Nicotine & Tobacco Research, 2018, 931–939
doi:10.1093/ntr/ntx166
Original investigation
Received April 6, 2017; Editorial Decision July 17, 2017; Accepted July 24, 2017

Original investigation

The Relationship of E-Cigarette Use to Cigarette Quit Attempts and Cessation: Insights From a Large, Nationally Representative U.S. Survey

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Abstract

Objectives: While cessation from cigarettes is a top priority for public health, controversy surrounds the role of e-cigarettes for quitting cigarettes. This study examines the role of e-cigarettes in quit attempts and 3-month cigarette abstinence using a large, recent nationally representative US sample.
Methods: Data from the 2014/15 Tobacco Use Supplement-Current Population Survey (TUS-CPS) on cigarette and e-cigarette use and individual characteristics were supplemented with information on state tobacco control policies. We estimated frequencies and multivariate logistic equations for making a quit attempt among those who smoked 1 year earlier and for remaining abstinent at least 3 months among those making a quit attempt. These two outcomes were related to demographic characteristics, tobacco control policies and different frequency measures of e-cigarette use (ever, at least 1, 5, 20 of the last 30 days, a continuous measure of days use).
Results: Having made a quit attempt was more likely among smokers using e-cigarettes than non-users. Among those making at least one quit attempt, quit success was lower among ever users, but higher among those with at least 5 days use of e-cigarettes in the last month. Both quit attempts and quit success were linearly related to the frequency of e-cigarette use.
Conclusions: Consistent with randomized trials and those observational studies that measure frequency of e-cigarette use, both quit attempts and quit success were positively associated with increased frequency of e-cigarette use. Frequency of e-cigarette use was important in gauging the nature of these relationships.
Implications: Previous studies have obtained mixed results regarding the relationship of e-cigarette use to cigarette smoking cessation. This study provides a more precise methodology for considering the relationship of e-cigarette use to quit attempts and to quit success, and finds that quit attempts and quit success increase with the number of days use in the past month.

Introduction

The 2014 Surgeon General's Report[1] states that "the burden of death and disease from tobacco use in the United States is overwhelmingly caused by cigarettes and other combusted tobacco products; rapid elimination of their use will dramatically reduce this burden." Accelerating smoking prevalence reduction remains one of the primary criteria for evaluating regulations under the Tobacco Control Act and the impact of policy on the public health benefit to the population as a whole.[2,3]

While the public health community agrees that cessation from cigarettes is a top priority, controversy surrounds the role of e-cigarettes as method for quitting cigarette use.[4,5] Of five recent reviews,

three reported a positive,[6–8] one a negative[5] and one an inconclusive[9] impact of e-cigarettes on cessation. Much of the controversy surrounds observational study issues related to heterogeneity of designs, samples, and measures of exposure to the independent variables. Many studies (reviewed in detail in Glasser et al.[4]) are subject to: selection bias (e.g. smokers who quit by using e-cigarettes were excluded from the sample); inadequate measures of exposure (e.g. ever use in one's lifetime, recent but infrequent use); and confounders (e.g. smokers who have repeatedly failed to quit or who are more nicotine dependent may be more likely to try e-cigarettes). The ability to control for the confounding factors that might influence e-cigarette use, i.e. whether or not those who use e-cigarettes are those who would have otherwise been likely to quit in the absence of e-cigarette use,[10] can play a key role.

Imprecise measures of exposure, unmeasured confounders, having appropriate comparison groups and the outcome measures of cigarette smoking cessation (e.g. quit attempts or maintenance of cessation) are all important considerations in interpreting the mixed results from observational studies. Observational studies suggest that regular (e.g. daily use) or more intensive (e.g. use of tank or mod devices) e-cigarette use can facilitate quit attempts and cessation.[11–14] Some studies with more precise measures and designs find that e-cigarette use increases quit attempts,[12,15,16] while others find that e-cigarette use is associated with quit success.[11,13,17]

Studies of the relationship of e-cigarette use and smoking span a wide range of methodologies and samples, including uncontrolled studies, case control studies of select populations and more broad-based studies that are meant to be more representative of the population. A recent US population level study[18] using a prospective follow-up from the 2010 Tobacco Use Supplement (TUS) of the Current Population Survey (CPS) found that e-cigarette use was not associated with successful cessation. However, the sample of e-cigarettes users included ever users, and consequently did not distinguish past failures, or frequency of e-cigarette use. In addition, the study was for the year 2010, and thus contained adopters of early generation e-cigarettes. Later generation models of e-cigarettes have been shown to more efficiently deliver nicotine,[4,19,20] thus increasing their potential to serve as alternatives or replacements for cigarettes, including as aids in quitting cigarette use.

