

Yale University

EliScholar – A Digital Platform for Scholarly Publishing at Yale

Public Health Theses

School of Public Health

1-1-2019

Nicotine Dependence And Alternative E-Cigarette Use Behaviors: Dripping And Vape Tricks

Harmanpreet Bhatti
harmanpreetbhatti@yahoo.com

Follow this and additional works at: <https://elischolar.library.yale.edu/ysphtdl>



Part of the [Public Health Commons](#)

Recommended Citation

Bhatti, Harmanpreet, "Nicotine Dependence And Alternative E-Cigarette Use Behaviors: Dripping And Vape Tricks" (2019). *Public Health Theses*. 1858.
<https://elischolar.library.yale.edu/ysphtdl/1858>

This Open Access Thesis is brought to you for free and open access by the School of Public Health at EliScholar – A Digital Platform for Scholarly Publishing at Yale. It has been accepted for inclusion in Public Health Theses by an authorized administrator of EliScholar – A Digital Platform for Scholarly Publishing at Yale. For more information, please contact elischolar@yale.edu.

Nicotine Dependence and Alternative E-Cigarette Use Behaviors:

Dripping and Vape Tricks

Name: Harmanpreet Bhatti

Year Completed: 2019

Year Degree Awarded: 2019

Degree Awarded: Master of Public Health

Department: School of Public Health

Advisor/Committee Chair: Ralitza Gueorguieva, PhD

Committee Members: Grace Kong, PhD

Abstract

Background: E-cigarette use among youth is concerning due to the risk of exposure to hazardous chemicals and future combustible cigarette use. Alternative e-cigarette use behaviors, or dripping (i.e., applying drops of e-liquids directly onto heated coils) and vape tricks (i.e., blowing shapes or large clouds of visible exhaled aerosol), may also increase this risk. However, little is known about the risk of nicotine dependence among adolescents who engage in these behaviors. Therefore, the aim of this study was to determine the association between these alternative e-cigarette use behaviors and nicotine dependence among adolescents.

Research Design: Cross-sectional data were collected from four Connecticut high schools. Students reported use of tobacco products, including e-cigarettes, dripping and vape trick behaviors, nicotine dependence, sex, race, grade, socioeconomic status, age of e-cigarette onset, and past 30 day e-cigarette frequency. Two general linear models were generated with and without covariates to evaluate the association between alternative e-cigarette use behaviors and nicotine dependence.

Results: Based on the unadjusted model, individuals who engaged in both vape tricks and dripping displayed greater nicotine dependence than individuals who engaged in either (Mean difference = 0.27, 95% CI = [0.13, 0.42]) or neither behaviors (Mean difference = 0.31, 95% CI = [0.10, 0.52]). However, after adjusting for demographic and other tobacco use characteristics, the association was no longer significant. Rather, age of e-cigarette onset ($\beta = -0.07$ [SE = 0.02], $p = 0.002$) and e-cigarette frequency ($\beta = 0.01$ [SE = 0.005], $p = 0.01$) significantly predicted nicotine dependence.

Conclusions: Future research should further evaluate levels of nicotine concentration used for alternative use behaviors and potential pathways in which nicotine dependence can develop among adolescents who engage in vape tricks and/or dripping as they are at risk for engaging in more frequent use of e-cigarettes.

Acknowledgements

Throughout the completion of this thesis project, I have received a great amount of support and assistance. I would firstly like to acknowledge my readers and thesis advisors, Dr. Ralitzia Gueorguieva and Dr. Grace Kong, for their assistance in planning, drafting, and revising this thesis project. Dr. Gueorguieva provided an immense amount of guidance in solidifying my thesis topic and in reviewing the analysis of this project. She kindly sacrificed her time to remotely assist me throughout this process, which I am especially thankful for. Dr. Kong also provided an immeasurable amount of support on this project, responding to frantic emails and reviewing several drafts in her free time. She has been an amazing mentor not only on this project but also throughout the year and a half that I have spent at the Yale Tobacco Center of Regulatory Science, and I am profoundly grateful for this support.

I would also like to thank the researchers at the Yale Tobacco Center of Regulatory Science, who have encouraged and comforted me throughout my time in the field of tobacco research. I must also acknowledge my academic advisor, Dr. Andrew DeWan, for his guidance throughout the process of completing this thesis and for the advice he has given me in my past two years of study at the Yale School of Public Health. I am also thankful for the support of Dr. Georgiana Bostean from Chapman University, who was the main driver of my public health education and inspired me to continue studying tobacco and electronic cigarette use behaviors in adolescents.

Finally, I must express my gratitude to my family for their continuous support and encouragement throughout my years of study. This accomplishment could not have been possible without them. Thank you.

Table of Contents

Abstract.....	i
Acknowledgements.....	ii
Table of Contents.....	iii-iv
List of Tables.....	v
Overview of Study Objectives.....	1-2
Background.....	2-6
Electronic Cigarettes.....	2
Alternative E-cigarette Use Behaviors.....	2-5
Vape Tricks.....	3
Dripping.....	3-4
Vape Tricks and Dripping.....	4-5
Nicotine Dependence.....	5-6
Research Design.....	6-10
Procedures.....	6
Measures.....	7-9
E-cigarette Nicotine Dependence.....	7
Alternative E-cigarette Use Behaviors.....	7-8
Covariates.....	8-9
Statistical Methods.....	9-10
Results.....	10-16
Descriptive Statistics.....	10-13
Unadjusted Model.....	13-14
Adjusted Model.....	14-16

Conclusions.....	16-19
Limitations and Future Directions	17-19
References.....	20-21

