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Original Investigation
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Original Investigation

Patterns of E-cigarette Use and Subsequent Cigarette Smoking Cessation Over 2 Years (2013/2014–2015/2016) in the Population Assessment of Tobacco and Health Study

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Abstract

Introduction: Understanding the population impact of e-cigarettes requires determining their effect on cigarette smoking cessation.

Methods: Using the US Population Assessment of Tobacco and Health cohort, we examined smoking cessation among adult current cigarette smokers at Wave 1 with follow-up data at Waves 2 and 3 ($n = 9724$).

Results: By Wave 3 (2015/2016), 17.3% of smokers had quit smoking. Smokers using e-cigarettes daily or who increased to daily use over the three waves were two to four times more likely to have quit in the short term (<1 year) and long term (1+ years) compared with never e-cigarette users ($p < .001$). E-cigarette use in the last quit attempt was associated with a higher likelihood of short-term (<1 year) quitting at Wave 3 (adjusted relative risk ratio: 1.33; 95% confidence interval: 1.04, 1.71) compared with smokers who did not use an e-cigarette in their last quit attempt. Noncurrent (no use in any wave) e-cigarette users and users who were unstable in use frequency were 33% and 47% less likely to quit in the short-term, respectively ($p < .001$). Flavored (vs nonflavored) and using a rechargeable (vs disposable) e-cigarette device was associated with an increased likelihood of both short- and long-term quitting.

Conclusion: Smoking cessation was more likely among frequent e-cigarette users, users of e-cigarettes in last quit attempt, and users of flavored and rechargeable devices. Less frequent, unstable, past, or never e-cigarette users were less likely to quit smoking. Monitoring the relationship between patterns of e-cigarette and cigarette use is complex but critical for gauging the potential of e-cigarettes as a harm reduction tool.

Implications: This study suggests that consistent and frequent e-cigarette use over time is associated with cigarette smoking cessation among adults in the United States. In addition, findings suggest that flavored e-cigarette use and use of rechargeable e-cigarette devices can facilitate smoking cessation. These results underscore the importance of carefully defining and characterizing e-cigarette exposure patterns, potential confounders, and use of e-cigarettes to quit smoking, as well as variations in length of the smoking cessation.

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Introduction

Cigarette smoking remains the leading cause of preventable death and disease in the United States.[1] Although current cigarette smoking has declined among adults in the United States to a record low of 13.7% in 2018,[2] progress has been slow to prevent the nearly half million deaths that occur each year due to smoking.[1] In 2015, although 55.4% of adult smokers in the United States made a quit attempt in the past year, only 7.4% of adults successfully quit.[3] In addition, less than one third of smokers who tried to quit used an evidence-based cessation method to quit.[3] As a consumer product in the United States, electronic cigarettes (e-cigarettes) are increasingly used and possess the potential to help more smokers quit smoking.[4]

E-cigarette use has increased in popularity with 3.2% of adults reporting current e-cigarette use in 2018 in the United States.[2] The majority of adult e-cigarette users are current or recent former smokers.[5,6] From 2014 to 2016, nearly two thirds of US adult cigarette smokers reported having used e-cigarettes in their last quit attempt, with 35.3% substituting some regular cigarettes with e-cigarettes and 24.7% switching completely to e-cigarettes.[7] E-cigarettes have the potential to be an effective aid to smoking cessation that is more accessible and appealing[8] than some other quit methods, such as nicotine replacement therapy. Two reviews have concluded that e-cigarettes inhibit smoking cessation,[9,10] whereas others conclude that e-cigarettes facilitate smoking cessation, but that low-quality studies necessitate more high-quality randomized controlled trials and prospective studies.[11–13] A Cochrane review in 2014 found that two randomized controlled trials demonstrated long-term success in smoking cessation with use of a nicotine-containing e-cigarette.[14] Since then, more randomized controlled trials[15–18] and several strong observational studies[19–25] have generally found that e-cigarette use can facilitate quit attempts and cessation.[26,27] These findings are supported by recent e-cigarette comprehensive reviews from Public Health England[28] and the National Academies of Sciences, Engineering and Medicine.[29]

