HHS Public Access

Author manuscript

J Adolesc Health. Author manuscript; available in PMC 2018 August 01.

Published in final edited form as:

J Adolesc Health. 2017 August ; 61(2): 155–162. doi:10.1016/j.jadohealth.2017.02.004.

E-cigarette use, cigarette smoking, dual use and problem behaviors among U.S. adolescents: Results from a national survey

Sean Esteban McCabe, Ph.D.[a], **Brady West, Ph.D.**[b], **Phil Veliz, Ph.D.**[a], and **Carol J. Boyd, Ph.D.**[a,c,d]

[a]Institute for Research on Women and Gender, University of Michigan, Ann Arbor, MI, 48109

[b]Survey Research Center, Institute for Social Research, University of Michigan, Ann Arbor, MI 48016

[c]School of Nursing, University of Michigan, Ann Arbor, MI 48109

[d]Addiction Research Center, Department of Psychiatry, University of Michigan, Ann Arbor, MI 48109

Abstract

Purpose—There is a need to obtain greater clarity regarding adolescents' e-cigarette use and their use with a wider range of risk behaviors. This study examines the associations among past-month e-cigarette use only, traditional cigarette smoking only, dual use (i.e., concurrent e-cigarette use and cigarette smoking), school-related (i.e., truancy and poor academic performance), and substance-related (i.e., alcohol use, binge drinking, marijuana use, illicit drug use, and nonmedical prescription drug use) risk behaviors.

Methods—Data were collected via self-administered questionnaires from a nationally representative sample of 8,696 high school seniors.

Results—An estimated 9.9% of U.S. high school seniors reported past-month e-cigarette use only, 6.0% reported past-month cigarette smoking only, and 7.3% reported past-month dual use. School-related and substance-related risk behaviors had strong associations with past-month e-cigarette use. Adolescents who only used e-cigarettes had significantly greater odds of all school-related and substance-related risk behaviors relative to non-users. Dual users had significantly greater odds of frequent/daily e-cigarette use as well as all school-related and substance-related risk behaviors relative to those who only used e-cigarettes. Finally, adolescents who engaged in frequent/daily e-cigarette use had significantly greater odds of binge drinking, marijuana use, other illicit drug use and nonmedical prescription drug use, relative to experimental e-cigarette users.

Please send correspondence to: Sean Esteban McCabe, Ph.D. Institute for Research on Women and Gender, University of Michigan, 204 S. State St., Ann Arbor, MI, 48109, PHONE: (734) 615-8840 FAX: (734) 998-6508, plius@umich.edu.

Conclusion—E-cigarette use is common among U.S. adolescents and there are robust associations between e-cigarette use and school-related and substance-related risk behaviors. There is evidence that e-cigarette use clusters with risk behaviors and appears to represent a problem behavior, especially dual use of e-cigarettes and traditional cigarettes.

Introduction

Past-month e-cigarette use is more prevalent among U.S. adolescents than any other nicotine or tobacco product, including traditional cigarette smoking [1–3]. Based on the National Youth Tobacco Survey, past-month e-cigarette use among U.S. high school students increased from 1.5% to 16.0% between 2011 and 2015, while past-month traditional cigarette smoking decreased from 15.8% to 9.3% over this same time period [3]. Adolescents' e-cigarette use is more prevalent than any other nicotine or tobacco product in part due to e-cigarettes having the lowest perceived risk for regular use relative to any other substance [2].

Initial findings indicate that while e-cigarette use is associated with higher odds of cigarette smoking and lower intentions to quit smoking, more than a quarter million adolescent e-cigarette users have no history of cigarette smoking or other tobacco use [4–10]. Based on the recent increases in e-cigarette use among U.S. adolescents, there are growing concerns that early exposure to these products could lead to increased risk of cigarette smoking and other tobacco products [8–10].

More than one in every six U.S. high school seniors reports past-month e-cigarette use [2]. This raises new public health concerns about the health implications of this behavior, which include acute toxicity, asthma, nicotine dependence/tobacco use disorder, adverse brain development, adverse fetal development, lung cancer, injuries related to e-cigarette battery explosions and accidental overdose [11,12]. While prior empirical and theoretical work has posited that cigarette smoking is associated with risk behaviors during adolescence such as binge drinking, marijuana use, illicit drug use, poor school work, and truancy [13–16], much less is known about the relationships between e-cigarette use and risk behaviors. There is preliminary evidence demonstrating an increased risk for individual substance use behaviors among e-cigarette users such as cigarette smoking and marijuana use, especially among older adolescents [8,16–19]. However, few studies have differentiated between dual users and e-cigarette only users, and no studies have examined a wider range of risk behaviors. Thus, it is imperative to obtain greater clarity regarding adolescents' e-cigarette use and its relationships with a wider range of school-related and substance-related risk behaviors, when adjusting for other relevant covariates based on prior research (including sex, age, race/ethnicity, parental education, college plans, urbancity, and geographical region [1–10,12,16–20].

