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Sex Differences in Electronic Cigarette Device Use Among College Students

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Abstract
Electronic cigarette use (vaping) has reached epidemic levels in the United States among teenagers and young adults. However, there is a paucity of studies that have examined the relationships between e-cigarette device types and user characteristics. Therefore, the main objective of this study was to characterize e-cigarette device use among a college population with a focus on sex differences in preferred vaping device. We employed a Qualtrics-based smartphone/online survey to gather responses on e-cigarette use; including device type, demographics and other related information during the period October 1, 2020 to January 30, 2022 in the Birmingham, AL metropolitan area. Participants were recruited via flyers with a QR code to the survey. The differences in e-cigarette device type used by the characteristics of the university e-cigarette users were assessed using either a Chi-square analysis or Fisher's Test. The magnitude of any association between the characteristics of the participants and vaping device used was analyzed via logistic regression. Out of 394 students who participated in the survey, 61 reported current exclusive e-cigarette use (15.5%) among our 18–24-year-old college student sample. Among vapers; more females reported use of Disposable e-cigarettes or Juul (pod-type) as their primary vaping device compared to males, who preferred Tanks and Mods + other rechargeable e-cigarettes ($p < 0.05$). Males also vaped more days per week compared to females. Vaping among young college students remains at concerning levels. The primary vaping device used significantly varies by the users' sex, making it an important factor to consider in future studies.

Keywords Electronic cigarettes · College students · Vaping prevalence · Vaping devices

Introduction

Electronic cigarette use, also known as 'vaping', has steadily grown in the United States (U.S.) reaching epidemic levels among teenagers and young adults [1–3]. Although electronic cigarettes (e-cigarettes) were initially promoted as a safer alternative to combustible cigarette smoking and a smoking cessation tool, this method of delivering nicotine via heating of an 'e-liquid' is now potentially an addictive behavior on its own [4]. E-cigarettes are now available in various forms such as disposable e-cigarettes, refillable Modular Devices (Mods) and 'tanks', and other 'pod-like' devices, collectively known as Electronic Nicotine Delivery Systems (ENDS).

Vaping prevalence in the U.S. is estimated to be between 3.2 and 4.8% among adults [5, 6], with at least 13 million total vapers now in the U.S. Prevalence among 18–35-year-old adults was 8.3% in 2018 [6]. Current vaping statistics in the U.S. present evidence of a growing young vaping population who are at risk of addiction and unique health effects [7, 8]. Teenagers are particularly vulnerable to addiction—possibly due to nicotine exposure during brain development through adolescence, the attraction of flavorings in e-cigarettes, and the influence of aggressive marketing tactics [9]. They are also more likely to start tobacco use with e-cigarettes [10]. As per the National Youth Tobacco Survey (NYTS), e-cigarettes are the most commonly used tobacco product among middle and high school students, with over 2 million users in 2021 [7]. Although smoking combustible cigarettes is declining, vaping

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has been increasing in recent years, particularly among young women [6].

Liquids used in e-cigarettes typically contain propylene glycol/vegetable glycerin with other volatile compounds and nicotine [11, 12]. The device designs allow manufacturers to add various solvents, flavorings and oils to increase the appeal of e-cigarettes among current smokers, former smokers, and young people who have never smoked [13]. However, inhalation of e-cigarette aerosols can be toxic [14, 15]. Newer 'pod' type devices such as 'Juul' contain nicotine in protonated/salt form [16, 17]. Although less irritative, nicotine salts deliver higher amounts of nicotine than freebase nicotine in traditional e-liquids, thereby increasing the internal dose in users [15, 18].

Current evidence suggests that vaping aerosols contain fewer toxic chemicals compared to combustible cigarettes [19, 20]. However, e-cigarettes contain additives and solvents that under heat can change to complex compounds, including carcinogens [20], leading to their own unique harms. While common flavorings and oils in e-liquids have been approved for oral consumption, they are not approved to be inhaled. Research on specific effects of such potential inhalation toxicants are ongoing, but indicate that vaping can lead to respiratory and cardiovascular inflammatory responses/diseases [21] and alter immune function [15]. The extent to which vaping can impact lungs was demonstrated during the nationwide E-cigarette or Vaping product use Associated Lung Injury (EVALI) outbreak in 2019. As of February 2020, over 2800 cases of EVALI have been reported including 68 confirmed deaths [22]. The median patient age was 24 years with women comprising approximately 34% of the cases [22].