A recent review found that the results of studies examining the impact of e-cigarette use on cigarette smoking cessation varied with the sample, study design, and the use of different exposures, covariates, and outcome measures.[26] Nationally representative prospective cohort studies in the United States show that more intense e-cigarette use, including daily and long-term use, is associated with smoking cessation.[19,20,22,23] Adult smokers followed from 2012 to 2014 reported more quit attempts and smoking cessation if they used e-cigarettes over the course of the study.[23] In 2014/2015, adult smokers in the United States who used e-cigarettes were more likely to have made a quit attempt.[20,30] Furthermore, quit success (quit for at least 3 months) was lower among ever (but noncurrent) and someday e-cigarette users and higher among users on at least 5 days in the past month and daily users.[20,31] Daily e-cigarette use was also associated with higher prevalence of having quit smoking within the past 5 years (52.2% daily e-cigarette users, 28.2% never e-cigarette users), and smokers who were someday e-cigarettes users were the least likely to have quit cigarettes (12.1%);[19] this was also found in 2016/2017.[22]

Some studies suggest that use of flavored e-cigarettes facilitates smoking cessation. The proportion of adult e-cigarette users in the United States who initiate with and currently use tobacco- and mint-flavored e-cigarettes has declined over time, even among dual users and former smokers.[32] Initiation of multiple flavors has been associated with complete switching from cigarettes to e-cigarettes (vs remaining a smoker and rejecting e-cigarettes) among adults.[33] In addition, e-cigarette users have reported initiating with tobacco- or mint-flavored e-cigarettes, but switching to fruit or candy flavors over time.[34] About 10% of these e-cigarette users indicated that if nontobacco-flavored e-cigarettes were no longer available, they would switch back to conventional cigarettes.[34] Device type may also play a role in smoking cessation. E-cigarette devices with tanks and cartridges appear to be substitutes for cigarettes, but disposable e-cigarettes are not.[35]

Similar to other national surveys, data from the Population Assessment of Tobacco and Health (PATH) cohort study show that from baseline (2013/2014—Wave 1) to the first follow-up (2014/2015—Wave 2), daily e-cigarette users (vs nondaily users) at baseline, those who indicated using an e-cigarette in their last quit attempt, and those who used an e-cigarette with one or more flavors were more likely to report smoking cessation 1 year later.[36–39] Another study found that e-cigarette use (regular use and noncurrent use groups) at baseline was associated with smoking relapse at the 1-year follow-up among baseline former smokers.[40,41] Two studies have examined three waves of PATH data (2 years of follow-up). One reported that daily (but not nondaily) e-cigarette use at baseline was associated with past 30-day smoking abstinence at both the 1- and 2-year follow-ups.[42] The other study compared groups of dual cigarette smokers and e-cigarette users based on the frequency of use of both products and found that the most common dual-use pattern, predominant smoking (daily smoking, someday e-cigarette use), was the least likely to result in complete switching to e-cigarettes at the 2-year follow-up.[43]

Taken together, the studies to date show variability in results due to different study designs and samples as well as variations in the definition of e-cigarette use, device type, flavors used, quit attempts, and smoking cessation outcomes. Although the different studies have shed light on the importance of e-cigarette use patterns, device type, and the nature of the quit attempt individually or in some combination, none has systematically attempted to comprehensively incorporate all of these factors. The aim of this study is to extend previous PATH and other related study approaches to explore in more depth the patterns of e-cigarette use on smoking cessation. We address this aim by examining data across three waves in the PATH cohort over 2 years. Based on the findings of prior studies, we hypothesize that frequent and consistent e-cigarette use, e-cigarette use in a quit attempt, flavored e-cigarette use, and use of rechargeable e-cigarette devices would be associated with increased smoking cessation.

Methods

Data Source

The PATH Study is an ongoing, nationally representative, longitudinal cohort study of adults and youth in the United States. The National Institutes of Health's National Institute on Drug Abuse and the Food and Drug Administration's Center for Tobacco Products have contracted Westat to conduct the PATH Study. Wave 1 data were collected from September 2013 to December 2014, Wave 2 data were collected from October 2014 to October 2015, and Wave 3 data were collected from October 2015 to October 2016. Participants were recruited by a stratified address-based, area-probability sampling design, oversampling adult tobacco users, young adults (18–24 years), and African American adults. Up to two adults ≥18 years were interviewed per household, resulting in 32

320 completed adult interviews at Wave 1, 28 362 at Wave 2, and 28 148 at Wave 3 for an overall weighted response rate of 78.4%. The differences in the number of completed interviews between waves reflect attrition due to nonresponse, mortality, and other factors.