Given existing studies on e-cigarette use among adolescents, the current research tests the following hypotheses: 1) Recent e-cigarette only users are more likely than non-users to engage in school-related and substance-related risk behaviors; 2) Dual users are more likely than non-users and e-cigarette only users to engage in school-related and substance-related risk behaviors; and 3) Frequent/daily e-cigarette users are more likely than non-users and

less frequent e-cigarette users to engage in school-related and substance-related risk behaviors. Accordingly, the hypotheses to be tested in this study will help in understanding whether e-cigarette use clusters with other risk behaviors, or reduces the likelihood of risk behaviors.

Methods

Study Design

The Monitoring the Future (MTF) study annually surveys a cross-sectional, nationally representative sample of high school seniors in over 120 U.S. public and private schools, using self-administered paper-and-pencil questionnaires in classrooms. The samples analyzed in this study consisted of high school seniors from the 2014 cohort, and the MTF study used a multistage sampling procedure. The response rate in the MTF study for high school seniors was 82% in 2014.

Because so many questions are included in the MTF study, much of the questionnaire content is divided into six different questionnaire forms which are randomly distributed to students. This approach results in six identical subsamples. The measures most relevant for this study were asked on Forms 1, 2, 5 and 6, so this study focuses on the cross-sectional subsamples receiving these four forms. Additional details about the MTF design and methods are available elsewhere [2,20,21]. Approval was granted for this study by the University of Michigan Institutional Review Board.

The sample for this study included 8,696 individuals who completed questionnaires during the spring of their senior year. The sample represented a population that was 52% female, 54% White, 12% African-American, 16% Hispanic, and 18% other/not disclosed (see Table 1). The modal age of the individuals in the sample was 18 years of age, and the majority of the population represented was from urban areas, had parents with some college education, and had plans to attend college.

Measures

The MTF study assesses a wide range of variables relevant to e-cigarette use. For the present study, we selected validated measures for analyses, including demographic characteristics and standard measures of school-related and substance-related risk behaviors based on previous work using MTF data [2,18,20–23]. Demographic and background characteristics included sex, age (less than 18 years old or 18 years and older), race/ethnicity (Black, White, Hispanic, Other), parental education (some college vs. high school or less), college plans (any plans to attend college vs. no plans to attend college), metropolitan statistical area (MSA) (large, other, non-MSA), and U.S. Census geographical region (Northeast, Midwest, South, and West).

Past-month e-cigarette use was assessed with the following item: “During the last 30 days, on how many occasions (if any) have you used electronic cigarettes (e-cigarettes)?” The response options ranged from (1) none to (6) 20–30 days, and were dichotomized (yes / no) based on previous work [2,18,20].

Past-month traditional cigarette smoking was assessed with the following item: "How frequently have you smoked cigarettes during the past 30 days?" The response options ranged from (1) none to (7) two packs or more per day, and were dichotomized based on previous work [2,18,20–23].

Substance-related risk behaviors: Binge drinking was measured with a single item focused on the frequency of having five or more drinks in a row during the past 2 weeks. The response scale ranged from 1) none to 6) 10 or more times. *Marijuana and other illicit drug use*--including marijuana, cocaine, ecstasy, LSD, psychedelics other than LSD, heroin--were measured by asking respondents how many occasions (if any) they used [specified drug] in the past 30 days. The response scale for these items ranged from 1) no occasions to 7) 40 or more occasions. *Nonmedical use of prescription drugs* was assessed by asking respondents on how many occasions (if any) they used each prescription drug class [opioids, sedatives, stimulants, tranquilizers] on their own, without a doctor's orders during the past 30 days. The response scale for each drug class ranged from 1) no occasions to 7) 40 or more occasions. All substance-related measures were dichotomized based on previous work [2,18,20–23].

