

E-cigarette Use Patterns, Flavors, and Device Characteristics Associated With Quitting Smoking Among a U.S. sample of Adults Using E-cigarettes in a Smoking Cessation Attempt

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Abstract

Introduction: Many adults who smoke cigarettes use e-cigarettes to try to quit smoking; however, some are not successful. Identifying factors that are associated with successfully quitting smoking using e-cigarettes is important for maximizing cigarette cessation.

Aims and Methods: Online survey data were collected in 2021 from 857 adults in the United States who reported using e-cigarettes in a recent attempt to quit smoking. Survey items assessed patterns of e-cigarette use and device characteristics (flavors, device, and nicotine) used when trying to quit smoking. Multivariable linear regression models examined characteristics associated with the longest duration of smoking abstinence when using e-cigarettes to try to quit.

Results: The average duration of smoking abstinence when using e-cigarettes during a quit attempt was 65 days (SD = 104). In the multivariable model, greater frequency of e-cigarette use when quitting and abruptly switching to e-cigarettes from cigarettes (vs. gradually reducing) were significantly associated with longer durations of abstinence ($p < .001$). Preference for non-tobacco (relative to tobacco) flavors and nicotine concentration were not associated with duration of abstinence, although preference for rechargeable pod and mod device types (vs. cig-a-likes) was associated with longer durations of abstinence.

Conclusions: Patterns of e-cigarette use were related to abstinence duration, which may provide guidance for adults who are using e-cigarettes to quit smoking to encourage complete substitution and maximize smoking cessation. Findings indicate that non-tobacco e-cigarette flavors and nicotine strength are not related to longer durations of cessation success for adults, which may inform tobacco regulatory policies limiting these constituents to protect public health.

Implications: This study provides important new information about the characteristics of e-cigarettes used during an attempt to quit smoking among adults across the United States and identifies factors associated with quitting success. Patterns of e-cigarette use were associated with longer durations of abstinence. In contrast, few e-cigarette characteristics were associated with abstinence. Although preference for some pod and mod device types was associated with longer abstinence duration compared to earlier cig-a-like devices, preference for non-tobacco (vs. tobacco) flavor and nicotine concentration were not associated with abstinence. Findings may help inform guidance for adults using e-cigarettes to quit smoking and support tobacco regulatory policies.

Introduction

Cigarette use remains the leading cause of preventable death, accounting for more than 8 million global deaths annually.¹ While many adults who smoke cigarettes are motivated to quit and 50% or more make attempts to quit each year, most are unsuccessful, and less than 1/3 of those who attempt to quit using use evidence-based methods to support smoking cessation.^{2–4} E-cigarettes are an alternative nicotine delivery system that may encourage switching and cessation of combustible cigarettes. Evidence from a Cochrane review and meta-analysis of randomized controlled trials indicates using e-cigarettes may be an effective strategy to stop smoking, producing better quit rates than placebo e-cigarettes, and evidence-based nicotine replacement therapies.⁵ However,

other meta-analyses indicate that e-cigarettes are associated with smoking cessation in randomized controlled trials but not in real-world population studies.⁶ Thus, although evidence is mixed, some adults are able to stop smoking by using e-cigarettes, while others are not. Additional research is needed to identify factors that are associated with success quitting smoking when using e-cigarettes, as this can provide valuable information about who may benefit from using e-cigarettes to quit smoking, and how to use e-cigarettes to maximize cigarette cessation.

Specific characteristics of e-cigarettes, including patterns of use, flavors, device type, and nicotine concentration, may be important factors that relate to the use of these products when quitting smoking. For example, there is evidence from prior studies that people who use e-cigarettes more frequently

are more successful quitting smoking,^{6,7} although less is known about what patterns of use are related to quitting success, such as switching abruptly to e-cigarettes or gradually reducing cigarettes while vaping. Additionally, research is needed to understand whether e-cigarette flavors are important for adults who are using these products to quit smoking. There is tension between policies around e-cigarette flavors because flavor restrictions may prevent appeal and use among youth,⁸ while the availability of e-cigarette flavors may be useful for adults to quit smoking cigarettes.⁹ Currently, the FDA is reviewing premarket tobacco applications and has only approved e-cigarettes in tobacco flavor,¹⁰ so investigating whether additional nontobacco flavors are related to successfully quitting smoking for adults or whether tobacco flavor is sufficient will help inform tobacco regulatory policies. Furthermore, e-cigarette device type and nicotine concentration may be factors that relate to successful quitting. Early e-cigarette devices, such as the cig-a-like devices, deliver nicotine less efficiently compared to more advanced pod-style devices,^{11,12} and better nicotine delivery may be a critical factor for complete substitution of cigarettes and success quitting smoking.