This article specifically examines smoking cessation among adult current (report smoking cigarettes "every day" or "somedays") cigarette smokers at Wave 1 who have follow-up information at Waves 2 and 3 (n = 9724). Further details regarding the PATH study design and methods are published elsewhere[44] and can be viewed, along with information on accessing the data, at https://doi.org/10.3886/Series606.

Measures

Demographic and Tobacco Use Characteristics

Demographic information at Wave 1 was reported on gender, age, race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic other, and Hispanic any race), highest level of education, and household income. Tobacco use characteristics at Wave 1 were also reported. A tobacco dependence composite score was developed using 16 indicators of tobacco dependence based on previous analyses with this data set (eg, frequent craving, perception that use is out of control).[45] We also consider whether the participant had smoked 100 cigarettes in his/her lifetime, other past 30-day tobacco (hookah, traditional cigars, cigarillos, filtered cigars, pipe, smokeless tobacco, snus, or dissolvable tobacco) use, and use of other evidence-based methods to aid in quitting in the past year (support of friends/family, counseling/quitline/web-based program, nicotine patch/gum/spray/lozenge, or prescription drug).

Explanatory Variables

E-cigarette Use at Baseline and Stability Across Waves

Self-reported e-cigarette use was assessed at each wave. E-cigarette user groups at Wave 1 (baseline) were created to characterize the sample based on a previous study[5] and were defined as follows: never users (have never tried the product); former triers (have ever tried the product but report using "not at all" at the time of the baseline survey); someday users (use "somedays" at the time of the baseline survey); and daily users (use "every day" at the time of the baseline survey). Groups were additionally defined by reported use across the three waves (Table 1). *Stable never users* never used an e-cigarette at any wave; *stable noncurrent users* ever used an e-cigarette at any wave but never reported someday or daily use; *stable or increased daily users* consistently used e-cigarettes daily at each wave or increased from no or low e-cigarette use to daily use; and *unstable/decreased users* were those with inconsistent and/or low-level use across waves. These unstable users were combined into one group because they never achieved a high or consistent "dose" of exposure to e-cigarettes over the study.

Use of an E-cigarette in One's Last Quit Attempt

We measured whether e-cigarettes were used in the respondent's last attempt to quit smoking cigarettes among those who quit or attempted to quit in the past year (yes or no). The exposure of interest was whether smokers reported use of e-cigarettes in their last quit attempt at either Wave 2 or Wave 3 (reporting this at Wave 1 does not reflect quitting behavior during the study).

Flavored E-cigarette Use

We examined whether the respondent's regular or last brand of e-cigarettes was flavored. At Waves 1 and 2, e-cigarette users who reported a regular brand of e-cigarette were asked, "[Is | was] [your regular brand | the last brand] you [use | used] flavored to taste like menthol, mint, clove, spice, candy, fruit, chocolate, alcohol (such as wine or cognac), or other sweets?" At Wave 3, e-cigarette users were asked, "What flavor [is/was] [your regular brand/the brand you last used]? Choose all that apply (tobacco-flavored; menthol or mint; clove or spice; fruit; chocolate; an alcoholic drink [such as wine, cognac, margarita or other cocktails]; a nonalcoholic drink [such as coffee, soda energy drinks, or other beverages]; candy, dessert of other sweets; some other flavor). Those who responded "no" to the Waves 1 and 2 item and those who responded "tobacco-flavored" to the Wave 3 item were defined as having used a nonflavored e-cigarette. Flavored users were divided into those who used a flavored e-cigarette at only one out of the three waves and those who used a flavored e-cigarette at two or more waves.

E-cigarette Device Type

We also considered whether the e-cigarette device used most of the time was disposable or rechargeable. We defined exposure as using a disposable device, using a rechargeable device at only one out of the three waves, or using a rechargeable device at two or more waves.

Outcome Variable

We assessed quitting cigarette smoking between Waves 1 and 3, defined as being a current smoker (daily or someday) at Wave 1 and having quit at Wave 3 (reporting that they are "not at all" smoking currently or they have not smoked in the past 12 months). Quitters were divided into those who quit in the short term (within the past year; between Waves 2 and 3) or long term (more than 1 year ago; between Waves 1 and 2).