School-related risk behaviors: High school academic performance was measured using the following item: "Which of the following best describes your average grade so far in high school?" The response scale for cumulative average grade ranged from 1) "D" or below to 9) "A" or higher, and response options were dichotomized into two subgroups based on previous work: C+ or below and B- or higher [21–23]. *Truancy* was assessed with the following item: "During last four weeks, how many whole days of school have you missed because you skipped or cut?" The response scale for truancy ranged from 1) none to 7) 11 or more days, and response options were dichotomized into two subgroups based on previous work: did not skip or cut any whole days in the past four weeks vs. one or more skipped or cut whole days [21–23].

Data Analysis

We first generated a "stacked" data file that combined the data from all four forms. Next, we performed design-based analyses of the combined survey data from the four forms, using the MTF sampling weights in all estimation procedures to ensure that weighted estimates were fully representative of the target MTF population. We also employed Taylor Series Linearization for variance estimation, accounting for the variability in the sampling weights when estimating the standard errors of the weighted estimates. We began by comparing various past-month subgroups (non-use, e-cigarette use only, cigarette smoking only, and dual use) in terms of the available socio-demographic measures, to generate a demographic profile of each type of user. We then repeated these analyses for different subgroups based on frequency of past-month e-cigarette use (none, occasional, experimental, and frequent/daily).

The use of a complex multi-stage sampling procedure by the MTF study introduces the need to use weights and account for the effects of cluster sampling when making population inferences about descriptive parameters and associations between MTF variables [2,20,21]. Design-adjusted Rao-Scott chi-square tests [24] account for these complex sampling features

when testing the bivariate association between two categorical variables. We therefore employed these design-adjusted tests to examine the associations of the past-month e-cigarette use subgroups with the school-related (e.g., truancy) and substance-related (e.g., nonmedical prescription drug use) risk behaviors. Finally, given that several associations between the e-cigarette use subgroups and the socio-demographic covariates were found to be significant, we fit multivariate design-based logistic regression models predicting the risk behaviors as a function of past-month e-cigarette use subgroup, adjusting for all of the socio-demographic characteristics and other correlates of these behaviors from the literature [1–20]. This modeling approach resulted in estimates of adjusted odds ratios (AORs) (i.e., changes in the odds of a risk behavior due to changes in a particular predictor variable when holding all of the other covariates in the model fixed), enabling comparisons of the different subgroups defined by the past-month use measures in terms of the odds of risk behaviors when holding the other socio-demographic characteristics and relevant covariates suggested by the literature fixed.

Finally, given the presence of missing data on several of the covariates, the items used to compute the use outcome measures, and the risk behavior items, we found that the number of cases with complete data on all variables of interest was consistently smaller than the overall sample size of 8,696. To examine the sensitivity of our inferences to possible biases introduced by these missing data problems, we first imputed the missing values on each of these variables 10 times using the sequential regression (or “chained equations”) imputation approach, which can accommodate variables with different types of distributions [25]. We then performed the same analyses described above using each of the 10 imputed data sets, and combined the resulting estimates using the combining rules described by Little and Rubin (2002) for multiple imputation analyses [26].

Results

An estimated 9.9% (SE=0.4%) of U.S. high school seniors reported past-month e-cigarette use only, 6.0% (SE=0.3%) reported past-month cigarette smoking only, and 7.3% (SE=0.4%) reported past-month dual use. As illustrated in Table 1, there were significant associations between the category of past-month e-cigarette use and cigarette smoking (i.e., non-use, e-cigarette use only, cigarette smoking only, or dual use) and several demographic characteristics, including sex, race/ethnicity, age, geographical region, urbanicity, and college plans. The directions of these associations, including corresponding effect sizes (phi) indicating that the associations were generally small-to-moderate, are shown in Table 1. For example, Whites have a significantly higher probability of reporting dual use. In addition, dual users had significantly increased odds of frequent/daily e-cigarette use relative to those who reported e-cigarette use only (AOR=2.2; 95% CI=1.6–3.0, $p<0.001$) while the odds of daily cigarette smoking did not differ between dual users and cigarette smokers only.

Considering the frequency of past-month e-cigarette use, an estimated 7.6% (SE=0.3%) used e-cigarettes on 1–2 days (experimental use), an estimated 5.0% (SE=0.3%) used e-cigarettes on 3–9 days (occasional use), and an estimated 4.6% (SE=0.3%) used e-cigarettes on 10 or more days (frequent/daily use). As illustrated in Table 2, there were significant associations between different frequency categories of past-month e-cigarette use and several

demographic characteristics, including sex, race/ethnicity, geographical region, urbanicity, and college plans. The directions of these associations and corresponding effect sizes are shown in Table 2; for example, males indicated significantly higher frequencies of e-cigarette use.