To address these questions, the current study surveyed adults across the United States who used e-cigarettes in an attempt to quit smoking in the past 2 years to identify factors associated with duration of smoking abstinence achieved. We examined e-cigarette characteristics during the quit attempt including e-cigarette patterns (i.e. frequency of use and abrupt vs. gradual switching), flavors, device types, and nicotine concentration to identify factors associated with duration of abstinence, while controlling for demographic factors known to be associated with cigarette smoking and quitting success (e.g. age, sex, education, and cigarette dependence¹³⁻¹⁷).

Methods

Participants and Procedures

All procedures were approved by the Yale University Institutional Review Board. In summer of 2021, participants from across the United States were recruited directly by Qualtrics Online Sample, a secure market research service owned and operated by Qualtrics, Inc. Qualtrics emailed invitations to participate to registered panelists who were likely to be eligible based on information they provided on prior surveys (e.g. smoking status). Interested individuals completed several screening questions, and those who were eligible were invited to complete the full anonymous 20-minute survey.

Participants who completed the survey ($N = 857$) were compensated directly by Qualtrics Online Sample based on the pre-established terms between Qualtrics and its panelists. Estimated compensation is <\$11 in value, although the exact amount and type of compensation are not made available to researchers. Qualtrics states the specific type of rewards vary and may include cash, airline miles, gift cards, redeemable points, charitable donations, sweepstakes entrance, and vouchers, and participants “receive an incentive based on the length of the survey, their specific panelist profile, and target acquisition difficulty”.¹⁸

Participants completed a series of in-depth screening questions to ensure eligibility to participate in the survey. Basic eligibility included living in the United States, being

at least 21 years old, reporting a history of regular cigarette smoking (defined as smoking ≥ 1 year for ≥ 4 days/week, because we wanted to recruit adults who had established smoking patterns, and there is evidence that members of minoritized racial/ethnic groups are more likely to have non-daily smoking patterns¹⁹), and reporting using e-cigarettes in an attempt to quit smoking in the past 2 years. Quotas were set to ensure sample diversity by sex (approximately 50% male/50% female), ethnicity/race (at least 35% minority), and region of the country (Northeast, South, Midwest, and West). To ensure that we surveyed participants with a range of smoking abstinence durations, sampling quotas were set to recruit roughly equal numbers of participants who achieved at least 1 month of smoking abstinence when using e-cigarettes to quit versus those who achieved only shorter durations of abstinence (<1 month). We set this sampling quota based on studies of large international datasets indicating approximately 50% of adults who smoke have achieved at least 1 month of abstinence.³

Measures

Demographics

Participants reported age, sex (female/male), US region (West, Midwest, Northeast, and South), Hispanic identity (no/yes), race (White, Black or African American, Asian or Asian American, American Indian or Alaska Native, Pacific Islander, Native Hawaiian, and Other [select all that apply]), highest education achieved (less than high school to professional degree), and subjective financial situation (“I do not meet basic expenses,” “I just meet basic expenses,” “I meet needs with a little left over,” “I live comfortably”).²⁰

Screening Questions

To participate in the survey, participants had to endorse lifetime use of cigarettes and e-cigarettes from a list of 9 products (i.e. cigarettes, e-cigarettes, hookah, cigar or cigarillo, smokeless tobacco, nicotine pouch, heated tobacco like IQOS, alcohol, and marijuana), duration of smoking ≥ 1 year, and frequency of smoking ≥ 4 days/week (response options: Less than 1 day per week, 1 day per week, 2 days per week, 3 days per week, 4 days per week, 5 days per week, 6 days per week, and 7 days per week/every day). Additionally, participants had to endorse at least 1 attempt to quit smoking in the past 2 years. If they reported at least 1 quit attempt, they were asked to select all that apply from 11 methods used to try to quit in the past 2 years (i.e. “which of the following strategies did you use to help you quit smoking,” including counseling, nicotine replacement therapy, e-cigarettes). Those endorsing using e-cigarettes during a quit attempt in the past 2 years were eligible to continue the survey.

