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What substances are adolescents vaping? Estimating nicotine-specific and marijuana-specific vaping from US national youth surveys

Arielle Selya¹, Sooyong Kim¹, Saul Shiffman¹, Joe G. Gitchell¹, Floe Foxon¹

¹ Pinney Associates

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Abstract

Background: The prevalence of electronic cigarette (“e-cigarettes”) use among youth has raised alarm over recent years. Vaping is usually assumed to be of nicotine, but uncertainties in survey definitions may also include non-nicotine substances which can impose different risks (particularly marijuana). The current study quantifies the proportions of nicotine-specific and marijuana-specific vaping among adolescents.

Methods: Data from the Monitoring the Future (MTF) 2020 survey and National Youth Tobacco Survey (NYTS) 2021 were analyzed with respect to the substance vaped: nicotine, marijuana, or (in MTF) flavoring only. Past-30-day nicotine-specific vaping (exclusively, or also having vaped other substances) and marijuana-specific vaping were calculated. Results were also broken down by grade level, by cigarette smoking history (current, former, or never), and among frequent e-cigarette users (on 20+ days out of the past 30 days).

Results: Among past-30-day e-cigarette users, 14.6% (MTF) and 18.8% (NYTS) reported not vaping *any* nicotine in the past 30 days. Marijuana use was reported by 45.7% (MTF) and 42.5% (NYTS) of past-30-day vapers. Both *nicotine* vaping and marijuana vaping in the past 30 days were more common in current and former smokers than in never-smokers, and in frequent vapers (of any substance). Conversely, never-smokers were more commonly *exclusively* vaping marijuana compared to current and former smokers.

Conclusions: A notable proportion of self-reported past-30-day e-cigarette users reported not vaping nicotine, and nearly half of self-reported past-30-day e-cigarette users vaped marijuana. Inclusion of more detailed data capturing the variety of substances used in vaping devices is imperative for accurate public health surveillance of both nicotine and marijuana vaping among US adolescents, considering their different respective harms and regulatory mechanisms.

Arielle Selya¹, Sooyong Kim¹, Saul Shiffman¹, Joe Gitchell², Floe Foxon¹

¹ Pinney Associates, Inc., Pittsburgh, PA

² Pinney Associates, Inc., Bethesda, MD

Running Head: Nicotine- and marijuana-specific vaping

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Keywords: adolescents; e-cigarettes; marijuana; nicotine; tobacco; vaping.

Introduction

Adolescent e-cigarette use is a public health concern in the United States. E-cigarette use is tracked by national surveillance surveys in the US, most notably the National Youth Tobacco Survey (NYTS), the Monitoring the Future (MTF) Survey, and the Youth Risk Behavior Surveillance (YRBS) Survey. Vaping prevalence increased through 2019, with up to 35.0% of adolescents having ever used an e-cigarette, and 20.0% of middle and high school students combined reporting past 30-day use.^[1] Although adolescent e-cigarette had declined to 9.4% of middle and high school students combined in 2022,^[2] it continues to be a concern.

Although “e-cigarette use” or “vaping” is typically interpreted as *nicotine* vaping, and is counted as part of overall “tobacco use” figures in NYTS and secondary reports,^{[3][4][5]} the NYTS and YRBS definitions of e-cigarette use introduce uncertainty about the substance being vaped. NYTS 2021 provides the following instructions at the beginning of the section on e-cigarette use: “The next several questions are about electronic cigarettes or e-cigarettes, such as JUUL, SMOK, Suorin, Vuse, blu, Puff Bar, or STIG. You also may know them as vapes, mods, e-cigs, e-hookahs, or vape-pens. For the rest of this survey, these products and devices will be called e-cigarettes. E-cigarettes are battery powered devices that usually contain a nicotine-based liquid that is vaporized and inhaled.” The description “*usually* contain a nicotine-based liquid” is notable, as this explicitly allows the inclusion of non-nicotine substances in an affirmative response. Additionally, “vape pen” often refers to marijuana or THC vaping,^{[6][7][8]} and e-hookah often refers to flavored, non-nicotine vapes.^[9] Thus, adolescents who vape marijuana or flavoring, but not nicotine, may endorse e-cigarette use. However, positive answers to this question are typically assumed to be nicotine vaping in publications of survey results,^{[3][4][5][10]} thus simultaneously overestimating nicotine vaping and underestimating marijuana vaping.

