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Vaping cannabis among adolescents: prevalence and associations with tobacco use from a cross-sectional study in the USA

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ABSTRACT

Objective Previous research suggests that some adolescents are using e-cigarette devices to vaporise ('vaping') cannabis in the form of hash oil, tetrahydrocannabinol (THC) wax or oil, or dried cannabis buds or leaves. However, it is unclear how adolescents who vape cannabis use other tobacco products. This study examined the extent to which adolescents reported ever vaping cannabis and investigated how demographic variables and tobacco behaviours were associated with use.

Design We used cross-sectional data from adolescents (total response rate 64.5%) who participated in the 2017 North Carolina Youth Tobacco Survey. SAS logistic regression survey procedures were used to account for the complex survey design and sampling weights.

Setting North Carolina, USA.

Participants Adolescents in high school (n=2835).

Primary outcome and measure Adolescents were asked to indicate whether they had ever used an e-cigarette device with marijuana, THC or hash oil, or THC wax.

Results Approximately 1 in 10 high school students reported ever vaping cannabis in the overall sample (9.6%). In multivariable models, adolescents who reported using cigars (adjusted OR (aOR) 3.76, 95% CI 2.33 to 6.07), waterpipe (aOR 2.32, 95% CI 1.37 to 3.93) or e-cigarettes (aOR 3.18, 95% CI 2.38 to 4.25) in the past 30 days had higher odds of reporting ever vaping cannabis compared with their counterparts. There was no significant association between use of smokeless tobacco (aOR 0.89, 95% CI 0.42 to 1.91) or use of cigarettes (aOR 1.27, 95% CI 0.71 to 2.29) in the past 30 days and odds of reporting ever vaping cannabis.

Conclusions These findings provide evidence that large numbers of high school students who use tobacco products have vaped cannabis. As tobacco control policies—such as communication campaigns or smoke-free laws—increasingly focus on e-cigarettes, attention to understanding how adolescents use e-cigarettes to vape substances other than nicotine is essential.

INTRODUCTION

Although the prevalence of e-cigarette use among youth has increased dramatically in the past decade,[1] little epidemiologic data exist on the prevalence of using e-cigarette devices or other specialised devices to vaporise ('vape') cannabis in the form of hash oil, tetrahydrocannabinol (THC) wax or oil, or dried cannabis buds or leaves.[2] This is surprising given that (1) cannabis (also referred to as marijuana) and e-cigarettes are the most commonly used substances by adolescents in the USA,[3] (2) evidence exists that adolescents dual use both tobacco e-cigarettes and cannabis,[4] and (3) longitudinal research suggests that use of e-cigarettes is associated with progression to use of cannabis.[5]

A growing number of studies have examined prevalence of vaping cannabis among adults[6–8] and adolescents[9–11] in the USA. For example, a recent study used data from the 2016 National Youth Tobacco Survey (NYTS) and found that 8.9% of middle and high school students reported ever vaping cannabis.[10] Additionally, the researchers found that prevalence was higher among current e-cigarette users (39.5%) and current non-e-cigarette tobacco product users (38.5%).[9][10] Other studies have been

conducted in Connecticut[9] and California[11] and found similar prevalence estimates. While all studies have examined how demographic factors were associated with prevalence of vaping cannabis,[9–11] and one study examined how current e-cigarette and other tobacco product use was associated with prevalence of vaping cannabis,[10] no studies to our knowledge have examined how adolescents who vape cannabis use other specific tobacco products (ie, cigarettes, cigars, waterpipe, smokeless tobacco).

The US Food and Drug Administration (FDA) can now regulate the manufacture, marketing, sale and distribution of e-cigarettes and their components, including e-liquids, cartridges, flavourings and batteries.[12] Future FDA regulations for e-cigarettes may take years to implement across the USA; however, there is significant variation in state and local e-cigarette policies,[13] as well as state policies related to legal access to cannabis. Therefore, to provide evidence on how youth use e-cigarettes to vape cannabis, which can be useful to state and local authorities, we examined the prevalence of vaping cannabis among adolescents in North Carolina—a state that has not legalised medical or retail cannabis for adults. Extending previous research, we examined demographic variables and tobacco behaviours associated with use.

