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Co-substance use of nicotine vaping and non-cigarette tobacco products among U.S. grade 12 students from 2017–2019

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Abstract

Background: Nicotine vaping among U.S. adolescents has risen rapidly over the past decade, particularly for youth in grade 12. While previous studies examined the relationship between nicotine vaping and combustible cigarette use, less is known about the co-occurrence between vaping and other tobacco products.

Methods: Using Monitoring the Future grade 12 data (2017–2019), we investigated associations between past 30-day nicotine vaping and non-vaping, non-cigarette tobacco use (smokeless tobacco, large cigars, cigarillos, hookah). Population prevalences of four categories were assessed: neither, vaping only, non-vaping of non-cigarette tobacco only, or both. We further investigated these relationships with logistic regressions accounting for the complex survey design (unadjusted, demographic-adjusted, and further adjusted for other substance use). Finally, analyses were stratified by combustible cigarette use.

Results: Depending on the non-cigarette tobacco product, 2.5% to 5.4% of grade 12 students vaped nicotine and used a non-cigarette tobacco product. Controlling for demographics, cigarillo use was associated with nicotine vaping (adjusted RR = 3.44, 95% CI: 3.08, 3.84), as was hookah

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Contributors

Kreski and Keyes conceived of the initial study, conducted analyses, and collaboratively created the initial draft; All remaining authors provided substantial feedback and assistance with the revision and expansion of subsequent drafts.

Declaration of Competing Interest

Authors have no interests to declare.

use (aRR = 3.51, 95% CI: 2.92, 4.23), smokeless tobacco (aRR = 2.97, 95% CI: 2.51, 3.52), and cigar use (aRR = 2.90, 95% CI: 2.49, 3.37). Controlling for cannabis and all non-cigarette tobacco products simultaneously attenuated associations. Associations were stronger among students who did not use cigarettes.

Discussion: Nicotine vaping is associated with use of many non-cigarette tobacco products, including smokeless tobacco, cigarillos, cigars, and hookah. As prevalence of nicotine vaping remains high among adolescents, we should monitor co-use of vaping and other tobacco products.

Keywords

Vaping; Tobacco; Adolescents; Smoking; Nicotine

1. Introduction

Nicotine vaping is the most common mode of nicotine administration among US adolescents in grade 12 (Miech et al., 2019). As of 2020, one in five 12th grade students vaped nicotine in the past 30 days (Miech et al., 2021), which is concerning due to evidence of toxicant and carcinogen exposure linked to e-cigarette use (Jenssen et al., 2019) as well as the potential development of current and future nicotine addiction.

However, the extent to which e-cigarette use is linked to broader patterns of nicotine or tobacco use among adolescents is not fully understood, especially for products such as hookah or smokeless tobacco that are alternatives to cigarettes. Prior literature suggests overlap of cigarette smoking and vaping among adolescents (Hamberger and Halpern-Felsher, 2020; Lanza et al., 2017; Soneji et al., 2017), as well as overlap between cigarettes and hookah, smokeless tobacco, and other non-cigarette tobacco administration methods (Agaku et al., 2013; Kader et al., 2019; Kong et al., 2019). However, associations between nicotine vaping and these non-cigarette products are relatively unexamined, particularly among adolescents who are especially vulnerable to the harmful effects of these products. Non-cigarette tobacco products have been linked to numerous health consequences, including oral and respiratory cancers (Chang et al., 2015; Cullen et al., 1986; Pratiti and Mukherjee, 2019), cardiovascular disease ((US), 1998; Cullen et al., 1986; Rezk-Hanna and Benowitz, 2019), and chronic obstructive pulmonary disease ((US), 1998; Pratiti and Mukherjee, 2019).

Considering only the associations between vaped nicotine and combustible cigarettes underestimates the total burden of the co-occurrence of nicotine and tobacco products. If nicotine and tobacco administration methods and products like hookah and smokeless tobacco co-occur with vaping, then clinicians and researchers developing cessation interventions need that information to guide the creation of comprehensive programs that account for all relevant forms of substance use. Additionally, prevention efforts can benefit from these findings to better understand risk factors for vaping and to target young people at elevated risk for vaping and other forms of nicotine administration.

The aim of this study was to examine the associations between nicotine vaping and non-cigarette modes of tobacco and nicotine administration (smokeless tobacco, hookah,

cigarillos and cigars) in a large, nationally representative adolescent sample. We aimed to examine these links overall and stratified by cigarette use in order to explore whether these relationships differed between those who do and do not smoke cigarettes; given that cigarette and non-cigarette forms of nicotine and tobacco use often co-occur, we wanted to determine the extent to which non-cigarette forms of tobacco use are linked to vaping among adolescents independently of cigarette use.

