

Brief report

Type of E-Cigarette Device Used Among Adolescents and Young Adults: Findings From a Pooled Analysis of Eight Studies of 2166 Vapers

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Abstract

Background: A recent study of adult smokers who vape found that disposable/cigalike electronic (e-) cigarette devices were more commonly used than later generation devices. However, whether these trends reflect patterns among adolescents and young adults, many of whom have limited or no history of combustible cigarette use, has not been studied.

Methods: Participants were drawn from eight locally, regionally, and US nationally representative studies. Surveys took place between Fall 2014 and Spring 2016; participants were residents of California (3 studies), Texas (2 studies), Connecticut (1 study), or randomly selected from the US population (2 studies). Data were collected from middle and high school students (4 studies), young adults under 30 (3 studies), or a mixture (1 study) to assess type of e-cigarette device used among past-30 day e-cigarette users: disposable/cigalike, or later generation e-cigarette device.

Results: Fewer than 15% of participants in each study reported primarily using a disposable/cigalike device in the past month (across all studies: 7.5%; 95%CI: 4.9%, 10.5%). The proportion using later generation devices ranged from 58% to 86% across studies; overall, 77.0% (95%CI: 70.5%, 82.9%) reported primary use of a later generation device. Combined, 13.2% (95%CI: 5.9%, 22.8%) reported “don’t know” or were missing data.

Conclusions: Among adolescent and young adult e-cigarette users, primary use of disposable/cigalike devices was rare. Future research should continue to evaluate the type of device used by adolescents and young adults, as these data may be relevant to regulatory oversight of e-cigarettes recently acquired by the Food and Drug Administration Center for Tobacco Products.

Implications: In this pooled analysis of adolescent and young adult vapers, primary use of later generation e-cigarette devices was substantially more common than use of disposable/cigalike

devices. The type of device predominantly used by adolescents and young adults has regulatory implications for policy to reduce adolescent use of e-cigarettes.

Introduction

E-cigarettes have risen in popularity, especially among adolescents and young adults.¹⁻⁴ There is considerable variability in the different types of commercially available e-cigarettes, and in terminology used to describe e-cigarettes, which makes assessment of e-cigarette use difficult and poses challenges for translating e-cigarette research into evidence-based regulatory policy.^{5,6} In a recent study of US adult smokers who vape, 51% used only disposable e-cigarettes (or “cigalikes”), 41% used only later generation models (eg, rechargeable, pen-like devices, devices that use tanks or cartridges, or mods/mech-mods), and 8% did not have a preferred device.⁷ No data have been published on the device type used in the adolescent and young adult population of vapers, many of whom do not smoke combustible cigarettes.⁸⁻¹⁰

Different devices produce aerosols that may differ in the levels of toxins^{11,12} and nicotine delivery and absorption into the bloodstream,¹³ and may result in disparate use patterns.^{7,14} Therefore, the type of device predominantly used by adolescents and young adults has important methodological implications for experimental and observational research on the toxicity, abuse liability, health hazards (eg, respiratory or cardiovascular effects), possibilities for smoking-cessation, and other public health impact of e-cigarette use. Here, we report the prevalence of using different device types among a combined 2166 adolescent and young adult e-cigarette users across eight different studies.

Methods

Participants

Participants were past 30-day e-cigarette users from eight locally, regionally, and US nationally representative studies (Supplementary Table 1).^{9,10,15-20} Surveys took place between Fall 2014 and Spring 2016 and participants were residents of California (3 studies), Texas (2 studies), Connecticut (1 study), or randomly selected from the US population (2 studies). Data were collected from middle and high school students (4 studies), young adults under 30 years old (3 studies), or both (1 study). Surveys were administered in school (2 studies), online (5 studies), or by phone (1 study).

Measures

In addition to demographics and past 30-day e-cigarette use, each study included questions asking respondents to select all e-cigarette device types they had used, or the device type that they had used most often (see Supplementary Table 2). Five studies also included a photo of different device types corresponding with the text descriptions of each type. All studies asked participants whether their device was either disposable or a “cigalike”; later generation devices were assessed using terminology such as “containing tanks or cartridges,” “vape pen or pen-like device,” “mod or mech-mod/rebuildable” and/or another term (see Table 1 note for details). For this report, we grouped all non-cigalike models into a combined *Later Generation Device* category to be compared with cigalike models in the combined *Disposable/Cigalike* category.

Analysis

For individual studies, proportions and 95% confidence intervals [CI] were computed, using either a Wald-type interval on the log-odds scale obtained from a weighted logistic regression model

transformed to the probability scale (weighted samples; studies 1–2) or using the Wilson method (unweighted samples; studies 3–8).