METHODS
Settings, participants, procedures
We used data from the 2017 North Carolina Youth Tobacco Survey (NCYTS). Similar to the NYTS,[14] the NCYTS is a public and charter school-based survey of students in grades 6–12. A multi-stage cluster sampling design in three distinct regions of the state was used. School districts were first selected within three geographic regions of the state; a school's probability for selection was proportional to its enrolment size for the survey year. Classes were then randomly selected within each school. Participation was voluntary and anonymous. Passive consent forms were utilised, unless an active consent form was required according to a specific school district policy. Our analyses focused on data from high school students. The overall response rate was 64.5% (75.2% school response rate, 85.8% student response rate), which is similar to the response rate from the 2016 NYTS survey (71.6%).[15]

Measures
Vaping cannabis
Our main outcome of interest was whether adolescents had used e-cigarette devices to vape cannabis. Our measure of ever vaping cannabis came from the 2016 NYTS survey.[10] Adolescents were asked, 'Have you ever used an e-cigarette device with a substance besides nicotine?' Participants could choose one or more of the following response options: (1) Yes, I have used an e-cigarette device with marijuana, THC or hash oil, or THC wax; (2) Yes, I have used an e-cigarette device with another substance that is not marijuana, THC or hash oil, or THC wax; (3) No, I have only used an e-cigarette device with nicotine; (4) No, I have never used an e-cigarette device; and (5) Don't know/not sure. If participants selected 'Yes' to the first response option, they were coded as having vaped cannabis. Adolescents selecting any other response option were coded as never having vaped cannabis.

In a previous section of the survey, e-cigarettes were described as: "battery powered devices that usually contain a nicotine-based liquid that is vaporised and inhaled. You may know them as vape-pens, hookah-pens, e-hookahs, e-cigars, e-pipes, personal vaporizers or mods. Some brand examples include NJOY, Blu, Vuse, MarkTen, Logic, Vapin Plus, eGo and Halo."

Tobacco use
The survey assessed ever and past 30 days use of five tobacco products, including: (1) cigarettes, (2) cigars (including cigars, little cigars, and cigarillos), (3) smokeless tobacco (SLT) (including chewing tobacco, snuff, or dip; snus; and dissolvable tobacco products), (4) waterpipe (ie, hookah), and (5) e-cigarettes. Using this information, adolescents were classified as current users of that tobacco product if they indicated that they had ever used the product and reported using it on at least 1 day in the past 30 days. Otherwise, participants were coded as non-current tobacco users of the product.

Demographics
Demographic variables included sex (female or male), grade (9th, 10th, 11th, or 12th), race/ethnicity categorised into non-Hispanic white, non-Hispanic black, Hispanic, or non-Hispanic other race, and whether students reported receiving free or reduced-price lunch at school (yes or no).

Statistical analysis
Of the 3133 high school students, we dropped data for 62 participants (2%) who had missing or inconsistent responses to whether they had vaped cannabis or not and data for 236 participants (7.5%) who had missing data on any of the other variables examined, creating an analytic sample of 2835 participants. We first examined correlates of vaping cannabis using bivariate χ^2 tests. We then conducted a multivariable logistic regression, including correlates from the bivariate analyses with p<0.10—an approach that has been used in previous research.[16] Collinearity among the tobacco use variables and demographic characteristics was low, with variance inflation factor values <2 for all independent variables. Correlations among tobacco use variables, calculated using phi coefficients which are measures of association between dichotomous variables, ranged from 0.20 to 0.47. Analyses used SAS version 9.4 survey procedures (SAS Inc, Cary, NC, USA). We set critical α=0.05 and used two-tailed statistical tests. Results include weighted percentages, adjusted odds ratios (aOR) and 95% confidence intervals (95% CI).

Participant involvement

This research was done without participant involvement. Participants were not invited to comment on the study design and were not consulted to develop patient relevant outcome. Participants were not invited to contribute to the writing or editing of this document for readability or accuracy. However, there are plans to disseminate the results of the research to North Carolina residents, through website materials and infographics of results.