Longest Duration of Smoking Abstinence

Participants reported the longest duration of smoking abstinence achieved when they were using e-cigarettes to try to quit smoking in the past 2 years. Responses were assessed as a categorical variable with 9 levels: A total of 7.9% reported less than a day, 23.0% reported less than a week, 22.1% reported 1–3 weeks, 15.6% reported 1 month, 13.9% reported 2–3 months, 6.5% reported 4–6 months, 3.7% reported 7–9 months, 3.2% reported 10–12 months, and 4.1% more than a year. To utilize the full range and variability of the data, rather than coding into a binary outcome or adding excessive complexity with multiple contrast-coded outcomes, the

categorical variable was used as a single ordinal outcome for analysis to examine factors associated with the longest duration of smoking abstinence. For each level of the categorical variable, the ordinal outcome value was coded as the mid-point of the interval in days (e.g. 2–3 months was 75 days).²¹

Tobacco Use History

Participants who reported a lifetime history of cigarette use were asked about their current smoking status and reported on smoking characteristics based on their current use pattern (if they were currently smoking) or based on their usual use pattern (if they had quit smoking). Smoking history characteristics examined here included the number of years smoked, average number of cigarettes smoked per day, cigarette dependence (measured with the PROMIS scale),²² the number of lifetime attempts to quit smoking, usual cigarette flavor (menthol or non-menthol), whether they lived with someone who smokes/vapes, and lifetime history of other tobacco product use (i.e. hookah, cigar or cigarillo, smokeless, nicotine pouch, and heated tobacco products like IQOS). Smoking history characteristics were included as covariates in the multivariable models.

E-cigarette Use When Trying to Quit Smoking

Participants reported their e-cigarette use behaviors when trying to quit smoking, including whether they had a quit plan (yes vs. no): “when you decided to use e-cigarettes/vapes to try to quit smoking, did you make a specific quit plan (e.g. decided what day you would quit smoking)” and what their quit strategy was: “stop smoking and switch completely to vaping (an abrupt switch)” versus “use both cigarettes and e-cigarettes/vaping to try and slowly stop smoking (gradual reduction in smoking).” Participants also reported on their frequency of using e-cigarettes when trying to quit smoking, coded as “once or twice a day or less,” “several times throughout the day,” “many times throughout the day,” or “almost constantly throughout the day.”

E-cigarette Flavors Used During an Attempt to Quit Smoking

Participants reported the e-cigarette flavors used when trying to quit smoking and could select all that apply from the following flavor categories: Tobacco, menthol, mint, fruit, candy or dessert, vanilla, coffee, spice (e.g. clove), alcohol (e.g. pina colada), other beverage, and other (write-in). These responses were used to calculate the total number of flavors used when quitting. Additionally, participants were asked to select their preferred e-cigarette flavor used when trying to quit smoking (select one) from the same categories. Given the importance of evaluating whether the availability of e-cigarette flavors is important for adults using e-cigarettes to quit smoking, preference for non-tobacco e-cigarette flavor (relative to tobacco flavor, i.e. fruit vs. tobacco) was examined in the model predicting smoking abstinence.

E-cigarette Devices Used During an Attempt to Quit Smoking

Participants reported the e-cigarette devices used when trying to quit smoking and could select all that apply from the following: cig-a-like, vape pen, disposable pod, JUUL, rechargeable pod system other than JUUL (e.g. Phix, Suorin, and Vuse Alto), Mod or Advanced Personal Vaporizers (APVs),

E-hookah. Specific brand examples and pictures were included for each device type to aid in accurate recall.²³ These responses were used to calculate the total number of device types used when quitting. Additionally, participants were asked to select their preferred e-cigarette device that was most helpful for quitting smoking (select one) from the same categories.

