



The national prevalence of adolescent nicotine use in 2017: Estimates taking into account student reports of substances vaped[☆]



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ABSTRACT

Introduction: This study presents the first nationally-representative estimates of adolescent nicotine prevalence that take into account adolescent reports of substances vaped. These reports allow nicotine estimates that consider the impact of the newly-emerged group of adolescents who report vaping only non-nicotine substances such as flavoring and/or marijuana and do not use nicotine in any form – a group typically treated as nicotine users.

Methods: Data come from Monitoring the Future and are a randomly-selected subsample of 2231 U.S. 12th grade students who answered surveys with detailed questions on tobacco use and vaping in 2017.

Results: Among 12th grade students 24.7% used nicotine in the last 30 days. This estimate does not include the 3.8% of students who vaped only non-nicotine substances and did not use nicotine in any other form. These students more closely resemble their peers who do not use nicotine than those who do, in terms of perceived risk and disapproval of cigarettes, as well as percentage of friends who use cigarettes.

Conclusions: A decline in nicotine prevalence was statistically significant, but not strikingly large, after taking into account students who vape non-nicotine substances and do not use nicotine in any form. These students are largely similar to their peers who do not use nicotine, which underscores the importance of efforts to alert youth that they may be vaping nicotine unknowingly, and prevent them from doing so.

1. Introduction

Vaping presents new challenges in assessing the prevalence of nicotine use among adolescents. As cigarette prevalence has steadily and dramatically declined over the past two decades (Miech et al., 2018), one concern is that adolescents may switch to alternative tobacco products and/or vape nicotine, and thereby substitute one form of nicotine for another. Vaping is unique from alternative tobacco products because it is possible for adolescents to vape non-nicotine substances, and consequently use of a vaping device may not necessarily indicate nicotine use.

To our knowledge this is the first national study to estimate adolescent nicotine use that takes into account 12th grade student reports of what substances they are vaping. To date, national estimates assume that all vaping is an indicator of nicotine use (Jamal, 2017). In this study we ask whether estimated adolescent nicotine use diminishes – and if so by how much – when we omit from the numerator the group of youth who report both vaping only non-nicotine e-liquids and also report no use of any tobacco products.

2. Background

“Vapers” use a battery-powered device with a heating element and inhale an aerosol that it produces. Typically, these devices heat a liquid, referred to as an e-liquid. The e-liquid often contains nicotine, which the device converts into an aerosol form that the user inhales. The e-liquids for these devices come in a large variety of flavors that can appeal to youth, such as bubble gum and chocolate cream. Today the market contains dozens of vaping devices, including e-cigarettes, “mods,” and “pod-mods” (which include the brand name JUUL).

Vaping may now account for a substantial percentage of adolescent nicotine use because vaping prevalence has increased rapidly to one of the most common forms of adolescent substance use. As of 2015 16% of 12th grade students in the United States reported that they had vaped a substance in the past 30 days, and prevalence has hovered around that level since (Miech et al., 2018). Vaping now ranks behind only alcohol and marijuana use in prevalence among 12th grade students (Miech et al., 2018). This marks a rapid change from a near-zero prevalence of adolescent vaping as recently as 2011 (Arrazola, Singh, Corey, et al., 2015).

A major challenge to assessing vaping's contribution to nicotine prevalence is that it is possible for adolescents to vape and not use

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nicotine. More than 80% of all vaping brands offer versions of their e-liquids advertised as 0% nicotine (Zhu, Sun, Bonnevie, et al., 2014). It is possible a group of youth may vape non-nicotine substances (such as flavoring or marijuana) and not use any tobacco products, and therefore not use nicotine.

Nicotine use among adolescents may consequently be overestimated when using the current assumption that all vaping indicates nicotine use. Under this assumption youth would be incorrectly considered nicotine users if they both (a) vape non-nicotine substances and (b) do not use any tobacco products. An accurate nicotine prevalence estimate would not include this group among nicotine users.

