Similar increases were seen in past 30-day cannabis vaping, from 4.9% in 2017 to 11.2% in 2022 among college students.[9] Although vaping cannabis avoids combustion, the primary source of harmful byproducts in traditional smoking, vaping presents its own set of hazards.[10] For example, cannabis oil typically contains substantially higher concentrations of THC than cannabis flower, thus producing higher concentrations of THC in blood and greater pharmacodynamic effects than smoked cannabis.[11,12] Vaping cannabis oil containing THC and terpenes can also generate toxic emissions with adverse respiratory effects, although in lesser amounts than smoking cannabis.[13]

There is some evidence that cannabis vaping and smoking, especially chronic use, are independently associated with respiratory symptoms and pulmonary conditions.[14] Cannabis smoking may cause chronic bronchitis and lead to chronic cough, phlegm production, wheeze, and acute bronchitis[15–17]; there is insufficient evidence to link cannabis smoking to lung cancer.[18] Cannabis vaping has been associated with increased odds of bronchitis symptoms and wheeze.[19,20] A cross-sectional study examining U.S. young adults reported increased risks of respiratory symptoms associated with vaping cannabis exclusively and with vaping both nicotine and cannabis.[20] Mixing cannabis concentrates with other additives could substantially increase the risk of lung injury. For example, vitamin E acetate, an additive found in some cannabis vapes, was strongly linked to the 2019 E-cigarette or vaping product use-associated lung injury outbreak.[21]

It is not clear whether dual cannabis vaping and smoking is associated with increased respiratory risks compared with vaping or smoking alone. This question is critical given the high prevalence of dual cannabis use. Among adults who reported current cannabis use with multiple routes, more than half (54.5%) vaped and smoked cannabis in 2022.[7] However, there are some challenges in identifying the effects of dual cannabis use on respiratory outcomes. First, this relationship is highly confounded by tobacco use, principally cigarette smoking and E-cigarette use. It is estimated that a third to a half of young adults who use tobacco also consume cannabis products.[22–24] Another challenge is the lack of national surveys that ask about cannabis administration routes. Although some surveys have included questions on general cannabis use, few have distinguished between cannabis vaping, smoking, or other routes, such as oral ingestion. Finally, to examine the temporal relationship between cannabis use and respiratory symptoms, longitudinal data rather than cross-sectional data are needed.

This study examined the longitudinal association between cannabis use and the development of respiratory symptoms in a national cohort of young adults. Young adults were examined because cannabis use is common in this age group, and cigarette smoking is less prevalent, whereas the opposite pattern in older adults could increase confounding when assessing cannabis-related respiratory symptoms. Cannabis use was categorized as vaping only, smoking only, and dual vaping and smoking. To control for a potential dose–response relationship between cannabis use and respiratory symptoms, the analysis adjusted for frequent cannabis use. In addition, both current and past use of various tobacco products were considered.

METHODS

Study Sample

The Population Assessment of Tobacco and Health (PATH) Study is a national longitudinal study of U.S. youth and adults. Since the first wave in 2013, annual or biennial follow-up surveys have been conducted. This study used the 2 most recent waves of the PATH Study: Wave 6 (March 2021–November 2021) and Wave 7 (January 2022–April 2023). Questions about past 30-day cannabis administration routes were first introduced in the Wave 6 survey.

The sample consisted of 5,211 young adults aged 18–24 years at PATH Study Wave 6 who participated in the Wave 7 survey; had never been diagnosed with chronic pulmonary disease, chronic bronchitis, emphysema, asthma, or some other lung or respiratory symptoms by Wave 6; and had a zero respiratory index score at Wave 6. Appendix Figure 1 (available online) shows the sample flow diagram. Details of the respiratory index score can be found in the following section and in Appendix Table 1 (available online). The University of Alabama at Birmingham IRB exempted this study from review because it used deidentified data.

Measures

The main independent variable of this study is cannabis vaping and smoking. On the basis of participants' answers to the question, *In the past 30 days, which of the*

following ways did you use marijuana?, 4 mutually exclusive categories were created: no vaping or smoking, vaping only, smoking only, and dual vaping and smoking. Note that respondents who did not vape or smoke cannabis could have consumed cannabis in other ways, such as oral ingestion or topical use.

The outcome variable is a respiratory symptoms index score (range 0−9) at Wave 7. This index score was modified for adult use from the International Study of Asthma and Allergies of Childhood and has been validated using PATH Study data.[25] Seven questions were asked: (1) *Have you ever had wheezing or whistling in the chest at any time in the past?*; (2) *Have you ever had wheezing or whistling in the chest at any time in the past 12 months?*; (3) *How many attacks of wheezing have you had in the past 12 months?*; (4) *In the past 12 months, how often, on average has your sleep been disturbed due to wheezing?*; (5) *In the past 12 months, has wheezing ever been severe enough to limit your speech to only one or two words between breaths?*; (6) *In the past 12 months, has your chest sounded wheezy during or after exercise?*; and (7) *In the past 12 months, have you had a dry cough at night?* Participants' responses to these questions were used to construct the index score, where a score of 0 represents no respiratory symptoms, and 9 represents the highest level of symptoms. Appendix Table 1 (available online) contains the details of the survey questions and the respiratory symptoms index. On the basis of recommendations,[25] a cut off of 3 was applied to create a binary measure (<3 vs ≥ 3) for functionally important respiratory symptoms.