Table 1. E-Cigarette User Groups by Transition Across Waves

User group	Definition
Stable never user	Never used an e-cigarette at any wave
Stable noncurrent user	Ever used an e-cigarette at any wave, but never reported someday or daily use
Decrease/unstable	Decrease • Reported someday or daily use of an e-cigarette at Wave 1 and reduced frequency (daily to someday) or stopped e-cigarette use at subsequent waves Unstable • Increased, then decreased frequency of e-cigarette use (or stopped e-cigarette use) across waves • Decreased (or stopped e-cigarette use), then increased frequency of e-cigarette use across waves • Reported someday use of e-cigarettes at all waves
Increase/stable daily user	Reported never, ever, or someday use of e-cigarettes at Wave 1 and increased to daily use at Wave 2 or 3 Reported daily use of e-cigarettes at all waves

Analyses

The PATH Study population and replicate weights were used to adjust for complex study design characteristics such as oversampling and nonresponse. The weights produce estimates that are representative of the US noninstitutionalized, civilian population ages 18 years and older adjusting for nonresponse from Wave 1. Demographic distributions were calculated for Wave 1 everyday or someday smokers. Crude and adjusted relative risk ratios were estimated to examine smoking cessation by e-cigarette use (use status, use in last quit attempt, regular brand flavored use, and device type) between Waves 1 and 3 using multinomial logistic regression analyses. Effect measure modification by daily and nondaily smoking was explored. All analyses were conducted using Stata SE Version 15.1.

Results

Sample Characteristics at Wave 1

At Wave 1, current smokers were majority male, 25–44 or 45–64 years of age, White (non-Hispanic), with a high school education or some college, and with a household income of <$25 000 per year (Table 2). Smokers were mostly tobacco dependent and had smoked at least 100 cigarettes in their lifetime (85.5%). Less than one third (26.3%) of smokers had used another tobacco product (other than cigarettes or e-cigarettes) in the past 30 days. Among smokers who made an attempt to quit in the past year, over half (53.9%) reported using an evidence-based smoking cessation method.

At Wave 1, 42.8% of smokers had never used an e-cigarette, 36.6% had formerly used an e-cigarette but were noncurrent users, 17.4% used an e-cigarette somedays, and 3.3% used an e-cigarette daily. Less than a third (27.1%) of smokers at Wave 1 who had made a quit attempt in the past year reported using an e-cigarette to quit in their last quit attempt. The majority of smokers who used e-cigarettes reported that their regular e-cigarette brand was flavored (63.4%) and used a rechargeable device most of the time (69.8%).

Across the three waves, 28.1% of respondents were lost to follow-up. There were few significant ($p < .05$) differences between participants who were retained in the study and those lost to follow-up. Participants who were lost to follow-up were more likely to be male, young adults (18–24 years), White, non-Hispanic, and made a household income of $50 000–$99 999 annually. There were no differences in exposure (e-cigarette use) or having made a quit attempt in the past year.

Smoking Cessation

Of the 9724 smokers from Wave 1 with follow-up data at Waves 2 and 3, 8.5% ($n = 810$) quit smoking a year ago or more (we refer to them as long term) at Wave 3 (ie, quit between Waves 1 and 2), 8.8% ($n = 895$) quit <1 year ago (we refer to them as short term; between Waves 2 and 3), and 82.7% ($n = 8019$) did not quit smoking (Table 3).

Patterns of E-cigarette Use

Increasing frequency of e-cigarette use across waves was associated with a higher likelihood of quitting both in the short term (<1 year) (relative risk ratio [RRR]: 4.36, 95% confidence interval [CI]: 3.35, 5.66) and long term (1+ year) (RRR: 1.44, 95% CI: 1.04, 1.99) (vs did not quit) compared with never e-cigarette users, and these associations remained significant after adjusting for covariates ($p < .001$). In unadjusted analyses, stable noncurrent use of e-cigarettes across waves (RRR: 0.57, 95% CI: 0.45, 0.72) and decreasing frequency/unstable use (RRR: 0.46, 95% CI: 0.37, 0.58) were associated with a lower likelihood of long-term quitting (vs did not quit) compared with never users of e-cigarettes. These associations remained significant after adjusting for covariates. Short-term quitting (vs did not quit) was significantly more likely among stable noncurrent e-cigarette users compared with never users (RRR: 1.31, 95% CI: 1.04, 1.65), but after adjusting for covariates, this association was no longer significant. There was significant ($p < .0001$) effect measure modification of the effect of e-cigarette use frequency on smoking cessation by smoking frequency at baseline (Supplementary Figure 1). Specifically, the likelihood of quitting smoking long term was lower for nondaily smokers who increased e-cigarette use across waves (vs never users), whereas the likelihood of quitting was higher for daily smokers who increased e-cigarette use.