This potential for overestimation has increased as advances in technology and cultural changes increase the opportunities for adolescents to vape non-nicotine substances and avoid use of tobacco and other nicotine-containing products. Today a much wider array of vaping devices and non-nicotine vaping substances are available to adolescents than in the past decade, when e-cigarettes with nicotine were essentially the only vaping devices available. As more opportunities to vape non-nicotine have proliferated, adolescent tobacco use has continued its long, two-decade decline. Taken together, these two trends make possible the growing emergence of a group of adolescents who share the general negative attitudes toward tobacco held by non-tobacco users, and see vaping non-nicotine as a form of substance use consistent with these negative beliefs.

To our knowledge this study contributes the first national estimates of adolescent nicotine prevalence that take into account adolescent reports of the substances they are vaping. Two hypotheses guide the analysis:

Hypothesis 1. Nicotine prevalence estimates will be significantly lower in analyses that do not consider as nicotine users adolescents who vape only non-nicotine substances and do not use nicotine.

Hypothesis 2. Adolescents who vape only non-nicotine substances and do not use nicotine will have tobacco attitudes and behaviors that more closely resemble their peers who do not use nicotine than their peers who do.

3. Methods

Analyses used data from the 2017 Monitoring the Future (MTF) study, which is a nationally representative cross-sectional sample of 12th grade students in the coterminous U.S. A University of Michigan Institutional Review Board approved the study (Bachman, Johnston, O'Malley, Schulenberg, & Miech, 2015). Personnel from the University of Michigan administered the surveys in classrooms, and students self-completed questionnaires during a normal class period. A total of 13,522 12th grade students (response rate 79%) responded in 2017. MTF uses six randomly-distributed questionnaire forms that consist of core and form-specific questions. Questions for the current study were available on one of the six forms, which 2252 students completed. Of these, 2231 (99.1%) answered one or more of the vaping- or tobacco-related attitude/behavior outcomes included in the current study.

All survey questions on vaping in the past 30 days were prefaced with the introduction: "To 'vape' is to use a device such as a vape-pen, an e-cigarette, an e-hookah, or e-vaporizer to inhale a mist or vapor into the lungs." Separate questions then followed worded as, "On how many occasions (if any) have you vaped [substance] during the last 30 days?" with the substance wording specifying (a) "NICOTINE"; (b) "MARIJUANA"; and (c) "just FLAVORING, without any nicotine or marijuana in it." Response options for each question were "0", "1-2", "3-5", "6-9", "10-19", "20-30", "40+." **Vape nicotine** is coded 1 for respondents who reported vaping nicotine on 1 or more occasions and 0 if they report no occasions. **Vape any substance** is coded 1 for respondents who report vaping either nicotine, marijuana, or 'just flavoring,' and coded 0 for respondents who did not report vaping any of these

substances.

Questions on tobacco assessed use of six products. **Smoke cigarettes** were based on the question "How frequently have you smoked cigarettes during the past 30 days?" and coded "0" for the response of "Not at all" and 1 for responses of "Less than one cigarette per day", "One to five cigarettes per day", "About one-half pack per day", "About one pack per day", "About one and one-half packs per day", and "Two packs or more per day." Use of five additional products was measured with separate questions that used the shared question stem, "During the LAST 30 DAYS, on how many days (if any) have you [behavior]?" with the following behaviors listed: (a) "smoked large cigars"; (b) "smoked flavored little cigars or cigarillos"; (c) "smoked regular little cigars or cigarillos"; (d) "smoked tobacco using a hookah (water pipe)"; (e) "used smokeless tobacco". Responses included "none", "1-2", "3-5", "6-9", "10-19", or "20-30." Three dichotomous measures of 0 vs. 1 (any use) were coded: **smoke large cigars, small cigars, and/or cigarillos; use smokeless tobacco; and smoke hookah.**