2. Methods

Monitoring the Future includes an annual survey of school-attending adolescents. This survey is nationally representative and relies on self-reported data, with topics including vaping and tobacco products. We included data from grade 12 as the survey of this grade level included multiple years of data querying both nicotine vaping and other tobacco products. Monitoring the Future was approved through the Institutional Review Board of University of Michigan (Johnston et al., 2020). We included data from 2017 to 2019 given the consistency of vaping questions across the time frame. Survey questions were randomly distributed among different subsets of the overall grade 12 survey population through different versions of the survey known as subforms. Consequently, these analyses focus on the subform for 12th grade students that included questions on both nicotine vaping and use of one of the four tobacco products. Only one of the six subforms in grade 12 met these criteria, meaning that approximately a sixth of the full sample was included in our analyses. The resulting sample size was approximately 5,600 total adolescents for each of the four samples. Further detail on the study design and questionnaire instrument can be found elsewhere (Bachman et al., 2015).

2.1. Measures

In 2017 and 2018, the nicotine vaping item read as follows: “On how many occasions (if any) have you vaped nicotine during the last 30 days?” In 2019, the item was: “On how many days (if any) have you vaped nicotine during the last 30 days?” These items were dichotomized as “Any” vs “None” and combined into an overall nicotine vaping item.

Cigar smoking was assessed as follows: “During the last 30 days, on how many days (if any) have you smoked large cigars?” Hookah use was assessed as follows: “During the last 30 days, on how many days (if any) have you smoked tobacco using a hookah (water pipe)?” Smokeless tobacco use was assessed as follows: “During the last 30 days, on how many days (if any) have you used smokeless tobacco?” All of these were dichotomized into “Any” vs “None”. Cigarillo use was operationalized using two items: “During the last 30 days, on how many days (if any) have you smoked regular little cigars or cigarillos?” and “During the last 30 days, on how many days (if any) have you smoked flavored little cigars or cigarillos?” Overall past 30-day cigarillo use was considered positive if either were used.

Cigarette smoking was examined as follows: “How frequently have you smoked cigarettes during the past 30 days?” (“Any” vs “None”). Cannabis use, examined as a potential confounder, was assessed as follows: “On how many occasions (if any) have you used marijuana (grass, pot) or hashish (hash, hash oil) during the last 30 days?” (“Any” vs “None”)

Demographics included sex (male/female), race/ethnicity (white, Black, Hispanic/Latino, Multiracial, Asian/Pacific Islander, and American Indian/Alaskan Native), parental education (at least one parent with a college degree vs none) and urbanicity (urban, suburban, rural).

2.2. Analyses

For each of our four non-vaping, non-cigarette tobacco administration methods (cigars, cigarillos, hookah, and smokeless tobacco), we examined population prevalences of four mutually exclusive categories: using neither method, vaping only, non-vaping non-cigarette tobacco method only, or both. Further analyses used survey-weighted logistic regressions to assess the associations between nicotine vaping and the tobacco administration methods (unadjusted [Model 1], adjusting for demographics [Model 2], and further adjusting for cannabis use and the remaining non-cigarette tobacco administration methods [Model 3]). We tested interactions between cigarette smoking and each of the four non-vaping tobacco administration methods predicting nicotine vaping to test for heterogeneity. Subsequent analyses stratified by cigarette smoking. Analyses were conducted in STATA 17.

3. Results

Fig. 1 shows the prevalence of tobacco use patterns for each tobacco product. Among those reporting any tobacco use, nicotine vaping was the most prevalent nicotine/tobacco product used. In the sample that was questioned about hookah use, for instance, 17.5% of students only vaped nicotine and did not use hookah. This was followed by 2.6% of adolescents who used both products, and 1.4% who only used hookah. Similar prevalences were reported among those questioned about smokeless tobacco use; 17.5% of adolescents only vaped nicotine, 2.5% used both products, and 1.3% just used smokeless tobacco. Among those asked about cigar use, 16.7% vaped nicotine only, 2.1% used cigars only, and 3.2% used both. Those asked about cigarillo use had the lowest prevalence for vaping-only (14.6%), and the highest prevalence for co-use, with 5.4% of students reporting use of both nicotine vapes and cigarillos. The prevalence of the group using neither product varied by analysis, ranging from 76.6% (cigarillo analysis) to 78.8% (smokeless tobacco analysis).