While the potential harms of nicotine vaping are extensively discussed in publications and reports on youth tobacco surveys,^{[3][4][5]} underestimating marijuana vaping overlooks marijuana-specific risks. Adolescents who use marijuana are more likely to have impaired cognition^[11] and a higher likelihood of psychiatric morbidities.^{[12][13]}

Thus, accurate and separate tracking of nicotine and marijuana vaping is essential for effective public health monitoring and response, which must be particular to the substance. The 2019 outbreak of e-cigarette or vaping associated lung injury (EVALI) is illustrative in this respect, as the crude aggregation of all vaping behaviors confounded a critical public health issue.^[14] EVALI was first believed to be caused by nicotine vaping, but was later traced to a cutting agent in marijuana vapes. There is continued conflation of the risks of contaminated marijuana vaping products with nicotine vaping, which obscures the actual risk behaviors that individuals should avoid, while misattributing risk to nicotine vaping.^[15] Additionally, an effective response would necessarily need to target illicit marijuana products; yet the conflation of nicotine with marijuana vaping led to nicotine-specific policies (e.g. local bans on nicotine e-cigarettes) that did not address the actual cause of EVALI. The regulations that resulted from this misperception of the causes failed to give specific guidance to those actually at risk (i.e. users of illicit marijuana products), while likely having harmful consequences such as worsened risk perceptions about nicotine e-cigarettes^[16] among those *not* at risk (i.e. users of branded nicotine e-cigarettes).

Previous publications on MTF data that have examined the substances being vaped found that the majority of adolescents who vape, report vaping flavoring only (~65% in 2015^[17] and 66% in 2017^[18]) with nicotine being the second most prevalent substance vaped (13-20% in 2015^[17] and 61% in 2017^[18]) followed by marijuana (5-10% in 2015^[17] and 30% in 2017^[18]). Given that substance use and vaping trends have changed over the past few years, the question of which substances youth are vaping warrants a re-examination using the most recent available data. Recent data show that 40% of current youth and young adult e-cigarette users^[19] have vaped marijuana. However, little is known about *exclusive* nicotine and non-nicotine vaping, i.e. how many self-reported e-cigarette users report exclusively report vaping substances other than nicotine.

This paper presents analyses of 2020 MTF and 2021 NYTS data with respect to what proportion of reported vaping is nicotine-specific (vs. exclusively non-nicotine substances such as marijuana and flavoring) and marijuana-specific (vs. exclusively non-marijuana substances such as nicotine and flavoring). We report the nicotine-specific and marijuana-specific vaping proportions identified in MTF 2020 and NYTS 2021, both overall and by tobacco use history and frequency of vaping.

Methods

Sample

The most recent available data from MTF and NYTS were used in this study (2020, and 2021, respectively). MTF is an annual study on drug use that includes nationally representative samples of 8th, 10th, and 12th grade students from 112 public and private schools in the 48 contiguous US states. MTF is an annual survey on tobacco use and tobacco-related indicators collected from a nationally representative survey of middle and high school students (grades 6-12) in all 50 US states. NYTS is an annual survey on youth tobacco use conducted by the Centers for Disease Control and Prevention (CDC).

For estimating nicotine-specific and marijuana-specific vaping, data were primarily drawn from the MTF survey, the only such survey to assess substances vaped every year since 2017, using raw data from 2020 [20]. With the COVID-19 pandemic in 2020 and related school closures, the data collection procedure was prematurely halted, resulting in a smaller sample size (approximately 25% of the regular cycles). However, sensitivity analyses conducted by the MTF study team demonstrated the 2020 data, despite the interruption, remain representative of the target population [20].

A total of 2,506 students (8th grade: 383; 10th grade: 1,124; 12th grade: 1,001) reported vaping one or more substances and provided valid responses on past-month vaping of nicotine, marijuana, and/or flavoring only. Response rates were 88%, 89%, and 79% for each grade, respectively.

Additional data were drawn from NYTS 2021, as it was the first NYTS to assess past-30-day marijuana vaping. Analyses were restricted to the N=1436 adolescents (age 9-19+) who reported current (past-30-day) e-cigarette use.

Measures

MTF 2020

Separate questions assessed vaping frequency for each substance (nicotine, marijuana, and “just flavoring”). Participants were asked, “On how many days (if any) have you vaped [substance] during the last 30 days?” Past-month vaping was defined as ‘1 or more days’ vs. ‘0 days’ in the past 30 days.