List of Tables

Table 1: Descriptive statistics on all study variables across the total analytic sample	12
Table 2: Descriptive statistics on all study variables by behavior group.....	13
Table 3: Unadjusted (least squares) mean values of the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior.....	14
Table 4: Unadjusted (least squares) mean differences in the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior.....	14
Table 5: Adjusted associations between alternative e-cigarette use behavior and the log-transformed e-cigarette nicotine dependence scale.....	15
Table 6: Adjusted (least squares) mean values of the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior.....	16
Table 7: Adjusted (least squares) mean differences in the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior.....	16

Overview of Study Objectives

Electronic cigarettes (e-cigarettes) are battery-powered devices that can vaporize e-liquids containing nicotine and flavorants. These devices have grown in popularity over time and are currently the most commonly used tobacco products among youth (Gentzke et al., 2019). Preliminary studies suggest that adolescents who use these devices engage in “alternative use behaviors,” including vape tricks, or blowing various shapes or large clouds of visible exhaled aerosol (Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2015; Pepper et al., 2017), and dripping, which is applying drops of e-liquids directly onto heated coils (Krishnan-Sarin et al., 2017). For instance, among Connecticut youth in 2017, 54.9% reported conducting vape tricks and 20.5% reported dripping (Kong et al., under review). Dripping involves heating e-liquids to high temperatures, which can expose users to higher concentrations of nicotine than if they used e-cigarettes normally (Talih, Balhas, Salman, Karaoghlanian, & Shihadeh, 2016). Vape tricks may also pose health risks to youth given that they are often performed using devices with large batteries that can also reach high temperatures and increase exposure to dangerous chemicals (Pepper et al., 2017). Currently, limited research exists regarding both dripping and vape tricks, but, given their high prevalence, the health risks of conducting these behaviors require more examination. One health risk that is especially concerning for adolescent populations is nicotine dependence.

Thus, the primary aim of this investigation is to explore differences in e-cigarette nicotine dependence among adolescents who engage in alternative e-cigarette use behaviors (i.e., dripping and/or vape tricks). It was hypothesized that adolescents who engage in both behaviors will have greater nicotine dependence compared to those who engage in neither behavior given previous research findings suggesting that they are more “advanced users” in the sense that they use e-

cigarettes more frequently, began using e-cigarettes earlier, and use higher nicotine concentrations when vaping (Kong et al., under review).

Background

Electronic Cigarettes

According to the 2016 report of the U.S. Surgeon General, e-cigarette use among high school students increased by 900% between 2011-2015, creating cause for concern among public health professionals (United States Department of Health and Human Services, 2016). 2018 U.S. national data suggest that e-cigarettes are the most commonly used tobacco products among high and middle school students with 20.8% and 4.9% of surveyed students reporting current use of these devices, respectively (Gentzke et al., 2019). While e-cigarettes are less harmful than combustible cigarettes, any form of tobacco use among youth is troubling (United States Department of Health and Human Services, 2016). Furthermore, a growing body of literature suggests that adolescent e-cigarette users have an increased risk of future combustible tobacco use (Bold et al., 2018; Miech, Patrick, O'Malley, & Johnston, 2017; Murthy, 2017; Soneji et al., 2017). In fact, a meta-analysis of longitudinal studies found that e-cigarette users had 3.5 times the odds of future cigarette smoking compared to non-users (Soneji et al., 2017). Additionally, e-cigarettes can be used to vape other substances, including cannabinoids, which have additional adverse health consequences for adolescents (i.e., greater risk of developing dependence to nicotine and cannabis) (Murthy, 2017). Given these health risks, understanding and preventing youth e-cigarette use has become an important goal of public health professionals (United States Department of Health and Human Services, 2016).

Alternative E-cigarette Use Behaviors

The increased prevalence of e-cigarette use among adolescents is concerning given the unclear evidence of the short- and long-term health consequences of these devices (United States

Department of Health and Human Services, 2016). An emerging body of literature suggests that e-cigarettes are used for other understudied “alternative use behaviors” among adolescents, including vape tricks (Cooper, Harrell, & Perry, 2016; Kong et al., 2015; Pepper et al., 2017; Wagoner et al., 2016) and dripping (Krishnan-Sarin et al., 2017). These behaviors are concerning given that they are often practiced using devices that can heat e-liquids to high temperatures, increasing exposure to high concentrations of nicotine and non-nicotine toxicants, such as volatile aldehydes (Kosmider et al., 2014; Pepper et al., 2017; Talih et al., 2016). Online sources also suggest that different batteries or e-liquids can be used to conduct better vape tricks, possibly encouraging youth to engage in behaviors that they may not have considered trying otherwise (Pepper et al., 2017). Moreover, the ability to engage in these alternative use behaviors could enhance the appeal of e-cigarettes among youth (Pepper et al., 2017). Youth who find e-cigarettes appealing are more susceptible to future use of these devices and may have lower levels of perceived harm of vaping (Krishnan-Sarin, Morean, Camenga, Cavallo, & Kong, 2015). Therefore, it is necessary to minimize the appeal of these devices to youth.

Vape Tricks

Vape tricks (or “cloud chasing”) refer to when e-cigarettes are used to create vapor clouds, rings, or other shapes from the exhaled aerosol (Kong et al., under review; Pepper et al., 2017). Vape tricks are a common reason for beginning e-cigarette use among youth (Kong et al., 2015). Indeed, among adolescents who had ever used e-cigarettes, 77.8% had tried vape tricks (Pepper et al., 2017). Still, there is little information regarding the harms of conducting vape tricks (Kong et al., under review; Pepper et al., 2017).