Initial bivariate Rao-Scott Chi-square tests revealed significant associations between each of the seven risk behaviors and the four different categories of past-month e-cigarette use and cigarette smoking ($p<0.0001$). The prevalence of each risk behavior was highest among individuals who reported dual use, followed by cigarette smoking only and e-cigarette use only, and lowest among non-users. Bivariate Rao-Scott Chi-square tests also revealed significant associations between each of the seven risk behaviors and frequency of past-month e-cigarette use ($p<0.0001$). The prevalence of each risk behavior was highest among individuals who reported frequent/daily e-cigarette use, followed by occasional e-cigarette use, experimental e-cigarette use, and lowest among non-users. Finally, there were significant associations between the covariates/demographic characteristics and the seven risk behaviors (see Supplemental Table A).

As illustrated in Table 3, multiple logistic regression analyses indicated that adolescents who only used e-cigarettes had significantly greater adjusted odds of all school-related and substance-related risk behaviors relative to non-use. In addition, dual use was associated with increased adjusted odds of all seven risk behaviors relative to non-users and adolescents who only used e-cigarettes. Dual use was also associated with increased adjusted odds of past-month alcohol use and binge drinking relative to adolescents who only used traditional cigarettes (results not shown).

The logistic regression analyses presented in Table 4 indicate that the risk behaviors were also significantly associated with frequency of past-month e-cigarette use after adjusting for the relevant covariates. Adolescents who engaged in experimental, occasional, and frequent/daily e-cigarette use had significantly greater adjusted odds of all school-related and substance-related risk behaviors relative to non-users. In addition, adolescents who engaged in frequent e-cigarette use had significantly greater odds of four substance use behaviors relative to experimental e-cigarette users, while there were no differences between these two subgroups in the odds of truancy, low grade point average, or monthly alcohol use. Finally, dual users engaging in both daily cigarette smoking and near-daily/daily e-cigarette use had significantly greater odds of all risk behaviors relative to non-daily users. The odds of all risk behaviors were similar or significantly higher (e.g., for alcohol use) for the daily/near-daily dual users relative to individuals engaging in either daily cigarette smoking or near-daily/daily e-cigarette use (results not shown).

When performing the multiple imputation analyses, we found that our primary inferences based on the results in Tables 3 and 4 were unaffected. In other words, we can view these relationships as robust to any slight biases that may have been introduced by the item-missing data. We therefore report results in Tables 3 and 4 based on the number of cases with complete data on all of the variables being considered for a given model, which introduces variance in the analytic sample sizes for these models. Finally, all of the multivariate analyses were repeated using the original ordinal categories for selected

dependent variables (i.e., truancy, grade point average, alcohol use, binge drinking, marijuana use), and we found similar overall patterns of results (specific coefficients for these additional ordinal models are available upon request).

Discussion

To our knowledge, this is the first study to examine the associations between e-cigarette use and school-related and substance-related risk behaviors among U.S. adolescents. The findings of the present study provided support for the first hypothesis since e-cigarette use was significantly associated with all school-related and substance-related risk behaviors relative to non-users. There was also robust support for the second hypothesis because dual users had significantly greater odds than single users of e-cigarettes and non-users to engage in school-related and substance-related risk behaviors. The four subgroups assessed in the present study appeared to form a tiered risk gradient for engaging in all risk behaviors led by 1) dual users with the highest risk, followed by 2) traditional cigarette smokers only, 3) e-cigarette users only, and 4) non-users with the lowest risk. The third hypothesis was partially supported because 1) e-cigarette users (regardless of frequency) had increased odds of all school-related and substance-related risk behaviors relative to non-users while 2) frequent/daily e-cigarette users had increased odds of four substance-related risk behaviors relative to experimental e-cigarette users but school-related risk behaviors did not differ as a function of frequency of e-cigarette use.

The present study provides new evidence that *any* e-cigarette use is associated with increased risk of a wide range of school-related and substance-related risk behaviors relative to non-use. Based on the Problem Behavior Theory, the evidence for covariation between risk behaviors is strongest for those risk behaviors that are also problem behaviors [13–15]. The robust associations between e-cigarette use and multiple risk behaviors in the present study suggest behavior clustering that may form a risk behavior syndrome representing a problem behavior more similar to cigarette smoking than non-use, especially for dual use of e-cigarettes and traditional cigarettes. The multivariate analyses revealed that dual users have significantly increased odds of several substance use behaviors relative to those who engage in only e-cigarette use, only cigarette smoking or non-users. At least one other school-based survey conducted among 10th grade students in Iceland also found higher rates of substance use behaviors (e.g., drunkenness, marijuana, tranquilizers) among dual users relative to single users of e-cigarettes or traditional cigarettes [17]. However, these authors noted that one major limitation was no access to demographic characteristics (e.g., parental education) to adjust for as covariates in their statistical models [17].