Use of E-cigarettes in Last Quit Attempt

A higher proportion of smokers who had quit within the past year at Wave 3 had used an e-cigarette to quit compared with those who did not quit and those who quit for a year or more. Smokers who used an e-cigarette in their last quit attempt were 1.32 (95% CI: 1.03, 1.71) times more likely to quit in the short term (<1 year) (vs did not quit) compared with those who made a quit attempt but did not use an e-cigarette in that attempt. This effect differed ($p < .01$) by baseline smoking frequency in that the likelihood of quitting long term among daily smokers was higher if smokers used an e-cigarette in their last quit attempt, but nondaily smokers were less likely to quit (Supplementary Figure 2).

Flavored E-cigarette Use

Flavored e-cigarette use at two or more waves was associated with a higher likelihood of quitting smoking both for those who quit in the short term (RRR: 1.75, 95% CI: 1.18, 2.60) and long term (RRR: 2.83, 95% CI: 1.69, 4.73), and this result held after adjusting for covariates for long-term quitters. In unadjusted models, use of a flavored e-cigarette at one wave was associated with increased likelihood of quitting (vs did not quit) in the long term (ie, quit between Waves 1 and 2), but not for users who quit less than a year ago (ie, quit between Waves 2 and 3). After adjusting for covariates, flavored e-cigarette use at one wave was not significantly associated with quitting smoking. No effect modification was found by baseline smoking frequency.

E-cigarette Device Type

Quitting smoking was higher among rechargeable device users than disposable device users. Those who used a rechargeable device were 1.9 (95% CI: 1.16, 3.09) times more likely to quit within the past year (vs did not quit) than those who used a disposable device, and those who used a rechargeable device at two or more waves were 2.08 (95% CI: 1.27, 3.39) times more likely. Device type was not associated with long-term quitting. However, there were differences by baseline smoking frequency (Supplementary Figure 3); among nondaily smokers, e-cigarette device type did not affect smoking cessation, but among daily smokers, those who used a rechargeable device at two or more waves were significantly more likely to quit.

Discussion

This study examined the impact of e-cigarette use on smoking cessation over 2 years (Waves 1–3) using the longitudinal nationally

Table 2. Characteristics of Current (Daily or Someday) Smokers at Baseline (Wave 1)

Baseline (Wave 1) characteristics	Wave 1 current (daily/someday) smoker, n = 9724[a]		
	n	%	95% CI
Demographic characteristics			
Gender			
Male	4915	53.09	(52.17, 54.52)
Female	4809	46.91	(45.58, 47.83)
Missing	0	—	—
Age			
18–24	2239	14.81	(14.00, 15.65)
25–44	3800	41.97	(40.59, 43.36)
45–64	3114	36.11	(34.73, 37.50)
65+	570	7.12	(6.49, 7.80)
Missing	1	—	—
Race/ethnicity			
White, non-Hispanic	5834	64.57	(63.12, 65.99)
Black, non-Hispanic	1540	16.08	(15.09, 17.12)
Hispanic	1489	13.63	(12.88, 14.41)
Other, non-Hispanic	669	5.73	(5.15, 6.36)
Missing	192	—	—
Education			
Less than high school	1780	17.55	(16.77, 18.36)
High school or GED	3555	38.93	(37.67, 40.20)
Some college	3343	32.60	(31.38, 33.86)
Bachelor's degree +	999	10.92	(10.20, 11.67)
Missing	47	—	—
Income			
<$25 000	4954	52.54	(50.88, 54.20)
$25 000–$49 999	2138	24.61	(23.51, 25.74)
$50 000–$99 999	1383	16.45	(15.45, 17.50)
$100 000+	521	6.40	(5.76, 7.11)
Missing	728	—	—
Tobacco use characteristics			
Tobacco dependence			
1st quartile	1364	13.86	(13.00, 14.77)
2nd quartile	2411	24.85	(23.77, 25.96)
3rd quartile	2968	31.11	(30.06, 32.18)
4th quartile	2865	30.18	(28.99, 31.41)
Missing	116	—	—
100 Cigarette lifetime threshold			
No	1473	14.55	(13.82, 15.30)
Yes	8212	85.45	(84.70, 86.18)
Missing	39	—	—
Past 30-d other tobacco product use			
No	6895	73.69	(72.47, 74.87)
Yes	2829	26.31	(25.13, 27.53)
Missing	0		
Use of a method to quit smoking in the past year (except e-cigarettes)[b]			
No	1726	46.12	(44.25, 48.00)
Yes	2016	53.88	(52.00, 55.75)
Missing	5982	—	—
E-cigarette use characteristics			
E-cigarette use status			
Never user	3923	42.75	(41.50, 44.02)
Former trier	3696	36.60	(35.51, 37.71)
Someday user	1758	17.35	(16.47, 18.28)
Daily user	327	3.29	(2.86, 3.78)
Missing	20	—	—
E-cigarette used in last quit attempt[b]			
No	2483	72.88	(71.13, 74.56)
Yes	942	27.12	(25.44, 28.87)
Missing	6299	—	—