Dripping

Dripping involves applying drops of e-liquid to the e-cigarette atomizer coil before it is heated and inhaling the vapor produced (Krishnan-Sarin et al., 2017). A study among Connecticut

high school students found that 26.1% of e-cigarette users had tried dripping and individuals who used e-cigarettes more frequently were also more likely to engage in dripping (Krishnan-Sarin et al., 2017). Advanced generation devices, or e-cigarettes with unique hardware features (including button activation and adjustable screens to change airflow) or customizable settings (to adjust air flow rate, coil temperature, etc.), are often used and manipulated to engage in this behavior (DeVito & Krishnan-Sarin, 2018; Krishnan-Sarin et al., 2017). However, the use of such advanced generation e-cigarette devices is concerning because of the ability to vape at very high temperatures, which results in production of nicotine levels comparable to cigarettes (Wagener et al., 2017). Several research studies have shown that users use advanced generation devices to drip, and dripping can expose e-cigarette users to high temperatures, which may lead to increased levels of exposure to chemicals such as acetone and aldehydes (e.g., formaldehyde, acetaldehyde) (Kosmider et al., 2014; Talih et al., 2016). Exposure to these chemicals is troubling given that some volatile aldehydes, such as formaldehyde and acetaldehyde, are classified as group 1A (carcinogenic to humans) or group 2B (possibly carcinogenic to humans) carcinogens by the International Agency for Research on Cancer (Talih et al., 2016). For this reason, minimizing the exposure to such hazardous chemicals is crucial, especially in adolescents still undergoing brain development.

Vape Tricks and Dripping

According to a 2017 study among Connecticut high school students, 18.9% of ever e-cigarette users reported ever trying both vape tricks and dripping (Kong et al., under review). In fact, a commonly reported reason for dripping among adolescents is to conduct vape tricks (Kong et al., under review; Krishnan-Sarin et al., 2017). Study findings suggest that adolescents who engage in both behaviors are likely to engage in “riskier tobacco use” behaviors, including using e-cigarettes more frequently and using higher nicotine concentrations when vaping (Kong et al.,

under review). These users also begin vaping at younger ages and often use other tobacco products (Kong et al., under review). However, less known is whether engaging in vape tricks and dripping is also associated with nicotine dependence. A previous study with youth e-cigarette users found that adolescents who use e-cigarettes more frequently or with higher nicotine concentrations exhibit greater nicotine dependence (Morean, Krishnan-Sarin, & O'Malley, 2018). Therefore, studying the potential association between alternative e-cigarette use behaviors and nicotine dependence may be meaningful.

Nicotine Dependence

Nicotine dependence is defined by symptoms of impaired control, risky use, social impairment, tolerance, and withdrawal (American Psychiatric Association, 2013). Dependence typically begins during youth when exposure to nicotine is extremely detrimental to adolescent brain growth and development (Benowitz, 2010; Centers for Disease Control and Prevention, 2019; Yuan, Cross, Loughlin, & Leslie, 2015). In fact, studies using animal models suggest that exposure to high doses of nicotine during adolescence disrupts serotonin receptor function, reduces attention span, and increases impulsivity later in life (Yuan et al., 2015). Nicotine dependence is even more concerning given that it increases the likelihood of maintaining tobacco use behaviors from adolescence to adulthood (Colby, Tiffany, Shiffman, & Niaura, 2000). Studies suggest that youth are being exposed to nicotine through e-cigarettes, and higher e-liquid nicotine concentrations result in greater nicotine dependence (Krishnan-Sarin et al., 2015; Morean, Kong, Camenga, Cavallo, & Krishnan-Sarin, 2015; Morean et al., 2018). Studying how other e-cigarette characteristics, including engagement in alternative e-cigarette use behaviors, can increase levels of nicotine dependence in adolescence is therefore vital to this field.

Since there is a limited amount of research on alternative e-cigarette use behaviors and even less information on how these behaviors are associated with nicotine dependence among

youth, the purpose of this thesis project is to evaluate the relationship between alternative use behaviors (i.e., dripping and/or vape tricks) and nicotine dependence among adolescent e-cigarette users. We examined grade, age of e-cigarette onset, e-cigarette frequency in the past 30 days, and use of other tobacco products as covariates because previous research observed that being in a higher grade, beginning e-cigarette use at a younger age, using e-cigarettes more frequently, and using other tobacco products (specifically cigarettes) were positively associated with e-cigarette nicotine dependence (Morean et al., 2018). Sex, race, and socioeconomic status (SES) were also included as covariates given previous research findings that men, non-Whites, and individuals of low SES had higher rates of nicotine dependence compared to women, Whites, and individuals of high SES, respectively (Luo et al., 2008; Pennanen et al., 2014; Shiffman & Paton, 1999). The findings from this study will add to the growing body of literature on the addiction potential of e-cigarettes among youth.

Research Design

Procedures

The dataset used for this investigation is from a cross-sectional, anonymous school-based study conducted by the Yale Tobacco Center of Regulatory Science in Spring 2017. The Yale School of Medicine Institutional Review Board approved all study procedures. The total sample for this study consists of 2,945 high school students from four Southeastern Connecticut high schools. Students completed a 20-minute, paper-and-pencil survey regarding tobacco products (e-cigarettes, cigarettes, hookah, cigars, cigarillos, blunts, and smokeless tobacco). Of the total sample, 202 students who reported having used e-cigarettes at least ten times in the past month (response between 10 - 30 to the question “Approximately how many days out of the past 30 days did you vape an e-cigarette?”) and did not have missing data for the covariates described below were included in the analytic sample to accurately assess nicotine dependence.