The findings of the present study indicate that dual users might be exposed to higher levels of nicotine during adolescence than single users of e-cigarettes or traditional cigarettes, because dual users engaged in more frequent/daily e-cigarette use (relative to single users of e-cigarettes) and comparable rates of daily cigarette smoking (relative to single users of traditional cigarettes). While some adolescents have reported using nicotine-free flavoring in their e-liquid during their last use of e-cigarettes, there is also evidence that dual users are more likely to use nicotine in their e-liquid and a considerable proportion of adolescents are unaware and do not know the nicotine concentration of the e-liquid contained in their e-

cigarettes [27,28]. There is evidence from pre-clinical research that nicotine exposure during adolescence has adverse effects on brain development that may lead to long-lasting vulnerability to nicotine and other substances of abuse [11,29–32]. Based on the increased risk associated with dual use found in the present study, future research is needed to examine the exact substances and nicotine levels consumed by dual users relative to single users of e-cigarettes and cigarettes.

While previous studies provide mixed evidence regarding the role of e-cigarettes in short-term reductions in, or complete abstinence from cigarette smoking among regular adult smokers [33–36], growing cross-sectional and longitudinal evidence also suggests that e-cigarette use is associated with higher odds of initiating cigarette smoking among adolescents [6–9]. Although the long-term health effects of e-cigarettes remain unknown, nicotine exposure during adolescence may have long-term adverse consequences for brain development and could lead to nicotine dependence and initiation or sustained use of more harmful tobacco products [10,19,37]. The findings of the present cross-sectional study also indicate that e-cigarette use is associated with other substance use behaviors among adolescents, and future research is needed to investigate the temporal order of initiating these substances.

The present study has several strengths that build upon previous literature examining e-cigarette use and other health behaviors. This MTF study includes a nationally representative diverse sample of U.S. high school seniors that allowed for subgroups to be defined based on past-month e-cigarette use and cigarette smoking. The present study also had limitations that need to be taken into account when considering the implications of the findings. First, the cross-sectional nature of the study precludes any conclusions about the causal relationships between e-cigarette use and risk behaviors. Second, there are some important subgroups of the U.S. youth population missing from the MTF data collected each year, such as students who were home-schooled, have dropped out of school, or were absent on the day of data collection and did not participate in the study. Home-schooled youth are less likely to engage in substance use behaviors [38], while those who drop out or often absent from school are more likely to engage in substance use and other risk behaviors [12,18]. Third, all measures were based on self-reports, and while prior work has found that these self-report measures in the MTF study have been found to be reliable and valid, studies on youth suggest that misclassification and under-reporting of sensitive behaviors such as substance use can occur [2,20,39,40]. In the MTF study, no adjustments are made to correct for any missing data or under-reporting; thus, results from the present study may be conservative and underreport the actual prevalence of sensitive behaviors. Multiple imputation analyses to examine the sensitivity of our inferences to possible biases introduced by missing data indicated our results were robust to the possibility of bias introduced by item-missing data in the analysis variables.

The robust associations between e-cigarette use and substance use, truancy and poor academic performance provide evidence that e-cigarette use clusters with risk behaviors and appears to represent a problem behavior (especially dual use). The majority of recent cigarette smokers were dual users who had the greatest risk for engaging in risk behaviors, followed by single users of cigarettes, single users of e-cigarettes and non-users. Future

longitudinal research is needed to assess a more comprehensive set of long-term health outcomes (e.g., asthma, nicotine/tobacco use disorder, lung cancer) as a function of e-cigarette use among U.S. adolescents.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This work was supported by research grants from the National Cancer Institute [R01CA203809] and the National Institute on Drug Abuse [R01DA031160 and R01DA036541], National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Cancer Institute, National Institute on Drug Abuse, or the National Institutes of Health. The Monitoring the Future data were collected by a research grant from the National Institute on Drug Abuse [R01DA01411], National Institutes of Health. The authors would like to thank the Substance Abuse and Mental Health Data Archive for providing access to these data.

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Implications and Contribution

The academic-related and substance-related risk behaviors associated with e-cigarette use were examined among high school seniors. E-cigarette use was common and significantly associated with all risk behaviors. Dual users had the greatest risk for engaging in risk behaviors followed by single users of cigarettes, single users of e-cigarettes and non-users.