Several covariates at Wave 6 were included to adjust for sociodemographic characteristics, other substance use, health conditions, obesity, and frequent cannabis use. Sociodemographic characteristics included sex at birth (female versus male), race and ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic other [i.e., American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander], and Hispanic of any race), and highest parental educational attainment (lower than high-school graduate, high-school graduate or GED, some college or associate's degree, and bachelor's or advanced degree). Past 30-day use of other substances was assessed by measures of combustible tobacco smoking (cigarettes, cigars, pipe, and hookah), E-cigarette use (or nicotine vaping), alcohol use, and other drug use (Ritalin or Adderall, painkillers, sedatives or tranquilizers, cocaine or crack, stimulants such as methamphetamine or speed, heroin, inhalants or solvents, and hallucinogens). Health conditions were measured by lifetime diagnosis of any heart condition (congestive heart failure, stroke, heart attack, and other heart conditions) and lifetime diagnosis of other chronic conditions (high blood pressure, high cholesterol, diabetes, and cancer). Obesity was assessed by BMI ≥ 30 kg/m^2. Finally, frequent cannabis use, defined as ≥ 20 days of use in the past 30 days, was included. The survey does not distinguish use frequency by administration route.

Statistical Analysis

Because missing data were minimal (<2%), multivariable logistic regressions using complete-case analysis were performed to examine the longitudinal association between cannabis vaping and smoking and functionally important respiratory symptoms, controlling for the covariates identified earlier. A separate regression analysis was also conducted among young adults who did not use past 30-day combustible tobacco products or E-cigarettes at Wave 6 to more accurately identify the effect of cannabis vaping and/or smoking on respiratory symptoms. The findings were reported as AORs. Given the complex sample designs of the PATH Study, survey weights were incorporated to compensate for attrition, variable probabilities of selection, differential nonresponse rates, and possible deficiencies in the sampling frame. Fay's method of balanced repeated replication was used to estimate variance. Two-sided $p<0.05$ was considered statistically significant.

Two sensitivity analyses were conducted: (1) using an alternative cut off of 2 for the functionally important respiratory symptom measure and (2) including combustible tobacco product and E-cigarette use history as additional control variables. The history of use of combustibles (binary) was assessed by the respondent's having smoked 100 cigarettes or more or having ever used a cigar, pipe, or hookah fairly regularly. Similarly, E-cigarette use history (binary) was assessed by the respondent's having ever used any electronic nicotine product fairly regularly.

RESULTS

Among young adults at Wave 6, 18.8% vaped or smoked cannabis in the past 30 days, including 2.1% who vaped only, 11.3% who smoked only, and 5.3% who both vaped and smoked cannabis. Descriptive statistics are shown in Table 1. A total of 49.7% were female, 51.7% were non-Hispanic White, and 47.6% had at least 1 parent with a bachelor's or advanced degree. In the past 30 days, 12.9% smoked tobacco, 15.9% used nicotine E-cigarettes, 43.1% consumed alcohol, and 2.3% used other drugs. Health conditions were uncommon, with 6.9% reporting any heart condition and 9.9% reporting any chronic condition. These characteristics varied across cannabis use

Table 1. Sample Characteristics by Cannabis Use Status, the Population Assessment of Tobacco and Heath Study Wave 6 (N=5,211)