Table 2. Continued

Baseline (Wave 1) characteristics	Wave 1 current (daily/someday) smoker, n = 9724[a]		
	n	%	95% CI
Flavored e-cigarette use[c]			
No	327	36.59	(33.09, 40.25)
Yes	662	63.41	(59.75, 66.91)
Missing	8735		
Device type[d]			
Disposable	675	30.23	(27.90, 32.67)
Rechargeable	1588	69.77	(67.33, 72.10)
Missing	7461	—	—

CI = confidence interval.

[a]All three waves: N = 23 670.

–Eleven observations were missing r01_ac1002, 5219 replied "no" to r01_ac1002, resulting in 18 440 ever smokers with follow-up data.

–Twelve observations were missing r01_ac1003, 8696 replied "not at all," resulting in 9732 everyday/someday smokers with follow-up data.

–Eight observations were missing r03_AC1003, resulting in 9724 everyday/someday smokers with follow-up data on quitting.

[b]Among those who made a past-year quit attempt.

[c]Among current e-cigarette users who reported a regular brand.

[d]Among current e-cigarette users.

representative PATH survey of US adults. In this study, smokers who indicated using e-cigarettes in their last quit attempt were more likely to have quit within the past year at Wave 3 (short term) compared with those who had not used an e-cigarette to quit. In addition, e-cigarette users who had either used e-cigarettes daily throughout the 2 years of the study or increased their frequency of use to daily use over the study were more likely to report both short- and long-term cessation from cigarette smoking versus never e-cigarette users. By contrast, smokers who had only used e-cigarettes in the past (ever use or use prior to Wave 1) but never became a daily or someday user over the course of the study were less likely to have stopped cigarette smoking for more than a year by Wave 3 than those who never used e-cigarettes. The effects of using an e-cigarette to quit and greater frequency of e-cigarette use on the likelihood of quitting appears to be stronger among daily smokers versus nondaily smokers. Thus, the impact of e-cigarettes on smoking cessation depends not only on the frequency, duration, and consistency of e-cigarette use, but potentially on smoking frequency.

Taken together, our findings are consistent with the growing body of evidence from prospective and cross-sectional observational studies[19,20,22,23,26] showing that more frequent and stable e-cigarette use can help smokers to quit smoking, but that intermittent or infrequent use can be associated with poorer smoking cessation outcomes, especially if the e-cigarette exposure is poorly defined or measured as historical, but not current use.[26] Studies that do not consider the potential complexity of use patterns may fail to capture quit success in the short term and smoking cessation maintenance over time. Our study demonstrates that combining daily and non-daily e-cigarette users or including ever but not current users can preclude examining important differences among subgroups of e-cigarette users and can potentially reduce the association between e-cigarette use and smoking cessation.[42] These groups may differ in a number of other ways (either measured or unmeasured), including in their reasons for using e-cigarettes, such as use specifically to stop smoking in their most recent quit attempt. Such differences introduce unknown bias into longitudinal studies that attempt to select out subgroups or make causal inferences even if the available measured covariates seem to take some of the common confounds into account.[46,47] Similar discrepancies in smoking cessation effectiveness between observational studies and numerous randomized controlled trials on use of nicotine replacement therapy have also been reported historically and explained in terms of selection bias.[26,48,49]