For studies that used a “choose-all-that-apply” question format for type of device (eg, allowing multiple responses; studies 5–7), categories were constructed based on whether participants selected only a disposable/cigalike device or only a later generation device; participants who selected both types of devices or reported “don’t know” are included in the “other” category (Table 1). Summary estimates were calculated by type of study (choose-all-that-apply vs. forced-choice) using a pooling procedure for analysis of multiple studies using a random effects model with the estimate of heterogeneity from the inverse-variance fixed-effect model, and inclusion of the Freeman–Tukey Double Arcsine Transformation to stabilize variances; 95% CI were computed using the Wilson method, with a test for heterogeneity between subgroups. A ratio of later generation device use to disposable/cigalike use was computed by dividing prevalence estimates, respectively. Pooled analyses were completed using Stata v.13.1.

Results

Past 30-day e-cigarette use ranged from 3.5% (95% CI: 2.8%, 4.3%; study 6) to 13.2% (95% CI: 11.6%, 15.1%; study 4; Supplementary Table 1). Across the eight studies, 8.0% (95% CI: 5.1%, 11.5%) reported primary use of a disposable/cigalike device and 77.0% (95% CI: 70.6%, 82.9%) reported primary use of a later generation device (Table 1). The proportion using later generation devices ranged from 58% to 86% across studies, with most studies reporting around 80% use. In all studies, the prevalence of using later generation devices was substantially higher than disposable/cigalike use. The heterogeneity in prevalence across studies overall for later generation ($I^2 = 89.1\%$; $p < .05$) or cigalike/disposable ($I^2 = 82.2\%$; $p < .05$) devices was high; however, later generation devices were preferred regardless of age, geographic location, date of data collection, method of data collection, or the specific questionnaire item used in each study.

Discussion

As the first report of the prevalence of e-cigarette device types used among adolescents and young adults, this study provides new evidence that the majority of young vapers use later generation devices. Although there was variation in terminology²¹ to identify the products on surveys, use of later generation devices was more common in all studies. Predominant use of disposable/cigalike devices was relatively rare among the adolescents and young adults surveyed in the eight studies included in this report. In contrast, an earlier study of adult smokers (with 96% of the sample aged 25 or older) found that the prevalence of disposable/cigalike use was slightly higher than later generation device use overall, and substantially higher among adults 65 or older (27.4% later generation use only vs. 66.6% disposable/cigalike use), and among adults aged 45–64 (31.4% vs. 59.8%).⁷

Differences between later generation and disposable/cigalike devices may be responsible for different physiological (eg, health effects) or behavioral consequences (eg, abuse liability, utility as a cessation aid) of e-cigarette use. Later generation devices allow the user

Table 1. Past 30-Day Use of Each Type of Device, by Study

Study	Type of device used						Ratio of later generation to disposable/cigalike
	Disposable/Cigalike		Later generation		Other		
	% (95%CI)	N	% (95%CI)	N	% (95%CI)	N	
1 ^a	14.4% (8.9%, 22.5%)	37	85.6% (77.6%, 91.1%)	222	0%	0	5.94
2 ^b	11.1% (4.8%, 23.3%)	9	75.6% (62.5%, 85.3%)	76	13.3% (6.8%, 24.4%)	12	6.82
3 ^c	8.7% (4.9%, 15.0%)	11	82.5% (75.0%, 88.2%)	104	8.7% (4.9%, 15.0%)	11	9.48
4 ^d	1.0% (0.3%, 3.7%)	2	82.8% (76.8%, 87.5%)	159	16.1% (11.6%, 22.0%)	31	82.8
5 ^e	8.7% (3.4%, 20.3%)	4	58.7% (44.3%, 71.7%)	27	32.6% (20.9%, 47.0%)	15	6.75
6 ^f	5.3% (2.3%, 11.7%)	5	73.7% (64.0%, 81.5%)	70	21.0% (14.1%, 30.3%)	20	13.9
7 ^g	9.7% (7.4%, 12.5%)	51	65.7% (61.5%, 69.6%)	346	24.7% (21.2%, 28.5%)	130	6.78
8 ^h	10.5% (8.4%, 13.1%)	68	80.2% (76.9%, 83.1%)	518	9.3% (7.3%, 11.8%)	60	7.64
Summary ⁱ	8.1% (3.8%, 13.7%)†	127	82.0% (79.5%, 84.4%)	1079	7.6% (2.0%, 16.3%)†	114	10.9
Summary ^j	8.7% (6.6%, 11.0%)	60	66.9% (60.2%, 73.2%)	443	24.5% (20.9%, 28.4%)	165	7.77
Overall summary ^k	8.0% (5.1%, 11.5%)	187	77.0% (70.6%, 82.9%)‡	1522	13.2% (5.9%, 22.7%)‡	279	10.1

^aTerminology used to determine Disposable/Cigalike: “cigalike”; terminology used to determine Later Generation: “not cigalike”.

^bTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “cartridge”, or “tank”; cartridge: $n = 31$; tank: $n = 45$; other includes respondents who indicated they “didn’t know” to one or more of the device type questions ($n = 8$) or who indicated that their device was rechargeable but neither a tank nor cartridge system ($n = 4$).

^cTerminology used to determine Disposable/Cigalike: “cig-a-like, mini e-cig, or slim model”; terminology used to determine Later Generation: “mid-size e-cig or vape pen”, “advanced personal vaporizer (APV) or mod”; midsize/vape pen: $n = 42$; APV or mod: $n = 84$; other includes respondents who indicated they “didn’t know” to the device type questions ($n = 6$), or who didn’t answer the question ($n = 5$); adolescents who reported that they did not have an e-cigarette device ($n = 49$) were excluded from this analysis.

^dTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “vape pen or pen-like rechargeable device”, “mod or mech-mod rechargeable device”; vape pen: $n = 46$; mod/mech-mod: $n = 113$; other includes respondents who did not answer the question ($n = 31$).

^eTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “rechargeable”, “press button, e-Go”, “large tank”, or “other”; rechargeable only: $n = 2$; press button/e-Go only: $n = 10$; large tank only: 10; more than one type of later generation device: $n = 12$; other includes respondents who were missing data ($n = 7$) or who were using both disposable and later generation devices ($n = 8$).

^fTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “cartridge” or “refillable with e-liquid”; cartridge only: $n = 3$; refillable only: $n = 63$; cartridge or refillable: $n = 4$; other includes participants who did not provide a device type ($n = 10$) or who used both disposable and later generation devices ($n = 10$).

^gTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “vape/pen” or “mod/rebuildable”; vape pen only: $n = 165$ (47.7%); vape pen and mod/rebuildable: $n = 181$ (52.3%); “other” includes participants who reported disposable and later generation devices ($n = 67$) or who did not specify a device type ($n = 63$).

^hTerminology used to determine Disposable/Cigalike: “disposable”; terminology used to determine Later Generation: “tank” or “cartridge”; cartridge only: $n = 47$; tank only: $n = 310$; both: $n = 161$; other includes participants who were missing data ($n = 60$); adolescents who responded “I have not used e-cigarettes in the past 30 days” to the device question despite reporting earlier in the survey that they had used e-cigarettes in the past 30 days were excluded from this analysis ($n = 129$).

ⁱSummary measure based on studies assessing which device was used most commonly (studies 1–4,8).

^jSummary measure based on studies assessing which devices were used, with multiple response options (studies 5–7); disposable users include those who only reported use of a disposable device; later generation users include those who reported only use of a later generation device.

^kPooled summary measure based on summary measures by type of question asked (multiple response vs. most common use)

†Significant heterogeneity observed ($p < .05$).

‡Significant heterogeneity between groups ($p < .05$).

to customize their product (e.g., temperature and power settings for vaporization can often be adjusted), and e-cigarette solutions in a wide variety of flavors and nicotine levels can be purchased independently of the device. Later generation devices also typically deliver aerosols to the lungs more efficiently,¹³ with greater variability in delivery depending on voltage and temperature settings.^{11,13} The type of device used can thus affect the level of toxins^{11,12} and concentration of nicotine¹³ in the aerosol; in combination with e-liquid solutions, the type of device may also impact the overall sensory experience, appeal, and abuse liability of e-cigarette use. Thus, characteristics of the device (eg, voltage, temperature) and e-cigarette solution (eg, flavorings, nicotine level) in concert with overall device type (disposable vs. later generation) are relevant to research and to the development of policy. Future research is warranted to evaluate factors that may explain the observed preference for later generation devices among adolescents and young adults.

In light of e-cigarettes recently being deemed a “tobacco product” under the regulatory authority of the Food and Drug Administration,²² understanding the prevalence as well as the adverse and beneficial effects of using different e-cigarette device types is needed. The new regulations will require a premarket review and approval by August 2018 for most e-cigarette devices and e-liquids²² which may present a greater burden on manufacturers and retailers of later generation devices that are owned primarily by smaller companies,²³ possibly resulting in decreased availability of such products. Consequently, disposable/cigalike products, which are largely owned by large tobacco companies,²³ may become the dominant device type available on the market. Based on the current results, such a change in the regulatory environment could potentially reduce initiation of e-cigarette use among adolescents and young adults, although it is unclear whether current e-cigarette users would discontinue use of e-cigarettes or would transition to disposable/cigalike devices or other nicotine products.

Supplementary Material

Supplementary data are available at *Nicotine & Tobacco Research* online.

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Declaration of Interests

None declared.