Nicotine Concentration Used During an Attempt to Quit Smoking

Participants reported whether they used nicotine in their e-cigarette when they were trying to quit smoking with the following response options: “I only used NO nicotine (nicotine-free) e-liquids or pods,” “I only used nicotine e-liquids or pods,” “I used BOTH no nicotine (nicotine-free) and nicotine e-liquids or pods,” and “I don’t know.” Additionally, participants were asked how the nicotine concentration was labeled (mg/mL, %, “I don’t know”). Those who responded with mg/mL or percent nicotine subsequently provided details about the nicotine concentration they preferred when quitting. Nicotine concentration response options in mg/mL and percent nicotine were equivalent to one another (e.g. 24 mg/mL and 2.4%, 30 mg/mL, and 3%). Therefore, to assess average nicotine concentration preferred, all concentrations were converted to the value for mg/mL for the purposes of analyses.

Data Analysis

Analyses were conducted using SPSS (version 28.0). Descriptive statistics were used to characterize demographic and tobacco use variables and e-cigarette characteristics used during the quit attempt (Table 1). Multivariable linear regression models were used to identify characteristics that were associated with longer durations of abstinence (a continuous outcome). The first model included demographic and tobacco use variables (e.g. cigarette dependence), and e-cigarette use patterns when quitting (e.g. vaping frequency). These were initially examined separately from the e-cigarette characteristics used when quitting (i.e. flavors, device types, and nicotine) to reduce the complexity of the models given the number of items included. Next, a final multivariable linear regression model (Table 2) was used to examine associations between characteristics of e-cigarettes used when quitting (flavors, device types, and nicotine) and duration of smoking abstinence while controlling for demographic variables and significant tobacco use variables from the first model. Results were consistent when e-cigarette characteristics (flavors, device types, and nicotine) were entered into separate models, so results are presented from the model combining flavors, device types, and nicotine for parsimony.

Results

Table 1 presents demographic and tobacco use characteristics for the sample. In total, we surveyed 857 adults (52.4% male). The average age was 40.8 (SD = 12.3), and respondents had been smoking on average 11.6 cigarettes per day (SD = 7.6) for 17.5 years (SD = 12.7). In terms of race/ethnicity, 62.8% identified as non-Hispanic (NH) white, 21.7% identified as Hispanic, 7.7% identified as NH black, and 7.8% identified as NH other. The average duration of smoking abstinence achieved when using e-cigarettes during a quit attempt was 65 days (SD = 104).

Table 1. Demographic and Tobacco Use Characteristics Among Adults From the United States Using E-cigarettes to Try to Quit Smoking (*N* = 857)

Variable	Mean (SD) or N (%)
Age	40.8 (12.3)
Male (ref: female)	449 (52.4%)
Region	
West (ref)	212 (24.7%)
Northeast	160 (18.7%)
Midwest	145 (16.9%)
South	340 (39.7%)
Race/Ethnicity	
NH white (ref)	538 (62.8%)
Hispanic	186 (21.7%)
NH black	66 (7.7%)
NH other ¹	67 (7.8%)
Education	
HS degree/GED or less (ref)	165 (19.3%)
Some college or Associates Degree	296 (34.5%)
Bachelor's degree	244 (28.5%)
Advanced degree	152 (17.7%)
Income	
Do not meet basic needs (ref)	62 (7.2%)
Just meet basic needs	199 (23.2%)
Meet needs with a little leftover	237 (27.7%)
Live comfortably	359 (41.9%)
Tobacco use history	
Years smoked	17.5 (12.7)
Cigarette dependence ²	2.5 (0.9)
Cigarettes per day	11.6 (7.6)
Number of smoking quit attempts	5.7 (2.8)
Living with someone who smokes/vapes	447 (52.2%)
Usual cigarettes menthol (vs. non-menthol)	488 (56.9%)
Lifetime use of other tobacco products ³	671 (78.3%)
E-cig use when trying to quit smoking	
Abrupt switch to vaping (vs. gradual reduction)	315 (36.8%)
Had a specific plan to quit (e.g. quit day)	410 (47.8%)
E-cigarette use in nonsmoking places (e.g. indoors)	535 (62.4%)
E-cig frequency when trying to quit smoking	
Once or twice a day or less (ref)	209 (24.4%)
Several times throughout the day	318 (37.1%)
Many times throughout the day	231 (27.0%)
Almost constantly throughout the day	99 (11.5%)
E-cigarette flavors used when quitting	
Flavor preferred	
Fruit	239 (28.0%)
Tobacco	176 (20.6%)
Menthol	168 (19.7%)
Mint	90 (10.5%)
Candy	67 (7.8%)
Vanilla	32 (3.7%)
Alcohol	32 (3.7%)
Coffee	29 (3.4%)

