



Dripping and vape tricks: Alternative e-cigarette use behaviors among adolescents

Grace Kong^{a,*}, Meghan E. Morean^{a,b}, Krysten W. Bold^a, Ran Wu^a, Harmanpreet Bhatti^a, Patricia Simon^a, Suchitra Krishnan-Sarin^a

^a Department of Psychiatry, Yale University, New Haven, CT 06519, USA

^b Department of Psychology, Oberlin College, OH 44074, USA

HIGHLIGHTS

- 21% of ever e-cigarette users ever dripped and 55% ever conducted vape tricks.
- The most frequently endorsed flavors used for both behaviors were fruit, candy, and mint.
- Nicotine concentrations for dripping was 3 mg and for vape tricks was 0 mg.
- Source for learning these behaviors were friends.
- Risky tobacco use behaviors were associated with dripping and vape tricks.

ARTICLE INFO

Keywords:

E-cigarettes
Adolescents
Vape tricks
Dripping

ABSTRACT

Introduction: E-cigarettes appeal to adolescents because of alternative uses, such as dripping (i.e., applying e-liquid directly on the atomizer) and conducting vape tricks (i.e., creating shapes from exhaled aerosol). However, little is known about these behaviors and adolescents who engage in these behaviors.

Methods: Using cross-sectional surveys from 4 high schools in Connecticut in 2017 (N = 2945), we assessed the frequency of dripping and conducting vape tricks, product characteristics (e.g., nicotine, flavor) used for these behaviors, and where adolescents learn about these behaviors. We also conducted multinomial logistic regression analysis to assess whether demographics, age of e-cigarette use onset, past-month-use of e-cigarettes, and lifetime use of other tobacco products were associated with dripping and/or vape tricks.

Results: Among ever e-cigarette users (N = 1047), 20.5% ever dripped and 54.9% ever conducted vape tricks. The most frequently endorsed 1) flavors used for both behaviors were fruit, candy, and mint, 2) nicotine concentrations used for dripping was 3 mg and for vape tricks was 0 mg, and 3) the top source for learning these behaviors were friends. The multinomial model showed that earlier age of e-cigarette use onset, past-month-use of e-cigarettes, and lifetime use of other tobacco products were associated with dripping and vape tricks.

Discussion: Engaging in dripping and vape tricks was associated with risky tobacco use behaviors (e.g., earlier age of onset, other tobacco use), and involved exposure to nicotine and flavors. Reducing appeal of dripping and vape tricks and preventing product characteristics that facilitate these behaviors may reduce harm to adolescents.

1. Introduction

E-cigarettes are the most commonly used tobacco product among U.S. adolescents (Gentzke et al., 2019). Currently, 20.8% of U.S. high school students reported using e-cigarettes in the past month (Gentzke et al., 2019). E-cigarette use among adolescents is concerning because of the detrimental effect of nicotine on the developing brain (Abreu-

Villaça, Seidler, Tate, & Slotkin, 2003; Yuan, Cross, Loughlin, & Leslie, 2015), the potential for developing nicotine addiction (Case et al., 2018; Morean, Krishnan-Sarin, & O'Malley, 2018), and the increased risk of combustible tobacco product use (Barrington-Trimis et al., 2018; Bold et al., 2017; Primack, Soneji, Stoolmiller, Fine, & Sargent, 2015; Soneji et al., 2017). Thus, preventing adolescent e-cigarette use is an important national public health objective (USDHHS, 2016). The U.S.

* Corresponding author at: 34 Park Street, Room S-211, New Haven, CT 06519, USA.

E-mail address: grace.kong@yale.edu (G. Kong).

<https://doi.org/10.1016/j.addbeh.2020.106394>

Received 6 December 2019; Received in revised form 6 March 2020; Accepted 10 March 2020

Available online 21 March 2020

0306-4603/ © 2020 Elsevier Ltd. All rights reserved.

Food and Drug Administration (FDA) has the authority to regulate e-cigarettes as a tobacco product and to educate the public to prevent adolescent e-cigarette use (FDA, 2016). To support the FDA's initiative to regulate the manufacturing, sales, and distribution of e-cigarettes to prevent adolescent e-cigarette use, more information is needed on e-cigarette appeal and use behaviors among adolescents.

Initial evidence from qualitative focus groups and quantitative surveys conducted with adolescents in Connecticut suggested that e-cigarette appeal among adolescents may stem from the ability to manipulate e-cigarette devices and other related components (e.g., e-liquid) to use for alternative e-cigarette use behaviors such as dripping and vape tricks (Camenga, Morean, Kong, Krishnan-Sarin, Simon, & Bold, 2018; Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2015; Krishnan-Sarin et al., 2017). Dripping is applying drops of e-liquid directly onto heated coils (Krishnan-Sarin et al., 2017; Talih, Balhas, Salman, Karaoghanian, & Shihadeh, 2016) and vape tricks involve blowing aerosol into various shapes and or large clouds ("cloud chasing") (Kong et al., 2015).

Evidence showed that among adolescents who have tried an e-cigarette, 26.1% have ever used e-cigarettes for dripping (Krishnan-Sarin et al., 2017). Dripping is concerning because it can expose users to e-liquid aerosol that is heated to high temperatures, which can yield greater levels of nicotine and non-nicotine toxicant emissions (Talih et al., 2016). There are specific devices that are available for dripping which may also facilitate dripping among adolescents. Mechanical mods are devices that supply battery power to a heating element (also called an atomizer) (P. T. Harrell & Eissenberg, 2018). They allow the users to modify different components, such as changing the battery power. The ability to customize these devices may make them more amenable to use for dripping. Unlike mechanical mods, rebuildable atomizers (RDAs) allow users to build or add their own coil. RDAs allow users to drip the e-liquid from a bottle directly to the drip tip. Rebuildable tank atomizers (RTAs) have a tank that users fill with e-liquid and vape. Individuals can use RTAs to drip by not filling the tank completely. Despite the available devices for dripping, it is currently unknown which of these devices adolescents use for dripping.