Nearly 66.8% of students who used smokeless tobacco also vaped nicotine (95% CI: 56.8, 76.8), compared with 18.1% of adolescents who did not use smokeless tobacco (95% CI: 15.9, 20.4). This high prevalence of co-use was consistent across tobacco products: 59.9% of students who reported cigar use also vaped (95% CI: 51.8, 67.9), and the rates of vaping for those using cigarillos or hookah were 61.3% (95% CI: 55.4, 67.2) and 64.6% (95% CI: 56.5, 72.7) respectively. This suggests that those using each tobacco product were more likely to be vaping than not.

Table 1 describes associations between the tobacco products and nicotine vaping, with unadjusted associations in Model 1, demographic adjustment in Model 2, and further substance use adjustment in Model 3. In Model 2, all four products were positively associated with vaping in the overall sample, ranging in magnitude from cigars (aRR: 2.90, 95% CI: 2.49, 3.37) to hookah (aRR: 3.51, 95% CI: 2.92, 4.23). However, associations were weaker in Model 3. Still, with the exception of cigars, all non-cigarette tobacco

administration methods were positively linked to nicotine vaping at all levels of adjustment ($p < .05$).

For those who do not smoke cigarettes, all four administration methods were associated with nicotine vaping, even after adjusting for demographic factors (Model 2: aRR range: 2.95 to 3.64). Conversely, adjusted associations between the administration methods and vaping were weaker for those who smoke cigarettes (Model 2: aRR range: 1.16 to 1.50). While adjustment for cannabis use and all non-cigarette tobacco administration methods simultaneously in Model 3 reduced these associations, associations were consistently larger among those who do not smoke cigarettes. Interactions between cigarette use and tobacco administration methods predicting vaping had p -values $< .001$, providing statistical evidence for the heterogeneity in the association between non-cigarette tobacco products and nicotine vaping by cigarette use.

4. Discussion

Smokeless tobacco, cigars, cigarillos, and hookah are positively associated with nicotine vaping. Our findings demonstrate that those using each product were more likely to be vaping than not. The strong associations between using these products and nicotine vaping persisted after adjustment for demographic factors and other forms of substance use, and were larger for participants who did not smoke combustible cigarettes. As vaped product use continues to be highly prevalent among US adolescents, this co-use could portend increased harm to the US adolescent population. This is of particular concern with cigarillos, which when used alone have a higher nicotine yield than combustible cigarettes, and had the highest rate of co-use with e-cigarettes in our study (Goel et al., 2018).

This study adds to the literature on nicotine vaping, which had previously focused primarily on the links between vaping and cigarette smoking. Indeed, meta-analytic estimates suggest an adjusted odds ratio of 2.93 (95% CI: 2.22, 3.87) between vaping and cigarette smoking (Chan et al., 2021). We demonstrate here that there are also strong connections between nicotine vaping and several other nicotine and tobacco administration methods and products. Given that co-use between vaping and tobacco may be driven by displacement (using one product to offset use in another) or differing social contexts (Berg et al., 2021), future cessation interventions will need to comprehensively examine and address different administration methods. Further, future longitudinal studies should assess the association between vaping and not only future cigarette use, but transition to non-cigarette products as well.

Future studies should examine the health consequences of vaping and non-cigarette tobacco product co-use, as this simultaneous use could potentially magnify health consequences. While previous studies have investigated the co-use phenomenon, much research in this area has been restricted to use of e-cigarettes and combustible cigarettes (Cooper et al., 2016; Kristjansson et al., 2015; McCabe et al., 2017). The sparse literature that does include additional forms of tobacco has largely been limited to associations between polytobacco use and mental health outcomes, such as substance use disorders (Cavazos-Rehg et al., 2014). Further longitudinal studies are needed to determine whether use of multiple non-

cigarette tobacco products is linked to increased risks of adverse outcomes including cancers and cardiovascular diseases.

The associations between non-cigarette tobacco products and vaping were stronger for students who did not use cigarettes. The reasons underlying these differences in the strength of association likely correspond to differences in underlying risk. Students who use cigarettes are already at increased risk of nicotine vaping; the addition of other forms of tobacco use continue to increase risk, but at a higher baseline rate than students who do not use cigarettes, leading to a smaller relative increase. In contrast, students who do not use cigarettes have lower baseline rates of vaped product use, leading to higher multiplicative increases in risk. In other words, among students who do not use cigarettes, use of hookah or smokeless tobacco and other tobacco products provide novel information on risk of vaping, whereas cigarette smoking already carries a significant increased association with vaping even in the absence of other tobacco products. Efforts to prevent or reduce vaping should query adolescents about their use of the broad array of non-cigarette tobacco products, because querying only cigarette use will underestimate risk.