Therefore, although e-cigarettes may be comparatively less toxic compared to combustible cigarettes (based on current evidence) they cannot be considered objectively safe, and the complex chemicals and devices can still pose significant health risks to youth. Importantly, there is a paucity of studies that have examined e-cigarette device types and user characteristics and their relationships among young adults. The device types used can impact concentrations of nicotine and other chemicals delivered, and also influence user behavior. Given the freedom to purchase e-cigarettes and financial choice, the usage of e-cigarettes by college students can vary from high school students, which warrants further study. Therefore, the main objective of this study was to characterize e-cigarette device use among a college population and explore how user characteristics impact usage, with a focus on sex differences.

Methods

Questionnaire Design

There was no standardized questionnaire that contained the questions of our interests for this study. Therefore, the study team developed the questionnaire, based on their knowledge of e-cigarette use, literature reviews, and knowledge of demographics of college populations. The questionnaire was entered into Qualtrics™, an online survey program. Qualtrics generates a QR code and web link that potential participants used to access the questionnaire. Once accessed by smartphones or online, a consent to participate was shown on the screen. If respondents did not consent, the questionnaire was stopped. After the consent question, participants were asked if they were 18 years or older. Only participants who self-reported their age ≥ 18 were able to continue. Participants answering the questionnaire took 5–7 min to respond. Participant responses were recorded in Qualtrics under a unique identifier and no names or home addresses of participants were recorded. Data were collected from 1st October 2020 to 30th January 2022 in the Birmingham, AL metropolitan area.

Recruitment Strategy

The primary mode of recruitment for the survey was using flyers with the QR code. Hard copies of flyers were posted in various locations around the University of Alabama at Birmingham campus, and the soft copies (in PDF form) and the web link to the questionnaire were shared via social media posts, email, and other forms of online communication. In person recruitment was also conducted in popular campus locations including libraries, cafeterias and common areas around campus. During in-person recruitment, research students presented a hard copy of the flyer, which participants scanned to take the questionnaire on their smartphones.

Statistical Analysis

Data from participants were retrieved from Qualtrics into an Excel file, that recorded the data based on the assigned questionnaire numbers. Participants who were 18–24 years old and attended UAB were included in the analysis. Descriptive techniques were used to characterize the demographics of the entire UAB college population compared to the e-cigarette users. Due to the limited number of participants who selected "I prefer not to answer" (n = 2) for their sex, we removed these respondents from the analysis. SAS 9.4 (Cary, NC) was used for all statistical analysis while figures were generated using the Minitab Version 19 statistical software (State College, PA; Minitab Inc.).

The primary outcome variable for this study, which is e-cigarette device type used by participants, originally had five categories: 'Disposable e-cigarettes', 'Tanks and Mods', 'Rechargeable e-cigarettes/Blu', Juul, and 'Other'. Due to the small number of participants in some of the outcome categories, we created a dichotomized variable for the outcome

where: 0 = Disposable e-cigarettes + Juul and 1 = Tanks and mods + Rechargeable e-cigarettes/Blu + others.

In order to utilize the exposures of interest (sex, self-reported race, field of study, year in university, and place of residence), we created either 2 level or 3 level variables, based on the number of participants that responded. We coded the exposure variables in the following way: *Self-Reported Race*: 0 = White, 1 = other; *Year in College*: 0 = Freshman/Sophomore, 1 = Junior, 2 = Senior/Graduate students; *Field of Study*: 0 = Health sciences (medicine + nursing + public health), 1 = Sciences, 2 = Other (prelaw/law + business + engineering), and *Place of Residence*: 0 = Downtown, 1 = University residence hall, 2 = Other.

To assess the differences in e-cigarette device type used by the characteristics of the university e-cigarette users, Chi-square analysis or Fisher's Test was used based on the sample size. Fisher's was used when cells had ≤ 5 participants. To evaluate the magnitude of any association between the characteristics of the participants (self-reported race, sex, field of study, and place of residence) and vaping device used, logistic regression was used to calculate crude and adjusted odds ratios (OR) and 95% confidence intervals. In the adjusted model, OR were adjusted for place of residence.