Another concern is that adolescents may be exposed to harmful flavoring chemicals if they are using flavors for dripping and for vape tricks (Allen et al., 2016). While flavors used for dripping and for vape tricks among adolescents is unknown, self-report data suggest that one appeal of dripping among adolescents is to experience stronger flavors (Krishnan-Sarin et al., 2017). Thus, more research is needed to understand flavors used for dripping and for vape tricks and potential health risks due to exposure to flavoring chemicals through these behaviors.

One reason for the appeal of dripping among adolescents may be related to the ability to conduct vape tricks because dripping can produce thicker clouds of vapor (Krishnan-Sarin et al., 2017). Additionally, vape tricks may have broad appeal among adolescent e-cigarette users. For instance, Pepper et al. (2017) conducted a detailed study on vape tricks among adolescents and observed that among adolescent ever e-cigarette users, 77.8% reported trying vape tricks, 83.7% reported watching vape tricks in person, and 74.0% reported watching vape tricks online. Indeed, vape tricks are prominently featured on YouTube videos that could be accessed by adolescents with appealing features such as hip hop music (Kong, LaVallee, Rams, Ramamurthi, & Krishnan-Sarin, 2019). Analysis of the content of these videos showed that vape tricks range from blowing simple rings to complex shapes like "dragon" (where users blow out large amounts from the nose) (Kong et al., 2019). Despite the evidence that suggests that vape tricks and dripping behaviors appear to co-occur (Krishnan-Sarin et al., 2017), little is known about these alternative uses of e-cigarettes and who are at risk for engaging in these behaviors.

We aimed to examine the prevalence and frequency of dripping and vape tricks and the concentrations of nicotine and flavors being used for these behaviors. We also examined which adolescents engage in these behaviors and how they learn to conduct these behaviors. Because these

behaviors could co-occur (Krishnan-Sarin et al., 2017), we examined demographic and tobacco use predictors of engaging in both of these behaviors (i.e., dripping and vape tricks), in a single behavior (i.e., dripping only or vape tricks only), or not engaging in either of these behaviors. Finally, we assess which devices were used for dripping.

2. Methods

2.1. Procedures/sample

In Spring 2017, we administered paper/pencil school-wide surveys about tobacco use during advisory periods in four Southeastern Connecticut high schools (N = 2945; 53.7% female, 16.1 years old [SD = 1.28], 72.3% White). Prior to survey administration, we distributed information sheets to notify parents about the study and to provide them with instructions to contact the school if they wanted to decline their child's participation. On the day of survey administration, the research staff distributed the surveys and informed students that the survey was anonymous and that their participation was voluntary. Students received a pen for participating. Of all students who were in school on the days that the surveys were administered, 76.4% completed the survey. Study procedures were approved by the Yale University Institutional Review Board and school administrators.

2.2. Measures

2.2.1. Demographics

Demographics measured were age, sex at birth, race/ethnicity, and socioeconomic status (SES; determined by the Family Affluence Scale [FAS (Boyce & Dallago, 2004; Boyce, Torsheim, Currie, & Zambon, 2006)]). A summary score was created from the four items of the FAS (range 0–9).

2.2.2. E-cigarette use

Ever e-cigarette use was determined by a response of "yes" to "Have you ever tried an e-cigarette, even just one or two puffs?" or providing a valid age to "How old were you when you first tried an e-cigarette, even just 1 or 2 puffs?"

Past-30-day e-cigarette use was determined by a response of ≥ 1 day to the question, "Approximately how many days out of the past 30 days did you vape an e-cigarette?"

2.2.3. Ever tobacco use

Ever tobacco use was determined by a response of "yes" to any of the questions assessing ever use of cigarettes, hookah, cigars, cigarillos, or smokeless tobacco (i.e., "Have you ever tried...?").

2.2.4. Dripping and vape tricks

Ever dripped: Students were provided with the following description of dripping, accompanied by images 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." Responses of "yes" to "Have you ever dripped?" or ≥ 1 days to the question, "Approximately how many days out of the past 30 days did you drip?" were coded as having ever dripped.

Ever conducted vape tricks: Students were shown pictures of vape tricks (e.g., vapor rings; large vapor clouds) along with 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')." Responses of "yes" to "Have you ever tried vape tricks?" or ≥ 1 days to the question, "Approximately how many days out of the past 30 days did you do vape tricks?" were coded as ever having conducted vape tricks.

Frequency of dripping and vape tricks conducted in the past 30 days was

assessed with two separate questions, “Approximately how many days out of the past 30 days did you [drip/do vape tricks]?” Responses for each question ranged from 0 to 30 days.

Nicotine concentrations used for dripping and vape tricks were assessed with two separate questions, “What level of nicotine do you typically use when [dripping/doing vape tricks]?” Response options for each question were: “0mg, 3 mg, about 6 mg, about 12 mg, about 18 mg, about 24 mg, I don’t know, and other.”

Flavors used for dripping and vape tricks were assessed with two separate questions, “What flavors do you like to use when you [drip/do vape tricks]?” (select all that apply) Response options were: “mint (spearmint, wintergreen, peppermint), menthol, tobacco, fruit (cherry, blueberry, strawberry, coconut), coffee (espresso, latte, cappuccino), candy or dessert (chocolate, Jolly Rancher), spice (clove, cinnamon, nutmeg), vanilla, alcohol (pina colada, strawberry daiquiri, bourbon, rum, brandy), I don’t know, and other.”

Sources of information about dripping and vape tricks were assessed by asking two separate questions, “How did you learn to [drip/do vape tricks]?” (select all that apply) Response options were: “friends, vape shops, YouTube, online forums/message boards, I taught myself, and other.”

Devices used for dripping were assessed among adolescents who had ever dripped with a question, “What device do you use when dripping?” (select all that apply) Response options were “mechanical mod (mech mod), rebuildable atomizer (RDA)/rebuildable tank atomizer (RTA), and other.”