Measures

E-cigarette Nicotine Dependence

The dependent variable, e-cigarette nicotine dependence, was evaluated using the 4-item Patient-Reported Outcomes Measurement Information System Nicotine Dependence Item Bank for E-cigarettes (PROMIS-E) that has previously been found to be reliable, with strong internal consistency (Cronbach's $\alpha = 0.91$), and has demonstrated convergent validity in assessing youth e-cigarette nicotine dependence (Morean et al., 2018). The four items of the dependence scale were: When I haven't been able to vape for a few hours, the craving gets intolerable, I drop everything to go out and get e-cigarettes or e-juice, I vape more before going into a situation where vaping is not allowed, and I find myself reaching for e-cigarettes without thinking about it. Responses for the four questions included: never (0), rarely (1), sometimes (2), often (3), and always (4). The items were summed for each participant to create a dependence scale variable. Four participants (2.0% of the analytic sample) had missing responses for at least one, but not all, of the dependence questions. The data for these participants were manually imputed using the average value of their provided responses to the e-cigarette dependence items.

Alternative E-cigarette Use Behaviors

Ever conducted vape tricks: Students were provided images and the following description of vape tricks: "Vape tricks refer to using an e-cigarette to create vapor rings, other shapes, or clouds of vapor (which is sometimes referred to as 'cloud chasing' or 'blowing clouds')." A "yes" response to the question "Have you ever tried vape tricks?" was coded as having ever conducted vape tricks and a "no" response was coded as having never conducted vape tricks.

Ever dripped: Students were provided images and the following description of dripping: "The following questions ask about dripping, which is applying drops of e-liquid directly onto an atomizer to saturate its wick prior to heating. Some people use a 'drip tip,' which is a hollow,

metal, glass, or plastic mouthpiece that fits over an atomizer and helps to funnel vapor into your mouth.” A “yes” response to the question “Have you ever dripped?” was coded as having ever dripped whereas a “no” response was coded as having never dripped.

Behavior Categories: Individuals who had never conducted vape tricks or tried dripping were classified as “neither vape tricks nor dripping.” Participants who had ever practiced either behavior were grouped into the “either vape tricks or dripping” category. Finally, participants who had ever tried both vape tricks and dripping were categorized as “both vape tricks and dripping.”

Covariates

Sex: Students were asked the question “At birth, what was your sex?” with response options of male and female.

Grade: Students reported their grade by responding to the question “What grade are you in?” Responses ranged from 9th to 12th grade.

Race: Race was evaluated by asking participants “How would you describe yourself? (Select all that apply).” Response options were White, Black/African American, Asian, American Indian/Alaska Native, Native Hawaiian/other Pacific Islander, Middle Eastern, and other. For the final models, race was assessed as a dichotomous variable – White vs. non-White – to account for low endorsements of certain race options (Black – 2.0%, Hispanic – 13.9%, Multiracial – 6.9%, Other – 2.0%).

Socioeconomic status (SES): SES was determined using the Family Affluence Scale (FAS) that included four items: (1) whether an adolescent’s family owns a car, van, or truck (no = 0; yes, one = 1; yes, two or more = 2), (2) whether an adolescent has his/her own bedroom (no = 0; yes = 1), (3) the number of laptops/computers an adolescent’s family owns (none = 0; 1 = 1; 2 = 2; more than 2 = 3), and (4) whether an adolescent’s family had vacationed in the past 12 months (not at

all = 0; once = 1; twice = 2; more than twice = 3). The sum of the four items was calculated for each participant to determine an SES score.

Age of e-cigarette onset: Students who responded “yes” to the question “Have you ever tried an e-cigarette, even just one or two puffs?” were asked “How old were you when you first tried an e-cigarette, even just 1 or 2 puffs?” with response options ranging from 8 years old or younger to 19 years old.

E-cigarette use frequency: Students who responded “yes” to the question “Have you ever tried an e-cigarette, even just one or two puffs?” were asked “Approximately how many days out of the past 30 days did you vape an e-cigarette?” with options ranging from 0 to 30 days.

Current use of other tobacco products: Students were provided images and asked if they had ever used the following tobacco products separately: cigarettes, hookah, cigars, cigarillos, blunts, and smokeless tobacco. For each product, participants were asked “Approximately how many days out of the past 30 days did you use a cigarette/hookah/cigar/cigarillo/blunt/smokeless tobacco?” with response options ranging from 0 to 30 days. Due to missing data and low sample size, each tobacco product could not be evaluated separately. Rather, a single “use other tobacco products” variable was created. A response greater than 0 days for any of the tobacco products was coded as “yes.” A response of 0 days for all tobacco products was coded as “no.”

Statistical Methods

The analysis for this study was conducted using SAS 9.4. Descriptive statistics were calculated prior to statistical analysis. ANOVA and chi-square tests were used to compare the three e-cigarette use groups on demographic and e-cigarette use characteristics. When overall differences were observed, they were followed up by pairwise comparisons. Because the distribution of the dependence scale variable was positively skewed, a log transformation was

applied and the log-transformed dependence scale was used in statistical modeling. The residuals were used to evaluate the model assumptions and determine if the transformation was appropriate.

To assess differences in e-cigarette nicotine dependence among individuals who engage in alternative e-cigarette use behaviors, two general linear models were assessed. The first model included only the main independent variable, vape tricks/dripping (e-cigarette use behavior: neither vape tricks nor dripping (0), either vape tricks or dripping (1), both vape tricks and dripping (2)) and the dependent variable (e-cigarette nicotine dependence). The second model included vape tricks/dripping while controlling for sex, grade, race, SES, age of e-cigarette onset, frequency of e-cigarette use in the past 30 days, and the use of other tobacco products in predicting e-cigarette nicotine dependence. Of main interest was the assessment of the main effect of e-cigarette behaviors. Least square means and mean differences were evaluated to describe the nature of the main effect. The alpha level used to determine statistical significance for both models was 0.05. The residuals were assessed to evaluate the overall fit of the models and identify outliers.