We applied the 2014/15 TUS-CPS to examine the relationship between frequency of e-cigarette use, quit attempts and 3-month cigarette abstinence. That survey contains information on the frequency of use (the number of days use in the last 30 days), and provides information that can be used to construct a retrospective examination of cessation and e-cigarette use in the last year. Specifically, current smokers are asked about quit attempts in the previous year and former smokers are asked when they quit, so that past year cessation behaviors can be gauged among those who were smokers 1 year ago. We considered different measures of e-cigarette use, including ever use, past 30 day use, and the number of days use.

Methods

We adopted a methodology previously applied by Levy et al.[21] and we separately considered past year quit attempts and quit success. For the sample of smokers 1 year ago, we estimated frequencies and conducted multivariate logistic equations for quit attempts as a function of individual socio-demographic characteristics, tobacco control policies, cigarette use, smokeless tobacco (SLT) and e-cigarette use. For the sample of those who made at least one quit attempt in the last year, we next estimated frequencies and conducted multivariate analysis for quit success as a function of individual characteristics, policy variables, cigarette use, SLT use and e-cigarette use.

Primary Data

The primary source of data in this study was the 2014/15 TUS. The TUS is a special supplement to the CPS, and is designed to ask extensive questions on tobacco use. A probability sample employs stratified clusters of households drawn from an initial sampling frame that covers the civilian, non-institutionalized population. The 2014/15 TUS-CPS consisted of three samples collected in July 2014, January 2015, and May 2015. Each of the surveys includes about 54 000 households containing over 150 000 persons. The TUS-CPS asked certain tobacco use questions of both self-respondents and proxy respondents, but only self-responders, which were over 35% for each of the 3 months, were eligible to answer the more detailed tobacco-use questions. We limit the sample to ages 18 and above, self-responders, and to individuals who were smokers 1 year ago with known cigarette use.

Cigarette Smoking Cessation and Use Variables

Respondents to the TUS-CPS were first asked whether they had smoked at least 100 cigarettes in their lifetime, and then asked whether they currently smoked every day, some days, or not at all (leaving 162 079 records of individuals with valid responses to these two questions). A current smoker was defined as someone who had smoked at least 100 cigarettes and who was smoking some or every day at the time of the survey. Current smokers were asked whether they were smoking cigarettes "every day, some days, or not at all around this time 12 months ago." We included current smokers who were smoking every day or some days 12 months ago in our study samples (N = 21 226). Respondents who smoked 12 days or less in the past 30 days were queried about whether they "tried to quit smoking completely during the past 12 months". Those who smoked 12 or fewer days were considered to have made a quit attempt if they tried to quit completely. Respondents who smoked more than 12 days were queried whether they "stopped smoking for one day or longer because of trying to quit smoking during the past 12 months" and those who answered "yes" were considered to have made a quit attempt.

Former smokers were also included among those who had made a quit attempt in the past year. This group included individuals who had smoked at least 100 cigarettes and were smoking 12 months ago, but who were not smoking at the time of the survey. Former smokers were asked how long ago they quit. To capture the quitters who were more likely to remain abstinent among those who have made a quit attempt, quit success was measured by those ex-smokers who have remained abstinent for at least 3 months, since about 65% of quitters relapse within the first 3 months.[22–24]

Among current smokers who smoked more than 12 months (N = 21 226) and former smokers who quit within 12 months (N = 3212), there was a total sample of 24 438. We first omitted current smokers with unknown quit attempts (N = 147), leaving a sample of 24 291 with a valid response regarding quit attempts. We also omitted former smokers who quit within the last 12 months but reported no cigarettes smoked 12 months ago (N = 626) or unknown smoking frequency 12 months ago (N = 32) from the dataset, leaving a sample of 23 633 as shown in Figure 1. In the quit attempt model, the sample included those who were smokers 1 year ago (N = 23 633) and the outcome is whether those smokers made a quit attempt