Characteristics	Overall Weighted % (95% CI)	Cannabis use status Weighted % (95% CI)				
	N=5,211	No vaping or smoking *n*=4,241 (81.2%)	Vaping only *n*=113 (2.1%)	Smoking only *n*=573 (11.3%)	Dual vaping and smoking *n*=284 (5.3%)	*p*-value[a]
Sex						0.043
Female	49.7 (48.0, 51.5)	50.4 (48.6, 52.3)	49.5 (39.2, 60.1)	49.1 (44.6, 53.7)	40.7 (34.0, 47.5)	
Male	50.3 (48.5, 52.0)	49.6 (47.8, 51.4)	50.5 (39.9, 61.0)	50.9 (46.3, 55.5)	59.4 (52.5, 66.1)	
Race/ethnicity						<0.001
NHW	51.7 (47.9, 55.5)	51.3 (47.4, 55.3)	56.6 (45.1, 67.4)	50.3 (44.7, 55.8)	57.9 (51.1, 64.5)	
NHB	13.4 (11.4, 15.6)	13.4 (11.3, 15.8)	6.4 (2.7, 14.6)	18.9 (15.0, 23.6)	3.7 (1.8, 7.5)	
Hispanic	25.0 (21.8, 28.4)	25.2 (21.8, 28.9)	27.1 (18.8, 37.3)	23.6 (19.4, 28.4)	23.6 (18.4, 29.7)	
NHO[b]	10.0 (8.6, 11.6)	10.1 (8.6, 11.8)	9.9 (4.8, 19.6)	7.2 (5.0, 10.3)	14.8 (10.2, 21.0)	
Parental education						<0.001
Lower than high school	10.9 (9.6, 12.3)	11.6 (10.2, 13.2)	7.8 (4.4, 13.4)	8.4 (6.1, 11.5)	6.7 (4.3, 10.3)	
High school or GED	21.0 (19.2, 22.9)	21.2 (19.3, 23.3)	14.4 (8.8, 22.8)	22.8 (19.0, 27.0)	16.5 (11.7, 22.7)	
Some college or associates	20.5 (19.1, 22.0)	19.8 (18.3, 21.3)	25.1 (18.4, 33.2)	23.4 (19.4, 27.8)	23.5 (18.0, 30.0)	
Bachelor's or advanced degree	47.6 (44.9, 50.3)	47.4 (44.6, 50.2)	52.7 (42.6, 62.6)	45.5 (40.8, 50.2)	53.3 (46.4, 60.1)	
Past 30-day combustible tobacco use[c]						<0.001
Yes	12.9 (11.7, 14.2)	8.6 (7.6, 9.9)	13.5 (8.0, 21.8)	31.8 (26.7, 37.3)	37.3 (31.4, 43.6)	
No	87.1 (85.8, 88.3)	91.4 (90.1, 92.4)	86.5 (78.2, 92.0)	68.2 (62.7, 73.3)	62.7 (56.4, 68.6)	
Past 30-day E-cigarette use						<0.001
Yes	15.9 (14.6, 17.3)	10.5 (9.3, 11.8)	33.0 (23.7, 44.0)	34.9 (30.2, 39.8)	51.4 (44.3, 58.4)	
No	84.1 (82.7, 85.4)	89.5 (88.2, 90.7)	67.0 (56.1, 76.3)	65.2 (60.2, 69.8)	48.6 (41.6, 55.7)	
Past 30-day alcohol use						<0.001
Yes	43.1 (40.6, 45.6)	36.6 (34.0, 39.3)	75.5 (65.6, 83.2)	65.2 (60.8, 69.3)	81.9 (77.2, 85.8)	
No	56.9 (54.4, 59.4)	63.4 (60.8, 66.0)	24.6 (16.8, 34.4)	34.8 (30.8, 39.2)	18.1 (14.2, 22.8)	
Past 30-day drug used[d]						<0.001
Yes	2.3 (1.8, 2.9)	0.9 (0.6, 1.3)	4.1 (1.3, 11.8)	5.9 (3.9, 8.7)	15.4 (11.3, 20.7)	
No	97.7 (97.1, 98.2)	99.1 (98.7, 99.4)	95.9 (88.2, 98.7)	94.2 (91.3, 96.1)	84.6 (79.3, 88.7)	
Any heart condition[e]						0.160
Yes	6.9 (6.0, 7.8)	6.4 (5.5, 7.6)	5.9 (2.1, 15.1)	9.6 (7.0, 13.0)	7.9 (4.8, 12.9)	
No	93.1 (92.2, 94.0)	93.6 (92.5, 94.5)	94.2 (84.9, 97.9)	90.4 (87.0, 93.0)	92.1 (87.2, 95.3)	
Other chronic condition[f]						0.112
Yes	9.9 (8.9, 11.0)	9.7 (8.6, 10.9)	15.9 (9.4, 25.7)	9.1 (6.7, 12.1)	12.5 (9.0, 17.2)	
No	90.1 (89.0, 91.1)	90.4 (89.1, 91.4)	84.1 (74.3, 90.6)	91.0 (87.9, 93.3)	87.5 (82.8, 91.0)	
Obesity[g]						0.267
Yes	21.8 (20.3, 23.4)	22.3 (20.6, 24.1)	21.0 (13.9, 30.4)	20.4 (17.1, 24.1)	17.4 (13.2, 22.6)	
No	78.2 (76.7, 79.7)	77.7 (75.9, 79.4)	79.0 (69.6, 86.1)	79.6 (75.9, 82.9)	82.6 (77.4, 86.8)	
Frequent cannabis use[h]						<0.001
Yes	7.0 (6.3, 7.9)	0	16.6 (10.4, 25.3)	34.4 (30.2, 38.8)	52.1 (45.8, 58.3)	
No	93.0 (92.2, 93.7)	1	83.4 (74.7, 89.6)	65.7 (61.2, 69.9)	47.9 (41.7, 54.2)	

[a]Pearson chi-square test of independence was performed to assess the association between cannabis use status and sample characteristics.
[b]NHO includes American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander.
[c]Combustible tobacco includes cigarettes, cigars, pipe, and hookah.
[d]Drug use includes Ritalin or Adderall, painkillers, sedatives or tranquilizers, cocaine or crack, stimulants such as methamphetamine or speed, heroin, inhalants or solvents, and hallucinogens.
[e]Assessed by lifetime diagnosis of congestive heart failure, stroke, heart attack, and other heart conditions.
[f]Assessed by lifetime diagnosis of high blood pressure, high cholesterol, diabetes, and cancer.
[g]Obesity is defined as BMI ≥30 kg/m^2.
[h]Frequent cannabis use is defined as cannabis use on ≥20 days in the past 30 days.
NHB, non-Hispanic Black; NHO, non-Hispanic other; NHW, non-Hispanic White.