There is a need for further studies with large, nationally-representative samples (such as the PATH data or similar longitudinal samples) to identify adolescents at higher risk for non-cigarette tobacco products. Recent evidence demonstrates, for example, that particular tobacco products are currently more prevalent among specific racial/ethnic groups, such as cigars/cigarillos among Black adolescents (Gentzke et al., 2020, 2019) and smokeless tobacco among Native American youth (Odani et al., 2018). Nationwide surveillance is needed to gain insight into these disparities to help target interventions.

Vaping interventions and prevention programs should address co-use with non-cigarette tobacco products and aim to help participants abstain from both types of products. These programs could be implemented in schools to target adolescents, and at the community level to reach a wide range of adults. Although interventions currently exist for specific products such as smokeless tobacco (Stevens et al., 1995; Walsh et al., 2003) and hookah (Leavens et al., 2018; Lipkus et al., 2011), these programs have been targeted at specific audiences (e.g. smokeless tobacco interventions for student athletes)(Walsh et al., 2003) and should be modified to address the increasing rate of polytobacco use among adolescents.

These data are nationally representative and thus generalizable to U.S. adolescents that currently attend school. Despite this, limitations should be considered. First, MTF data is cross-sectional, so directionality of associations cannot be established. Second, as stated in the methods, the analysis was restricted to grade 12 as it was the only grade level with multiple years of data examining both nicotine vaping and other tobacco products. Third, MTF is only administered to adolescents who are currently in school and therefore does not generalize to those who have voluntarily or involuntarily withdrawn from schooling, are homeschooled, or were absent on the day of survey administration.

5. Conclusion

Non-cigarette tobacco product use is positively associated with nicotine vaping among U.S. adolescents. This association is particularly pronounced for students who do not smoke combustible cigarettes. Given that nicotine vaping is now an endemic component of adolescent substance use, public health practitioners should continue to monitor the intersection between these products and develop interventions that comprehensively address the cessation of all types of nicotine products.

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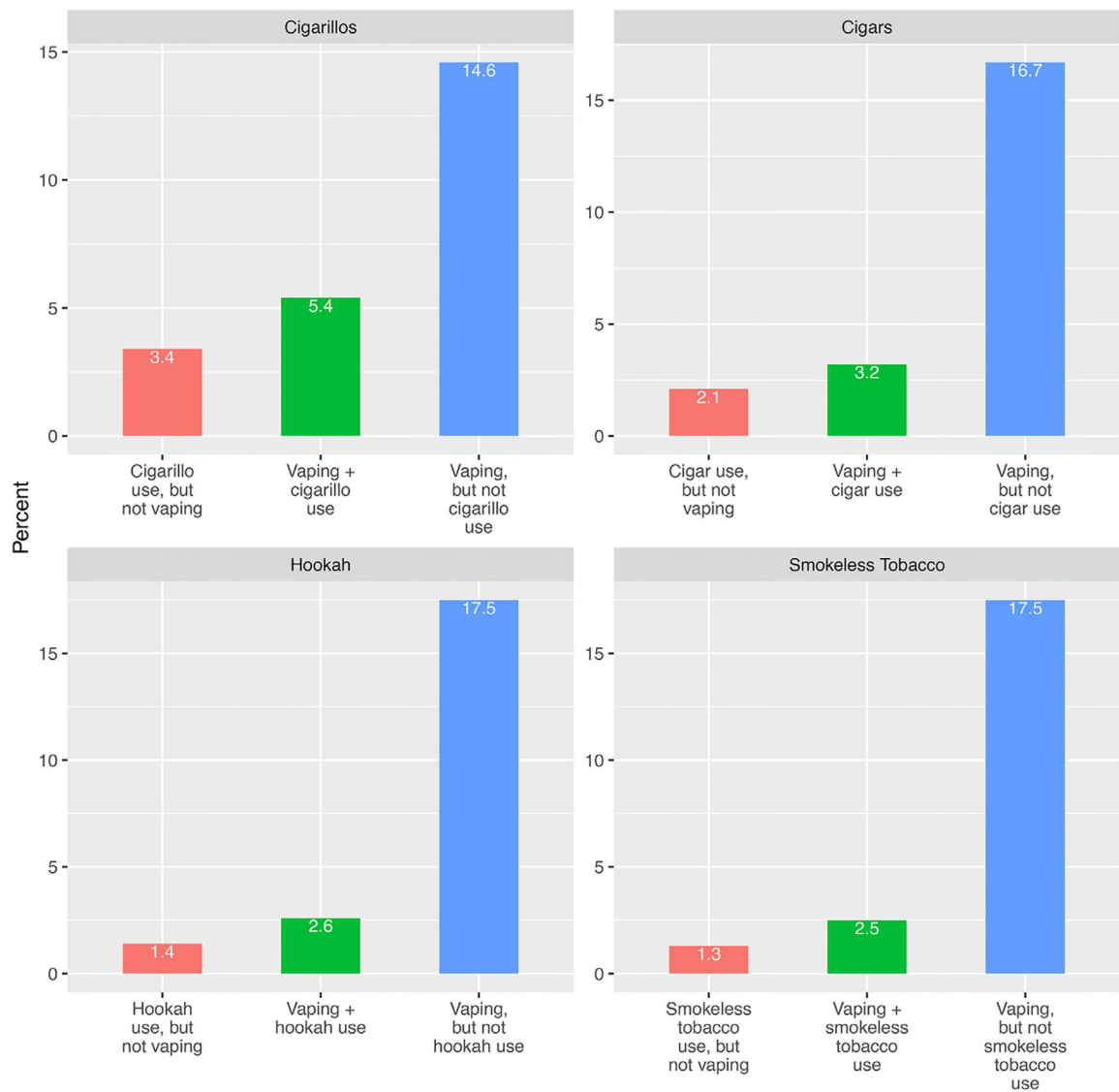
Data availability