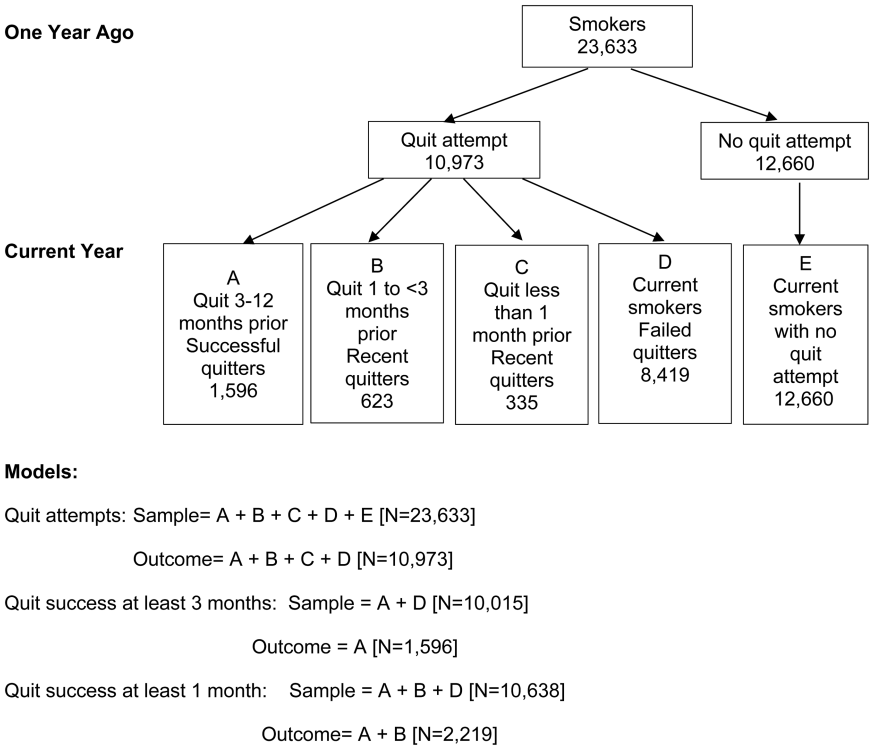

Figure 1. Sample Design, CPS-TUS 2014/15.

(including those currently quit) in the last year. In the quit success model, the sample was limited to those having made a quit attempt but failed and those who quit more than 3 months (N = 10 015) and the outcome is whether they succeeded (former smokers at least 3 months). Those who had quit less than 3 months were omitted from the sample, but included in the quit attempt model sample. We also considered quit success measured as smokers who quit in the last year, but not the last month.

We characterized smokers by the quantity smoked per day. Those who smoked every day 12 months ago, regardless of current smoking status, were asked the average number of cigarettes they smoked per day (cpd) 12 months ago. For those who smoked some days, we weighted their response by the number of days they smoked per month 12 months ago. We classified smokers 12 months ago as *very light* (< 5 cpd), *light* (5–14 cpd), *medium* (15–24 cpd), and *heavy* (25 or more cpd). We also included an indicator for those who consider themselves someday smokers.

E-cigarette and Smokeless Tobacco Use

Three questions were asked in the TUS-CPS about current and past use of e-cigarettes. After the respondents were given a description of e-cigarettes, they were asked, "Have you ever used e-cigarettes even one time?" Those who answer yes were asked, "Do you now use an e-cigarettes every day, some days or not at all?" Finally, respondents who used e-cigarette some days were asked, "On how many of the past 30 days did you use e-cigarettes?" We created different measures for e-cigarette use. Ever use of e-cigarettes is defined if they answer "yes" to the first question. Among those who answered "every day" and "some days" to the second question, we distinguished those who currently used e-cigarettes at least 1 day, at least 5 days, and at least 20 days in the last month. Respondents with an unknown history of e-cigarette use were treated as a separated group by creating an indicator variable as a control. In our frequency evaluations, we also considered 5 day intervals. Since SLT use may also affect cessation, corresponding measures were also developed for these users.

To examine the specific relationship of quitting behaviors to e-cigarette use, we created a continuous e-cigarette use variable, measured as the number of days of e-cigarette use in the past 30 days. In addition to the continuous measure of use, we also included a variable for at least one day use in the last 30 days to serve as the intercept term (any use). To allow for a potential non-linear relationship between days used and cessation behaviors, we examined whether the addition of squared and cubic forms of the frequency variable improved the fit of the equation. A corresponding measure was also developed for SLT users.

Socio-demographic Variables

Using socio-demographic information included in the TUS-CPS data, the sample was divided by gender, age (18–21, 22–25, 26–29, 30–34, 35–44, 45–64, 65+), and racial/ethnic groups (White, Black or African American, Asian only, and other races). A separate variable was created to distinguish Hispanics. Educational levels were classified into four groups (less than high school, high school graduate, some college but no degree, and college graduate and above). Four family income levels (less than $19 999, $20 000–$39 999, $40 000–$74 999, and greater than $74 999) were distinguished. We also included marital status (never married, married-spouse present, married-spouse absent, widowed/divorced/ separated), urban-rural residency, and employment status (employed vs. unemployed or not in the labor force, with the latter including those retired, those having long-term physical or mental illness, students and persons keeping house). Indicator variables were created for each of these classifications.

Policy Variables

For cigarettes, we used state prices (including generics) by year for the month of November from Orzechowski et al.[25] Since monthly price data were not available, we estimated the price at the time of TUS-CPS survey (July 2014, January 2015, May 2015) by the price in November 2014 and the price in November 2015 and adjusted by the state tax change (11 states) if a change occurred between July 2014 and May 2015.[26] To control for inflation, the cigarette price variable was adjusted by the consumer price index corresponding to the wave and year.[27]

Since smoking-free worksites have been associated with reduced smoking,[28] we included an indicator for smoke-free worksites by state law. We also included e-cigarette-free worksites (only in North Dakota, New Jersey, and Utah when the survey was conducted). Since the impact is likely to depend on whether the individual works indoors, an indicator from the TUS-CPS for working indoors, but not at home is included.