RESULTS

Approximately 1 in 10 adolescents reported ever vaping cannabis in the overall sample (9.6%) (table 1), which was a majority non-Hispanic white (52.8%) and evenly distributed by sex and grade. Ever vaping cannabis was significantly associated with sex, grade and race in bivariate results. Specifically, prevalence was significantly higher among males (11.0%) compared with females (8.2%) (p=0.04). In addition, grade was associated with

Table 1 Weighted participant characteristics stratified by ever vaping cannabis status, n=2835; data collected from the 2017 North Carolina Youth Tobacco Survey

Variable	Total sample, n=2835 % (n)	Has never vaped cannabis, n=2582 % (n)	Has ever vaped cannabis, n=253 % (n)	P value
Ever used an e-cigarette to vape cannabis				
No	90.4 (2582)	–	–	
Yes	9.6 (253)	–	–	
Sex				
Female	51.2 (1428)	91.8 (1323)	8.2 (105)	0.04
Male	48.8 (1407)	89.0 (1259)	11.0 (148)	
Grade				
9th	28.7 (904)	95.3 (856)	4.7 (48)	<0.001
10th	26.2 (696)	90.9 (638)	9.1 (58)	
11th	24.0 (577)	89.4 (515)	10.6 (62)	
12th	21.0 (658)	84.5 (573)	15.5 (85)	
Race				
Non-Hispanic white	52.8 (1503)	88.7 (1352)	11.3 (151)	0.02
Non-Hispanic black	26.0 (650)	95.0 (617)	5.0 (33)	
Hispanic	14.1 (517)	89.5 (468)	10.5 (49)	
Non-Hispanic other	7.2 (167)	88.2 (145)	11.8 (20)	
Free or reduced-price lunch				
Yes	44.1 (1362)	90.1 (1249)	9.9 (113)	0.73
No	55.9 (1473)	90.7 (1333)	9.3 (140)	
Current cigarette use				
No	92.7 (2617)	92.2 (2436)	7.8 (181)	<0.001
Yes	7.3 (218)	67.8 (146)	32.2 (72)	
Current cigar use				
No	88.9 (2497)	93.6 (2346)	6.4 (151)	<0.001
Yes	11.1 (338)	65.2 (236)	34.8 (102)	
Current smokeless tobacco use				
No	94.3 (2649)	91.6 (2451)	8.4 (198)	<0.001
Yes	5.7 (186)	71.7 (131)	28.3 (55)	
Current waterpipe use				
No	96.6 (2722)	91.6 (2516)	8.4 (206)	<0.001
Yes	3.4 (113)	57.0 (66)	43.0 (47)	
Current tobacco e-cigarette use				
No	84.2 (2334)	94.2 (2217)	5.8 (117)	<0.001
Yes	15.8 (501)	70.7 (365)	29.3 (136)	

Table 2 Weighted multivariable logistic regression results, *†n=2835; data collected from the 2017 North Carolina Youth Tobacco Survey

Variable	aOR (95% CI)
Male (ref female)	1.33 (0.87 to 2.04)
10th grade (ref 9th grade)	**1.87 (1.01 to 3.47)**
11th grade (ref 9th grade)	**1.99 (1.21 to 3.26)**
12th grade (ref 9th grade)	**2.88 (1.46 to 5.67)**
Black (ref non-Hispanic white)	0.51 (0.22 to 1.16)
Hispanic (ref non-Hispanic white)	1.03 (0.78 to 1.38)
Other race (ref non-Hispanic white)	1.38 (0.72 to 2.64)
Current cigarette use (ref no current use)	1.27 (0.71 to 2.29)
Current cigar use (ref no current use)	**3.76 (2.33 to 6.07)**
Current smokeless tobacco use (ref no current use)	0.89 (0.42 to 1.91)
Current waterpipe use (ref no current use)	**2.32 (1.37 to 3.93)**
Current tobacco e-cigarette use (ref no current use)	**3.18 (2.38 to 4.25)**

*Only variables that were statistically significant (p<0.10) in bivariate analyses were included in the multivariable model (ie, sex, grade, race, current use of cigarettes, cigars, smokeless tobacco, waterpipe, or e-cigarettes, and ever use of e-cigarettes).
†Bold text indicates significance p<0.05.