Any nicotine use or nicotine vaping is coded 1 for respondents who reported past 30-day use of any of these tobacco products and/or nicotine vaping, and 0 otherwise. **Any nicotine use or vaping any substance** is coded 1 for respondents who reported past 30-day use of any of these tobacco products and/or vaping of nicotine, marijuana, or flavoring, and coded 0 otherwise. **Vape only non-nicotine, no other tobacco products** is coded 1 for respondents who do not report 30-day use of any tobacco product but do report vaping a substance other than nicotine, and coded 0 otherwise. **No vaping or tobacco use** is coded 1 for respondents who report no past 30-day vaping of any substance and also no use of any of the tobacco products listed above, and coded 0 otherwise.

Also included in the analyses are questions on perceived harm of cigarette use (perceive "great risk" in smoking one or more packs per day vs. no/slight/moderate risk), disapproval of cigarette use (disapprove/strongly disapprove of smoking one or more packs per day vs. don't disapprove), perceived e-cigarette risk (perceive "great risk" in using electronic cigarettes regularly vs. no/slight/moderate risk), friends' cigarette use (most/all friends smoke cigarettes vs. none/a few/some), and lifetime cigarette use (ever smoked cigarettes vs. never).

4. Statistical analyses

All analyses used SAS v9.4 and took into account the complex sample design, including sample weights and clustering of respondents in primary sampling units and strata. The analyses used the SURVEYMEANS procedure to estimate prevalence with 95% confidence intervals, as well as SURVEYLOGISTIC models to test differences across vaping/tobacco use groups in tobacco attitudes and behaviors. To address missing data the analyses used fully conditional specification multiple imputation (Berglund & Heeringa, 2014; Heeringa, West, & Berglund, 2010; Enders, Keller, & Levy, 2018) (MI) and created a total of 15 imputed data sets. The MIANALYZE procedure combined the results of analyses from the imputed data sets, and took into account the complex sample design by using sampling weights and adjusting variance for clustering (Berglund & Heeringa, 2014; Heeringa et al., 2010). Analytic models with imputed datasets were limited to cases with no missing data on the outcome variables of this study.

5. Results

Table 1 shows that the estimated prevalence of nicotine use was lower when student reports of the substances they vaped were taken into account. Specifically, the estimate of adolescent overall nicotine prevalence in the past 30 days was 28.4% when the definition of nicotine use included any vaping, regardless of substance. The estimate decreased to 24.7% when the definition of nicotine use omitted non-nicotine users who vaped non-nicotine substances, a group that is 3.8% of the 12th grade population. The difference between the two nicotine

Table 1
Past 30-day vaping and tobacco prevalence among U.S. 12th grade students, 2017 (95% confidence intervals in parentheses), n = 2231.

	30-Day prevalence
Estimates of total nicotine use	
Any nicotine use or nicotine vaping	24.7 (21.8–27.5)
Any nicotine use or vaping any substance	28.4 (25.5–31.4)
Type of user	
Vape only non-nicotine, no other tobacco products	3.8 (2.8–4.8)
No vaping or tobacco use	71.6 (68.6–74.5)
Specific product	
Vape any substance ^a	19.0 (16.2–21.8)
Vape nicotine	12.7 (10.4–15.0)
Smoke cigarettes	9.6 (7.8–11.5)
Smoke large cigars, small cigars, and/or cigarillos	13.0 (10.9–15.1)
Use smokeless tobacco	4.7 (3.2–6.2)
Smoke hookah	6.2 (4.4–8.0)

Note: Due to rounding, the size of the non-nicotine user group that vapes is 3.8% when estimated alone and 3.7% when calculated as the difference between the two overall nicotine use estimates (28.4–24.7 = 3.7).

^a This measure indicates vaping of nicotine, ‘just flavoring’, and/or marijuana.

prevalence estimates is statistically significant (p < .01).