2.3. Data analysis

We first conducted descriptive statistics to examine dripping and vape trick rates, product characteristics (e.g., nicotine concentrations, flavor) used for these behaviors, and where adolescents learn about these behaviors. Then we conducted multinomial regression analysis to examine predictors of engaging in alternative e-cigarette use behaviors (i.e., vape tricks only, vape tricks and dripping) versus never engaging in these behaviors. The predictors were sex (male vs. female), age, race (White vs. non-White), SES, age of e-cigarette use onset, past-30-day e-cigarette use (no vs. yes), and ever use of other tobacco products (no vs. yes). We could not do similar comparisons between adolescents who only dripped because of the small sample size of this group ($n = 17$). SAS version 9.4 was used in conducting the analyses.

3. Results

Among ever e-cigarette users (35.6% of the total sample; $N = 1047$), 20.5% ever dripped ($n = 215$; 34.3% female, 16.6 years old [$SD = 1.15$], 83.7% White) and 54.9% ever conducted vape tricks ($n = 575$, 51.7% female, 16.3 years old [$SD = 1.20$], 80.9% White).

3.1. Frequency and E-Cigarette characteristics for dripping and vape tricks

The frequency of dripping and vape tricks conducted in the past 30 days is shown in Fig. 1A, nicotine concentration used while conducting these behaviors in Fig. 1B, flavors in Fig. 1C, and source of information for these behaviors in Fig. 1D. Frequency of engaging in dripping and vape tricks varied. Although about a quarter of adolescents reported that they had not engaged in either behavior in the past month, 20.0% and 21.0% reported that they had dripped and conducted tricks 15–30 days in the past month, respectively (Fig. 1A).

Nicotine concentrations used while conducting these behaviors also varied from 0 mg to > 24 mg. Among those who had tried vape tricks, the most frequently endorsed responses for nicotine concentrations used were “I don’t know” (25.6%), 0 mg (17.6%), and 3 mg (13.6%). Among those who had ever dripped, the most frequently endorsed responses for nicotine concentrations were 3 mg (19.1%), “don’t know” (13.0%), and 0 mg (10.7%).

Top endorsed flavors used for both dripping and vape tricks were fruit (dripping: 40.5%, vape tricks: 50.6%), candy (dripping: 27.4%, vape tricks: 27.3%), and mint (dripping: 23.3%, vape tricks: 31.1%). Top sources of learning how to conduct these behaviors were friends (dripping: 51.2%, vape tricks: 61.9%), “taught self” (dripping: 23.3%, vape tricks: 43.5%), and YouTube (dripping: 10.2%, vape tricks: 26.3%).

Among adolescents who had ever dripped, 53.5% used an RDA/RTA for dripping, 39.1% used a mech mod, and 7.0% reported “other.” Other responses mostly included “I don’t know.”

3.2. Predictors of engaging in dripping and vape tricks or vape tricks only

Ever e-cigarette users were further categorized into those who 1) never conducted dripping or vape tricks (33.7%; $n = 353$), 2) conducted vape tricks only (36.0%; $n = 377$), 3) conducted both dripping and vape tricks (18.9%; $n = 198$), and 4) conducted dripping only (2%; $n = 17$).

To assess predictors of these groups, we conducted multinomial logistic regression analysis. Again, we excluded the “dripping only” group in the analysis because of small sample size. Multinomial logistic regression analyses (Table 1) showed that relative to adolescents who never conducted dripping/vape tricks, adolescents who conducted vape tricks only were more likely to be female, while those who conducted both vape tricks and dripping were more likely to be male and older. Furthermore, relative to adolescents who never conducted dripping/vape tricks, those who conducted vape tricks only or both vape tricks and dripping 1) used e-cigarettes at a younger age, 2) used e-cigarettes in the past 30 days, and 3) tried other tobacco products.

4. Discussion

The goal of this study was to assess the prevalence of dripping and vape tricks, product characteristics associated with these behaviors (e.g., flavors, nicotine concentrations used), and source of information used to learn to conduct these behaviors among adolescents e-cigarette users. We also assessed predictors of dripping and/or vape tricks.

We observed that among ever e-cigarette users, 20.5% ever dripped and 54.9% ever conducted vape tricks. Interestingly, a large majority (92%) of adolescents who dripped have also conducted vape tricks, which supports prior findings that the main reason that adolescents drip is to conduct vape tricks (Krishnan-Sarin et al., 2017). Our findings also indicated that adolescent ever e-cigarette users who engaged in either vape tricks and/or dripping were more likely to engage in riskier tobacco use than adolescent e-cigarette users who never engaged in these behaviors, suggesting the need for focused efforts to prevent these alternative uses of e-cigarettes among adolescents.

The prevalence of ever dripping identified in this study with data collected from 2017 was comparable to the prevalence observed in a previous study in 2015 (Krishnan-Sarin et al., 2017), indicating that dripping may not be a “fad” but a behavior that is persisting over time. The availability and sales of devices specifically used for dripping (e.g., rebuildable drip atomizers [RDAs] and rebuildable tank atomizers [RTAs]) may be maintaining these use rates over time. We observed that the most commonly used e-cigarette devices for dripping were RDAs and RTAs, followed by mechanical mods (i.e., mech mods). Very few students reported using other devices for dripping. Future studies need to better understand how each of these, and other devices could be modified to engage in alternative behaviors such as dripping, and also determine the toxicity of using these devices.