Table 1

Weighted estimates of demographic distributions for different categories of past-month e-cigarette use and cigarette smoking

	No recent 30-day use % (n)	30-day e-cigarette use only % (n)	30-day cigarette smoking only % (n)	30-day dual use % (n)	Overall sample % (n)
Sex (ES = 0.08)					
Male	45.5% (2607)	57.7% (446)	49.9% (208)	57.6% (298)	47.8% (3559)
Female	54.5% (3153)	42.3% (331)	50.1% (197)	42.4% (219)	52.2% (3900)
Race/ethnicity (ES = 0.12)					
Black	13.6% (772)	5.8% (51)	9.7% (33)	3.6% (20)	11.9% (876)
White	52.1% (3105)	57.1% (449)	62.4% (271)	69.3% (379)	54.4% (4204)
Hispanic	16.6% (1108)	18.6% (160)	11.2% (53)	11.1% (74)	16.1% (1395)
Other/missing	17.7% (1085)	18.6% (158)	16.7% (81)	16.1% (98)	17.6% (1422)
Age (ES = 0.06)					
Less than 18 years	43.3% (2655)	41.4% (339)	29.2% (135)	36.8% (201)	41.8% (3330)
18 years or older	56.7% (3282)	58.6% (456)	70.8% (280)	63.2% (344)	58.2% (4362)
Geographical region (ES = 0.07)					
Northeast	18.8% (1204)	17.0% (153)	16.5% (79)	16.7% (109)	18.4% (1545)
Midwest	19.7% (1454)	22.8% (214)	20.2% (106)	23.3% (153)	20.3% (1927)
South	38.8% (2134)	33.8% (251)	48.8% (204)	37.1% (200)	38.7% (2789)
West	22.7% (1278)	26.4% (200)	14.5% (49)	22.9% (109)	22.6% (1636)
Metropolitan statistical area/ urbanicity (ES = 0.10)					
Large MSA	28.6% (1867)	26.7% (247)	21.9% (110)	23.5% (156)	27.7% (2380)
Other MSA	50.1% (2876)	61.3% (473)	42.2% (166)	55.3% (297)	51.1% (3812)
Non-MSA	21.3% (1327)	12.1% (98)	35.9% (162)	21.2% (118)	21.2% (1705)
Parental education (ES = 0.04)					
No college	24.6% (1508)	23.5% (195)	33.1% (141)	26.0% (145)	25.1% (1989)
Some college	68.8% (4151)	69.1% (573)	58.3% (256)	67.3% (388)	68.0% (5368)
Don’t know/missing	6.7% (411)	7.4% (50)	8.6% (41)	6.6% (38)	6.9% (540)
College plans (ES = 0.12)					
Definitely will attend	60.3% (3717)	56.8% (473)	36.9% (157)	38.7% (233)	57.0% (4580)

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	No recent 30-day use % (n)	30-day e-cigarette use only % (n)	30-day cigarette smoking only % (n)	30-day dual use % (n)	Overall sample % (n)
Will not attend/other	39.7% (2353)	43.2% (345)	63.1% (281)	61.3% (338)	43.0% (3317)

Note: The bivariate associations between different categories of recent 30-day e-cigarette use and cigarette smoking (i.e., non-use, e-cigarette use only, cigarette smoking only, and dual use) and all demographic characteristics shown in Table 1 were significant: sex ($p < 0.001$), race/ethnicity ($p < 0.001$), age ($p < 0.001$), geographical region ($p < 0.001$), metropolitan statistical area/urbanicity ($p < 0.001$), parental education ($p < 0.05$), and college plans ($p < 0.001$). ES = Effect size (phi), based on the design-adjusted Rao-Scott chi-square test statistic and the nominal sample size used to test each association; 0.1 is considered small, 0.3 is considered moderate, and 0.5 is considered large.

Data source: 2014 Monitoring the Future Study, Forms 1, 2, 5 and 6.