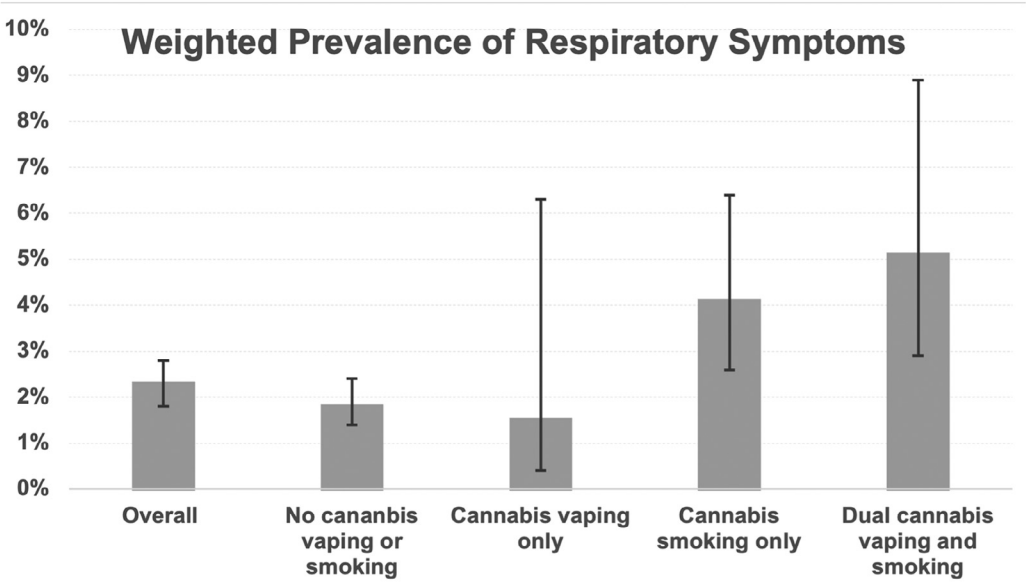

Figure 1. Weighted prevalence of functionally important respiratory symptoms at follow-up by baseline cannabis vaping and smoking status (N=5,211).

Note: Cannabis vaping and smoking status were determined by participants' self-reported cannabis use in the past 30 days at Wave 6 of the Population Assessment of Tobacco and Health Study.

groups. Young adults who both smoked and vaped cannabis were more likely to be male; to be non-Hispanic White; to have higher parental educational attainment; and to report tobacco use, E-cigarette use, alcohol consumption, and other drug use than others. They also had the highest prevalence of frequent cannabis use, at 52.1%, significantly higher than the 16.6% among those who only vaped cannabis and the 34.4% among those who only smoked cannabis. Notably, about one third of the participants who smoked cannabis also smoked tobacco.

Figure 1 illustrates the weighted prevalence of functionally important respiratory symptoms. Overall, 1.8% (95% CI=1.4%, 2.4%) of young adults who did not vape or smoke cannabis at Wave 6 reported respiratory symptoms at Wave 7. Compared with this group, the prevalence was similar among those who vaped cannabis only (1.5%, 95% CI=0.4%, 6.3%) but was significantly higher for those who smoked cannabis only (4.1%, 95% CI=2.6%, 6.4%) and those who both vaped and smoked cannabis (5.1%, 95% CI=2.9%, 8.9%).

The association of baseline cannabis vaping and smoking with the subsequent onset of functionally important respiratory symptoms is shown in Table 2. Compared with no cannabis vaping or smoking, cannabis vaping only had a nonsignificant difference (AOR=0.93, 95% CI=0.20, 4.43). However, cannabis smoking only and dual vaping and smoking showed significantly increased odds of respiratory symptoms, with AORs of 3.04 (95% CI=1.64, 5.64) and 4.36 (95% CI=2.12, 8.96), respectively. All other covariates were nonsignificant, except for past 30-day alcohol use (AOR=0.57, 95% CI=0.34, 0.96).

In addition to the overall sample, the association among young adults who did not use combustible tobacco products or E-cigarettes at baseline was also examined (Table 3). Similar to the results in Table 2, compared with no cannabis vaping or smoking, dual use was associated with increased odds (AOR=4.20, 95% CI=2.03, 8.70). Cannabis vaping only (AOR=1.15, 95% CI=0.23, 5.79) and cannabis smoking only (AOR=2.09, 95% CI=0.82, 5.29) were not associated with respiratory symptoms. This nonsignificant association of cannabis smoking may reflect a limited sample size, because the AOR remained substantially greater than 1.

Results of the sensitivity analyses are in Appendix Tables 2–4 (available online). Adopting a cut off of 2 for the respiratory symptoms index, cannabis smoking only and dual use were associated with increased odds of respiratory symptoms in the overall sample (Appendix Table 2, available online) and in the sample of young adults who did not use tobacco or nicotine products at baseline (Appendix Table 3, available online). In Appendix Table 4 (available online), with additional covariates of combustible tobacco and E-cigarette use history, the findings for the overall sample yielded results similar to the main findings. However,

Table 2. Association of Baseline Cannabis Vaping and Smoking With the Subsequent Onset of Functionally Important Respiratory Symptoms (N=5,211)