Separate time indicators were included for survey months. We initially included state level indicator variables to distinguish state sentiment towards tobacco from the effect of policies, and thus better distinguish the role of policies. Based on goodness of fit and to reduce collinearity, we aggregated the state indicators into census regions: New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific.[29]

Statistical Methods

Frequencies were calculated separately for the quit attempt and quit success outcomes. A chi-square analysis of within-category differences was conducted for each of the socio-demographic factors, policies, smoking frequency, and the measures of e-cigarette/SLT use status.

Separate multivariate equations were estimated corresponding to each of the two quit measures to isolate the contribution of e-cigarette use from other variables. We conducted two-tailed tests of statistical significance, where a positive sign on the use coefficient indicates that e-cigarette use was associated with increased quit attempts and a negative sign indicates that e-cigarette use was associated with fewer quit attempts. Similarly, we conducted two-tailed tests of statistical significance to determine whether use was positively or negatively associated with quit success among those making a quit attempt.

Using the SURVEYLOGISTIC procedure of SAS (version 9.4), the quit attempt and quit success equations were estimated as weighted (using self-response weights) logistic regression models, using Fisher's scoring method as the optimization technique. We first estimated separate equations for males and females. Based on the similarity of results, we pooled the equations, and included interactive terms for the only variable which was found to be substantively differ (widow). We also estimated separate equations by age group to focus on the ages when initiation of e-cigarettes often takes place.

Results

Mean Quit Attempts and Quit Success

Table 1 presents the means for each independent variable in terms of quit attempts among smokers and whether there was quit success among those making a quit attempt.

Among all smokers, quit attempt rates showed significant differences for all of the individual characteristic measures, except by whether the individual was employed. The quit attempt rate also differed among smokeless tobacco users, everyday vs. someday smokers and by quantity smoked. Among the policy variables, differences were found only for the retail cigarette price. Significant differences in quit attempt rates were found for e-cigarette use at different frequencies: never use (39.5%), ever but not current use (54.2%), and for 1–4 days (51.3%), 5–9 days (61.1%), 10–14 days (61.4%), 15–19 days (72.9%), 20–24 days (72.5%), and at least 25 days in the last month (79.4%).

Among all smokers 12 months ago who made at least one quit attempt during the past 12 months, quit success rates showed significant differences among individual characteristics, except whether Hispanic. Quit success rates differed by smoking cigarette frequency, cigarette quantity smoked and whether used smokeless tobacco. Significant differences were observed in quit success between e-cigarette use at different frequencies: never use (16.9%), ever but not current use (13.9 %), and for 1–4 days (5.2 %), 5–9 days (4.6 %), 10–14 days (6.6 %), 15–19 days (11.2 %), 20–24 days (17.1 %), and at least 25 days in the last month (32.6%).

Logistic Regression

Tables 2 and 3 reports the results for the coefficients of the cigarette, SLT and e-cigarette use variables in the quit attempt and quit success logistic regression equations. The complete results, including the coefficients of the socio-demographic, policy, region and time indicator variables, are contained in Supplement 1. The different measures of e-cigarette and smokeless tobacco use are distinguished by column.

Quit Attempts by Smokers

Among smokers 12 months ago, having made at least one quit attempt was generally more likely among those at lower ages (age 18–44), African Americans, those with higher education (some college but no degree, college degree or higher), and someday smokers. A quit attempt was less likely among those with income of $20 000–$39 999, the employed, those never married, non-metropolitan residents, and among those heavy smokers (smoking 15–24 and at least 25 cigarettes per day). Compared to those never married, males who are widowed, divorced or separated were less likely to make a quit attempts than females.

While all measures of e-cigarette use showed a significant relationship ($p < 0.001$) with having made a quit attempt, the adjusted odds ratios (AOR) increased continuously with e-cigarette frequency from 2.3 for ever use to 4.9 for 20+ days use in the last month. For the continuous use variable, the linear use variable was significant, but the quadratic and cubic terms were not significant and reduced overall equation fit in terms of the Wald statistic. With only the linear use variable, the AOR had a value of 1.05, indicating the odds of a quit attempt increased by 5% with each additional day of use. None of the SLT use variables, continuous or otherwise, were significant. Similar results (not shown) in terms of the sign of the coefficient and level of significance for the e-cigarette and SLT use variables were found for males and females when we estimated separate equations by gender, and for those ages 18–34 when distinguished from other ages.