Results

Descriptive Statistics

There was a total of 394 students who participated in the survey. Of those, 61 reported current exclusive e-cigarette use, demonstrating an estimated vaping prevalence of 15.5% among our 18–24-year-old college student sample. The majority of the total sample self-identified as white, female, and were juniors. Table 1 shows the demographics of the sample. Although there were more female users among e-cigarette users, there was a higher percentage of male e-cigarette users compared to the total college sample of males (25.6% of males in total sample vs. 42.6% males among e-cigarette users). Most participants lived in residence halls (35.5%), however, a higher percentage of e-cigarette users lived outside of the residence halls in downtown Birmingham, AL (37.7%). Overall, the most used primary device type among all e-cigarette users was Disposable e-cigarettes (47%) followed by Tanks and Mods (19%) and Rechargeable e-cigarettes/Blu (17%) and Juul (12%).

Characteristics of E-Cigarette Use Among College Students

Among e-cigarette users who were grouped into two main device categories; more females reported use of Disposable e-cigarettes + Juul as their primary vaping device type

Table 1 Demographics characteristics of college students, 18–24 years old (N = 394)

Demographics	College students in total sample, N = 394 N, %	Among all college students E-cigarette users only, N = 61 N, %
Sex		
Female	285 (72.3%)	33 (54.1%)
Male	101 (25.6%)	26 (42.6%)
Prefer not to answer	8 (2.0%)	2 (3.3%)
Self-reported race		
White	236 (61.3%)	46 (79.3%)
Black	75 (19.5%)	4 (6.9%)
Middle Eastern	9 (2.3%)	2 (3.5%)
South Asian	28 (7.3%)	3 (5.2%)
East Asian	18 (4.7%)	2 (3.5%)
Other	19 (4.9%)	1 (1.7%)
Year in college		
Freshman	71 (18.0%)	6 (9.8%)
Sophomore	91 (23.1%)	15 (24.6%)
Junior	122 (31.0%)	21 (34.4%)
Senior	95 (24.1%)	14 (23.0%)
Graduate student	14 (3.6%)	5 (8.20%)
Other	1 (0.3%)	0
Field of study		
Medicine	64 (16.2%)	6 (9.8%)
Nursing	30 (7.6%)	4 (6.6%)
Engineering	24 (6.1%)	4 (6.6%)
Law (pre)	5 (1.3%)	2 (3.3%)
Business	36 (9.1%)	8 (13.1%)
Sciences	90 (22.8%)	18 (29.5%)
Arts	20 (5.1%)	4 (6.6%)
Public health	102 (25.9%)	12 (19.7%)
Other	23 (5.8%)	3 (4.9%)
Place of residence		
Residence hall	140 (35.5%)	13 (21.3%)
Downtown	97 (24.6%)	23 (37.7%)
Suburban	100 (25.4%	19 (31.2%)
Other	57 (14.5%)	6 (9.8%)

Percentages may not add to 100%, due to missing values

compared to males, whose preferred device types were Tanks and Mods + other rechargeable e-cigarettes/Blu (Table 2, Fig. 1). This difference in primary device type used between males and females was statistically significant (p < 0.05). We did not observe statistically significant differences between other variables and device use. However, a higher proportion of Juniors preferred tanks, Mods and rechargeable e-cigarettes compared to other years in

Table 2 Type of primary e-cigarette device used by characteristics of college students and the logistic regression results for associations between characteristics and device use (N = 58)

Characteristic	Disposable and Juul (N = 34)	Tanks/mods/rechargeable/other (N = 24)	p value
Sex			0.049*
Male (n = 25)	11 (32.4%)	14 (58.3%)	
Female (n = 33)	23 (67.6%)	10 (41.7%)	
Self-reported race			0.88
White (n = 44)	26 (76.4%)	18 (75.0%)	
Other (n = 14)	8 (23.6%)	6 (25.0%)	
Year in college			0.50
Fresh/sophomore (n = 19)	13 (38.2%)	6 (25.0%)	
Junior (n = 20)	10 (29.4%)	10 (41.7%)	
Senior/Grad (n = 19)	11 (32.3%)	8 (33.3%)	
Field of study			0.37
Medicine/nursing/PH (n = 18)	9 (26.5%)	9 (37.5%)	
Sciences (n = 18)	13 (38.2%)	5 (20.8%)	
Other (n = 18)	10 (29.4%)	8 (33.3%)	
Place of residence			0.08
Dormitory (n = 12)	8 (23.5%)	4 (16.7%)	
Downtown (city) (n = 22)	16 (47.0%)	6 (25.0%)	
Other (n = 24)	10 (29.4%)	14 (58.3%)	