Access to these devices among adolescents may change based on the recent passage of the Tobacco 21 Law that raises the minimum sales age for all tobacco products to 21 years old. Existing evidence shows that comprehensive Tobacco 21 laws and proper enforcement of these laws is important in reducing youth tobacco use (Morain, Winickoff, & Mello, 2016). Therefore, this law also could reduce e-cigarette use

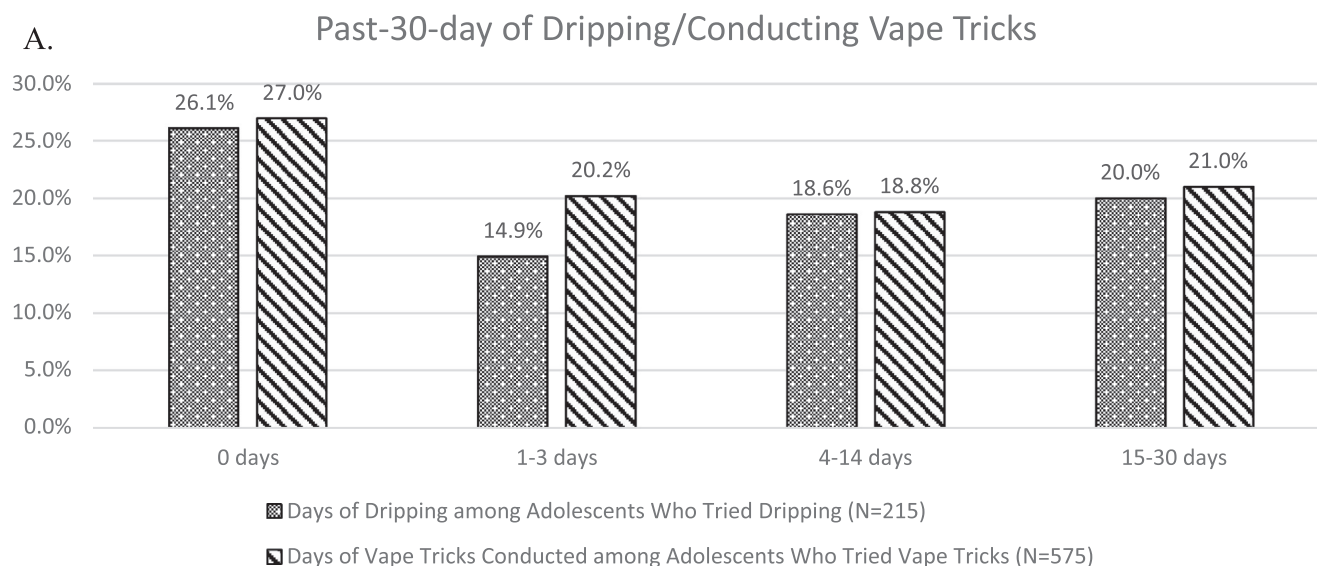


Fig. 1. Dripping and vape tricks characteristics.

among youth. However, it is important to note that Tobacco 21 is one aspect of youth tobacco control efforts, and other efforts such as marketing restrictions, prevention and cessation programs, and other tobacco-free policies are needed to have a significant impact on youth e-cigarette use behaviors (CDC, 2014).

Of note, 20.0% of adolescents reported dripping frequently in the past 30 days (15–30 days). Frequent dripping is particularly concerning because dripping exposes users to high temperatures which can increase exposure to nicotine and other toxicants (Talih et al., 2016). Given the increased concern about lung injuries related to use of vaping products (Moritz et al., 2019), developing a better understanding of the potential toxicity of dripping as well as vape tricks is an important goal.

We examined the use of flavors and nicotine for dripping and vape tricks. The top flavors used for dripping and vape tricks were fruit, candy, and mint. These e-liquid flavors are also the most commonly used flavors for e-cigarette use among adolescents (Harrell et al., 2017). Adolescents perceive e-cigarette flavors such as candy or fruit to be less harmful to health than tobacco flavored e-cigarettes (Pepper, Ribisl, & Brewer, 2016). Preferring more e-liquid flavors or preferring certain flavors such as fruits, dessert, and alcohol also is associated with more

frequent e-cigarette use among adolescents compared to adults (Morean et al., 2018). Dripping and vape tricks may allow adolescents to experience different flavor strengths and throat hit from nicotine. Importantly, flavors are composed of chemicals like aldehydes (Tierney, Karpinski, Brown, Luo, & Pankow, 2015), and dripping (or exposure to high temperatures) and vape tricks (or exposure to large amounts of vapor) could expose adolescents to higher levels of these toxic chemicals and their metabolites (Allen et al., 2016; O'Brien, Siraki, & Shangari, 2005). Further research is needed to understand potential toxicant exposure from using flavored e-liquids via vape tricks and dripping.

Nicotine concentrations used for conducting both of these behaviors varied from 0 mg to over 24 mg. While we observed variability in use of different nicotine concentrations for both behaviors, adolescents most frequently endorsed using 3 mg of nicotine for dripping (19%) and using 0 mg when conducting vape tricks (18%). These findings suggest that a sizeable portion of adolescents report being exposed to nicotine when they engage in alternative use behaviors with e-cigarettes, and their exposure to nicotine could vary depending on the devices that are used for these alternative uses. It is also important to note that a large