Table 2 compares tobacco-related attitudes and behaviors for non-nicotine users who vape as compared to those who do not vape, as well as to nicotine users. Among non-nicotine users, those who vape are similar to those who do not on most tobacco-related attitudes and behaviors considered. These two groups differ little, never more than an absolute 6%, in their levels of perceived risk of cigarette use, disapproval of cigarette use, and percentage of friends who use cigarettes. While the vapers are significantly more likely than the non-vapers to have ever smoked a cigarette, with prevalence levels of 28% and 13%, respectively, these levels are closer to each other than they are to the level for nicotine users, which is 66%.

The one exception to the close similarity between the two groups of non-nicotine users who vape and those who do not is for the outcome of

Table 2
Comparison of cigarette and vaping attitudes/beliefs across three groups, 2017.

	Non-nicotine users		Nicotine users
	Vapes only non-nicotine, and does not use any tobacco product	Does not vape or use any tobacco product	Vapes nicotine, and/or uses any tobacco product
% of total sample	3.8%	71.6%	24.7%
Great risk in cigarette use	78.4 (67.0–89.8)	83.8 (81.3–86.3)	72.2 ^b (66.5–77.8)
Disapprove of cigarette use	81.1 (69.7–92.5)	84.2 (81.8–86.5)	69.6 ^b (63.2–76.0)
Great risk in e-cigarette use	9.5 (2.6–16.4)	20.9 ^a (18.4–23.4)	9.1 ^b (6.1–12.1)
Friends use cigarettes	5.0 (0–10.9)	2.8 (1.8–3.8)	19.1 ^{a,b} (14.4–23.7)
Ever smoked a cigarette	28.4 (16.6–40.1)	13.4 ^a (11.2–15.5)	65.8 ^{a,b} (60.4–71.3)

^a Estimate significantly differs from first column, p < .05.

^b Estimate significantly differs from second column, p < .05.

perceived risk for e-cigarette use. Among vapers 10% see great risk in regular e-cigarette use, as compared to 21% for non-vapers. The level of 10% for non-nicotine vapers is very close to the 9% levels for nicotine users.

Youth who use nicotine stand out from the two groups of non-nicotine users on most outcomes considered. Nicotine users were at least two times more likely to have smoked a cigarette, at least three more times as likely to have friends who use cigarettes, and 17% less likely to disapprove of cigarette use.

6. Discussion

A substantial portion of youth report that they vape non-nicotine substances, such as flavoring or marijuana. Of these youth, some also do not use nicotine in any other tobacco products. This study is one of the first to examine the influence of this group on estimates of overall nicotine prevalence among adolescents. Surveys that do not ask about substances vaped do not have the capability to consider this group’s potential influence.

The results support Hypothesis 1: estimates of adolescent nicotine use significantly declined when taking into account the group of youth who report vaping only non-nicotine substances and also do not use tobacco products. While the decline was statistically significant, it was not particularly large. The prevalence estimate declined from 28.5% to 24.7%, a relative difference of 15%.

We interpret the size of this decline to be an upper bound, and the real decline is likely smaller because some youth who report that they are not vaping nicotine may actually be doing so unknowingly. Many adolescents report that they do not know the nicotine contents of the substances they vape (Morean, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2016; Pepper, Farrelly, & Watson, 2018). This issue is particularly salient for younger adolescents, who often rely on older friends for vaping devices and e-liquids, and may have little knowledge about the substances they are using (Alexander, 2017). While the question used in this study explicitly asks 12th grade students if they vaped flavoring “without any nicotine in it,” a portion may mark this response not knowing that they are actually vaping nicotine. If these youth had correctly answered that they vaped nicotine then the difference between the two estimates of nicotine vaping would be smaller.