	Respiratory symptoms	
Variable	**OR (95% CI)**	**AOR (95% CI)**
Cannabis use (no vaping or smoking as reference)		
Vaping only	0.82 (0.18, 3.80)	0.93 (0.20, 4.43)
Smoking only	**2.30 (1.39, 3.81)**	**3.04 (1.64, 5.64)**
Dual vaping and smoking	**2.88 (1.48, 5.58)**	**4.36 (2.12, 8.96)**
Frequent cannabis use[a]	1.84 (0.94, 3.60)	0.79 (0.37, 1.71)
Sex (male as reference)		
Female	1.22 (0.80, 1.89)	1.26 (0.81, 1.96)
Race/ethnicity (NHW as reference)		
NHB	0.74 (0.40, 1.38)	0.60 (0.29, 1.26)
Hispanic	0.78 (0.48, 1.29)	0.62 (0.31, 1.22)
NHO[b]	0.92 (0.38, 2.19)	0.86 (0.36, 2.04)
Parental education (lower than high school as reference)		
High school or GED	1.11 (0.48, 2.54)	0.90 (0.35, 2.31)
Some college or associates	0.94 (0.43, 2.07)	0.69 (0.26, 1.83)
Bachelor's or advanced degree	0.88 (0.39, 1.95)	0.74 (0.26, 2.10)
Past 30-day combustible tobacco use[c]	1.66 (0.93, 2.96)	1.49 (0.73, 3.04)
Past 30-day E-cigarette use	1.35 (0.83, 2.21)	0.96 (0.53, 1.72)
Past 30-day alcohol use	0.74 (0.47, 1.17)	**0.55 (0.33, 0.91)**
Past 30-day drug used[d]	0.60 (0.16, 2.19)	0.21 (0.04, 1.07)
Any heart condition[e]	1.42 (0.66, 3.07)	1.27 (0.63, 2.57)
Other chronic condition[f]	1.31 (0.67, 2.59)	0.96 (0.49, 1.85)
Obesity[g]	1.52 (0.92, 2.52)	1.48 (0.89, 2.45)

Note: Boldface indicates statistical significance ($p<0.05$).
AORs were calculated adjusting for all study covariates.
[a]Frequent cannabis use is defined by cannabis use on ≥20 days in the past 30 days.
[b]NHO includes American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander.
[c]Combustible tobacco includes cigarettes, cigars, pipe, and hookah.
[d]Drug use includes Ritalin or Adderall, painkillers, sedatives or tranquilizers, cocaine or crack, stimulants such as methamphetamine or speed, heroin, inhalants or solvents, and hallucinogens.
[e]Assessed by lifetime diagnosis of congestive heart failure, stroke, heart attack, and other heart conditions.
[f]Assessed by lifetime diagnosis of high blood pressure, high cholesterol, diabetes, and cancer.
[g]Obesity is defined as BMI ≥30 kg/m^2.
NHB, non-Hispanic Black; NHO, non-Hispanic other; NHW, non-Hispanic White.

cannabis use was not associated with respiratory symptoms among young adults who did not use combustible tobacco or E-cigarettes in the past 30 days. This nonsignificant association may reflect a limited sample size, given the magnitude of the AORs.

DISCUSSION

Compared with young adults who did not vape or smoke cannabis, those who only vaped cannabis had similar odds of developing functionally important respiratory symptoms, whereas those who only smoked cannabis or both vaped and smoked cannabis had higher odds. Among young adults who did not use combustible tobacco products or E-cigarettes at baseline, only dual cannabis vaping and smoking was associated with increased odds of respiratory symptom onset. However, the association for cannabis smoking alone warrants further investigation, because the AOR suggested a positive association, despite not reaching statistical significance. Alcohol use was inversely associated with respiratory symptom onset in one adjusted model, but this finding was not consistent across analyses and should be interpreted cautiously.

Dual cannabis vaping and smoking was consistently associated with higher odds of respiratory symptom onset. This pattern may suggest a greater respiratory risk associated with dual use than with vaping or smoking alone. Similar patterns have been reported for tobacco/nicotine products, where those who use both cigarettes and E-cigarettes experience more respiratory symptoms than those who use either product exclusively.[26,27] These findings raise the possibility that exposure to multiple inhaled products

Table 3. Association of Baseline Cannabis Vaping and Smoking With the Subsequent Onset of Functionally Important Respiratory Symptoms Among Young Adults Who Did Not Use Combustible Tobacco Products or E-Cigarettes in the Past 30 Days at Baseline (*n*=4,134)

	Respiratory symptom	
Variable	**OR (95% CI)**	**AOR (95% CI)**
Cannabis use (no vaping or smoking as reference)		
Vaping only	1.09 (0.24, 5.01)	1.15 (0.23, 5.79)
Smoking only	**2.46 (1.18, 5.13)**	2.09 (0.82, 5.29)
Dual vaping and smoking	**4.69 (1.98, 11.09)**	**4.20 (2.03, 8.70)**
Frequent cannabis use[a]	**4.18 (1.76, 9.92)**	2.18 (0.83, 5.76)
Sex (male as reference)		
Female	1.43 (0.86, 2.39)	1.51 (0.89, 2.55)
Race/ethnicity (NHW as reference)		
NHB	1.20 (0.61, 2.38)	1.04 (0.44, 2.45)
Hispanic	0.91 (0.51, 1.60)	0.74 (0.35, 1.58)
NHO[b]	1.46 (0.60, 3.58)	1.50 (0.64, 3.50)
Parental education (lower than high school as reference)		
High school or GED	0.84 (0.33, 2.12)	0.64 (0.23, 1.79)
Some college or associates	1.11 (0.45, 2.73)	0.81 (0.27, 2.40)
Bachelor's or advanced degree	0.93 (0.39, 2.21)	0.80 (0.25, 2.54)
Past 30-day alcohol use	0.89 (0.51, 1.54)	0.78 (0.44, 1.38)
Past 30-day drug used[c]	0.98 (0.20, 4.84)	0.14 (0.02, 1.31)
Any heart condition[d]	1.61 (0.68, 3.79)	1.38 (0.57, 3.34)
Other chronic condition[e]	1.59 (0.74, 3.39)	1.05 (0.48, 2.29)
Obesity[f]	**1.99 (1.12, 3.53)**	**1.94 (1.10, 3.42)**