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References

1. Singh T, Arrazola RA, Corey CG, et al. Tobacco use among middle and high school students—United States, 2011–2015. *MMWR Morb Mortal Wkly Rep.* 2016;65(14):361–367.
2. Johnston LD, O'Malley PM, Miech RA, et al. *Monitoring the Future National Survey Results on Drug Use 1975–2014: Overview: Key Findings on Adolescent Drug Use.* Ann Arbor, MI: Institute for Social Research, The University of Michigan; 2015.
3. Hu SS, Neff L, Agaku IT, et al. Tobacco product use among adults - United States, 2013–2014. *MMWR Morb Mortal Wkly Rep.* 2016;65(27):685–691.
4. King BA, Patel R, Nguyen KH, Dube SR. Trends in awareness and use of electronic cigarettes among US adults, 2010–2013. *Nicotine Tob Res.* 2015;17(2):219–227.
5. Hinds JT III, Loukas A, Chow S, et al. Using cognitive interviewing to better assess young adult e-cigarette use. *Nicotine Tob Res.* 2016;18(10):1998–2005.
6. Wagoner KG, Cornacchione J, Wiseman KD, Teal R, Moracco KE, Sutfin EL. E-cigarettes, hookah pens and vapes: adolescent and young adult perceptions of electronic nicotine delivery systems. *Nicotine Tob Res.* 2016;18(10):2006–2012.
7. Chen C, Zhuang YL, Zhu SH. E-cigarette design preference and smoking cessation: a U.S. population study. *Am J Prev Med.* 2016;51(3):356–363.
8. CDC. Notes from the field: electronic cigarette use among middle and high school students—United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2013;62(35):729.
9. Leventhal AM, Strong DR, Kirkpatrick MG, et al. Association of electronic cigarette use with initiation of combustible tobacco product smoking in early adolescence. *JAMA.* 2015;314(7):700–707.
10. Barrington-Trimis JL, Berhane K, Unger JB, et al. Psychosocial factors associated with adolescent electronic cigarette and cigarette use. *Pediatrics.* 2015;136(2):308–317.
11. Gillman IG, Kistler KA, Stewart EW, Paolantonio AR. Effect of variable power levels on the yield of total aerosol mass and formation of aldehydes in e-cigarette aerosols. *Regul Toxicol Pharmacol.* 2016;75:58–65.
12. Jensen RP, Luo W, Pankow JF, Strongin RM, Peyton DH. Hidden formaldehyde in e-cigarette aerosols. *N Engl J Med.* 2015;372(4):392–394.
13. Talih S, Balhas Z, Eissenberg T, et al. Effects of user puff topography, device voltage, and liquid nicotine concentration on electronic cigarette nicotine yield: measurements and model predictions. *Nicotine Tob Res.* 2015;17(2):150–157.
14. Hitchman SC, Brose LS, Brown J, Robson D, McNeill A. Associations between e-cigarette type, frequency of use, and quitting smoking: findings from a longitudinal online panel survey in great britain. *Nicotine Tob Res.* 2015;17(10):1187–1194.
15. Hornik, G. *Evidence for a Plateau in Use of E-Cigarettes Since mid-2014.* Chicago, IL: Society for Research on Nicotine and Tobacco; 2016.
16. Gorukanti A, Delucchi K, Ling P, Fisher-Travis R, Halpern-Felsher B. Adolescents' attitudes towards e-cigarette ingredients, safety, addictive properties, social norms, and regulation. *Prev Med.* 2017;94:65–71.
17. Krishnan-Sarin S, Morean ME, Camenga DR, Cavallo DA, Kong G. E-cigarette use among high school and middle school adolescents in Connecticut. *Nicotine Tob Res.* 2015;17(7):810–818.
18. Pérez A, Harrell MB, Malkani RL, et al. Texas adolescent tobacco and marketing surveillance system's design. *Tob Regul Sci.* 2017; 3(2).In press.
19. Loukas A, Chow S, Pasch KE, et al. College students' polytobacco use, cigarette cessation, and dependence. *Am J Health Behav.* 2016;40(4):514–522.
20. Spears CA, Jones DM, Weaver SR, et al. Use of electronic nicotine delivery systems among adults with mental health conditions, 2015. *Int J Environ Res Public Health.* 2016;14(1):10.
21. Alexander JP, Coleman BN, Johnson SE, Tessman GK, Tworek C, Dickinson DM. Smoke and vapor: exploring the terminology landscape among electronic cigarette users. *Tob Regul Sci.* 2016;2(3):204–213.
22. Food and Drug Administration H. 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 products; Final Rule (21 CFR Parts 1100, 1140, and 1143). *Fed Reg.* 2016;81(90):28974–9106.
23. Seidenberg AB, Jo CL, Ribisl KM. Differences in the design and sale of e-cigarettes by cigarette manufacturers and non-cigarette manufacturers in the USA. *Tob Control.* 2016;25(e1):e3–e5.