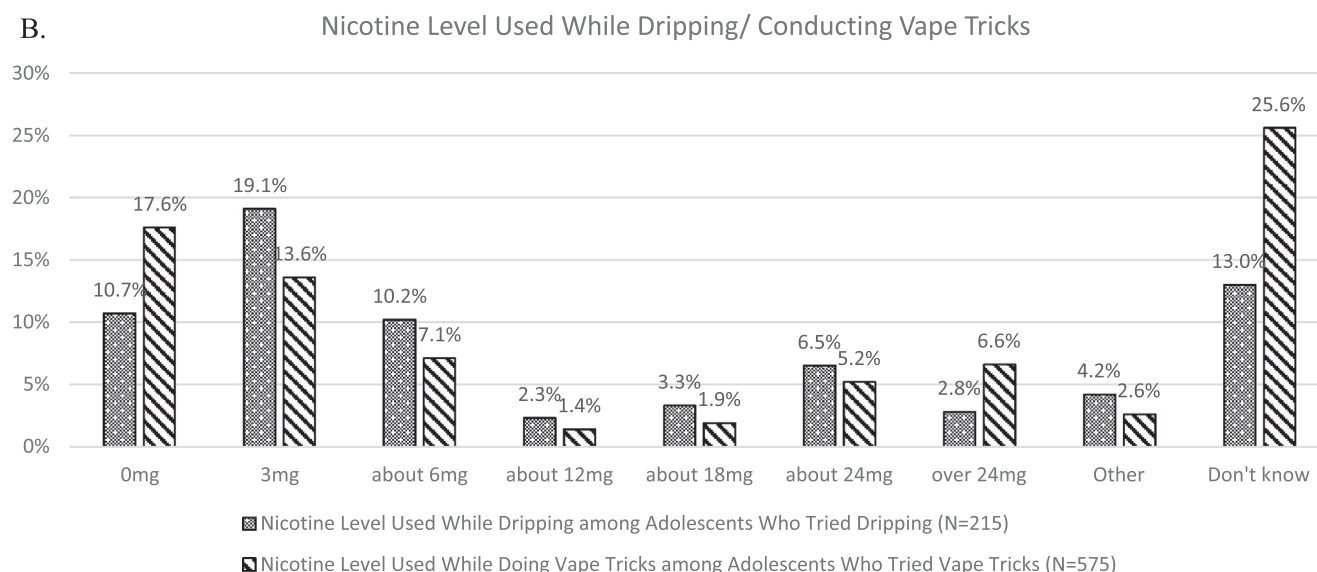


Fig. 1. (continued)

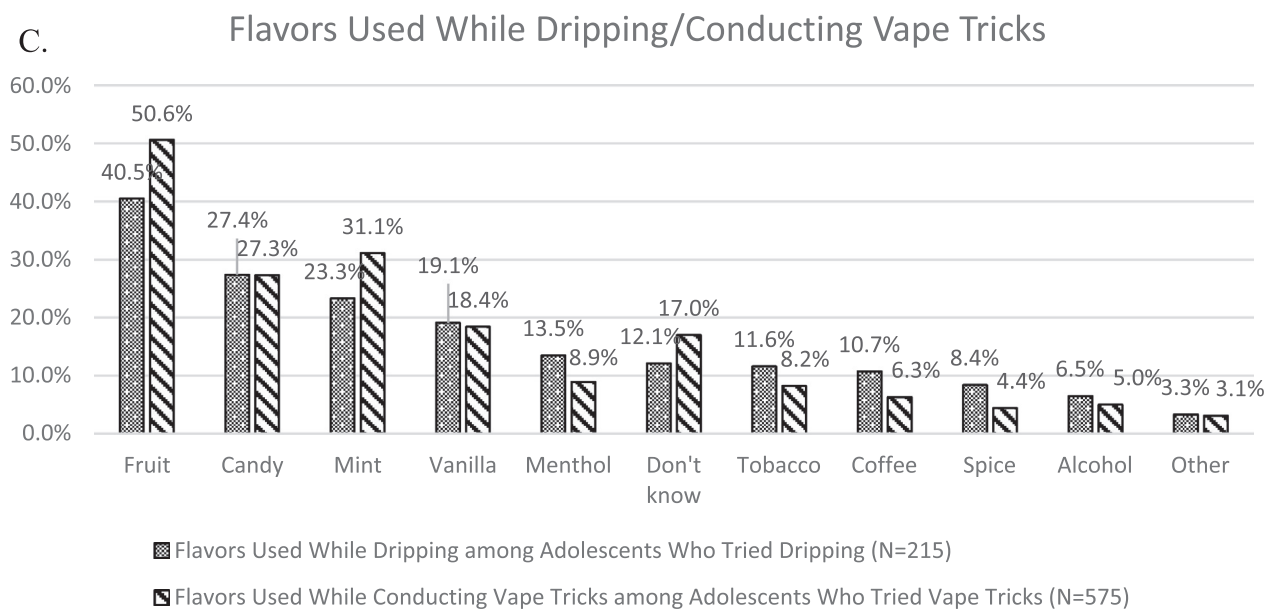


Fig. 1. (continued)

number of adolescents did not know what nicotine concentration they were using for these behaviors. This raises further concerns about unintended exposure to nicotine and also suggests that effective labeling of the nicotine concentrations on e-liquids is needed.

Friends were the most frequently endorsed source for learning how to conduct these alternative e-cigarette use behaviors. This finding is consistent with the role of friends in influencing adolescent risk taking behaviors including cigarette (Cavalca et al., 2013) and e-cigarette use (Kong et al., 2015). Interestingly, we also observed that adolescents use YouTube, a popular social media website to share and watch videos, to learn about these behaviors. This finding is consistent with a recent YouTube study documenting the large presence of videos on how to conduct vape tricks on YouTube (Kong et al., 2019). Adolescents' use of YouTube to learn about alternative e-cigarette use behaviors is concerning because the majority of e-cigarette videos on YouTube have pro-e-cigarette content (Huang, Kornfield, & Emery, 2016; Luo, Zheng, Zeng, & Leischow, 2014). Vape tricks are also featured on other social media websites used by adolescents (Pepper et al., 2017; Unger et al., 2016). Further research should document how alternative e-cigarette

use behaviors, including dripping, are promoted on YouTube and on other popular social media websites. Furthermore, the FDA need to consider how promotion of dripping and vape tricks could be restricted on social media websites to reduce the appeal of e-cigarettes to youth.

We also observed sex differences; males were more likely to engage in both dripping and vape tricks and were less likely to engage in vape tricks only. These findings suggest that adolescent boys may be more likely to engage in riskier e-cigarette use.