Unadjusted and adjusted odds ratios (95% confidence intervals) for students[a]

Characteristic	Unadjusted	Adjusted[b]
Sex (ref = females)	2.93 (1.0–8.65)	5.01 (1.37–18)*
Self-reported race (ref = white)	1.08 (0.32–3.66)	1.21 (0.34–4.32)
Field of study		
Health services[c]	2.60 (0.65–10.4)	3.41 (0.77–15)
Other[c]	2.08 (0.52–8.30)	2.44 (0.57–10)
Ref = sciences		
College level		
Freshman/Sophomore	0.64 (0.17–2.40)	0.64 (0.16–2.51)
Junior	1.38 (0.39–4.87)	1.20 (0.32–4.54)
Ref = others[d]		

Percentages may not add to 100% because of missing values

One male participant missing from total sample—did not respond to device type used

*Statistically significant at p < 0.05

[a]Modeling for use of tanks/mods/rechargeable (Blu)/other

[b]Adjusted for place of living (UAB residence hall, downtown, other)

[c]Health services (medicine, nursing, public health), other (engineering, pre-law/law, business, arts)

[d]Others (seniors, graduate students)

college, and a higher proportion of students living in the Downtown area preferred Disposable e-cigarettes + Juul.

The number of self-reported days per week that e-cigarettes were used were also analyzed by sex (given the initial significance of this variable with device type). A higher percentage of female users reported 1–3 days of use per week compared to males who predominantly reported 6–7 days per week of vaping (Fig. 2) (i.e., within their respective sexes, males tended to vape more days per week compared to females).

Associations Between Vaping Device and Student Characteristics

The sex of college users was significant in our adjusted model that examined device use by characteristics (Table 2).

Fig. 1 Primary electronic ciga-
rette device type used by sex
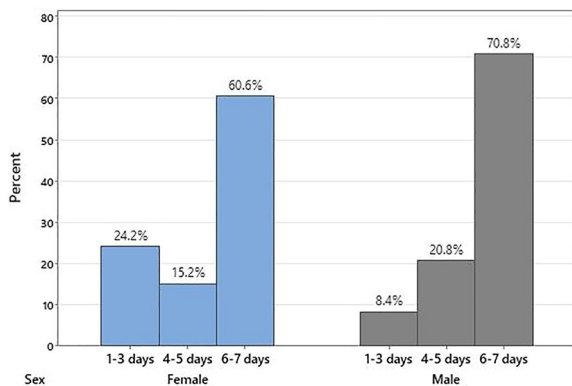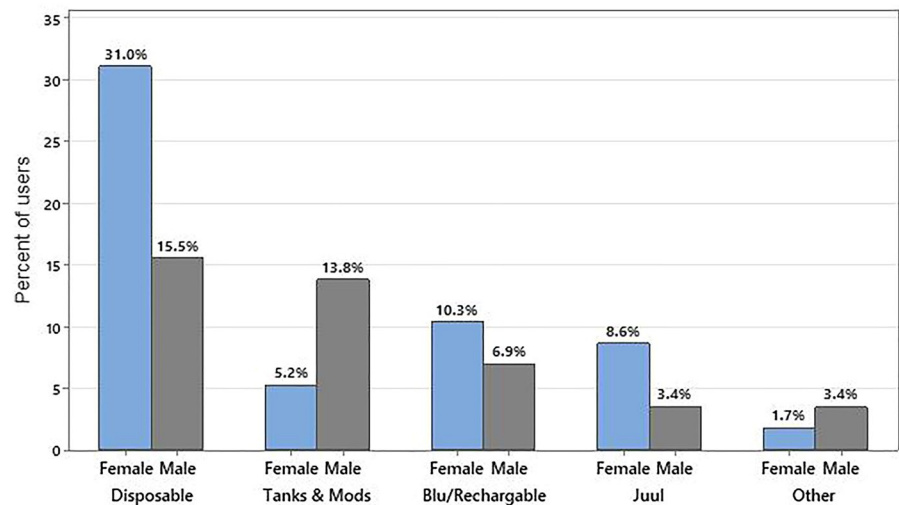(total n = 58)

Fig. 2 Percent of users vs. number of days per week e-cigarettes were
used by sex (n = 59). The percent is calculated within levels of sex

When adjusted for place of living, males were five times
more likely to use tank and mod type devices + recharge-
able e-cigarettes compared to females (OR 5.01, 95% CI
1.37–18.0). Also demonstrated in Table 2 are elevated AORs
for the field of study, albeit not statistically significant, pos-
sibly due to the smaller sample sizes in each sub category.
Freshman and Sophomores were less likely to use tanks and
mods, although again, this association was not statistically
significant.