Quit Success among Smokers Making a Quit Attempt

For smokers having made a quit attempt, including those who failed to quit and those who quit smoking for at least 3 months, quit

Table 1. Quit Attempts among Smokers and Quit Success Among Those Making a Quit Attempt, CPS-TUS 2014/15

		Quit attempt model			Quit success model		
			Quit attempts[§]	Chi-square		Quit success[†]	Chi-square
Variable	Categories	Sample size	%	(*p* value)	Sample size	%	(*p* value)
Overall		23633	46.4%		10015	15.9%	
Gender	Male	11767	44.9%	20.73	4801	16.9%	6.02
	Female	11866	47.9%	<0.001	5214	15.1%	0.014
Age	18–21	555	57.8%		290	19.0%	
	22–25	1446	55.5%		714	22.0%	
	26–29	1745	53.8%		838	18.3%	
	30–34	2522	50.6%		1162	18.9%	
	35–44	4452	48.6%		1972	15.4%	
	45–64	9962	42.8%	229.15	3946	13.2%	56.02
	65+	2951	41.1%	<0.001	1093	17.0%	<0.001
Race	White	19624	45.9%		8198	17.0%	
	Black	2551	49.0%		1168	9.6%	
	Asian	471	48.2%	12.36	208	15.4%	43.62
	Other Races	987	49.2%	0.006	441	13.6%	<0.001
Hispanic	Hispanic	1592	49.9%	8.44	711	15.5%	0.12
	Non-Hispanic	22041	46.2%	0.004	9304	16.0%	0.725
Education	Less than 12 years	3690	43.4%		1485	10.0%	
	High school degree	9234	43.3%		3673	14.3%	
	Some college, no degree	7688	49.9%	112.22	3472	16.5%	136.85
	College degree or higher	3021	50.9%	<0.001	1385	25.3%	<0.001
Family income	$0–$19999	6678	46.6%		2882	11.8%	
	$20000–$39999	6625	45.3%		2757	14.7%	
	$40000–$74999	6120	46.1%	10.64	2539	17.4%	97.12
	$75000 or more	4210	48.4%	0.014	1837	22.2%	<0.001
Marital status	Never Married	6750	48.6%		2997	16.4%	
	Married Present	8766	46.6%		3714	18.4%	
	Married – Spouse Absent	352	47.7%	26.11	151	9.3%	44.92
	Widowed/Div./Sep.	7765	44.4%	<0.001	3153	12.9%	<0.001
Employment	Employed	13639	46.9%	2.29	5796	17.7%	30.78
	Not in labor force or unemployed	9994	45.9%	0.130	4219	13.6%	<0.001
Metropolitan status	Metropolitan	16815	47.4%	19.82	7249	16.8%	14.70
	Non-metropolitan	6818	44.2%	<0.001	2766	13.7%	<0.001
Indoor workers	No	14963	45.7%	9.93	6263	14.2%	37.85
	Yes	8670	47.8%	0.002	3752	18.8%	<0.001
Cigarette retail price per pack	Above mean price	8683	47.6%	7.38	3748	16.5%	1.64
	Below mean price	14950	45.8%	0.007	6267	15.6%	0.200
State level worksite cigarette ban	Not highest level	8936	46.3%	0.19	3783	16.1%	0.16
	Highest level	14697	46.5%	0.666	6232	15.8%	0.688
State level worksite e-cigarette ban	Not highest level	22760	46.4%	0.01	9654	15.8%	3.34
	Highest level	873	46.6%	0.909	361	19.4%	0.068
Cigarette per day 12 months ago	1–4	4426	57.7%		2349	19.3%	
	5–14	8075	48.4%		3582	15.1%	
	15–24	8361	40.4%		3058	13.8%	
	25+	2015	35.9%	469.00	650	17.4%	35.04
	Unknown CPD	756	54.2%	<0.001	376	18.4%	<0.001
Smoking frequency	Every day smokers 12 months ago	18890	42.7%	538.80	7292	14.6%	35.47
	Someday smokers 12 months ago	4743	61.5%	<0.001	2723	19.5%	<0.001
Smokeless use frequency in last month	Unknown use frequency	282	43.6%		108	16.7%	
	Never use	20158	45.7%		8,408	15.4%	
	1–4 days	111	41.4%		45	4.4%	
	5–9 days	67	46.3%		30	23.3%	
	10–14 days	45	53.3%		23	4.3%	
	15–19 days	41	58.5%		24	12.5%	
	20–24 days	22	54.5%		9	11.1%	
	25–30 days	257	49.8%	42.23	117	33.3%	40.53
	Ever, non-current use	2650	51.8%	<0.001	1251	18.1%	<0.001

Table 1. *Continued*

		Quit attempt model			Quit success model		
			Quit attempts[§]	Chi-square		Quit success[†]	Chi-square
Variable	Categories	Sample size	%	(*p* value)	Sample size	%	(*p* value)
E-cigarette use frequency in last month	Unknown use frequency	484	49.0%		219	10.0%	
	Never use	14469	39.5%		5216	16.9%	
	1–4 days	698	51.3%		346	5.2%	
	5–9 days	329	61.1%		197	4.6%	
	10–14 days	295	61.4%		166	6.6%	
	15–19 days	170	72.9%		116	11.2%	
	20–24 days	120	72.5%		82	17.1%	
	25–30 days	947	79.4%	984.83	623	32.6%	209.19
	Ever, non-current use	6121	54.2%	<0.001	3050	13.9%	<0.001

[§]Quit attempts are from the sample of those who smoked 1 year ago.