Note: Boldface indicates statistical significance ($p<0.05$).
AORs were calculated adjusting for all study covariates.
[a]Frequent cannabis use is defined as cannabis use on ≥20 days in the past 30 days.
[b]NHO includes American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, and other Pacific Islander.
[c]Drug use includes Ritalin or Adderall, painkillers, sedatives or tranquilizers, cocaine or crack, stimulants such as methamphetamine or speed, heroin, inhalants or solvents, and hallucinogens.
[d]Assessed by lifetime diagnosis of congestive heart failure, stroke, heart attack, and other heart conditions.
[e]Assessed by lifetime diagnosis of high blood pressure, high cholesterol, diabetes, and cancer.
[f]Obesity is defined as BMI ≥30 kg/m^2.
NHB, non-Hispanic Black; NHO, non-Hispanic other; NHW, non-Hispanic White.

may compound respiratory risks. Future research is needed to better understand the mechanisms and long-term health effects of dual cannabis use.

Another crucial finding is the difference in frequent use by administration routes. Young adults who both vaped and smoked cannabis reported the highest prevalence of frequent use, followed by those who smoked only and then those who vaped only. Frequent use, independent of administration routes, may contribute to the onset of respiratory symptoms. The PATH Study measured the overall cannabis use frequency but did not assess frequency by administration route. As a result, the frequency of vaping versus smoking cannot be determined among those who both vaped and smoked cannabis. On the basis of existing knowledge of tobacco use,[28–30] individuals who smoke and vape report a wide range of different dual-use patterns, ranging from mostly smoking to mostly vaping. Future surveys should collect route-specific cannabis use frequency to better evaluate the relationship between cannabis administration routes and respiratory outcomes.

The findings highlight the complex relationship between cannabis and tobacco co-use and the onset of respiratory symptoms. After adjusting for current combustible tobacco and E-cigarette use in the overall sample, both cannabis smoking only and dual cannabis vaping and smoking were associated with higher odds of respiratory symptoms. Excluding young adults who reported baseline current combustible tobacco or E-cigarette use, dual cannabis vaping and smoking was the only cannabis use group associated with increased respiratory symptoms. A prior analysis of 2014–2016 PATH data similarly found that cannabis use, in addition to cigarette smoking, was longitudinally associated with worsening respiratory symptoms.[31] Because PATH did not capture the route of cannabis administration, the mechanism

cannot be determined; however, cannabis vaping was likely uncommon during this early study period. Because tobacco use history (e.g., duration of E-cigarette use or lifetime cigarette pack years) may be more strongly associated with respiratory conditions than current use, combustible tobacco and E-cigarette use history was added to the sensitivity analysis. The results remained largely unchanged, suggesting a limited effect of tobacco/nicotine use history. Furthermore, the history of cannabis vaping and smoking, such as cumulative exposure by Wave 6, could be key risk factors associated with respiratory symptoms. Unfortunately, the PATH Study did not ask about the history of cannabis vaping or smoking. Future research is needed to address this important issue.

Several factors may affect the association of cannabis vaping and smoking with the onset of respiratory symptoms. First, patterns of dual cannabis vaping and smoking can vary substantially across individuals, and the combined frequency and intensity of use may collectively determine the associated respiratory harm. Another factor is the diversity of cannabis products.[32,33] For nicotine products, vaping is generally considered less harmful than smoking because of reduced exposure to combustion-related chemicals and toxins.[34] However, less is known about the profile of cannabis vaping products, which vary across a wide range of factors, including the chemical profile of vaping liquids and the vaping of solid concentrates.[35–37] More research is needed to clarify how patterns of cannabis use and product characteristics influence respiratory health.

Limitations

This study has limitations. First, as mentioned earlier, the measure of cannabis frequency concerns only overall use and does not reflect the frequency of use by administration routes. Second, the exposure measures rely on point prevalence (e.g., past 30-day use). Cannabis use history and cumulative exposure are likely to be strong predictors of respiratory symptoms. Another limitation is the recall and reporting biases associated with self-reported data. Next, the follow-up period between PATH Study Wave 6 and Wave 7 is 1 year; the longitudinal association may change with a longer follow-up time. Finally, the PATH Study contains limited information on the profile of cannabis products.

CONCLUSIONS

This is one of the first studies to examine dual cannabis vaping and smoking and the subsequent development of respiratory symptoms, analyzing a nationally representative sample of young adults. Cannabis smoking only and cannabis vaping and smoking are associated with higher odds of developing functionally important respiratory symptoms than no cannabis vaping or smoking, whereas cannabis vaping only is not. However, given the limitations noted, these findings must be considered preliminary. More detailed data on cannabis use frequency, product profile, co-use with tobacco, and use history are needed to better assess the effects of cannabis use on respiratory health.

ACKNOWLEDGMENTS

Funding: The authors received no specific funding for this work.

Declaration of interest: NLB is a consultant to Achieve Life Sciences, Qnovia, and Lilly, companies that are developing smoking cessation medications, and has been a paid expert in litigation against tobacco companies. DH has served as a paid expert witness on behalf of public health authorities in response to legal challenges from the cannabis, tobacco, and vaping industries.