Results

Descriptive Statistics

Descriptive statistics for the overall sample and for each behavior group are presented in Tables 1 and 2, respectively. Among individuals who used e-cigarettes at least ten times in the past month ($n = 202$), 39.6% ($n = 80$) engaged in both vape tricks and dripping, 45.5% ($n = 92$) endorsed either behavior (dripping only: 1.5% ($n = 3$), vape tricks only: 44.1% ($n = 89$)), whereas only 14.9% ($n = 30$) had done neither (Table 1). Of the total sample, 54.0% ($n = 109$) was male and 89.1% ($n = 180$) was White. The majority of the sample (77.2%, $n = 156$) had also used at least one other tobacco product within the past 30 days. The average e-cigarette nicotine dependence score, which ranged from values of 0.0 to 4.0, was 0.9 ($SD = 1.0$) for the overall sample. The median of the log-transformed nicotine dependence scale for the overall sample was 0.4 (IQR = 0.0, 0.92).

Of the individuals who reported practicing both behaviors, 65.0% ($n = 52$) were male, which was higher than the either (42.4%, $n = 39$) and neither (60.0%, $n = 18$) behavior groups ($F(2, 199) = 4.81, p = 0.01$). However, this difference was only significant between individuals who endorsed both vs. either behavior ($p < 0.05$) (Table 2). Additionally, individuals who conducted both vape tricks and dripping had the earliest age of e-cigarette onset (Mean (M) = 13.6 years old [$SD = 2.1$], $F(2, 199) = 6.64, p = 0.002$). Participants who endorsed both behaviors had a significantly higher e-cigarette frequency in the past month ($M = 24.5$ days [$SD = 7.0$]) compared to those who endorsed either behavior ($M = 19.4$ [$SD = 7.7$], $p < 0.05$), but not compared to those who endorsed neither behavior ($M = 22.7$ [$SD = 7.8$], $p > 0.05$). Among individuals who engaged in both behaviors, 91.3% ($n = 73$) had used other tobacco products in the past 30 days compared to 72.8% ($n = 67$) of individuals who endorsed either behavior and 53.3% ($n = 16$) of individuals who endorsed neither ($F(2, 199) = 10.75, p < 0.0001$) (Table 2). The median of the log-transformed nicotine dependence score was also highest for individuals who practiced both behaviors (Median = 0.6 [IQR = (0.0, 1.1)], $F(2, 199) = 8.12, p = 0.0004$).

Table 1: Descriptive statistics on all study variables across the total analytic sample (n = 202)

Characteristic	N (%) or Mean \pm SD
Behavior	
Both vape tricks and dripping	80 (39.6)
Either vape tricks or dripping	92 (45.5)
Neither vape tricks nor dripping	30 (14.9)
Sex	
Male	109 (54.0)
Female (ref.)	93 (46.0)
Race	
White	180 (89.1)
Non-White (ref.)	22 (10.9)
Grade	10.7 \pm 1.0
SES	6.9 \pm 1.6
Age of e-cigarette onset (years)	14.2 \pm 1.8
E-cig frequency in past 30 days (days)	21.9 \pm 7.8
Use other tobacco products	
Yes	156 (77.2)
No (ref.)	46 (22.8)

Note: Percentages may not sum to 100% due to rounding.

Ref. = reference group

SD = standard deviation of the mean

Table 2: Descriptive statistics on all study variables by vape trick/dripping status

Characteristic	Both vape tricks and dripping (n = 80)	Either vape tricks or dripping (n = 92)	Neither vape tricks nor dripping (n = 30)	p**
	N (%) or Mean ± SD*			
Sex				0.01
Male	52 (65.0) ^a	39 (42.4) ^{b,c}	18 (60.0) ^{a,c}	
Female	28 (35.0) ^a	53 (57.6) ^{b,c}	12 (40.0) ^{a,c}	
Race				0.68
White	70 (87.5) ^a	82 (89.1) ^a	28 (93.3) ^a	
Non-White	10 (12.5) ^a	10 (10.9) ^a	2 (6.7) ^a	
Grade	11.0 ± 1.0 ^a	10.4 ± 1.0 ^b	10.8 ± 0.9 ^a	0.0004
SES	6.9 ± 1.5 ^a	6.7 ± 1.6 ^a	7.2 ± 1.7 ^a	0.37
Age of e-cigarette onset (years)	13.6 ± 2.1 ^a	14.5 ± 1.3 ^b	14.6 ± 1.8 ^b	0.002
E-cig frequency in past 30 days (days)	24.5 ± 7.0 ^a	19.4 ± 7.7 ^b	22.7 ± 7.8 ^a	< 0.0001
Use other tobacco products				< 0.0001
Yes	73 (91.3) ^a	67 (72.8) ^b	16 (53.3) ^c	
No	7 (8.8) ^a	25 (27.2) ^b	14 (46.7) ^c	

Note: Percentages may not sum to 100% due to rounding. Superscript letters reflect the results of pairwise comparisons between characteristic categories. Cell values with matching superscript letters do not differ significantly from one another ($p > 0.05$). Cells with different superscript letters are statistically significantly different ($p < 0.05$).

Ref. = reference group.

*Table values are mean ± SD for continuous variables and n (column %) for categorical variables.

**p-value is for analysis of variance F-test (continuous variables) or χ^2 test (categorical variables). Statistically significant differences ($p < 0.05$) are denoted in bold.