[†]Quit success is among those who made a quit attempt and stopped smoking for at least 3 months.

success was higher among those at age 18–34 and age 65 and above compared with those ages 35–64, those with more education (some college but no degree, college degree or higher) and higher income ($75 000 or more), and someday smokers compared to every day smokers. Quit success was less likely among Blacks, those never married, those married but spouse absent, those widowed, divorced or separated, and non-metropolitan residents. Among the policy variables, no significant associations were found.

A negative relationship was obtained between quit success and e-cigarette ever use, but a positive relationship was observed with current e-cigarette use measures. Moreover, the AOR of quit success was 59% higher with 5+ days use and 181% higher with 20+ days use. For the continuous use variable, the linear use variable quit was significant, but the quadratic and cubic terms were not significant and worsened overall fit. In linear form, the AOR had a value of 1.10, indicating the odds of quit success increase by 10% with each additional day of use. Quit success was found to be positively related to SLT use for 20+ days use (AOR = 2.00) and continuous use (AOR = 1.05). Similar results (not reported) in terms of the sign of the coefficient and level of significance of the e-cigarette and SLT use were obtained for males and females and for those ages 18–34 as obtained for the whole sample.

Discussion

Unlike an earlier study using the 2010 TUS-CPS[18] and some earlier observational studies that employed heterogeneous and imprecise measures of e-cigarette frequency of use,[4,5] we found that more precise measures of use yielded a common and consistent set of results. Results revealed that greater frequency of e-cigarette use beyond ever use and especially with 20 or more days of use in the past month was strongly associated with both having made a quit attempt and a greater likelihood of 3 months or more of cigarette smoking cessation. In particular, we found that quit success was negatively related to ever use, but positively related to 5 or more days use in the last month. The consistency of positive associations with quit attempts or cessation success suggests that more frequent e-cigarette use may be effective as a smoking cessation aid.

Amato et al.[30] reported that e-cigarette use of 6 or more days in the previous month was more likely to be related to use for the purposes of quitting cigarette smoking. Also consistent with our results, Biener and Hargrave[11] reported that daily use of e-cigarettes for a month or more was associated with 6 times greater likelihood of smoking cessation measured 2 years later, whereas ever use or use on a few occasions was either unrelated to cessation or negatively associated with cessation. In recent national surveys conducted during approximately the same time periods as our TUS-CPS results, recent quitters are nearly four times more likely to be exclusive daily users of e-cigarettes than current smokers (13.0% vs. 3.5%, respectively).[31] A similar relationship is found with almost two times as many daily e-cigarette users among smokers who had quit smoking 2 to 3 years ago.[31,32] Our results are also consistent with the few randomized trials[6–8] and the better controlled observational studies[12–14] that suggest more intensive patterns of e-cigarette use can encourage quit attempts or quit success. Since our sample contained those who currently or previously smoked, these results suggest the importance of frequency in measures of dual (both e-cigarette and cigarette) use. It is noteworthy that previous studies with negative associations of e-cigarette use to cessation generally did not measure the frequency of exposure and some only included ever e-cigarette use in one's lifetime.[5]

An important part of our study was to distinguish the effect of e-cigarette use on quit attempts and quit success by separately considering the smokers who might attempt to quit and those that have actually made a quit attempt. While some early studies found a relationship with either quit attempts or quit success,[11–13,15–17] the large TUS-CPS sample enabled us to distinguish effects on both quit attempts and quit success. Our results indicate that e-cigarettes played a greater role (i.e. had a higher odd ratio) in getting smokers to make a quit attempt than in quit success. We obtained similar results for those ages 18–34 suggesting that e-cigarette use may be especially beneficial at ages when quit success tends to be low.

We also examined the relationship between e-cigarette use and quit success using a 1-month rather than 3-month cut-off measure, and obtained consistent results. Different questions were asked in the CPS-TUS survey about quit attempts for those who smoked 12 or less days in the last month compared to those who smoker more than 12 days. Those who had smoked more than 12 days in the past 30 days and had not stopped for one day or longer to quit smoking were also asked if they "made a serious attempt to stop smoking because of trying to quit - even if [s/he] stopped for less than one day." When we included this group as having made a quit attempt, their inclusion did not substantively affect the results.