Table 2

Weighted estimates of demographic distributions for different categories of recent 30-day e-cigarette use (none, experimental, occasional and frequent use)

	No recent e-cigarette use (0 days) % (n)	Experimental e-cigarette use (1–2 days) % (n)	Occasional e-cigarette use (3–9 days) % (n)	Frequent/daily e-cigarette use (10+ days) % (n)
Sex (ES = 0.08)				
Male	45.9% (2854)	53.1% (302)	56.3% (226)	66.5% (225)
Female	54.1% (3397)	46.9% (279)	43.7% (162)	33.5% (113)
Race/ethnicity (ES = 0.10)				
Black	13.5% (830)	5.3% (34)	3.0% (16)	6.4% (23)
White	52.5% (3406)	64.4% (383)	62.1% (244)	58.5% (210)
Hispanic	16.3% (1178)	15.5% (107)	13.9% (69)	16.6% (60)
Other/missing	17.7% (1191)	14.8% (108)	21.0% (81)	18.6% (72)
Age (ES = 0.03)				
Less than 18 years	42.2% (2824)	42.2% (257)	39.0% (162)	35.5% (127)
18 years or older	57.8% (3615)	57.8% (346)	61.0% (236)	64.5% (226)
Geographical region (ES = 0.06)				
Northeast	18.7% (1304)	19.4% (130)	14.5% (69)	15.3% (66)
Midwest	19.7% (1580)	26.5% (181)	21.1% (103)	20.3% (91)
South	39.6% (2379)	31.7% (186)	39.7% (142)	35.5% (127)
West	22.1% (1342)	22.4% (135)	24.7% (96)	28.9% (81)
Metropolitan statistical area/urbanicity (ES = 0.07)				
Large MSA	28.2% (2012)	27.8% (196)	22.2% (110)	24.8% (103)
Other MSA	49.6% (3083)	54.6% (330)	62.0% (239)	62.2% (212)
Non-MSA	22.3% (1510)	17.5% (106)	15.8% (61)	13.0% (50)
Parental education (ES = 0.02)				
No college	25.2% (1677)	22.6% (142)	26.2% (106)	26.7% (99)
Some college	67.7% (4454)	70.4% (447)	67.3% (281)	64.7% (239)
Don’t know/missing	7.1% (474)	7.0% (43)	6.5% (23)	8.6% (27)
College plans (ES = 0.07)				
Definitely will attend	58.2% (3911)	54.9% (352)	47.1% (201)	41.7% (159)
Will not attend/other	41.8% (2694)	45.1% (280)	52.9% (209)	58.3% (206)

Note: The bivariate associations between different categories of recent 30-day e-cigarette use (i.e., no e-cigarette-use, experimental use, occasional use, and frequent/daily use) and the demographic characteristics shown in Table 2 were as follows: sex ($p < 0.0001$), race/ethnicity ($p < 0.0001$), age ($p = 0.132$), geographical region ($p < 0.01$), metropolitan statistical area/urbanicity ($p < 0.0001$), parental education ($p = 0.795$), and college plans ($p < 0.0001$). ES = Effect size (phi), based on the design-adjusted Rao-Scott chi-square test statistic and the nominal sample size used to test each association; 0.1 is considered small, 0.3 is considered moderate, and 0.5 is considered large.

Data source: 2014 Monitoring the Future Study, Forms 1, 2, 5 and 6.

Table 3

Adjusted odds ratios of school-related and substance-related risk behaviors as a function of past-month e-cigarette use and cigarette smoking

	Truancy (4-week) (n= 7,337) AOR (95% CI)	Grade point average <= C+ (n = 7,545) AOR (95% CI)	Binge drinking (2-week) (n = 7,501) AOR (95% CI)	Alcohol use (30-day) (n = 7,589) AOR (95% CI)	Marijuana use (30-day) (n = 7,711) AOR (95% CI)	Illicit drug use (30-day) (n = 7,505) AOR (95% CI)	Nonmedical Rx drug use (30-day) (n = 7,531) AOR (95% CI)
Recent (30-day) use							
Non-user	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Only e-cigarette use	2.29 (1.90, 2.76)***	1.54 (1.22, 1.95)***	4.39 (3.60, 5.35)***	5.03 (4.17, 6.07)***	4.97 (4.09, 6.04)***	5.05 (2.88, 8.85)***	2.63 (1.88, 3.68)***
Only cigarette smoking	2.68 (2.06, 3.47)***	2.12 (1.57, 2.85)***	5.54 (4.21, 7.28)***	6.20 (4.79, 8.03)***	9.34 (7.21, 12.09)***	11.79 (5.92, 23.47)***	6.62 (4.53, 9.67)***
Dual use	3.22 (2.56, 4.04)***	2.25 (1.69, 2.98)***	11.26 (8.87, 14.29)***	12.26 (9.31, 16.16)***	12.58 (9.90, 15.97)***	18.49 (10.98, 31.14)***	7.21 (5.27, 9.87)***
Recent (30-day) use							
Only e-cigarette use	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Only cigarette smoking	1.17 (0.86, 1.58)	1.38 (0.96, 1.97)	1.26 (0.93, 1.72)	1.23 (0.91, 1.67)	1.88 (1.39, 2.53)***	2.34 (1.15, 4.75)*	2.52 (1.61, 3.94)***
Dual use	1.40 (1.07, 1.84)*	1.46 (1.04, 2.05)*	2.57 (1.94, 3.39)***	2.44 (1.77, 3.35)***	2.53 (1.91, 3.35)***	3.66 (2.12, 6.32)***	2.74 (1.88, 4.02)***
Non-user	0.44 (0.36, 0.53)***	0.65 (0.51, 0.82)***	0.23 (0.19, 0.28)***	0.20 (0.16, 0.24)***	0.20 (0.17, 0.24)***	0.20 (0.11, 0.35)***	0.38 (0.27, 0.53)***