Discussion

Our study focused on a young adult college student popula-
tion in the largest city in Alabama, USA and investigated
the prevalence of current e-cigarette use, usage variations by
device types, and relationships between usage and student
characteristics. The overall vaping prevalence was 15.5%,
which is consistent with other studies demonstrating alarm-
ing rates among young adults [23–25], further emphasizing

the problem of rising e-cigarette and tobacco product use
among youth. Although several studies have reported and
characterized adolescent and young adult e-cigarette use,
studies focused on young university populations are lim-
ited, particularly studies that have examined usage by device
type and sex among college students. Our study contributes
to fill this knowledge gap. College aged young adults are
unique due to their being (1) permitted to buy e-cigarettes
legally in many states (currently if over 21 years—illegal for
younger teens, high school and middle school students); (2)
financially more independent compared to younger users;
(3) have access to and are expected to be more knowledge-
able on the harms of using tobacco products; (4) are in a
critical stage of mental and physical development, and (5)
are vulnerable to stress due to academic performance, and
are vulnerable to experimentation and addiction. Thus, we
deemed it important to focus on this population, and dem-
onstrate the importance of further study. Although limited,
existing studies on e-cigarette use among university/college
students reveal that vaping is common in universities, and
demonstrate an association with a variety of mental health
and drug use problems. Those who vape are significantly
more likely to have mental health histories of ADHD, PTSD
and anxiety, and support traits of impulsivity [23, 24].

Our results found that 'Disposable e-cigarettes' were the
most used primary device type among 18–24-year-old col-
lege students, followed by 'Tanks and Mods', 'Blue/Other
Rechargeable' devices and 'Juul'. Importantly our research
showed that device type usage significantly varied by sex,
where female students reported a significantly higher prev-
alence of Disposable e-cigarette + Juul (which are mostly
pod-type devices) use compared to males, while males pre-
ferred to use Tank and Mod + Rechargeable type devices
as their primary vaping device. This difference in primary
device type between sexes is important because it points
towards variations in vaping behavior, nicotine content

expectations, and frequency of usage. This was further emphasized by the difference in the number of days vaped per week between sexes. Males vaped more days per week on average compared to females, demonstrating differences in usage patterns. It is also possible that the reasons for vaping are different between sexes, which results in selecting the primary device type.

This study's results reflect recent changes in device preference among youth, and variations in preferences by region and other demographics. Other studies that had surveyed young adults in the U.S. found that Juul was the most used product among teenagers and young adults aged 15–34 years [26, 27], followed by Juul-like pods and then Mod type devices [28]. Juul reached peak popularity among teens and young adults around 2016–2019 and is still popular, but in recent years disposable (mostly newer pod-type) e-cigarette use has increased significantly [7, 29]. In a study that analyzed retail scanner data of e-cigarette sales among youth in the U.S. from August 2019 to May 2020, the proportion of disposable vaping product sales increased from 10.3 to 19.8%, while the proportion of prefilled cartridge products decreased by approximately 4 percentage points [30]. Unlike previous 'cigalike' disposable e-cigarettes, the newer disposable devices have adopted innovations introduced by Juul and other pod-style brands. The newer disposable e-cigarettes are less expensive and easier to use than Juul and other device types and are available in many flavors, increasing their appeal among young users. Given that most pod-type disposable devices and Juul have nicotine in protonated form in their e-liquids, which is more 'potent' than freebase nicotine, the increase use of pod-type devices may lead to risk of nicotine addiction in young adults, particularly during early stages of college. Importantly, it is unclear if federal regulations that apply to Juul and other non-disposable products apply to disposable products [29]. Thus, disposable products are now widely available in many flavors and other additives, warranting further studies and scrutiny on possible health effects.

Factors to consider and Limitations: We categorized device types based on information in the Centers for Disease Control (CDC) website [31] and currently available e-cigarette product types in the market, however, other studies might have categorized them differently. The fast-evolving vaping device technologies, device types, and delivery modes make it challenging to have a universal method of categorizing them. However, we used the most up-to-date device categories to the best of our knowledge, which are popular and commonly available for sale.