An important part of the study was to control for the factors that are likely to affect quit attempts and quit success, including

Table 2. Logistic Regression Analysis of Having Made a Quit Attempt among a Sample of Smokers 1 Year Ago (N = 23,633), CPS-TUS 2014/15

		Ever use	Current use	5+ days in last 30 days	20+ days in last 30 days	Days of use in last 30 days
Variable (reference variable in parentheses)	Categories	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]
Cigarettes per day 12 months ago (1–4)	5–14	0.99 (0.87, 1.12)	1.04 (0.92, 1.17)	1.04 (0.92, 1.17)	1.05 (0.93, 1.18)	1.04 (0.92, 1.17)
	15–24	0.74 (0.65, 0.85)***	0.79 (0.70, 0.91)***	0.80 (0.70, 0.92)**	0.81 (0.71, 0.93)**	0.80 (0.70, 0.91)***
	25+	0.63 (0.54, 0.75)***	0.70 (0.59, 0.83)***	0.70 (0.60, 0.83)***	0.72 (0.61, 0.85)***	0.70 (0.59, 0.83)***
	Unknown CPD	0.96 (0.79, 1.17)	0.96 (0.79, 1.16)	0.95 (0.78, 1.16)	0.95 (0.78, 1.15)	0.95 (0.78, 1.16)
Smoking frequency (every day smoker)	Someday smoker	1.71 (1.52, 1.92)***	1.72 (1.52, 1.93)***	1.72 (1.53, 1.94)***	1.74 (1.55, 1.96)***	1.73 (1.54, 1.95)***
Smokeless use[†]	Yes	1.03 (0.92, 1.14)	0.87 (0.69, 1.09)	0.99 (0.76, 1.28)	0.95 (0.69, 1.30)	0.72 (0.48, 1.07)
	Unknown	0.59 (0.40, 0.85)**	0.58 (0.40, 0.84)**	0.58 (0.40, 0.84)**	0.59 (0.40, 0.86)**	0.58 (0.40, 0.85)**
E-cigarette use[†]	Yes	2.31 (2.15, 2.48)***	2.60 (2.32, 2.90)***	3.39 (2.97, 3.87)***	4.90 (4.09, 5.85)***	1.25 (1.05, 1.49)*
	Unknown	2.03 (1.55, 2.66)***	1.65 (1.26, 2.15)***	1.63 (1.25, 2.13)***	1.58 (1.21, 2.07)***	1.64 (1.25, 2.15)***
Smokeless use by number of days in last 30 days						1.01 (0.99, 1.03)
E-cigarette use by number of days in last 30 days						1.05 (1.04, 1.06)***
Model Fit	Wald Statistic	23.18***	17.68***	18.87***	18.55***	18.83***

[§]AOR: adjusted odds ratio. (LL, UL): lower and upper limit for 95% confidence interval. Significance codes for null hypothesis (AOR = 0): 0. "***" 0.001; "**" 0.01; "*" 0.05; "." 0.1.

[†]Smokeless and e-cigarette use were grouped by "Yes", "No", and "Unknown" in the first four models (Ever use, Current use, 5 or more, and 20 or more days in last 30 days) and were grouped by "Current use", "Non-current use", "Unknown", with a continuous variable for specific number of days of use in last 30 days in the last model.

Table 3. Logistic Regression Analysis of Quit Success (Abstinent at Least 3 Months) among a Sample of Those Making a Quit Attempt in the Last Year (N = 10,015), CPS-TUS 2014/15

		Ever use	Current use	5+ days in last 30 days	20+ days in last 30 days	Days of use in last 30 days
Variable (reference variable in parentheses)	Categories	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]	AOR (LL, UL) sig.[§]
Cigarettes per day 12 months ago (1–4)	5–14	0.91 (0.72, 1.13)	0.88 (0.70, 1.10)	0.87 (0.70, 1.09)	0.85 (0.68, 1.07)	0.86 (0.69, 1.08)
	15–24	0.90 (0.70, 1.16)	0.85 (0.66, 1.10)	0.84 (0.65, 1.08)	0.82 (0.63, 1.05)	0.84 (0.65, 1.09)
	25+	1.24 (0.88, 1.73)	1.13 (0.81, 1.58)	1.10 (0.78, 1.53)	1.04 (0.74, 1.45)	1.09 (0.78, 1.54)
	Unknown CPD	0.98 (0.69, 1.38)	0.97 (0.68, 1.38)	0.97 (0.68, 1.38)	0.97 (0.68, 1.38)	0.95 (0.67, 1.35)
Smoking frequency (every day smokers 12 months ago)	Someday smokers 12 months ago	1.23 (1.00, 1.52).	1.22 (0.99, 1.51).	1.21 (0.98, 1.50).	1.22 (0.99, 1.51).	1.24 (1.00, 1.53)*
Smokeless use[†]	Yes	1.06 (0.87, 1.29)	1.26 (0.85, 1.87)	1.50 (0.99, 2.28).	2.00 (1.21, 3.31)**	0.51 (0.19, 1.38)
	Unknown	1.78 (0.95, 3.33).	1.76 (0.94, 3.29).	1.75 (0.93, 3.31).	1.77 (0.92, 3.43).	1.87 (1.00, 3.53).
E-cigarette use[†]	Yes	0.80 (0.69, 0.92)**	1.22 (1.02, 1.46)*	1.59 (1.31, 1.92)***	2.81 (2.26, 3.49)***	0.17 (0.10, 0.28)***
	Unknown	0.47 (0.29, 0.74)**	0.54 (0.34, 0.85)**	0.56 (0.35, 0.88)*	0.57 (0.36, 0.91)*	0.52 (0.33, 0.82)**
Smokeless use by number of days in last 30 days						1.05 (1.01, 1.09)*
E-cigarette use by number of days in last 30 days						1.10 (1.08, 1.12)***
Model Fit	Wald Statistic	6.16***	6.01***	6.41***	7.63***	8.41***