prevalence of ever vaping cannabis (p<0.001), such that as grade increased, prevalence of ever vaping cannabis increased. Specifically, the prevalence among 9th grade students was 4.7% while the prevalence among 12th grade students was 15.5%. Prevalence was higher among non-Hispanic white students (11.3%), Hispanic students (10.5%), and non-Hispanic other students (11.8%), compared with non-Hispanic black students (5.0%) (p=0.02). Finally, prevalence was significantly higher among adolescents who reported using cigarettes, cigars, SLT, waterpipe or tobacco e-cigarettes in the past 30 days (ranging from 28.3% among those using SLT to 43.0% among those using waterpipe), all p values <0.001.

In multivariable models (table 2), 10th grade students (aOR 1.87, 95% CI 1.01 to 3.47), 11th grade students (aOR 1.99, 95% CI 1.21 to 3.26), and 12th grade students (aOR 2.88, 95% CI 1.46 to 5.67) had higher odds of ever vaping cannabis than 9th grade students. In addition, adolescents who reported using cigars (aOR 3.76, 95% CI 2.33 to 6.07), waterpipe (aOR 2.32, 95% CI 1.37 to 3.93) or tobacco e-cigarettes (aOR 3.18, 95% CI 2.38 to 4.25) in the past 30 days had higher odds of reporting ever vaping cannabis than adolescents not using those products in the past 30 days. There was no significant association between use of SLT (aOR 0.89, 95% CI 0.42 to 1.91) or use of cigarettes (aOR 1.27, 95% CI 0.71 to 2.29) in the past 30 days and odds of reporting ever vaping cannabis.

DISCUSSION

This is one of a growing number of research studies to show that many high school students who use tobacco products have vaped cannabis. Compared with previous research, we found a similar prevalence of vaping cannabis among adolescents: 9.6% in our study of North Carolina high school students who were mostly between the ages of 14–18 years, compared with 5.4% in a sample of high school students in Connecticut,[9] 8.2% in a sample of high school students in Canada aged 15–18,[17] 8.9% in a sample of middle and high school students in the USA,[10] and 10.5% in a sample of 10th graders in California[11] in previous research). Using current North Carolina enrolment figures, our findings suggest that over 46 000 high school students across the state have ever vaped cannabis. Moreover, in some sub-groups (ie, current waterpipe users), prevalence of ever vaping cannabis rose to 43%. These findings provide additional evidence that large numbers of adolescents—particularly those who currently use tobacco—are also vaping cannabis, even in areas where cannabis use is not legal for any adult.

The health effects of vaping cannabis are not yet known. Some research suggests that vaping cannabis may be associated with fewer respiratory symptoms than smoking cannabis.[2 18] However, this does not mean that adolescents' use of vaporised cannabis is safe[19]—particularly if it leads to earlier initiation of tobacco or cannabis use, concomitant tobacco and cannabis use, increased frequency of use or misuse of tobacco or cannabis, or increased potency of cannabis.[2 8 19] In addition, there are also concerns that qualities of non-combustible forms of cannabis (eg, availability of flavourings, no smell of smoke, lower harm perceptions) may attract youth who would otherwise not use combustible forms of cannabis. In a study of 10th graders in Los Angeles, California, researchers found that 7.8% had never smoked combustible cannabis but had used vaporised or edible cannabis.[11] It is possible that these adolescents would never have used cannabis if non-combustible forms of cannabis had not been available, although no research, to our knowledge, has examined this hypothesis. As has been done with e-cigarettes,[20] more research and simulation models are needed to quantify the population-level benefits and harms of non-combustible forms of cannabis, including the effects of vaporised cannabis use, combustible cannabis use, and use of other tobacco products. In other words, can vaporised cannabis divert adolescents from smoking cannabis, does the availability and acceptability of vaporised cannabis attract new adolescents to begin using cannabis who would not have otherwise used it, and does vaporised cannabis influence other tobacco use, including tobacco e-cigarette use?