Although our findings on the association between vaping and year at college was not significant, younger students (Freshmen + Sophomores) were less likely to use Tank and Mod types compared to other college years, again emphasizing the risk of younger people being more susceptible to

marketing and disposable product use, leading to behavioral change as they enter college. With regards to our sample, the participants that responded to our survey were predominantly female students and the e-cigarette users self-reported as white. This is consistent with other studies that have reported higher rates of females in sampled populations [25] and higher rates of e-cigarette users identifying as white [32, 33].

Our study had some limitations. The limited sample size did not allow for further analysis of sub-categories that impacted usage and device type as each sub-category had smaller numbers of participants. This resulted in wider CIs impacting statistical significance of some analyses. Although we tried to balance recruitment across campus, our recruitment methods may have been biased based on recruitment locations, strategies, and personnel recruiting participants. However, we attempted to reduce this bias by using social media all over the campus, and recruiters switching places and selecting randomly chosen locations. Using self-reported use of e-cigarettes, their types, and frequency may have introduced recall bias and social image bias. However, studies that have tested the validity of self-reported tobacco use among youth found that the magnitude of underreporting was exceedingly low [34, 35]. Finally, our estimates may vary from some studies due to our focus on exclusive vaping and our defined characteristics of interest. However, overall, most studies show prevalence rates close to our findings or higher [23–25, 28].

Conclusions

This study demonstrated that e-cigarette use among college students (18–24 years, sampled in the Southern U.S.) remains at levels considered to be concerning, and that importantly, vaping device preference significantly varies by sex. More students primarily used disposable e-cigarettes, which typically contain nicotine in protonated form. This form can deliver higher nicotine dosages during each vaping session. Additionally, although e-cigarette vapor may be less dangerous than combustible cigarettes, current evidence challenges the idea that e-cigarette vapor is safe, and may contain carcinogenic and other harmful compounds [20, 36]. Therefore, further studies on the harms of e-cigarette use during early years of adulthood are needed, and more importantly, active programs by colleges to educate youth on the risks of e-cigarette use.

Author Contributions Concept: MJRV; Study design: MJRV, KMZ, MF; Survey development, Qualtrics questionnaire management: All

authors; Recruitment material development, survey distribution: MJRV, SS, DJ; Data curation: MJRV, KMZ; Statistical analyses: KMZ; Initial manuscript preparation: MJRV and KMZ; Critical revision of manuscript and approved final manuscript for submission: All authors.

Declarations

Competing Interests The authors declare no competing interests.

References

1. Dai, H., & Leventhal, A. M. (2019). Prevalence of e-cigarette use among adults in the United States, 2014–2018. *Journal of the American Medical Association*. https://doi.org/10.1001/jama.2019.15331

2. Wang, T. W., Neff, L. J., Park-Lee, E., Ren, C., Cullen, K. A., & King, B. A. (2020). E-cigarette use among middle and high school students—United States, 2020. *MMWR Morbidity and Mortality Weekly Report, 69*(37), 1310–1312.

3. U.S. Department of Health and Human Services. (2016). *E-cigarette use among youth and young adults. A report of the surgeon general*. 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.

4. Mirbolouk, M., Charkhchi, P., Orimoloye, O. A., Uddin, S. I., Kianoush, S., Jaber, R., Bhatnagar, A., Benjamin, E. J., Hall, M. E., DeFilippis, A. P., & Maziak, W. (2019). E-cigarette use without a history of combustible cigarette smoking among U.S. adults: Behavioral risk factor surveillance system, 2016. *Annals of Internal Medicine, 170*(1), 76–79.

5. Creamer, M. R., Wang, T. W., Babb, S., Cullen, K. A., Day, H., Willis, G., Jamal, A., & Neff, L. (2019). Tobacco product use and cessation indicators among adults—United States, 2018. *MMWR Morbidity and Mortality Weekly Report, 68*(45), 1013–1019.

6. Al Rifai, M., Merchant, A. T., Nambi, V., Jia, X., Gulati, M., Valero-Elizondo, J., Nasir, K., Ballantyne, C. M., & Virani, S. S. (2020). Temporal trends in e-cigarette use among U.S. adults: Behavioral risk factor surveillance system, 2016 to 2018. *American Journal of Medicine, 133*(9), e508–e511.