[§]AOR: adjusted odds ratio. (LL, UL): lower and upper limit for 95% confidence interval. Significance codes for null hypothesis (AOR = 0): 0. "***" 0.001; "**" 0.01; "*" 0.05; "." 0.1.

[†]Smokeless and e-cigarette use were grouped by "Yes", "No", and "Unknown" in the first four models (Ever use, Current use, 5 or more, and 20 or more days in last 30 days) and were grouped by "Current use", "Non-current use", "Unknown", with a continuous variable for specific number of days of use in last 30 days in the last model.

not only individual characteristics, but also smoking characteristics. The relationship of days used to quitting behaviors changed, e.g. for the quit success variable, when we controlled for other variables in the logistic regression equations (Table 3) as compared to the simple frequencies (Table 1). The importance of SLT use diminished ($p > 0.1$) in the quit attempt model compared to simple frequencies and the importance of cigarette quantity diminished in the quit success model compared to the simple frequencies. While the results presented above included measures of someday versus every day and quantity smoked, we also estimated equations which included indicators of the time after awakening until smoking and of menthol cigarette use. The results for e-cigarette use changed little with this these variables included. We also considered an indicator variable based on a survey question to smokers regarding whether they tried to quit by switching to e-cigarette. That variable was often negative when included alone and was not significant when added to the multivariate logistic equations reported above.

The results were also robust to different measures of the policy variables, including cigarettes taxes rather than price, individual worksite restrictions rather than state worksite laws, and to the addition of a variable measuring state per capita tobacco control spending. Policy variables were generally not significant. However, the effect of e-cigarette smoke-free air laws merits further consideration, since the laws were adopted in only three states soon before the time of the survey.

We also considered smokeless tobacco use. We did not find a relationship to having made a quit attempt, but we did find that high rates of use were related to quit success.

Despite measuring frequency of e-cigarette use, controlling for many factors that may influence cessation, and having a large, representative sample, this study has limitations. Since our study is cross-sectional and used retrospective data over the past year, it is subject to the following limitations: recall bias; an inability to discern the temporality of precisely when the specific pattern of e-cigarette use and the quit attempt or quit episode of greater than 3 months occurred, and therefore whether use was most proximal to and preceded the quit attempt /3 month abstinent outcome; and omission of plausible confounders, cannot be ruled out.[4] Among plausible omitted confounders are the type of e-cigarette used (tank vs. cigalike), attempts to quit in previous years (with or without pharmacotherapy, and with or without e-cigarettes), or other factors which may reflect motivation to quit. Indeed, it is difficult to distinguish whether the increased probability of quitting is due to the frequent use of the product or that frequent users are more committed to quitting smoking, i.e. the motivations of the frequent users. In addition, our results may be understated to the extent that some smokers may have used e-cigarettes in the last year and quit both e-cigarettes and cigarettes, but may be overstated to the extent that those who quit smoking using e-cigarettes may be more prone to later relapse. Finally, our use measure focused on the number of days use in the last 30 days, and does not incorporate use over more prolonged periods of time than the previous month nor the intensity of daily use, i.e. the number of e-cigarette use occasions per day or the type of device. Future study should consider these other characteristics of use.

Despite this study's limitations, the more precise measures of frequency of e-cigarette use exposure and cessation outcomes appear to be a common thread across this and the other observational and RCT studies that show a positive association of greater frequency of e-cigarette use and cessation. Our results also show a strong positive association between greater frequency of e-cigarette use and both quit attempts and quit success. Nevertheless, further analysis is warranted. High quality randomized control trials with appropriate control groups and "real world" observational studies[4] are needed with sufficiently rigorous measures of exposure, plausible confounders and representative samples. In addition, it will be important to monitor this relationship for future cohorts of smokers that have different patterns of past use and exposures to e-cigarette availability, and to consider the type of product as new e-cigarette or heat-no-burn cigarettes come onto the market.

Supplementary Material

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

Funding

Funding was received by Drs. Levy and Abrams from the National Institute on Drug Abuse under grant R01DA036497. Dr. Levy also received funding from the National Cancer Institute under grant P01-CA200512.

Declaration of Interests

None declared.

Acknowledgments

We would like to thank Ron Borland of The Cancer Council Victoria, K. Michael Cummings of the Medical University of South Carolina, Maciej Goniewicz of the University of Buffalo, and Eric Lindblom, Georgetown University Law School, for their comments on an earlier draft.

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