Table 1. Continued

Variable	Mean (SD) or N (%)
Spice	13 (1.5%)
Beverage	7 (0.8%)
Other flavors	1 (0.1%)
Total number of flavors used	2.7 (1.7)
E-cigarette device type used when quitting	
Device Preferred	
Vape pen	224 (26.1%)
Cig-a-like	195 (22.8%)
JUUL	131 (15.3%)
Mod/APV	129 (15.1%)
Other rechargeable pod devices	92 (10.7%)
Disposable pod	71 (8.3%)
E-hookah	15 (1.8%)
Total number of devices used	2.3 (1.5)
Nicotine used when quitting	
Nicotine e-liquid (vs. no-nicotine)	684 (83.0%)
Preferred nicotine concentration (mg/ml)	19.7 (19.6)

¹NH Other: *N* = 29 multiracial, *N* = 23 Asian or Asian American, *N* = 9 American Indian or Alaska Native, *N* = 4 "Other", *N* = 2 Pacific Islander.

²Measured by the PROMIS nicotine dependence scale,²² range 0–4 with higher scores indicating greater dependence.

³Lifetime use of other tobacco products: heated tobacco (e.g. IQOS), hookah, cigar or cigarillo, smokeless tobacco, nicotine pouch.

E-cigarette Characteristics Associated With Abstinence Duration

In the first multivariable linear regression model examining demographic and tobacco use variables associated with the longest duration of smoking abstinence achieved when using e-cigarettes to quit, lower cigarette dependence ($B = -9.02$, $SE = 4.35$, $p = .03$), abruptly switching to e-cigarettes (rather than gradually switching and using both cigarettes and e-cigarettes, $p < .001$), and vaping frequency when trying to quit smoking (p 's $< .04$) were significantly associated with longer abstinence duration (Supplementary Table), and thus were included in the final model. The final model included all e-cigarette characteristics (flavor, device type, nicotine) while controlling for demographic variables, cigarette dependence, and e-cigarette use patterns when quitting (Table 2). In the final model, abruptly switching to e-cigarettes (rather than gradually switching and using both cigarettes and e-cigarettes, [$B = 42.42$, $SE = 7.48$, $p < .001$]) remained significantly associated with longer abstinence duration. Additionally, vaping more frequently when trying to quit smoking remained significantly associated with longer abstinence duration. Compared to vaping only once or twice per day, vaping several times throughout the day was associated with almost 19 more days of abstinence ($B = 18.95$, $SE = 9.50$, $p = .04$), vaping many times throughout the day was associated with 30 more days of abstinence ($B = 30.35$, $SE = 10.39$, $p = .004$), and vaping almost constantly throughout the day was associated with 75 more days of abstinence ($B = 75.04$, $SE = 13.57$, $p < .001$).

Flavor

On average, people reported using 2.7 (SD = 1.7) different e-cigarette flavors when trying to quit smoking, and most

Table 2. Multivariable Linear Regression Results Examining Associations Between E-cigarette Characteristics and Duration of Smoking Abstinence ($N = 857$)