Based on these questions, participants’ past-month vaping behaviors were classified into *any* nicotine-specific vaping in the past 30 days (with or without also vaping marijuana and/or flavoring in the past 30 days) and *any* marijuana-specific vaping (with or without also vaping nicotine and/or flavoring in the past 30 days). Follow-up analyses examined additional categories for nicotine only, both nicotine and marijuana, nicotine without marijuana, marijuana without nicotine, and neither nicotine nor marijuana (i.e., flavor only). These proportions of substances vaped were examined by smoking status. Participants were classified into never smokers, former smokers (i.e., have smoked in their lifetime but not in the past 30 days), or current smokers (i.e., have smoked in the past 30 days).

NYTS 2021

Participants were asked questions about vaping nicotine and marijuana. Among those reporting past-30-day vaping, nicotine vaping was assessed with the question “Did any of the e-cigarettes that you used in the past 30 days contain nicotine?” (yes/no/don’t know). Marijuana use was asked for four different product categories, including “marijuana [EN1] [AS2] (also called pot, weed, or cannabis), including THC, THC concentrates, hash oil, or waxes,” “CBD or CBD oils,” “Synthetic marijuana or cannabinoids, such as K2 or Spice.” Participants who reported “Yes” or “Don’t know” to the ever-use of such products were further inquired of their past-30-day use, with the question “Have you vaped any of the following substances during the past 30 days?” (for four product categories described above). A combined variable for any type of marijuana vaping was defined as yes (to any), no (to all), or don’t know (to all), in order to capture the widest

variety of substances vaped.

Analyses

MTF 2020

The proportions of participants reporting vaping each substance (nicotine, marijuana, and/or flavoring) were calculated. This was primarily examined as binary contrasts for nicotine-specific (alone, or also vaping other substances in the past 30 days) and marijuana-specific vaping (alone, or also vaping nicotine and/or flavoring in the past 30 days), but was also examined using finer-grained categories (nicotine without marijuana, both nicotine and marijuana, marijuana without nicotine; and neither nicotine nor marijuana). Survey-weighted prevalence of each vaping pattern was calculated in overall MTF participants, by grade levels, by smoking status, and by frequent vaping (on 20+ days out of the past 30 days). Weighted chi-square tests were used to compare substance-specific vaping prevalence across groups.

Since nicotine and marijuana can each be consumed via delivery methods other than vaping, it is informative to contextualize vaping prevalence of each substance as a proportion of *all* ways of using that substance. Thus, overall prevalence of *any* past-30-day nicotine product use and *any* past-30-day marijuana use was calculated. Additionally, nicotine vaping prevalence was also calculated as a proportion of *all* past-30-day nicotine use (i.e., nicotine e-cigarettes, cigarettes, large cigars, flavored little cigars/cigarillos, regular little cigars/cigarillos, hookah, smokeless tobacco); and marijuana vaping prevalence was calculated as a proportion of *all* past-30-day marijuana use (i.e., using “marijuana (weed, pot) or hashish (hash, hash oil)”).

NYTS 2021

The proportion of participants reporting past-month nicotine-specific vaping and past-month marijuana-specific vaping was calculated, along with exclusive nicotine vaping, exclusive marijuana vaping, and neither. “Don’t know” responses were also calculated for each substance. Survey-weighted prevalence of vaping patterns were calculated among those reporting past 30-day e-cigarette use.

All analyses incorporated complex survey design of each respective survey. Prevalence estimates are weighted and sample size is unweighted. This analysis was not pre-registered and the results should be considered exploratory.

Results

MTF 2020

Table 1 shows the vaping patterns reported by the 21.2% of MTF participants who vaped any substance in the past 30 days. Participants who vaped nicotine in the past 30 days (with or without also having vaped marijuana and/or flavoring in the past 30 days) comprise 85.4% of all those who vaped in the past month, with little variation across grade.

Past-30-day vapers had different patterns of nicotine and/or marijuana vaping according to their smoking status (overall chi-square $p < .001$). Specifically, current and former smokers were more likely to report that (at least some of) their vaping products contained nicotine (96.2% and 87.1% of past 30-day vapers, respectively) than never-smoking past-30-day vapers (81.8%). However, *exclusive* nicotine vaping was higher among former or never-smokers than among current smokers (49.0% and 52.8% vs. 45.7%, respectively). Directly examining “don’t know” responses was not possible in MTF, as this was not reported per substance.