A relative decline in adolescent nicotine prevalence of 15%, or smaller, suggests that the practice of treating all vaping as indicative of nicotine use does not have a major impact on current, national estimates of adolescent nicotine prevalence. Part of the reason why the decline is not larger is that many youth who report vaping non-nicotine also report using nicotine in other ways, either through the use of combustible tobacco (like cigarettes, cigars, etc.), vaping nicotine in addition to non-nicotine substances, or alternative tobacco products (like hookah or smokeless tobacco). While 19% of the 2017 12th grade class reported any vaping in the last 30 days, 79% of these vapers either vaped nicotine or used nicotine in some other way given that only 4% of the 12th grade class reported both vaping and no use of nicotine (79% = (19–4)/(19)). While the decline in overall adolescent nicotine prevalence that results from excluding non-nicotine vapers is currently small, nevertheless it warrants tracking in the future because it could potentially grow larger if more youth both take up vaping non-nicotine and also do not use other tobacco products.

The results also support Hypothesis 2 and indicate that the group of adolescents who vape non-nicotine substances and do not use nicotine are more similar to their peers who do not use nicotine than their peers who do. Among non-nicotine users, vapers and non-vapers share similar levels of perceived risk of cigarette use, disapproval of cigarette use, and both have few friends who use cigarettes. Taken as a whole, these two groups appear more similar to each other than they are to their peers who use nicotine.

A substantial group of youth believe they are not vaping nicotine or using nicotine in any other way, and this group holds unfavorable views

of tobacco use. It would be particularly unfortunate if this group unknowingly used nicotine and developed a nicotine addiction. One theoretical benefit of vaping is that it could potentially provide an opportunity for smoking-curious youth to experiment with smoking without exposing themselves to the dangers of nicotine. This benefit would be undermined if vaping as a diversion from smoking became an unintended portal into it. Strict regulation and labelling of e-liquids, as well as educational outreach to adolescents, may be necessary to prevent unknowing recruits to nicotine use. As a case in point, the majority of youth who use the new JUUL vaping devices did not know that the cartridges sold for this device always contain nicotine (Willett, Bennett, Hair, et al., 2018).

7. Limitations

We note three limitations of this study. First and foremost, the study does not collect or chemically analyze the substances that adolescents are vaping. Such information would fill a key gap in the field by identifying what percentage of youth are vaping nicotine unknowingly, and how much nicotine they are ingesting. While collecting e-liquids from a representative population would likely be expensive and complicated, at the same time the scientific contribution would be substantial and potentially transformative. Until such information is available, self-reports such as the ones used in this study provide the opportunity to assess the upper bound of the size and impact of the group of adolescents who do not use nicotine and vape.

A second limitation is the Monitoring the Future design excludes dropouts from high school. As a result, the size of the tobacco use group in the sample is slightly smaller than it would be for the entire population of adolescents who are the age of 12th grade students. We know that that cigarette smoking levels are substantially higher among high school dropouts, based on analyses of the National Survey on Drug Use and Health, which includes high school dropouts in its sampling frame (Tice, Lipari, & Van Horn, 2017). The impact of the heightened smoking levels of high school dropouts is attenuated by the small size of this group, which currently is about 7% of the 12th grade class (Snyder, de Brey, & Dillow, 2016).

A third limitation is that the survey did not ask about forms of tobacco use that are extremely rare among adolescents, such as bidis or pipe tobacco (Jamal, 2017). We expect that exclusion of information about these products has little effect on the results of this study, because youth who use these forms of tobacco are likely to use another form as well and therefore be correctly classified as a nicotine user in the study analyses.

8. Conclusion

A maximum of about 4% of the U.S. 12th grade population vape and do not use any form of nicotine, or at least believe they do not use

nicotine. Currently the small size of this group prevents it from having a substantial impact on national nicotine prevalence estimates that are corrected to classify this group as non-nicotine users. As a whole this group of students more closely resembles their peers who do not use nicotine than their peers who do in terms of tobacco attitudes and behavior. Regulation and education efforts are needed to ensure that this group does not unknowingly vape nicotine, and the need for these efforts will grow per any increases in the group's size.

Conflict of interest statement

All authors declare that they have conflicts of interest.

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