Recent data from Monitoring the Future, a large study of youth and young adults in the USA, suggest that prevalence of vaping cannabis increased from 2017 to 2018 among 8th graders, 10th graders and 12th graders.[21 p76] This finding, coupled with the number of high school students who have used an e-cigarette device to

vape cannabis in the current study, is concerning to the researchers. Many tobacco control policies and interventions, such as smoke-free laws, do not extend to e-cigarettes,[22] let alone using e-cigarettes for other substances, such as cannabis. Even though some states, such as Colorado, have included cannabis in smoke-free laws,[23] these laws do not cover vaping or vaping cannabis.[24] As tobacco control policies—such as national communication campaigns[25] or smoke-free laws[22]—begin focusing on e-cigarettes, attention to how e-cigarettes can be used for use of other substances is warranted. As more states and countries around the world begin to legalise marijuana for medicinal and recreational purposes, lessons learned from tobacco and alcohol regulation should be applied.[26]

Moreover, since many people believe that vaping cannabis is a safer way to use cannabis than other modes of administration (eg, smoking),[2] communication messages on actual safety should be reported. While these data are not yet available, two countries—Uruguay and Canada—have already legalised cannabis for recreational purposes, although neither country has legalised sales of non-combustible forms of cannabis yet. In addition, among the US states that have legalised medical marijuana for adults, Utah legalised only non-combustible forms of marijuana, including vaporised cannabis and edibles.[27] Findings from legalisation in these areas, which represent large-scale naturalised experiments, will offer insights into the safety of cannabis, effects of legalisation on use and/or other public health implications of legalisation (eg, prevalence of car accidents). Data from Utah, in particular, may be useful for answering research questions on trends, correlates and consequences of non-combustible forms of cannabis (ie, vaporised cannabis).

Limitations

Some limitations of the data exist. First, the survey included only one item to assess vaping cannabis, did not assess frequency of or current use of vaping cannabis, did not provide examples of specific products used to vape cannabis (eg, 'JuJu Joint' or 'Pax'), and did not assess current or ever use of cannabis without an e-cigarette device. Given these limitations, we were unable to examine more complex patterns of vaping cannabis, such as: prevalence and frequency of vaping cannabis in the past 30 days, the prevalence of vaping cannabis among cannabis users, and cannabis-related variables (eg, harm perceptions of cannabis) that could be associated with vaping cannabis. Future analyses using larger datasets in the USA, such as Monitoring the Future, and worldwide could help answer research questions that the current study was not able to assess.

Second, the item used to assess prevalence of vaping cannabis asked about use of an 'e-cigarette device with marijuana, THC or hash oil, or THC wax'. We are therefore unable to assess whether participants used tobacco e-cigarettes for cannabis or whether they used specialised cannabis devices. Relatedly, while the item used to assess prevalence of vaping cannabis in our study has been used previously in nationally representative surveys,[10] no studies, to our knowledge, have used observational or biological indicators to verify reports of vaping cannabis.

Third, before the question about ever vaping cannabis, the survey defined what an e-cigarette device was and provided examples of brand names (NJOY, MarkTen). This list did not include JUUL as an e-cigarette brand name, which is an important limitation given that JUUL became the most popular e-cigarette by the end of 2017,[28] and the description of e-cigarettes did not include any cannabis vaporisers.

Fourth, it is possible that students included in the final sample with complete data differed from those not included in the final sample. Indeed, in an attrition analysis (see online supplementary table A), we found that a higher proportion of females, non-Hispanic white adolescents and non-current tobacco product users were included in the final sample.

Fifth, all data were self-reported and subject to related biases. For example, given that cannabis use is illegal in North Carolina for adults and adolescents, it is possible that our prevalence estimate of ever vaping cannabis is conservative.

Finally, results can only be generalisable to adolescents in a specific state (North Carolina).

CONCLUSIONS

Findings suggest that adolescent cannabis vaping is an important public health issue that is likely to affect and be affected by tobacco control and cannabis policies in states and at the federal level in the USA.[29] In North Carolina, three different bills were introduced to make it legal for adults to possess medical cannabis in 2017.[30–32] While each of the bills were ultimately defeated, our study among North Carolina high school students is relevant for subsequent legislative initiatives in North Carolina. Increased research investigating how youth use e-cigarette devices for other purposes beyond vaping nicotine, like the current study, is needed.

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