Evidence is growing that flavor and device type play a role in smoking cessation. In the present study, consistent use (at two or more waves) of flavored e-cigarettes was associated with one or more years of smoking cessation compared with use of nonflavored/tobacco flavored e-cigarettes. However, it is unclear given the survey question's wording what respondents who said they did not use a flavored e-cigarette meant. All e-cigarettes do have some flavor and what may be meant by nonflavored is some form of tobacco flavor. In another PATH study, Chen et al. found a higher likelihood of smoking cessation/reduction when using a flavored e-cigarette.[39] Another study found that use of multiple flavors was associated with being a former smoker and current e-cigarette user, whereas use of tobacco flavor or no flavor was associated with being a current smoker and former e-cigarette user.[33] Other studies showed that over time, smokers who successfully stopped smoking had switched their e-cigarette use from tobacco flavors to nontobacco flavors including fruity and sweet flavors.[16,32] These studies, along with the findings from our study, suggest that flavors may play a facilitating role in cigarette smoking cessation among adults. Use of a rechargeable device consistently across two or more waves was also associated with a higher likelihood of smoking cessation within the past year when compared with use of disposable devices, although this effect was only found among daily smokers. This is consistent with evidence that advanced-generation, rechargeable devices are generally higher powered and have been known to deliver greater nicotine yields to the user.[50] Advanced-generation devices are also preferred by more experienced users.[51] However, using the PATH survey, Coleman 2017 found that the 2013–2014 Wave 1 customizable device use (vs noncustomizable device use) was not related to smoking abstinence 1 year later.[52] The PATH Wave 3 survey was conducted before newer devices that use nicotine salts and advanced technology (eg, JUUL) entered the market. Future studies should examine the role of different flavors and device types emerging in this rapidly evolving market that could help adult smokers quit smoking combustible tobacco products.[37]

Table 3. Smoking Cessation and E-cigarette Use from Wave 1 to Wave 3 of the PATH Study

n = 9724[a]	Did not quit (n = 8019, 82.73%)	Quit 1 y+ (n = 810, 8.45%)					Quit <1 y (n = 895, 8.82%)				
	n (%)	n (%)	RRR (95% CI)	p	aRRR (95% CI)[b]	p	n (%)	RRR (95% CI)	p	aRRR (95% CI)[b]	p
E-cigarette use											
Stable never user	2097 (28.28)	288 (40.66)	1 (Ref)				183 (21.93)	1 (Ref)			
Stable noncurrent user	2687 (33.23)	242 (27.24)	**0.57 (0.45, 0.72)**	**<.001**	**0.68 (0.49, 0.96)**	**.029**	305 (33.71)	**1.31 (1.04, 1.65)**	**.024**	1.08 (0.81, 1.44)	.60
Decrease/unstable	2828 (33.88)	200 (22.59)	**0.46 (0.37, 0.58)**	**<.001**	**0.52 (0.37, 0.72)**	**<.001**	274 (28.83)	1.10 (0.88, 1.36)	.4	0.93 (0.70, 1.23)	.60
Stable daily/increase	379 (4.6)	78 (9.51)	**1.44 (1.04, 1.99)**	**.03**	**1.81 (1.10, 2.97)**	**.02**	129 (15.53)	**4.36 (3.35, 5.66)**	**<.001**	**3.38 (2.28, 5.03)**	**<.001**
Missing[c]	28 (–)	2 (–)	—	—	—	—	4 (–)	—	—	—	—
Used e-cigarette to quit (Wave 2 or Wave 3)											
No	2631 (76.69)	320 (78.67)	1 (Ref)		1 (Ref)		470 (72.74)	1 (Ref)		1 (Ref)	
Yes	796 (23.31)	85 (21.33)	0.89 (0.66, 1.20)	.45	1.17 (0.84, 1.63)	.36	168 (27.26)	1.23 (0.99, 1.53)	.057	**1.32 (1.03, 1.71)**	**.03**
Missing[d]	4592 (–)	405 (–)	—	—	—	—	257 (–)	—	—	—	—
Flavored e-cigarette											
No	600 (27.25)	26 (14.17)	1 (Ref)		1 (Ref)		60 (21.25)	1 (Ref)		1 (Ref)	
1 wave	1098 (43.70)	90 (43.08)	**1.89 (1.12, 3.22)**	**.02**	1.40 (0.64, 3.08)	.40	135 (39.11)	1.15 (0.79, 1.67)	.47	0.93 (0.60, 1.43)	.72
2+ waves	733 (29.05)	94 (42.75)	**2.83 (1.69, 4.73)**	**<.001**	**2.54 (1.07, 6.01)**	**.035**	140 (39.64)	**1.75 (1.18, 2.60)**	**.006**	1.34 (0.84, 2.14)	.21
Missing[e]	5588 (–)	600 (–)	—	—	—	—	560 (–)	—	—	—	—
Device type											
Disposable	654 (19.83)	53 (17.09)	1 (Ref)		1 (Ref)		60 (14.05)	1 (Ref)		1 (Ref)	
Rechargeable at 1 wave	1302 (39.61)	103 (37.49)	1.10 (0.76, 1.58)	.61	1.00 (0.57, 1.75)	.99	170 (40.76)	**1.45 (1.05, 2.00)**	**.02**	**1.90 (1.16, 3.09)**	**.011**
Rechargeable at 2+ waves	1363 (40.56)	128 (45.42)	1.30 (0.90, 1.87)	.16	1.61 (0.88, 2.92)	.12	185 (45.19)	**1.57 (1.13, 2.19)**	**.008**	**2.08 (1.27, 3.39)**	**.004**
Missing[f]	4700 (–)	526 (–)	—	—	—	—	480 (–)	—	—	—	—