With respect to marijuana vaping (alone or also vaping nicotine and/or flavoring only), 45.7% of past 30-day vapers reported that (some of) their vaping products contained marijuana. Past-30-day vapers in 10th and 12th grade were more likely to report *any* vaping marijuana than those in 8th grade (47.9% and 46.6% vs. 36.7%, respectively, $p < .001$). *Any* marijuana vaping was more common among current and former cigarette smokers than never-smokers, (53.1% and 48.5% vs. 42.2%, respectively, $p < .001$), as was vaping *both* marijuana and nicotine in the past 30 days (50.3% and 38.1% vs. 29.0%, respectively; overall chi-square $p < .001$). However, *exclusive* marijuana vaping followed the opposite pattern (never-smokers: 13.0%; former smokers: 10.4%; current smokers: 2.8%, though this last estimate may be imprecise due to low numbers).

Frequent vapers were more likely to report *any* nicotine vaping (i.e. with or without having also vaped other substances) than infrequent vapers (95.6% vs. 80.8%, respectively, $p < .001$), as well as *any* marijuana vaping (57.2% vs. 40.7%, respectively, $p < .001$). Additionally, frequent vapers differ from infrequent vapers in terms of the patterns of nicotine and/or marijuana vaping (overall $p < .001$). Specifically, frequent users were approximately twice as likely than infrequent vapers to have vaped *both* nicotine and marijuana in the past 30 days (53.5% vs. 26.6%, respectively), and were correspondingly less likely to have exclusively vaped either nicotine (42.1% vs. 54.3%, respectively) or marijuana (3.4% vs. 14.1%, respectively).

To contextualize the above vaping percentages in terms of the overall use of each respective substance (including all available delivery methods), 19.9% of youth reported using *any* nicotine product in the past 30 days. Of these, 82.1% reported vaping as a delivery method (alone or with other products). Slightly fewer youth reported *any* marijuana use in the past 30 days (15.3%), and of these, 56.5% reported vaping as a delivery method.

Table 1. Proportion of past 30-day vapers who report that their vaping products contained any nicotine and/or any marijuana, Monitoring the Future 2020

		Mutually exclusive categories of substances vaped in the past month					Nicotine vaping subtotal ⁵		Marijuana vaping subtotal ⁶	
		Nicotine, no marijuana ¹	Both nicotine and marijuana ²	Marijuana, no nicotine ³	Neither nicotine nor marijuana ⁴	p-value	%	p-value	%	p-value
Overall		50.6% (N=1240)	34.8% (N=861)	10.8% (N=302)	3.8% (N=94)	-	85.4% (N=2108)	-	45.7% (N=1166)	
By grade	8th	57.3% (N=230)	28.1% (N=98)	8.1% (N=26)	6.5% (N=26)	<.001	85.4% (N=329)	.2096	36.7% (N=125)	<.001
	10th	47.9% (N=507)	36.3% (N=409)	11.5% (N=159)	4.3% (N=44)		84.2% (N=919)		47.9% (N=570)	
	12th	51.3% (N=503)	35.5% (N=354)	11.1% (N=117)	2.1% (N=24)		87.0% (N=860)		46.6% (N=471)	
By smoking status	Never	52.8% (N=720)	29.0% (N=398)	13.0% (N=203)	5.2% (N=69)	<.001	81.8% (N=1121)	<.001	42.2% (N=603)	<.001
	Former	49.0% (N=372)	38.1% (N=319)	10.4% (N=86)	2.5% (N=22)		87.1% (N=692)		48.5% (N=405)	
	Current	45.7% (N=146)	50.3% (N=142)	2.8% (N=11)	1.2% (N=3)		96.2% (N=291)		53.1% (N=153)	
By vaping frequency⁷	Infrequent	54.3% (N=920)	26.6% (N=478)	14.1% (N=264)	5.1% (N=89)	<.001	80.8% (N=1398)	<.001	40.7% (N=742)	<.001
	Frequent	42.1% (N=318)	53.5% (N=383)	3.4% (N=37)	1.0% (N=5)		95.6% (N=705)		57.2% (N=422)	

¹ Nicotine only, nicotine+flavoring

² Nicotine+marijuana, all three substances (nicotine+marijuana+flavoring)

³ Marijuana only, marijuana+flavoring

⁴ Flavoring only

⁵ Subtotal of (nicotine, no marijuana) + (both nicotine and marijuana), Ns may show small discrepancies due to missing data.