CREDIT AUTHOR STATEMENT

Ruoyan Sun: Conceptualization, Formal analysis, Investigation, Methodology, Writing — original draft. Neal L. Benowitz: Methodology, Validation, Writing — review & editing. David Hammond: Validation, Writing — review & editing. David Mendez: Validation, Writing — review & editing. Kenneth E. Warner: Validation; Writing — review & editing.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2026.108421.

REFERENCES

1. State medical cannabis laws National Conference of State Legislatures. https://www.ncsl.org/health/state-medical-cannabis-laws. Updated 2025. Accessed November 12, 2025.
2. Cannabis overview National Conference of State Legislatures. https://www.ncsl.org/civil-and-criminal-justice/cannabis-overview. Updated 2024. Accessed November 12, 2025.
3. Chiu V, Hall W, Chan G, Hides L, Leung J. A systematic review of trends in U.S. attitudes toward cannabis legalization. *Subst Use Misuse.* 2022;57(7):1052–1061. https://doi.org/10.1080/10826084.2022.2063893.
4. Pawar AK, Firmin ES, Wilens TE, Hammond CJ. Systematic review and meta-analysis: medical and recreational cannabis legalization and cannabis use among youth in the United States. *J Am Acad Child Adolesc Psychiatry.* 2024;63(11):1084–1113. https://doi.org/10.1016/j.jaac.2024.02.016.
5. Patrick ME, Miech RA, Johnston LD, O'Malley PM. *Monitoring the Future Panel study annual report: national data on substance use among adults ages 19 to 65, 1976-2024*. Ann Arbor, MI: Institute for Social Research, University of Michigan, Published 2025. https://doi.org/10.7302/26783.
6. Hammond D, Goodman S, Wadsworth E, et al. Trends in the use of cannabis products in Canada and the USA, 2018–2020: findings from the International cannabis Policy Study. *Int J Drug Policy.* 2022;105:103716. https://doi.org/10.1016/j.drugpo.2022.103716.