Quit 1 y+ = quit between Waves 1 and 2; Quit <1 y = quit between waves 2 and 3. aRRR = adjusted relative risk ratio; CI = confidence interval; RRR = relative risk ratio.

[a]All three waves: N = 23 670.

–Eleven observations were missing r01_ac1002, 5219 replied "no" to r01_ac1002, resulting in 18 440 ever smokers with follow-up data.

–Twelve observations were missing r01_ac1003, 8696 replied "not at all," resulting in 9732 everyday/someday smokers with follow-up data.

–Eight observations were missing r03_AC1003, resulting in 9724 everyday/someday smokers with follow-up data on quitting.

[b]Adjusted for gender, age, race/ethnicity, education, income, tobacco dependence composite score, other tobacco product use, 100 cigarette lifetime threshold, and use of other quit methods (support of friends/family, counseling/quitline/web-based program, nicotine patch/gum/spray/lozenge, prescription drug).

[c]Missing e-cigarette use ≥2 wave.

[d]Those who did not make a past-year quit attempt.

[e]Noncurrent e-cigarette users or those who did not report a regular brand.

[f]Noncurrent e-cigarette users.

There are several limitations to this study. First, because PATH is self-reported data, there may be some misclassification of the outcome or exposure. Second, we are unable to determine the exact timing of use of e-cigarettes, any quitting that occurred prior to Wave 1, or subsequent quitting after the end of the study as we were limited to the 2 years of follow up from the three waves of PATH data. Third, we did not know whether the regular device type (other than being rechargeable) and flavor reported by participants was consistently used over time, as the landscape of devices is ever evolving. The change in question wording from Wave 2 to Wave 3 to assess flavor (from "No" to "Tobacco" response options) could have changed how respondents answered the question. There is also heterogeneity in the e-cigarette product category in terms of device characteristics and nicotine concentrations, factors that might influence nicotine delivery and absorption (eg, nicotine salts), and how consumers use these products in the years after Wave 3 was conducted. Product-specific analyses are required to determine whether there is a particular profile of characteristics that are more likely to be associated with successful, sustained switching from cigarettes to e-cigarettes. As new products become available, it will be important to consider whether the relationships found here hold. Fourth, we were unable to examine the effect-measure modification by gender due to limited sample size across some categories of our exposure variables. Some studies suggest that females are less likely to quit smoking successfully than males,[53] so future studies are warranted on whether the impact of e-cigarette use on cigarette smoking differs by gender. Last, we cannot control for all possible confounding factors or interactions. For example, daily e-cigarette users may be more interested in quitting smoking or have other reasons for their stable use when compared with noncurrent or unstable e-cigarette users, but we were unable to examine such factors in this study in part due to the survey structure.

Conclusions

Results from this study indicate that consistent and frequent e-cigarette use and increasing use over time, as well as flavors and device type, are associated with smoking cessation among adult smokers. Replacement of cigarette smoking with e-cigarette use is projected to result in 1.6–6.6 million fewer premature deaths by 2026,[54] but future population-based studies are needed on the long-term relationships between e-cigarettes and smoking cessation and the overall public health impact of these less harmful ways to deliver nicotine in a sufficiently appealing way to completely displace deadly smoked tobacco products. Overall, our findings highlight the importance of carefully defining and characterizing independent variables such as e-cigarette exposure and patterns and duration of e-cigarette use, potential confounders, and whether e-cigarettes were specifically used to quit smoking, as well as variations in length of the smoking cessation.[26]

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

None declared.

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