Notes: The sample sizes for the models varied due to missing data on the individual covariates and dependent measures. Illicit drug use consisted of any 30-day use of cocaine, ecstasy, LSD, other hallucinogens, or heroin use. Nonmedical Rx drug use consisted of any nonmedical use of prescription opioids, sedatives, stimulants or tranquilizers. AOR's were adjusted for sex, race/ethnicity, age, school geographical region, metropolitan statistical area, parental education, and college plans.

* $p < 0.05$,

*** $p < 0.001$.

Data source: 2014 Monitoring the Future Study, Forms 1, 2, 5 and 6.

Table 4

Adjusted odds ratios of school-related and substance-related risk behaviors as a function of frequency categories of past-month e-cigarette use (none, experimental, occasional, and frequent/daily use)

	Truancy (4-week) (n= 7,430) AOR (95% CI)	Grade point average <= C+ (n = 7,640) AOR (95% CI)	Binge drinking (2-week) (n = 7,578) AOR (95% CI)	Alcohol use (30-day) (n = 7,667) AOR (95% CI)	Marijuana use (30-day) (n = 7,792) AOR (95% CI)	Illicit drug use (30-day) (n = 7,573) AOR (95% CI)	Nonmedical Rx drug use (30-day) (n = 7,620) AOR (95% CI)
E-cigarette frequency							
Non-user	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Experimental	2.25 (1.82, 2.77)***	1.55 (1.17, 2.03)**	4.22 (3.40, 5.24)***	5.08 (4.12, 6.26)***	4.57 (3.71, 5.63)***	3.40 (1.96, 5.90)***	2.02 (1.39, 2.95)***
Occasional	2.37 (1.83, 3.06)***	1.75 (1.30, 2.37)***	6.36 (4.94, 8.20)***	6.91 (5.14, 9.31)***	5.53 (4.27, 7.16)***	6.57 (3.94, 10.95)***	3.42 (2.43, 4.81)***
Frequent/daily	2.79 (2.12, 3.68)***	1.83 (1.31, 2.56)***	6.02 (4.57, 7.93)***	6.49 (4.83, 8.72)***	7.52 (5.69, 9.95)***	8.10 (4.98, 13.17)***	5.36 (3.78, 7.60)***
E-cigarette frequency							
Experimental	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Occasional	1.05 (0.77, 1.44)	1.13 (0.77, 1.66)	1.51 (1.11, 2.05)**	1.36 (0.96, 1.94)	1.21 (0.89, 1.65)	1.93 (1.02, 3.65)*	1.69 (1.07, 2.67)*
Frequent/daily	1.24 (0.89, 1.73)	1.19 (0.78, 1.79)	1.43 (1.03, 1.98)*	1.28 (0.90, 1.81)	1.65 (1.18, 2.29)**	2.38 (1.29, 4.42)**	2.65 (1.67, 4.19)***
Non-user	0.44 (0.36, 0.55)***	0.65 (0.49, 0.85)**	0.24 (0.19, 0.29)***	0.20 (0.16, 0.24)***	0.22 (0.18, 0.27)***	0.29 (0.17, 0.51)***	0.49 (0.34, 0.72)***

Notes: The sample sizes for the models varied due to missing data on the individual covariates and dependent measures. Illicit drug use consisted of any 30-day use of cocaine, ecstasy, LSD, other hallucinogens, or heroin use. Nonmedical Rx drug use consisted of any nonmedical use of prescription opioids, sedatives, stimulants or tranquilizers. AOR's were adjusted for sex, race/ethnicity, age, school geographical region, metropolitan statistical area, parental education, and college plans. $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$.

Data source: 2014 Monitoring the Future Study, Forms 1, 2, 5 and 6.