⁶ Subtotal of (marijuana, no nicotine) + (both nicotine and marijuana), Ns may show small discrepancies due to missing data.

⁷ Frequent vaping: vaping (of any substance) on 20+ out of the past 30 days

Gray cells: N<50; may be unreliable.

NYTS 2021

Table 2 shows the vaping patterns among NYTS participants who reported past-30-day e-cigarette use. Overall, 81.2% reported that (at least some of) their e-cigarettes contained nicotine, with higher rates among high school than middle school students (84.6% vs. 62.7%, $p<.001$), and among current and former smokers than never-smokers (90.1% and 91.3% vs. 72.6%, respectively, $p<.001$). Overall, however, 11.0% of youth did not know whether their e-cigarettes

contained nicotine; this was especially high in middle school students (23.2%).

With respect to marijuana vaping, 42.5% of youth overall reported vaping *any* marijuana in the past 30 days, and this was non-significantly higher among high school students than middle school students (43.9% vs. 35.1%, $p=.180$). *Any* marijuana vaping was more common among current and former smokers compared to never-smokers (62.9% and 47.6% vs. 34.1%, respectively, $p<.001$), as was vaping both marijuana and nicotine (58.7% and 45.2% vs. 26.8%, respectively, overall $p<.001$). Conversely, exclusively vaping marijuana and vaping neither nicotine nor marijuana were more common among never-smokers than current or former smokers (overall $p<.001$); however, frequencies were low and these results may be unreliable.

Frequent vapers were more likely than infrequent vapers to report *any* nicotine vaping (94.5% vs. 72.6%, respectively, $p<.001$) and any marijuana vaping (51.7% vs 36.8%, respectively, $p<.001$) in the past 30 days. Frequent vapers also had different patterns of nicotine and/or marijuana vaping than infrequent vapers (overall $p<.001$), with frequent vapers more often reporting having vaped *both* substances in the past 30 days (50.6% vs. 28.9%, respectively), and though estimates may be imprecise, correspondingly *less* often reporting exclusive marijuana vaping (3.3% vs. 0.2%) and something other than nicotine or marijuana (7.4% vs. 2.7%). Unlike MTF, rates of *exclusive* nicotine vaping were similar for frequent and infrequent vapers; however, frequent vapers were also more likely to respond “don’t know” regarding past-30-day nicotine vaping.

Table 2. Proportion of past 30-day vapers who report that their vaping products contained any nicotine and/or any marijuana, National Youth Tobacco Survey 2021

		Nicotine, no marijuana ¹	Both nicotine and marijuana ¹	Marijuana ¹ , no nicotine	Neither nicotine nor marijuana ¹	p-value	Nicotine vaping subtotal ²	p-value	Marijuana ¹ vaping subtotal ³	p-value	“Don’t know” nicotine vaping	“Don’t know” marijuana ¹ vaping
Overall		42.2% (N=486)	37.2% (N=419)	2.1% (N=24)	5.6% (N=60)	-	81.2% (N=1121)	-	42.5% (N=484)	-	11.0% (N=165)	2.2% (N=31)
By grade	Middle	29.9% (N=84)	27.7% (N=66)	2.9% (N=5)	12.1% (N=24)	<.001	62.7% (N=199)	<.001	35.1% (N=81)	.180	23.2% (N=64)	3.7% (N=10)
	High	44.3% (N=399)	39.0% (N=350)	2.0% (N=19)	4.4% (N=36)		84.6% (N=914)		43.9% (N=399)		8.7% (N=99)	2.0% (N=21)
By smoking status	Never	43.9% (N=270)	26.8% (N=169)	2.7% (N=16)	7.9% (N=48)	<.001	72.6% (N=525)	<.001	34.1% (N=213)	<.001	16.7% (N=120)	3.1% (N=23)
	Former	45.2% (N=156)	45.2% (N=144)	1.4% (N=3)	2.1% (N=9)		91.3% (N=359)		47.6% (N=152)		5.3% (N=20)	1.0% (N=3)
	Current	30.1% (N=57)	58.7% (N=103)	1.2% (N=5)	2.8% (N=2)		90.1% (N=192)		62.9% (N=116)		5.9% (N=21)	1.6% (N=5)
By vaping frequency⁴	Infrequent	42.0% (N=305)	28.9% (N=204)	3.3% (N=22)	7.4% (N=50)	<.001	72.6% (N=620)	<.001	36.8% (N=260)	.001	16.1% (N=145)	2.6% (N=24)
	Frequent	42.5% (N=181)	50.6% (N=215)	0.2% (N=2)	2.7% (N=10)		94.5% (N=493)		51.7% (N=224)		3.1% (N=20)	1.6% (N=7)