Unadjusted Model

The results for the unadjusted general linear model describing the relationship between the independent (alternative e-cigarette use behavior) and dependent (log-transformed e-cigarette nicotine dependence) variables are shown in Tables 3 and 4. The unadjusted model accounted for 7.5% of the variance of the log-transformed e-cigarette nicotine dependence variable. The unadjusted mean log-transformed e-cigarette nicotine dependence score was highest for individuals who engaged in both behaviors (Mean = 0.65 [SE = 0.05], 95% CI = [0.54, 0.76]) and

lowest for those who endorsed neither (Mean = 0.34 [SE = 0.09], 95% CI = [0.16, 0.52]) (Table 3). The average nicotine dependence score was significantly higher for individuals who conducted both behaviors compared to those who practiced either (Mean difference = 0.27, 95% CI = [0.13, 0.42]) and neither (Mean difference = 0.31, 95% CI = [0.10, 0.52]) behaviors (Table 4). This suggests that individuals who engaged in both behaviors were more nicotine dependent compared to those who endorsed either or neither behavior. In contrast, the difference in mean nicotine dependence scores was not significantly different for either vs. neither behavior (Mean difference = 0.03, 95% CI = [-0.17, 0.24]) (Table 4).

Table 3: Unadjusted (least squares) mean values of the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior

Behavior	Mean (SE)	95% CI
Both vape tricks and dripping	0.65 (0.05)	0.54, 0.76
Either vape tricks or dripping	0.37 (0.05)	0.27, 0.47
Neither vape tricks nor dripping	0.34 (0.09)	0.16, 0.52

SE = standard error of the mean
95% CI = 95% confidence interval

Table 4: Unadjusted (least squares) mean differences in the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior

Behavior	Difference in Means	95% CI*
Both vs. Either	0.27	0.13, 0.42
Both vs. Neither	0.31	0.10, 0.52
Either vs. Neither	0.03	-0.17, 0.24

95% CI = 95% confidence interval

*Statistically significant differences ($p < 0.05$) are denoted in bold.

Adjusted Model

The results for the adjusted general linear model containing the independent and dependent variables as well as the covariates described are presented in Tables 5, 6, and 7. The adjusted model accounted for 14.1% of the variance of the log-transformed e-cigarette nicotine dependence variable. After adjusting for demographic variables and other tobacco and e-cigarette use characteristics, alternative e-cigarette use behavior was no longer a significant predictor of e-

cigarette nicotine dependence ($F(2, 192) = 1.64, p = 0.20$) (Regression coefficients are shown in Table 5). Rather, age of e-cigarette onset ($F(1, 192) = 9.70, p = 0.002$) and e-cigarette frequency in the past 30 days ($F(1, 192) = 6.49, p = 0.01$) were the only significant predictors. More specifically, individuals with a later age of e-cigarette onset had a lower dependence score ($\beta = -0.07$ [SE = 0.02], $p = 0.002$) and those who used e-cigarettes more frequently in the past month had a higher dependence score ($\beta = 0.01$ [SE = 0.005], $p = 0.01$) (Table 5). While the nicotine dependence score was still higher for individuals who endorsed both behaviors (Least square mean = 0.55 [SE = 0.06], 95% CI = [0.44, 0.67]) compared to those who endorsed either (Least square mean = 0.45 [SE = 0.05], 95% CI = [0.35, 0.55]) or neither behaviors (Least square mean = 0.37 [SE = 0.09], 95% CI = [0.19, 0.54]), there were no significant differences in the mean nicotine dependence scores for any of the behavior groups (Table 6, Table 7).

Table 5: Adjusted associations between alternative e-cigarette use behavior and the log-transformed e-cigarette nicotine dependence scale

Characteristic	β (SE)	p^*
Behavior		
Both vape tricks and dripping	0.19 (0.11)	0.09
Either vape tricks or dripping	0.08 (0.10)	0.42
Neither vape tricks nor dripping	Reference	---
Sex (ref: female)	0.06 (0.07)	0.37
Race (ref: non-white)	-0.01 (0.09)	0.94
Grade	0.05 (0.04)	0.15
SES	-0.01 (0.02)	0.57
Age of e-cigarette onset (years)	-0.07 (0.02)	0.002
E-cig frequency in past 30 days (days)	0.01 (0.005)	0.01
Use other tobacco products (ref: no)	0.06 (0.08)	0.46

Ref. = reference group

β = estimated regression coefficient

SE = standard error of the regression coefficient estimate

*Statistically significant differences ($p < 0.05$) are denoted in bold.

Table 6: Adjusted (least squares) mean values of the log-transformed e-cigarette nicotine dependence by alternative e-cigarette use behavior

Behavior	Mean (SE)	95% CI
Both vape tricks and dripping	0.55 (0.06)	0.44, 0.67
Either vape tricks or dripping	0.45 (0.05)	0.35, 0.55
Neither vape tricks nor dripping	0.37 (0.09)	0.19, 0.54

SE = standard error of the mean
95% CI = 95% confidence interval

Table 7: Adjusted (least squares) mean differences in the log-transformed e-cigarette nicotine dependence scale by alternative e-cigarette use behavior

Behavior	Difference in Means	95% CI*
Both vs. Either	0.10	-0.06, 0.27
Both vs. Neither	0.19	-0.03, 0.40
Either vs. Neither	0.08	-0.12, 0.29

95% CI = 95% confidence interval

*Statistically significant differences ($p < 0.05$) are denoted in bold.

Conclusions

The primary objective of this study was to evaluate the relationship between alternative e-cigarette use behaviors (i.e., dripping and/or vape tricks) and nicotine dependence among adolescent e-cigarette users by evaluating differences in dependence among individuals who engaged in both, either, or neither behavior. It was hypothesized that adolescents who engage in both behaviors would have greater nicotine dependence compared to those who engage in neither, which was supported by the unadjusted associations between behavior and dependence. However, the results of the adjusted associations suggest that this relationship may be driven by other e-cigarette use behaviors. More specifically, e-cigarette use frequency in the past 30 days and age of e-cigarette onset were the only statistically significant predictors included in the final model. Therefore, it can be argued that age of e-cigarette onset and e-cigarette use frequency were stronger predictors of nicotine dependence compared to engaging in alternative e-cigarette use behaviors. However, individuals who endorsed engaging in both behaviors had an earlier age of e-cigarette onset compared to those who endorsed either or neither behavior and used e-cigarettes more

frequently in the past 30 days compared to those who endorsed either behavior (Table 2). These findings are consistent with previous research suggesting that individuals who endorse these behaviors are more “advanced users” (Kong et al., under review).