	B (SE) ³	<i>p</i> -Value
Age	0.02 (0.33)	.94
Male (ref: female)	3.80 (7.88)	.63
Region		
West (ref)		
Northeast	-6.69 (11.42)	.56
South	-5.54 (9.77)	.57
Midwest	-0.48 (11.87)	.97
Race/Ethnicity		
NH white (ref)		
Hispanic	1.42 (9.79)	.89
NH black	8.76 (13.78)	.53
NH other	-11.39 (13.78)	.41
Education		
HS degree/GED or less (ref)		
Some college or Associates Degree	-14.84 (10.37)	.15
Bachelor's degree	1.86 (11.65)	.87
Advanced degree	-1.61 (13.24)	.90
Income		
Do not meet basic needs (ref)		
Just meet basic needs	-24.60 (16.01)	.13
Meet needs with little left over	-13.82 (16.06)	.39
Live comfortably	-8.92 (16.78)	.60
Tobacco use history		
Cigarette dependence	-7.01 (4.27)	.10
E-cig use when trying to quit smoking		
Abrupt switch to vaping (vs. gradual reduction)	42.42 (7.48)	<.001
E-cig frequency when trying to quit smoking		
Once or twice a day or less (ref)		
Several times throughout the day	18.95 (9.50)	.04
Many times throughout the day	30.35 (10.39)	.004
Almost constantly throughout the day	75.04 (13.57)	<.001
Flavors used when quitting		
Flavor preferred (ref. tobacco)		
Menthol	5.34 (11.18)	.63
Mint	13.32 (13.49)	.32
Fruit	14.45 (10.78)	.18
Candy	19.31 (15.28)	.21
Other Flavors ¹	-7.00 (14.02)	.62
Total number of flavors used	-4.58 (2.48)	.07
Device type used when quitting		
Device Preferred (ref. cig-a-like)		
Vape pen	-8.90 (10.81)	.41
Disposable pod	-1.97 (15.24)	.90
JUUL	-13.81 (12.14)	.26
Other rechargeable pod devices	29.54 (13.53)	.03
Mod/APV	30.15 (12.81)	.02
E-hookah	1.68 (28.64)	.95
Total number of devices used	3.12 (2.79)	.27

Table 2. Continued

	B (SE) ³	<i>p</i> -Value
Nicotine used when quitting		
Nicotine e-liquid (ref: only nicotine-free)	10.19 (10.00)	.31
Preferred nicotine concentration ²	0.29 (0.20)	.16

¹Combines low-frequency flavors (< 5%) preferring vanilla, coffee, spice, alcohol, and other beverage.

²Preferred nicotine concentration examined in a separate model with the same covariates, data only available for those who reported knowing their nicotine concentration ($N = 688$). Participants provided data on preferred nicotine concentration in either mg/mL or %. Response options in mg/mL and % were equivalent to one another (e.g. 24 mg/mL and 2.4%) and were converted to the value for mg/mL for analyses. Range of preferred nicotine concentrations 0–70 mg/ml.

³Regression estimates are adjusted for all variables in the model.

people (71.9%) reported using more than one type of flavor. [Table 1](#) presents the frequency of e-cigarette flavors preferred among adults when trying to quit smoking. The most preferred e-cigarette flavor was fruit (28.0%), followed by tobacco (20.6%), menthol (19.7%), mint (10.5%), and candy (7.8%). All other flavor categories were preferred by <5% of the sample and were combined into an “other” category for analyses. In the multivariable model, neither the total number of flavors used ($p = .07$) nor preference for any non-tobacco e-cigarette flavor (relative to tobacco flavor) ($ps > .20$) was associated with duration of smoking abstinence ([Table 2](#)).

Device Type

On average, people reported using 2.3 (SD = 1.5) different types of e-cigarette devices when trying to quit smoking, and most people (69.4%) reported using more than one type of device. [Table 1](#) presents the frequency of e-cigarette devices preferred among adults when trying to quit smoking. The total number of device types used was not significantly associated with the duration of smoking abstinence ($p = .27$). However, compared to cig-a-like e-cigarettes, preferring rechargeable pods ($B = 29.54$, SE = 13.53, $p = .03$) or mod/APV devices ($B = 30.15$, SE = 12.81, $p = .02$) was associated with longer durations of abstinence ([Table 2](#)).