¹ Marijuana use is derived from 3 NYTS questions, and coded as “yes” (to any question), “no” (to all 3 questions), and “don’t know” (to all 3 questions).

² Subtotal of (nicotine, no marijuana) + (both nicotine and marijuana)

³ Subtotal of (marijuana, no nicotine) + (both nicotine and marijuana)

⁴ Frequent vaping: vaping on 20+ out of the past 30 days

Gray cells: N<50; may be unreliable.

Discussion

These analyses show that a non-negligible proportion of adolescents reporting vaping in the past 30 days (approximately 15–19% across surveys) indicate that their vaping products exclusively contain substances other than nicotine. Across the national surveys examined here, 2.1%–10.8% reported vaping marijuana (but not nicotine), and 3.8%–5.6% reported vaping neither substance. Additionally, there was a large degree of overlap between marijuana and nicotine vaping: approximately 35% of vapers reported vaping both nicotine and marijuana in the past 30 days. A notable proportion number of youth were uncertain about which substance(s) they vaped, according to NYTS. Thus, there is ambiguity in national youth surveys regarding which specific substances youth are vaping.

The imprecision in measuring substance-specific vaping leads to four major problems. First, it leads to incorrect prevalence estimates, especially considering that official reports of these national surveys often assume or present all vaping as being of nicotine.^{[3][4][5]} MTF and NYTS, despite some differences in marijuana vaping prevalence that are likely due to survey differences in assessment, both show that 14.6%–18.8% of all e-cigarette use is reported to be of a substance other than nicotine. As a result, national survey estimates of nicotine vaping are likely lower than reported. For example, MTF 2020 reports an overall past-30-day prevalence of 21.9% of *any* vaping, but only 18.7% for *nicotine* vaping. CDC reports of NYTS 2021 report a 7.6% prevalence rate of past-30-day e-cigarette use (presenting it as nicotine use)^{[10][21]}. However, taking into account data on the specific substances vaped, these NYTS data suggest *an nicotine* vaping rate of 6.2% to 7.0% (conservatively counting “don’t know” responses as nicotine vaping) – an estimated 379,000 fewer past-30-day youth nicotine vapers. Similarly, the most recent YRBSS in 2019 estimates past-30-day vaping among high school students at 32.7%, but assuming a proportion of nicotine vaping in the range of NYTS and MTF would put this estimate closer to around 27%. As a result, these survey estimates likely *overestimate* nicotine vaping and *underestimate* marijuana vaping. A second problem of not precisely accessing substance-specific vaping is the failure to detect risky patterns of use, including risks specific to marijuana use. While marijuana use prevalence across all methods of delivery has remained stable since 2010, at about 15.3% in the past 30 days,^[22] vaping is an increasingly common method of delivery,^{[22][23]} rising from 24.8% of adolescent marijuana users in 2017 to 56.5% in 2020; it is not clear whether potential under-detection of marijuana vaping impacts these trends. Adolescents who heavily use marijuana reportedly experience deficits in attention, learning, and processing speed, as well as sleep impairments and minor abnormalities in brain structure.^[11] These symptoms often resolve with abstinence. Marijuana use is also associated with psychiatric risks of depression and psychotic disorders^[12] as well as suicide ideation and attempts.^[13] With respect to physical health risks, adolescents who vape marijuana have significantly higher rates of respiratory symptoms indicative of lung injury than do adolescents who vape nicotine or smoke cigarettes,^[24] though the causality is unclear. Although the EVALI outbreak has subsided after identifying the cause (vitamin E acetate in illicit marijuana vapes), marijuana vaping remains unregulated^[25], in contrast to nicotine e-cigarettes. There is also recent evidence of racial-ethnic disparities in marijuana vaping^[26] that can inform public health prevention efforts.