7. Quader ZS, Roehler DR, Vivolo-Kantor AM, Ko JY. Routes of marijuana use—Behavioral Risk Factor Surveillance System, 22 U.S. states and two territories, 2022. *MMWR Morb Mortal Wkly Rep.* 2025;74(12):198–204. https://doi.org/10.15585/mmwr.mm7412a1.
8. Harrell MB, Clendennen SL, Sumbe A, Case KR, Mantey DS, Swan S. Cannabis vaping among youth and young adults: a scoping review. *Curr Addict Rep.* 2022;9(3):217–234. https://doi.org/10.1007/s40429-022-00413-y.
9. Patrick ME, Miech RA, Johnston LD, O'Malley PM. *Monitoring the Future Panel study annual report: national data on substance use among adults ages 19 to 60, 1976-2022*. Ann Arbor, MI: Institute for Social Research, University of Michigan, Published 2023. https://doi.org/10.7826/ISR-UM.06.585140.002.07.0002.2023.
10. Bonner E, Chang Y, Christie E, et al. The chemistry and toxicology of vaping. *Pharmacol Ther.* 2021;225:107837. https://doi.org/10.1016/j.pharmthera.2021.107837.
11. Spindle TR, Cone EJ, Schlienz NJ, et al. Acute effects of smoked and vaporized cannabis in healthy adults who infrequently use cannabis: a crossover trial. *JAMA Netw Open.* 2018;1(7):e184841. https://doi.org/10.1001/jamanetworkopen.2018.4841.
12. Stuyt E. The problem with the current high potency THC marijuana from the perspective of an addiction psychiatrist. *Mo Med.* 2018;115(6):482–486. Accessed November 12, 2025 https://pmc.ncbi.nlm.nih.gov/articles/PMC6312155/.
13. Munger KR, Anreise KM, Strongin RM. Cannabis concentrate vaping chemistry. *Front Toxicol.* 2025;7:1568207. https://doi.org/10.3389/ftox.2025.1568207.
14. Muheriwa-Matemba SR, Baral A, Abdshah A, et al. Cardiovascular and respiratory effects of cannabis use by route of administration: a systematic review. *Subst Use Misuse.* 2024;59(9):1331–1351. https://doi.org/10.1080/10826084.2024.2341317.
15. Moir D, Rickert WS, Levasseur G, et al. A comparison of mainstream and sidestream marijuana and tobacco cigarette smoke produced under two machine smoking conditions. *Chem Res Toxicol.* 2008;21(2):494–502. https://doi.org/10.1021/tx700275p.
16. Lee MH, Hancox RJ. Effects of smoking cannabis on lung function. *Expert Rev Respir Med.* 2011;5(4):537–547. https://doi.org/10.1586/ers.11.40.
17. Ghasemiesfe M, Ravi D, Vali M, et al. Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. *Ann Intern Med.* 2018;169(2):106–115. https://doi.org/10.7326/M18-0522.
18. National Academies of Sciences, Engineering, and Medicine. The Health Effects of Cannabis and Cannabinoids: the Current State of Evidence and Recommendations for Research. Washington, DC: National Academies Press, 2017. https://doi.org/10.17226/24625.
19. Braymiller JL, Barrington-Trimis JL, Leventhal AM, et al. Assessment of nicotine and cannabis vaping and respiratory symptoms in young adults. *JAMA Netw Open.* 2020;3(12):e2030189. https://doi.org/10.1001/jamanetworkopen.2020.30189.
20. Sun R, Oates GR. Association of vaping with respiratory symptoms in U.S. young adults: nicotine, cannabis, and dual vaping. *Prev Med.* 2024;189:108175. https://doi.org/10.1016/j.ypmed.2024.108175.
21. Outbreak of lung injury associated with the use of e-cigarette, or vaping, products Centers for Disease Control and Prevention https://archive.cdc.gov/www_cdc_gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html. Updated 2021. Accessed November 12, 2025.
22. Sun R, Mendez D, Warner KE. Evaluation of self-reported cannabis vaping among U.S. youth and young adults who use e-cigarettes. *JAMA Pediatr.* 2022;176(4):417–419. https://doi.org/10.1001/jamapediatrics.2021.6102.
23. Pulvers K, Jamalian N, Suh E, Faltaoos P, Stewart SL, Aston ER. Nicotine and cannabis routes of administration and dual use among U.S. young adults who identify as Hispanic, non-Hispanic Black, and non-Hispanic White. *Prev Med Rep.* 2024;48:102912. https://doi.org/10.1016/j.pmedr.2024.102912.
24. Cohn AM, Chen S. Age groups differences in the prevalence and popularity of individual tobacco product use in young adult and adult marijuana and tobacco co-users and tobacco-only users: findings from Wave 4 of the population assessment of tobacco and health study. *Drug Alcohol Depend.* 2022;233:109278. https://doi.org/10.1016/j.drugalcdep.2022.109278.
25. Halenar MJ, Sargent JD, Edwards KC, et al. Validation of an index for functionally important respiratory symptoms among adults in the nationally representative population assessment of tobacco and health study, 2014−2016. *Int J Environ Res Public Health.* 2021;18(18):9688. https://doi.org/10.3390/ijerph18189688.
26. Reddy KP, Schwamm E, Kalkhoran S, Noubary F, Walensky RP, Rigotti NA. Respiratory symptom incidence among people using electronic cigarettes, combustible tobacco, or both. *Am J Respir Crit Care Med.* 2021;204(2):231–234. https://doi.org/10.1164/rccm.202012-4441LE.
27. Karey E, Xu S, He P, et al. Longitudinal association between e-cigarette use and respiratory symptoms among U.S. adults: findings from the Population Assessment of Tobacco and Health Study Waves 4−5. *PLoS One.* 2024;19(2):e0299834. https://doi.org/10.1371/journal.pone.0299834.
28. Jackson SE, Cox S, Shahab L, Brown J. Trends and patterns of dual use of combustible tobacco and e-cigarettes among adults in England: a population study, 2016−2024. *Addiction.* 2025;120(4):608–619. https://doi.org/10.1111/add.16734.
29. Owusu D, Huang J, Weaver SR, et al. Patterns and trends of dual use of e-cigarettes and cigarettes among U.S. adults, 2015−2018. *Prev Med Rep.* 2019;16:101009. https://doi.org/10.1016/j.pmedr.2019.101009.
30. Lee SH, Han DH, Seo DC. Toward a better understanding of adult dual use of cigarettes and e-cigarettes based on use intensity and reasons for dual use. *Addict Behav.* 2023;137:107517. https://doi.org/10.1016/j.addbeh.2022.107517.
31. Sargent JD, Halenar MJ, Edwards KC, et al. Tobacco use and respiratory symptoms among adults: findings from the longitudinal Population Assessment of Tobacco and Health (PATH) Study 2014−2016. *Nicotine Tob Res.* 2022;24(10):1607–1618. https://doi.org/10.1093/ntr/ntac080.
32. Rossheim ME, Tillett KK, Vasilev V, et al. Types and brands of derived psychoactive cannabis products: an online retail assessment, 2023. *Cannabis Cannabinoid Res.* 2024;9(6):1478–1481. https://doi.org/10.1089/can.2023.0266.
33. Nali MC, Yang JS, Li Z, Larsen MZ, Mackey TK. Cannabis-derived product types, flavors, and compound types from an e-commerce website. *JAMA Netw Open.* 2024;7(10):e2440376. https://doi.org/10.1001/jamanetworkopen.2024.40376.
34. Health effects of vaping. Centers for Disease Control and Prevention. https://www.cdc.gov/tobacco/e-cigarettes/health-effects.html. Updated 2025. Accessed November 12, 2025.
35. Freeman TP, Craft S, Wilson J, et al. Changes in delta-9-tetrahydrocannabinol (THC) and cannabidiol (CBD) concentrations in cannabis over time: systematic review and meta-analysis. *Addiction.* 2021;116(5):1000–1010. https://doi.org/10.1111/add.15253.
36. Surgeon General's advisory: marijuana use and the developing brain. HHS.gov. U.S. Department of Health and Human Services. https://www.hhs.gov/surgeongeneral/reports-and-publications/addiction-and-substance-misuse/advisory-on-marijuana-use-and-developing-brain/index.html. Updated 2019. Accessed November 12, 2025.
37. Cannabis potency data. National Institute on Drug Abuse. https://nida.nih.gov/research/research-data-measures-resources/cannabis-potency-data. Updated 2024. Accessed November 12, 2025.