To the author’s knowledge, this study is the first to assess e-cigarette nicotine dependence among adolescents who engage in alternative use behaviors such as dripping and vape tricks. Given the growing prevalence of e-cigarette use, it is essential to study the potential health risks that these adolescent users may be exposed to, including nicotine dependence. While these findings suggest that there are no significant differences in nicotine dependence by alternative e-cigarette use behavior after controlling for various demographic and e-cigarette use characteristics, this study adds to the growing body of literature to characterize potential hazards of e-cigarette use. We observed that engaging in alternative use behaviors was not associated with nicotine dependence but engaging in more frequent and earlier use were predictive of greater nicotine dependence, suggesting that a prevention strategy could be developed to delay age of onset and lower the number of days of e-cigarette use. Future research should examine whether these prevention strategies are effective in lowering nicotine dependence. Future research should also elucidate the role of e-cigarette frequency, age of onset, and alternative use behaviors. It is possible that alternative use behaviors may contribute to nicotine dependence because engaging in these behaviors may lead to greater use frequency, but this relationship must be tested in future studies using a mediational analysis.

Limitations and Future Directions

When interpreting the findings of this study, several study limitations must be noted. Given that the data were self-reported, the findings rest on the assumption that participants provided accurate data. The sample used for this analysis consisted of individuals who used e-cigarettes at least ten times within the past month to exclude infrequent e-cigarette users who would naturally

have low levels of nicotine dependence. However, the participants included in the analysis account for only 19.2% ($n = 202$) of the original sample of ever e-cigarette users ($n = 1,047$). Given the small sample size and few participants who reported only dripping (1.5%, $n = 3$), nicotine dependence of individuals who conducted only dripping or only vape tricks could not be evaluated separately. While the majority of the analytic sample who endorsed dripping also conducted vape tricks, there is a possibility that levels of dependence differ for both behaviors. For this reason, future research should study this area further. Additionally, though participants who reported using e-cigarettes less than ten times within the past month were excluded from the sample, the overall level of nicotine dependence in the sample was still low (Mean = 0.9 [SD = 1.0]), which may explain the non-significant results seen in the final adjusted model between alternative use behaviors and nicotine dependence.

A limitation of this study was the exclusion of nicotine concentration from the full model. Previous studies have found that nicotine concentration is a significant predictor when evaluating e-cigarette nicotine dependence (Morean et al., 2018). However, due to a large proportion of missing responses (31.2%, $n = 63$), nicotine concentration could not be included in the final model. Accurate levels of nicotine concentration are difficult to ascertain because many adolescents report not knowing the level of nicotine concentration used. In fact, a 2015 study of e-cigarette use among Connecticut middle and high school students found that 12.0% of current users did not know the nicotine concentration they typically use when vaping (Krishnan-Sarin et al., 2015). It is possible that many adolescent users are sharing their friends' e-cigarettes, so they are unaware of the nicotine level. However, existing research suggests that individuals who engaged in both dripping and vape tricks use higher concentrations of nicotine compared to those who do not endorse these behaviors (Kong et al., under review). Therefore, one would expect nicotine concentration to follow trends similar to that of e-cigarette frequency in the past 30 days, where higher

concentrations of nicotine would result in greater dependence. However, these conclusions cannot be drawn with confidence due to the exclusion of this variable from the analysis. Further research is therefore necessary to better measure e-cigarette nicotine concentrations among adolescents and ensure that reported data are accurate to control for this variable when studying nicotine dependence.

Because of missing data, the current use of other tobacco products was also evaluated as a single covariate rather than as separate variables (i.e., current use of cigarettes, current use of cigars, etc.). However, levels of nicotine dependence may differ based on which other tobacco products adolescents use as well as the frequency by which they use these products. For this reason, future studies may benefit by identifying better ways of collecting data on these questions from younger populations to minimize the amount of missing responses.

Finally, the findings of this study may not be applicable to the general population given that participants were recruited from four Southeastern Connecticut high schools. However, given the lack of research on this topic, the findings of this study are novel and may lead to future studies in this area using more diverse populations.

Despite their limitations, the findings of this study are novel in that they highlight factors that can influence nicotine dependence among adolescents who engage in different alternative e-cigarette use behaviors. Future studies should continue evaluating the harms and health risks of practicing these behaviors, especially among younger populations.