Despite these interesting findings, certain study limitations should be noted. We only examined certain mods for dripping and did not examine a wide range of devices, but it should be noted that very few reported using "other" devices for dripping. Another limitation is not examining devices used for vape tricks. Given the recent innovations in e-cigarette device types (e.g., pod devices and disposable devices that resemble pod devices, which are extremely popular among adolescents (Huang et al., 2019; Krishnan-Sarin et al., 2019; Willett et al., 2018), future studies should investigate use of other device types used for vape tricks and dripping. Additionally, we could not compare adolescents who drip only to adolescent e-cigarette users who did not conduct vape

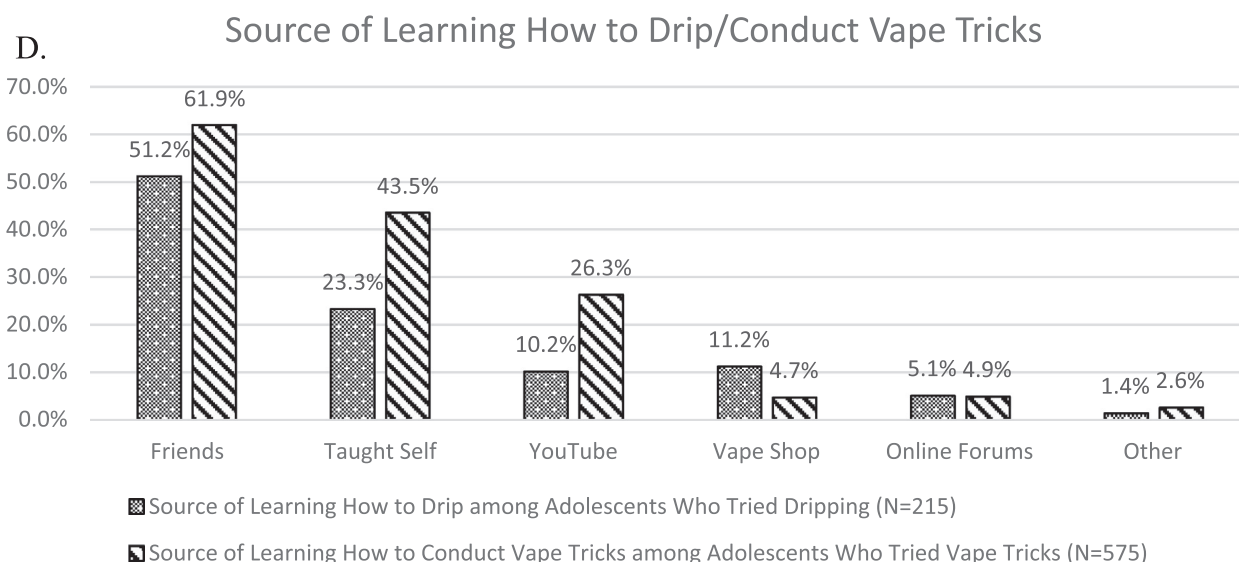


Fig. 1. (continued)

Table 1

Associations between adolescents who never tried vape tricks/dripping versus who tried vape tricks only and who tried vape tricks/dripping.

	Never Tried Vape Tricks/Dripping (N = 353; 33.7%)	Tried Vape Tricks Only (N = 377; 36.0%)	Tried Dripping and Vape Tricks (N = 198; 18.9%)	Tried Dripping Only (N = 17; 2%)	Vape Tricks Only vs. Never Tried Vape Tricks/Dripping			Vape Tricks and Dripping vs. Never Tried Vape Tricks/Dripping		
	% (n) or M (SD)	% (n) or M (SD)	% (n) or M (SD)	% (n) or M (SD)	AOR	95% CI		AOR	95% CI	
Sex										
Female	53.5 (189)	61.8 (233)	32.3 (64)	47.1 (8)	1.42	1.02	1.97	0.49	0.31	0.77
Male (ref.)	44.5 (157)	36.6 (138)	64.7 (128)	52.9 (9)	–	–	–	–	–	–
Age	16.37 ± 1.19	16.11 ± 1.18	16.61 ± 1.16	16.35 ± 1.00	0.87	0.74	1.02	1.25	1.01	1.53
Race/ethnicity										
White	80.2 (283)	79.3 (299)	83.8 (166)	82.4 (14)	0.73	0.48	1.13	1.42	0.73	2.75
Non-White (ref.)	19.8 (70)	20.7 (78)	16.2 (32)	17.7 (3)	–	–	–	–	–	–
SES	6.83 ± 1.66	6.73 ± 1.75	6.66 ± 1.57	5.94 ± 2.01	0.94	0.85	1.04	0.93	0.81	1.07
E-cigarette age of onset	14.97 ± 1.58	14.57 ± 1.49	14.02 ± 2.00	14.47 ± 1.50	0.88	0.78	0.99	0.71	0.61	0.82
Past-30-day e-cigarette use										
Yes	41.4 (146)	64.2 (242)	83.8 (166)	82.4 (14)	2.73	1.95	3.82	7.56	4.44	12.87
No (ref.)	56.9 (201)	35.3 (133)	16.2 (32)	17.7 (3)	–	–	–	–	–	–
Ever use of other tobacco products										
Yes	34.3 (121)	45.9 (173)	71.7 (142)	41.2 (7)	1.73	1.23	2.44	5.93	3.60	9.76
No (ref.)	63.5 (224)	49.1 (185)	17.2 (34)	52.9 (9)	–	–	–	–	–	–

Note: Users who tried dripping only were not included in the multinomial model due to small sample size. SES = socioeconomic status. AOR = adjusted odds ratio. 95% CI = 95% confidence interval. Ref. = reference group. All AORs adjusted for the variables listed here. Bold font indicates statistically significant difference, $p < .05$.

tricks or dripping because of the small sample size of respondents who only drip. Although our study findings showed that the majority of those who dripped were conducting vape tricks, there was a minority of those who dripped but who were not conducting vape tricks. This group needs further examination. Additionally, while this is the first study to examine dripping and vape tricks, more recent data are needed on these behaviors. Additionally, laboratory studies would be useful for better understanding vape tricks because there might also be differences in puffing topography of adolescents who conduct vape tricks versus users who do not engage in vape tricks. For instance, users who conduct vape tricks could inhale the aerosol deeper into their lungs and hold it for longer periods of time or inhale more aerosol, which may expose them to more harm.