Nicotine

Most participants reported using nicotine e-liquids/pods when trying to quit smoking (49.8% used only nicotine e-liquids, 30.0% used both nicotine and nicotine-free, 79.8% total), while 16.3% reported using only nicotine-free (no nicotine), and 3.9% reported: “I don’t know.” Data on preferred nicotine concentration was missing for 19.7% of the total sample because of participants who responded “I don’t know” to additional questions about nicotine labeling and concentration. Among the subsample who responded to this question ($N = 688$), the average preferred nicotine concentration used when quitting was 19.7mg/mL (SD = 19.6, range 0–70). These variables related to nicotine use in e-cigarettes when quitting were highly correlated with one another so were entered into separate multivariable models. Neither nicotine variable was associated with duration of smoking abstinence (use of nicotine vs. nicotine-free, $p = .31$, preferred nicotine concentration, $p = .16$) ([Table 2](#)).

Discussion

This study provides important new information about the characteristics of e-cigarettes used during an attempt to quit smoking among adults across the United States and identifies factors associated with quitting success. Of note, patterns of e-cigarette use were important predictors of longer durations of abstinence. Specifically, using e-cigarettes more frequently when trying to quit and abruptly switching from cigarettes to e-cigarettes (rather than gradually switching and using both) were associated with longer durations of abstinence. In contrast, few e-cigarette characteristics were associated with abstinence duration in the multivariable model. Although preference for some newer device types (e.g. rechargeable pods, mods) was associated with longer abstinence durations compared to earlier cig-a-like devices, preference for non-tobacco (relative to tobacco) flavor and nicotine concentration were not associated with abstinence duration.

Our findings are consistent with several other studies, including a meta-analysis of multiple studies, showing that more frequent e-cigarette use is associated with smoking cessation.^{6,24} Our study also provides new information that abruptly switching from cigarettes to e-cigarettes is associated with longer durations of smoking abstinence. This information can be helpful for providing guidance to adults using e-cigarettes to help them quit smoking by encouraging them to switch all at once rather than gradually trying to reduce the use of cigarettes while vaping. Abrupt switching may also have greater harm reduction benefits, because dual use of cigarettes and e-cigarettes is common²⁵ and may not reduce the negative health consequences of smoking since individuals remain exposed to the known harmful chemicals in combustible cigarettes,²⁶ and even low rates of smoking are associated with increased morbidity and mortality.^{27,28} Additional research is needed to identify factors that relate to more frequent use of e-cigarettes and abrupt versus gradual switching to better understand ways to optimize e-cigarette use to support smoking cessation.

In terms of e-cigarette characteristics, our findings indicate most people reported trying more than one e-cigarette flavor and more than one device type when trying to quit smoking. This may suggest e-cigarette use is a strategy people are committed to trying when quitting smoking, as compared to over-the-counter nicotine replacement products that are often quickly discontinued.^{29,30} However, using more flavors or more device types was not associated with successful quitting. Additionally, preference for a non-tobacco e-cigarette flavor (relative to tobacco) was not significantly associated with duration of smoking abstinence in the multivariable model, and these findings may be important for informing e-cigarette regulations that support e-cigarette use as a harm reduction tool. Our findings are consistent with studies showing that fruit flavors are commonly used by adults,^{31,32} and indicate that although fruit flavors are commonly preferred among adults using e-cigarettes to quit smoking, preference for a non-tobacco e-cigarette flavor (such as fruit) was not associated with longer durations of success quitting smoking in a multivariable model. This may suggest that e-cigarette regulatory policies that only allow tobacco flavors may not negatively impact smoking cessation success among adults, and may help reduce youth e-cigarette use, given that fruit flavors are highly appealing to youth.³³ However, the role of flavors in promoting and sustaining

smoking cessation remains unclear. For example, one study analyzing population-level data across three waves showed that the use of flavored e-cigarettes at two waves was associated with a greater likelihood of quitting, but this effect was not observed among those who used flavored e-cigarettes for only one wave.²⁴ Another study showed that frequent use of tobacco-flavored or non-tobacco-flavored e-cigarettes was associated with greater odds of making a quit attempt and quit success in the past year.³⁴ Additionally, e-cigarette flavors used when quitting may vary during this process, as studies show that flavor preference changes over time, and non-tobacco flavors are used with greater frequency over time among those who use e-cigarettes long-term.³⁵ Importantly, few prospective controlled studies have examined the role of flavors in smoking cessation or reduction,³⁶ and this work will be important for informing regulations to reduce the harms of cigarette smoking.