Additionally, there may be unique risks associated with co-use of marijuana and nicotine.^[27] Consistent with previous research that risky behaviors are correlated with each other^{[28][29][30]}, vaping both nicotine and marijuana may be a risky pattern of vaping, as the current findings show this to be more common among current and former cigarette smokers, as well as among frequent vapers. Thus, these upward trends in adolescent marijuana vaping along with its potential risks

(alone and in co-use with nicotine) underscore the need for accurate surveillance of marijuana vaping.

A third problem with imprecise definitions of vaping is introducing complications in current understanding of youth nicotine use patterns. In particular, (nicotine) e-cigarettes have been postulated to be a “gateway” to nicotine use among youth to combustible cigarette smoking.^{[31][32]} Though studies supporting the “gateway” hypothesis have been criticized for inadequate adjustment for confounding^{[28][33]} and inconsistency with larger-than-expected declines in smoking prevalence after e-cigarettes became popular,^{[34][35]} accuracy in measuring nicotine use is another likely limitation of “gateway” studies. For example, the PATH study, on which several longitudinal analyses are based, contains similar uncertainty in the provided definition of “electronic nicotine product” which allows for vaping of substances other than nicotine. Central to the “gateway” hypothesis is that nicotine exposure is often cited as a mechanism for later initiating cigarette smoking, but including non-nicotine vaping in the “exposure” introduces confusion into the analysis that biases the results in an unknown way. For example, reported “gateway” effects could include upward biases (if marijuana vapers are more likely to also smoke cigarettes due to common liability)^[36] as well as downward biases (as non-nicotine vaping dilutes the effect, all else being equal).

Finally, the distinction between marijuana vaping and nicotine vaping also has direct relevance to policy. Nicotine and marijuana are regulated independently of each other in the US. Recent US legislation increased the age of e-cigarette to 21 (T21), and individual states and localities have passed additional restrictions on flavors^{[37][38][39]} or even banned the sale of e-cigarettes altogether.^[40] Policies targeting flavored nicotine e-cigarettes were motivated based on the national survey results reported here, which are interpreted as nicotine vaping^[41]. As restrictions on nicotine tighten, marijuana restrictions are loosening, with recreational marijuana now being legal for adult consumption in 18 states and District of Columbia, which could increase availability for youth.^[42] The EVALI outbreak demonstrates the mismatch between the public health response (cautioning against nicotine e-cigarettes) and the underlying cause (additive to illicit marijuana vape liquid). Thus, even a stringent and maximally effective policy targeting nicotine vaping could not have prevented or reduced EVALI cases. It is essential to accurately understand the nature and scope of vaping behavior in order to design effective policies for reducing youth use.

Limitations

MTF and NYTS data are limited by self-report and by questionnaire design. Self-reported vaping may be underreported, particularly for illicit behaviors (e.g. marijuana, and underage nicotine use). Adolescents may also not know what substances they are vaping,^[43] as implied by the substantial percentage of youth in NYTS 2021 who did not know whether their vapes contained nicotine. Moreover, the MTF questionnaire design did not allow evaluation of “don’t know” responses; based on NYTS, the “don’t know” responses could be approximately as common as reports of non-nicotine vaping. This uncertainty may further limit the accuracy of self-report. Moreover, previous research reported that 40% of youth who report no use of nicotine products, have cotinine above the threshold indicating nicotine use^[44]. Additionally, other vaping substances such as alcohol^[45], MDMA, cocaine, mephedrone^[46], or essential oils^[47], etc. are not assessed in these surveys, but may be occurring in youth. Finally, youth vaping trends continue to change over time –

especially during the COVID-19 pandemic which impacted both MTF 2020 and NYTS 2021 methodology and may have impacted substance use trends; thus this topic warrants ongoing monitoring.

Conclusion

Youth vaping as assessed in several national US surveys is often reported as if it is exclusively nicotine vaping; however, vaping of other substances is common among adolescent past-month vapers. Marijuana vaping in particular is reported by up to 45% of past-month vapers, and 14.6%–18.8% of past-month vapers are not vaping nicotine at all. As vaping behaviors diversify, survey questionnaires should add or keep detailed questions on the substances being vaped.^[48] Nicotine vaping and marijuana vaping convey different sets of risks and are governed by different regulatory frameworks, and as such should be separately and carefully assessed to avoid confusion in measurement. Accurate surveillance of these separate behaviors is necessary in order to develop effective prevention efforts.

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