Limitations notwithstanding, this study provides novel information regarding alternative e-cigarette use behaviors among adolescents. The appeal of e-cigarettes for adolescents may be related to the ability to engage in dripping and/or vape tricks. Engaging in these behaviors could be harmful to the users because of exposure to toxic chemicals.

The findings of this study also suggest that public health campaigns that directly communicate the risks of engaging in dripping and vape tricks are needed. Appropriate regulations are also needed to prevent adolescents from engaging in these behaviors. For instance, the FDA could prohibit the manufacture and sale of modifiable devices that can be used specifically for dripping, which could also reduce the appeal of vape tricks. The FDA could also restrict e-liquid flavors that appeal to adolescents for conducting these alternative e-cigarette use behaviors, require appropriate labeling of nicotine to communicate about the nicotine level, and restrict promotional videos on YouTube and other social media websites that increase the appeal of these behaviors.

Funding

This research was supported by grants P50DA036151 and U54DA036151 (Yale Tobacco Centers of Regulatory Science [TCORS]) from the National Institute on Drug Abuse (NIDA) at the National Institutes of Health (NIH) and the Food and Drug Administration (FDA) Center for Tobacco Products (CTP). The funders had no role in the design and conduct of the study; collection, management, analysis, or

interpretation of the data; or preparation, review, or approval of the manuscript. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the FDA.

CRedit authorship contribution statement

Grace Kong: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Meghan E. Morean:** Conceptualization, Methodology, Investigation, Resources, Writing - review & editing. **Krysten W. Bold:** Conceptualization, Methodology, Investigation, Resources, Writing - review & editing. **Ran Wu:** Methodology, Validation, Formal analysis. **Harmanpreet Bhatti:** Methodology, Validation, Formal analysis, Data curation, Visualization. **Patricia Simon:** Conceptualization, Methodology, Investigation, Resources, Writing - review & editing. **Suchitra Krishnan-Sarin:** Conceptualization, Methodology, Investigation, Resources, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Abreu-Villaça, Y., Seidler, F. J., Tate, C. A., & Slotkin, T. A. (2003). Nicotine is a neurotoxin in the adolescent brain: Critical periods, patterns of exposure, regional selectivity, and dose thresholds for macromolecular alterations. *Neuropsychopharmacology*, 28, 1935–1949.
- Allen, J. G., Flanagan, S. S., LeBlanc, M., Vallarino, J., MacNaughton, P., Stewart, J. H., & Christiani, D. C. (2016). Flavoring chemicals in E-cigarettes: Diacetyl, 2,3-pentanedione, and acetoin in a sample of 51 products, including fruit-, candy-, and cocktail-flavored E-cigarettes. *Environmental Health Perspectives*, 126(6), 733 <https://search.proquest.com/docview/1793220075?accountid=15172>.
- Barrington-Trimis, J. L., Kong, G., Leventhal, A. M., Liu, F., Mayer, M., Cruz, T. B., ... McConnell, R. (2018). E-cigarette use and subsequent smoking frequency among adolescents. *Pediatrics*, 142(6), e20180486. <https://doi.org/10.1542/peds.2018-0486>.
- Bold, K. W., Kong, G., Camenga, D. R., Simon, P., Cavallo, D. A., Morean, M. E., &