References

- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*: American Psychiatric Pub.
- Benowitz, N. L. (2010). Nicotine addiction. *New England Journal of Medicine*, *362*(24), 2295-2303.
- Bold, K. W., Kong, G., Camenga, D. R., Simon, P., Cavallo, D. A., Morean, M. E., & Krishnan-Sarin, S. (2018). Trajectories of e-cigarette and conventional cigarette use among youth. *Pediatrics*, *141*(1), e20171832.
- Centers for Disease Control and Prevention. (2019). Quick Facts on the Risks of E-cigarettes for Kids, Teens, and Young Adults.
- Colby, S. M., Tiffany, S. T., Shiffman, S., & Niaura, R. S. (2000). Measuring nicotine dependence among youth: a review of available approaches and instruments. *Drug and Alcohol Dependence*, *59*, 23-39.
- Cooper, M., Harrell, M. B., & Perry, C. L. (2016). Comparing young adults to older adults in e-cigarette perceptions and motivations for use: implications for health communication. *Health education research*, *31*(4), 429-438.
- DeVito, E. E., & Krishnan-Sarin, S. (2018). E-cigarettes: Impact of e-liquid components and device characteristics on nicotine exposure. *Current neuropharmacology*, *16*(4), 438-459.
- Gentzke, A. S., Creamer, M., Cullen, K. A., Ambrose, B. K., Willis, G., Jamal, A., & King, B. A. (2019). Vital Signs: Tobacco Product Use Among Middle and High School Students — United States, 2011–2018. *MMWR Morb Mortal Wkly Rep*, *68*, 157–164.
- Kong, G., Morean, M. E., Cavallo, D. A., Camenga, D. R., & Krishnan-Sarin, S. (2015). Reasons for electronic cigarette experimentation and discontinuation among adolescents and young adults. *Nicotine & tobacco research*, *17*(7), 847-854.
- Kong, G., Morean, M. E., Wu, R., Bhatti, H., Bold, K. W., Simon, P., & Krishnan-Sarin, S. (under review). Alternative E-cigarette Use Behaviors among Adolescents: Dripping and Vape Tricks.
- Kosmider, L., Sobczak, A., Fik, M., Knysak, J., Zaciera, M., Kurek, J., & Goniewicz, M. L. (2014). Carbonyl compounds in electronic cigarette vapors: effects of nicotine solvent and battery output voltage. *Nicotine & Tobacco Research*, *16*(10), 1319-1326.
- Krishnan-Sarin, S., Morean, M. E., Camenga, D. R., Cavallo, D. A., & Kong, G. (2015). E-cigarette Use Among High School and Middle School Adolescents in Connecticut. *Nicotine Tob Res*, *17*(7), 810-818. doi:10.1093/ntr/ntu243
- Krishnan-Sarin, S., Morean, M. E., Kong, G., Bold, K. W., Camenga, D. R., Cavallo, D. A., . . . Wu, R. (2017). E-cigarettes and “dripping” among high-school youth. *Pediatrics*, *139*(3), e20163224.
- Luo, Z., Alvarado, G. F., Hatsukami, D. K., Johnson, E. O., Bierut, L. J., & Breslau, N. (2008). Race differences in nicotine dependence in the Collaborative Genetic study of Nicotine Dependence (COGENE). *Nicotine Tob Res*, *10*(7), 1223-1230. doi:10.1080/14622200802163266
- Miech, R., Patrick, M. E., O'Malley, P. M., & Johnston, L. D. (2017). E-cigarette use as a predictor of cigarette smoking: results from a 1-year follow-up of a national sample of 12th grade students. *Tobacco control*, *26*(e2), e106-e111.
- Morean, M. E., Kong, G., Camenga, D. R., Cavallo, D. A., & Krishnan-Sarin, S. (2015). High school students' use of electronic cigarettes to vaporize cannabis. *Pediatrics*, *136*(4), 611-616.

- Morean, M. E., Krishnan-Sarin, S., & O'Malley, S. S. (2018). Assessing nicotine dependence in adolescent e-cigarette users: The 4-item patient-reported outcomes measurement information system (PROMIS) nicotine dependence item bank for electronic cigarettes. *Drug and alcohol dependence, 188*, 60-63.
- Murthy, V. H. (2017). E-cigarette use among youth and young adults: a major public health concern. *JAMA pediatrics, 171*(3), 209-210.
- Pennanen, M., Broms, U., Korhonen, T., Haukkala, A., Partonen, T., Tuulio-Henriksson, A., . . . Kaprio, J. (2014). Smoking, nicotine dependence and nicotine intake by socio-economic status and marital status. *Addict Behav, 39*(7), 1145-1151. doi:10.1016/j.addbeh.2014.03.005
- Pepper, J. K., Lee, Y. O., Watson, K. A., Kim, A. E., Nonnemaker, J. M., & Farrelly, M. C. (2017). Risk factors for youth e-cigarette “Vape Trick” behavior. *Journal of Adolescent Health, 61*(5), 599-605.
- Shiffman, S., & Paton, S. M. (1999). Individual differences in smoking: gender and nicotine addiction. *Nicotine Tob Res, 1 Suppl 2*, S153-157; discussion S165-156.
- Soneji, S., Barrington-Trimis, J. L., Wills, T. A., Leventhal, A. M., Unger, J. B., Gibson, L. A., . . . Miech, R. A. (2017). Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. *JAMA pediatrics, 171*(8), 788-797.
- Talih, S., Balhas, Z., Salman, R., Karaoghlanian, N., & Shihadeh, A. (2016). “Direct dripping”: a high-temperature, high-formaldehyde emission electronic cigarette use method. *Nicotine & Tobacco Research, 18*(4), 453-459.
- United States Department of Health and Human Services. (2016). E-cigarette use among youth and young adults. A report of the Surgeon General. Retrieved March, 1, 2018.
- Wagener, T. L., Floyd, E. L., Stepanov, I., Driskill, L. M., Frank, S. G., Meier, E., . . . Queimado, L. (2017). Have combustible cigarettes met their match? The nicotine delivery profiles and harmful constituent exposures of second-generation and third-generation electronic cigarette users. *Tobacco control, 26*(e1), e23-e28.
- Wagoner, K. G., Cornacchione, J., Wiseman, K. D., Teal, R., Moracco, K. E., & Sutfin, E. L. (2016). E-cigarettes, hookah pens and vapes: adolescent and young adult perceptions of electronic nicotine delivery systems. *Nicotine & Tobacco Research, 18*(10), 2006-2012.
- Yuan, M., Cross, S. J., Loughlin, S. E., & Leslie, F. M. (2015). Nicotine and the adolescent brain. *The Journal of physiology, 593*(16), 3397-3412.