7. Gentzke, A. S., Wang, T. W., Cornelius, M., Park-Lee, E., Ren, C., Sawdey, M. D., Cullen, K. A., Loretan, C., Jamal, A., & Homa, D. M. (2022). Tobacco product use and associated factors among middle and high school students—National Youth Tobacco Survey, United States, 2021. *MMWR Surveillance Summaries, 71*(5), 1–29.

8. Cullen, K. A., Gentzke, A. S., Sawdey, M. D., Chang, J. T., Anic, G. M., Wang, T. W., Creamer, M. R., Jamal, A., Ambrose, B. K., & King, B. A. (2019). E-cigarette use among youth in the United States, 2019. *Journal of the American Medical Association*. https://doi.org/10.1001/jama.2019.18387

9. England, L. J., Bunnell, R. E., Pechacek, T. F., Tong, V. T., & McAfee, T. A. (2015). Nicotine and the developing human: A neglected element in the electronic cigarette debate. *American Journal of Preventive Medicine, 49*(2), 286–293.

10. Berry, K. M., Fetterman, J. L., Benjamin, E. J., Bhatnagar, A., Barrington-Trimis, J. L., Leventhal, A. M., & Stokes, A. (2019). Association of electronic cigarette use with subsequent initiation of tobacco cigarettes in US youths. *JAMA Network Open, 2*(2), e187794.

11. Stroud, L. R., Papandonatos, G. D., Borba, K., Kehoe, T., & Scott-Sheldon, L. A. J. (2019). Flavored electronic cigarette use, preferences, and perceptions in pregnant mothers: A correspondence analysis approach. *Addictive Behaviors, 91*, 21–29.

12. Benowitz, N. L., & Fraiman, J. B. (2017). Cardiovascular effects of electronic cigarettes. *Nature Reviews Cardiology, 14*(8), 447–456.

13. Bandi, P., Cahn, Z., Sauer, A. G., Douglas, C. E., Drope, J., Jemal, A., & Fedewa, S. A. (2021). Trends in e-cigarette use by age group and combustible cigarette smoking histories, U.S. adults, 2014–2018. *American Journal of Preventive Medicine, 60*(2), 151–158.

14. Gordon, T., Karey, E., Rebuli, M. E., Escobar, Y. H., Jaspers, I., & Chen, L. C. (2022). E-cigarette toxicology. *Annual Review of Pharmacology and Toxicology, 62*, 301–322.

15. Gotts, J. E., Jordt, S. E., McConnell, R., & Tarran, R. (2019). What are the respiratory effects of e-cigarettes? *BMJ, 366*, l5275.

16. Talih, S., Salman, R., El-Hage, R., Karaoghlanian, N., El-Hellani, A., Saliba, N., & Shihadeh, A. (2020). Effect of free-base and protonated nicotine on nicotine yield from electronic cigarettes with varying power and liquid vehicle. *Scientific Reports, 10*(1), 16263.

17. Talih, S., Salman, R., El-Hage, R., Karam, E., Karaoghlanian, N., El-Hellani, A., Saliba, N., & Shihadeh, A. (2019). Characteristics and toxicant emissions of JUUL electronic cigarettes. *Tobacco Control, 28*(6), 678–680.

18. Karam, E., Talih, S., Salman, R., El-Hage, R., Karaoghlanian, N., El-Hellani, A., Saliba, N., & Shihadeh, A. (2022). JUUL 'new technology' pods exhibit greater electrical power and nicotine output than previous devices. *Tobacco Control, 31*(5), 630.

19. Goniewicz, M. L., Gawron, M., Smith, D. M., Peng, M., Jacob, P., 3rd., & Benowitz, N. L. (2017). Exposure to nicotine and selected toxicants in cigarette smokers who switched to electronic cigarettes: A longitudinal within-subjects observational study. *Nicotine & Tobacco Research, 19*(2), 160–167.

20. Rubinstein, M. L., Delucchi, K., Benowitz, N. L., & Ramo, D. E. (2018). Adolescent exposure to toxic volatile organic chemicals from e-cigarettes. *Pediatrics, 141*(4), e20173557.

21. Xie, W., Kathuria, H., Galiatsatos, P., Blaha, M. J., Hamburg, N. M., Robertson, R. M., Bhatnagar, A., Benjamin, E. J., & Stokes, A. C. (2020). Association of electronic cigarette use with incident respiratory conditions among US adults from 2013 to 2018. *JAMA Network Open, 3*(11), e2020816.