- Krishnan-Sarin, S. (2017). Trajectories of e-cigarette and conventional cigarette use among youth. *Pediatrics*. <https://doi.org/10.1542/peds.2017-1832> e20171832.
- Boyce, W., & Dallago, L. (2004). Socioeconomic inequality. In C. Currie, C. Roberts, A. Morgan, R. Smith, W. Settertobulte, O. Samdal, & V. Rasmussen (Eds.), *Young people's health in context. Health behaviour in school-aged children (HBSC) study: International report from the 2001/2002 survey* (pp. 13–25).
- Boyce, W., Torsheim, T., Currie, C., & Zambon, A. (2006). The family affluence scale as a measure of national wealth: Validation of an adolescent self-report measure. *Social Indicators Research*, 78(3), 473–487. <https://doi.org/10.1007/s11205-005-1607-6>.
- Camenga, D. R., Morean, M. E., Kong, G., Krishnan-Sarin, S., Simon, P., & Bold, K. W. (2018). Appeal and use of customizable e-cigarette product features in adolescents. *Tobacco Regulatory Science*, 4, 51–60. doi: <https://doi.org/10.18001/TRS.4.2.5>.
- Case, K. R., Mantey, D. S., Creamer, M. R., Harrell, M. B., Kelder, S. H., & Perry, C. L. (2018). E-cigarette-specific symptoms of nicotine dependence among Texas adolescents. *Addictive Behaviors*, 84, 57–61. <https://doi.org/10.1016/j.addbeh.2018.03.032>.
- Cavalca, E., Kong, G., Liss, T., Reynolds, E. K., Schepis, T. S., Lejuez, C. W., & Krishnan-Sarin, S. (2013). A preliminary experimental investigation of peer influence on risk-taking among adolescent smokers and non-smokers. *Drug and Alcohol Dependence*, 129(1–2), 163–166. <https://doi.org/10.1016/j.drugalcdep.2012.09.020>.
- CDC. (2014). Best Practices for Comprehensive Tobacco Control Programs—2014. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.
- FDA. (2016). Deeming Tobacco Products To Be Subject to the Federal Food, Drug, and Cosmetic Act, as Amended by the Family Smoking Prevention and Tobacco Control Act; Restrictions on the Sale and Distribution of Tobacco Products and Required Warning Statements for Tobacco Product. Federal Register, 81.
- 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. *Morbidity and Mortality Weekly Report (MMWR)*, 68(6), 157–164.
- Harrell, P. T., & Eissenberg, T. (2018). Automated dripping devices for vapers: RDTAs, bottomfeeders, squonk mods and dripboxes. *Tobacco Control*, 27(4), 480. <https://doi.org/10.1136/tobaccocontrol-2017-053817>.
- Harrell, M. B., Weaver, S. R., Loukas, A., Creamer, M., Marti, C. N., Jackson, C. D., ... Eriksen, M. P. (2017). Flavored e-cigarette use: Characterizing youth, young adult, and adult users. *Preventive Medicine Reports*, 5, 33–40. <https://doi.org/10.1016/j.pmedr.2016.11.001>.
- Huang, J., Duan, Z., Kwok, J., Binns, S., Vera, L. E., Kim, Y., ... Emery, S. L. (2019). Vaping versus JUULing: How the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. *Tobacco Control*, 28, 146–151. <https://doi.org/10.1136/tobaccocontrol-2018-054382>.
- Huang, J., Kornfield, R., & Emery, S. L. (2016). 100 million views of electronic cigarette YouTube videos and counting: Quantification, content evaluation, and engagement levels of videos. *Journal of Medical Internet Research*, 18(3), e67. <https://doi.org/10.2196/jmir.4265>.
- Kong, G., LaVallee, H., Rams, A., Ramamurthi, D., & Krishnan-Sarin, S. (2019). Promotion of vape tricks on YouTube: Content analysis. *Journal of Medical Internet Research*, 21(6), e12709. <https://doi.org/10.2196/12709>.
- 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 and Tobacco Research*, 17(7), 847–854. <https://doi.org/10.1093/ntr/ntu257>.
- Krishnan-Sarin, S., Jackson, A., Morean, M. E., Kong, G., Bold, K. W., Camenga, D. R., ... Wu, R. (2019). E-cigarette devices used by high-school youth. *Drug and Alcohol Dependence*, 194, 395–400. <https://doi.org/10.1016/j.drugalcdep.2018.10.022>.
- Krishnan-Sarin, S., Morean, M. E., Kong, G., Bold, K. W., Camenga, D. R., Cavallo, D. A., ... Wu, R. (2017). E-cigarette and “dripping” among high-school youth. *Pediatrics*, 139, e20163224. <https://doi.org/10.1542/peds.2016-3224>.
- Luo, C., Zheng, X., Zeng, D., & Leischow, S. (2014). Portrayal of electronic cigarettes on YouTube. *BMC Public Health*, 14, 1028. <http://www.biomedcentral.com/1471-2458/14/1028>.
- Morain, S. R., Winickoff, J. P., & Mello, M. M. (2016). Have Tobacco 21 Laws Come of Age? *New England Journal of Medicine*, 374(17), 1601–1604. <https://doi.org/10.1056/NEJMp1603294>.
- Morean, M. E., Butler, E. R., Bold, K. W., Kong, G., Camenga, D. R., Cavallo, D. A., ... Krishnan-Sarin, S. (2018). Preferring more e-cigarette flavors is associated with e-cigarette use frequency among adolescents but not adults. *PLoS One*, 13, e0189015. <https://doi.org/10.1371/journal.pone.0189015>.
- Morean, M. E., Krishnan-Sarin, S., & O'Malley, 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. <https://doi.org/10.1016/j.drugalcdep.2018.03.029>.
- Moritz, E. D., Zapata, L. B., Lekichvili, A., Glidden, E., Annor, F. B., Werner, A. K., ... Group, L. I. R. E. S. (2019). Risk factors for E-cigarette, or Vaping, product use-Associated Lung Injury (EVALI) among Adults Who Use E-Cigarette, or Vaping, Products — Illinois, July–October 2019. *Morbidity and Mortality Weekly Report (MMWR)*, 68(4), 935–989.
- O'Brien, P. J., Siraki, A. G., & Shangari, N. (2005). Aldehyde sources, metabolism, molecular toxicity mechanisms, and possible effects on human health. *Critical Reviews in Toxicology*, 35, 609–662.
- Pepper, J. K., Lee, Y., 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. <https://doi.org/10.1016/j.jadohealth.2017.05.010>.
- Pepper, J. K., Ribisl, K. M., & Brewer, N. T. (2016). Adolescents' interest in trying flavoured e-cigarettes. *Tobacco Control*, 25, ii62–ii66.
- Primack, B. A., Soneji, S., Stoolmiller, M., Fine, M. J., & Sargent, J. D. (2015). Progression to traditional cigarette smoking after electronic cigarette use among US adolescents and young adults. *JAMA Pediatrics*, 169(11), 1018–1023. <https://doi.org/10.1001/jamapediatrics.2015.1742>.
- Soneji, S., Barrington-Trimis, J. L., Wills, T. A., Leventhal, A. M., Unger, J. B., Gibson, L. A., ... Sargent, J. D. (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, 788–797. <https://doi.org/10.1001/jamapediatrics.2017.1488>.
- Talih, S., Balhas, Z., Salaman, R., Karaoghlanian, N., & Shihadeh, A. (2016). “Direct Dripping”: A high-temperature, high-formaldehyde emission electronic cigarette use method. *Nicotine and Tobacco Research*, 18(4), 453–459. <https://doi.org/10.1093/ntr/ntv080>.
- Tierney, P. A., Karpinski, C. D., Brown, J. E., Luo, W., & Pankow, J. F. (2015). Flavour chemicals in electronic cigarette fluids. *Tobacco Control*, 25, e10–e15. <https://doi.org/10.1136/tobaccocontrol-2014-052175>.
- Unger, J. B., Escobedo, P., Allem, J.-P., Soto, D. W., Chu, K.-H., & Cruz, T. (2016). Perceptions of secondhand e-cigarette aerosol among Twitter users. *Tobacco Regulatory Science*, 2(2), 146–152. <https://doi.org/10.18001/TRS.2.2.5>.
- USDHHS. (2016). E-Cigarette Use Among Youth and Young Adults. A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.
- Willett, J. G., Bennett, M., Hair, E. C., Xiao, H., Greenberg, M. S., Harvey, E., ... Vallone, D. (2018). Recognition, use and perceptions of JUUL among youth and young adults. *Tobacco Control*.
- 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.