In terms of specific e-cigarette devices, the results indicated that preference for newer devices, specifically rechargeable pods and mod/APV e-cigarette devices, was associated with longer durations of abstinence compared to cig-a-like devices. This is consistent with other studies indicating use of rechargeable devices is common among those who switch from cigarettes,³⁷ and analyses of longitudinal population-level data from 2013 to 2016 showing that using a rechargeable (vs. disposable) e-cigarette device was associated with an increased likelihood of quitting.²⁴ Additional research is needed to understand reasons for these findings, although this may be due to the fact that advanced generation devices deliver nicotine more efficiently than cig-a-likes,¹¹ or are more expensive compared to other disposable devices, so people who invest in these devices may be more committed to quitting smoking or more likely to use them consistently.

Additionally, our results indicate that nicotine concentration used in e-cigarettes when quitting smoking was not associated with smoking abstinence duration. Specifically, abstinence duration did not differ between the use of nicotine versus nicotine-free e-cigarettes. These findings differ from results of the meta-analysis of randomized controlled trials indicating use of nicotine e-cigarettes are superior to placebo e-cigarettes for smoking cessation⁵ and may suggest differences in the sample studied or differences between efficacy in randomized controlled trials compared to real-world use of the products.⁶ Furthermore, preferred nicotine concentration was also not associated with abstinence duration in our sample. If nicotine concentration is not related to smoking cessation success, this may suggest that regulatory policies limiting the maximum nicotine concentration in e-cigarettes, similar to other countries like the United Kingdom (with a cap of 20 mg/ml), may be beneficial for reducing the abuse liability and addiction potential without compromising benefit to adults using e-cigarettes to quit smoking. Importantly, research suggests nicotine delivery to the user is also influenced by device characteristics such as wattage,^{38,39} so more comprehensive regulations on factors that influence nicotine delivery (e.g. wattage limits) may also be needed to reduce abuse liability.

Study results should be considered in light of several limitations. First, survey responses were collected from a sample of Qualtrics panel members across the United States which may limit the generalizability, and replication with larger, diverse populations is needed. However, a strength of the study design was using purposeful sampling to ensure recruitment

across regions of the United States and including multiple attention checks and screening questions to ensure recruitment of a valid sample of adults who had used e-cigarettes to quit smoking. Second, self-reported outcomes may be impacted by recall bias, and certain device characteristics may be difficult to accurately recall such as nicotine concentration or specific devices used.^{40,41} Device characteristics were not independently verified by researchers given that survey responses were assessing retrospective e-cigarette use when quitting. Additional prospective longitudinal studies would be beneficial to understand how these e-cigarette use characteristics impact smoking cessation outcomes. Furthermore, the manuscript focuses on the longest duration of abstinence achieved when using e-cigarettes to try to quit smoking in the past 2 years, so we do not have data on other quit attempts and smoking cessation outcomes were not biochemically verified. Finally, there may be unmeasured variables that relate to the decision to use e-cigarettes in an attempt to quit or success in achieving smoking abstinence (such as motivations to quit) that could be considered in future studies.

Conclusions

In conclusion, among a sample of adults in the United States who had used e-cigarettes to quit smoking, few characteristics of e-cigarettes were important for cessation success. Flavor preference and nicotine concentration were not associated with abstinence duration, although preference for rechargeable pod or mod/APV device types was associated with longer abstinence durations compared to earlier cig-a-like devices. Patterns of e-cigarette use, specifically abruptly switching from cigarettes to e-cigarettes (rather than gradually switching) and using e-cigarettes more frequently, were associated with longer durations of abstinence. These findings may help inform e-cigarette policy and recommendations for adults who are using e-cigarettes to quit to help maximize harm reduction and smoking cessation.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

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Declaration of Interests

Outside of the submitted work, Dr. O'Malley reports being a member of the American Society of Clinical Psychopharmacology's (ASCP's) Alcohol Clinical Trials Initiative, supported by Alkermes, Dicerna, Ethypharm, Lundbeck, Mitsubishi Tanabe, Otsuka; Consultant/advisory board member, Alkermes, Dicerna, Opiant; Medication

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Data Availability

Data are available upon request to the authors.

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