MTF data are publicly available.

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**Fig. 1.**

The prevalence (%) of tobacco vaping, other tobacco product use, or both among US adolescents from 2017–2019 (Overall N range: 5,620 – 5,663 by analysis).

Table 1

Associations between Past 30-Day Tobacco Administration Methods and Vaping, MTF 2017–2019, Grade 12.

Past 30-day tobacco administration method predicting past 30-day vaping		Sample size for analysis*	Model 1 ⁺ [RR (95% CI)]	Model 2 ⁺⁺ [RR (95% CI)]	Model 3 ⁺⁺⁺ [RR (95% CI)]
Overall			RR (95% CI)	RR (95% CI)	RR (95% CI)
Smokeless Tobacco		5621	3.68 (3.11, 4.36)	2.97 (2.51, 3.52)	1.55 (1.26, 1.91)
Cigars		5663	3.39 (2.91, 3.94)	2.90 (2.49, 3.37)	1.15 (0.95, 1.40)
Cigarillos		5620	3.84 (3.42, 4.30)	3.44 (3.08, 3.84)	1.77 (1.49, 2.09)
Hookah		5641	3.55 (3.04, 4.15)	3.51 (2.92, 4.23)	1.53 (1.19, 1.96)
Students who use cigarettes ^{**}					
Smokeless Tobacco		395	1.38 (1.16, 1.64)	1.43 (1.17, 1.75)	1.31 (1.06, 1.63)
Cigars		397	1.11 (0.92, 1.35)	1.16 (0.93, 1.44)	0.98 (0.79, 1.21)
Cigarillos		395	1.22 (1.01, 1.48)	1.30 (1.06, 1.60)	1.13 (0.89, 1.44)
Hookah		397	1.43 (1.21, 1.67)	1.50 (1.23, 1.83)	1.34 (1.09, 1.66)
Students who do not use cigarettes					
Smokeless Tobacco		5138	3.86 (3.06, 4.87)	3.02 (2.41, 3.79)	1.77 (1.32, 2.38)
Cigars		5180	3.57 (2.89, 4.41)	2.95 (2.44, 3.58)	1.14 (0.86, 1.52)
Cigarillos		5138	4.03 (3.52, 4.62)	3.60 (3.17, 4.08)	1.80 (1.49, 2.18)
Hookah		5156	3.58 (2.84, 4.50)	3.64 (2.80, 4.69)	1.59 (1.12, 2.26)

* Sample sizes differ due to data missingness

^{**} All interactions between cigarette use and tobacco administration methods predicting nicotine vaping $p < .001$ ⁺ Unadjusted⁺⁺ Adjusted for sex, race/ethnicity, parental education, and urbanicity⁺⁺⁺ Adjusted for sex, race/ethnicity, parental education, urbanicity, cannabis use and remaining non-cigarette tobacco administration methods,