22. Krishnasamy, V. P., Hallowell, B. D., Ko, J. Y., Board, A., Hartnett, K. P., Salvatore, P. P., Danielson, M., Kite-Powell, A., Twentyman, E., Kim, L., & Cyrus, A. (2020). Update: Characteristics of a nationwide outbreak of e-cigarette, or vaping, product use-associated lung injury—United States, August 2019–January 2020. *MMWR Morbidity and Mortality Weekly Report, 69*(3), 90–94.

23. Grant, J. E., Lust, K., Fridberg, D. J., King, A. C., & Chamberlain, S. R. (2019). E-cigarette use (vaping) is associated with illicit drug use, mental health problems, and impulsivity in university students. *Annals of Clinical Psychiatry, 31*(1), 27–35.

24. Lanza, H. I., & Teeter, H. (2018). Electronic nicotine delivery systems (e-cigarette/vape) use and co-occurring health-risk behaviors among an ethnically diverse sample of young adults. *Substance Use and Misuse, 53*(1), 154–161.

25. Jones, R. D., Asare, M., & Lanning, B. (2021). A retrospective cross-sectional study on the prevalence of e-cigarette use among college students. *Journal of Community Health, 46*(1), 195–202.

26. Vallone, D. M., Bennett, M., Xiao, H., Pitzer, L., & Hair, E. C. (2019). Prevalence and correlates of JUUL use among a national sample of youth and young adults. *Tobacco Control, 28*(6), 603–609.

27. Willett, J. G., Bennett, M., Hair, E. C., Xiao, H., Greenberg, M. S., Harvey, E., Cantrell, J., & Vallone, D. (2019). Recognition, use

and perceptions of JUUL among youth and young adults. *Tobacco Control, 28*(1), 115–116.

28. Lanza, H. I., Leventhal, A. M., Cho, J., Braymiller, J. L., Krueger, E. A., McConnell, R., & Barrington-Trimis, J. L. (2020). Young adult e-cigarette use: A latent class analysis of device and flavor use, 2018–2019. *Drug and Alcohol Dependence, 216*, 108258.

29. Leventhal, A. M., Dai, H., Barrington-Trimis, J. L., Tackett, A. P., Pedersen, E. R., & Tran, D. D. (2022). Disposable e-cigarette use prevalence, correlates, and associations with previous tobacco product use in young adults. *Nicotine & Tobacco Research, 24*(3), 372–379.

30. Ali, F. R., Diaz, M. C., Vallone, D., Tynan, M. A., Cordova, J., Seaman, E. L., Trivers, K. F., Schillo, B. A., Talley, B., & King, B. A. (2020). E-cigarette unit sales, by product and flavor type—United States, 2014–2020. *MMWR Morbidity and Mortality Weekly Report, 69*(37), 1313–1318.

31. Centers for Diesase Control and Prevention (CDC). (2022). *About electronic cigarettes (e-cigarettes)*. Retreived August 1, 2020, from https://www.cdc.gov/tobacco/basic_information/e-cigarettes/about-e-cigarettes.html

32. Dai, H., Ramos, A. K., Faseru, B., Hill, J. L., & Sussman, S. Y. (2021). Racial disparities of e-cigarette use among US youths: 2014–2019. *American Journal of Public Health, 111*(11), 2050–2058.

33. Stokes, A. C., Wilson, A. E., Lundberg, D. J., Xie, W., Berry, K. M., Fetterman, J. L., Harlow, A. F., Cozier, Y. C., Barrington-Trimis, J. L., Sterling, K. L., & Benjamin, E. J. (2021). Racial/ethnic differences in associations of non-cigarette tobacco product use with subsequent initiation of cigarettes in US youths. *Nicotine & Tobacco Research, 23*(6), 900–908.

34. Freier, M., Bell, R. M., & Ellickson, P. L. (1991). *Do teens tell the truth?: The validity of self-reported tobacco use by adolescents*. RAND Corporation.

35. Ramo, D. E., Hall, S. M., & Prochaska, J. J. (2011). Reliability and validity of self-reported smoking in an anonymous online survey with young adults. *Health Psychology, 30*(6), 693–701.

36. Goniewicz, M. L., Smith, D. M., Edwards, K. C., Blount, B. C., Caldwell, K. L., Feng, J., Wang, L., Christensen, C., Ambrose, B., Borek, N., & Van Bemmel, D. (2018). Comparison of nicotine and toxicant exposure in users of electronic cigarettes and combustible cigarettes. *JAMA Network Open, 1*(8), e185937.