E-cigarette characteristics and cigarette smoking cessation behaviors among U.S. Adult dual users of cigarettes and e-cigarettes

Luis Zavala-Arciniega [*], Jana L. Hirschtick, Rafael Meza, Nancy L. Fleischer

Department of Epidemiology, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI, United States

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ABSTRACT

It is critical to understand determinants of cigarette smoking cessation in the current tobacco product landscape. This study assesses the roles of e-cigarette flavoring, device type, and use frequency on cigarette smoking cessation behaviors among US adult dual users of cigarettes and e-cigarettes. We analyzed a sample of 1,038 adult dual users of cigarettes and e-cigarettes from the 2018–2019 Tobacco Use Supplement-Current Population Survey.

We defined three smoking cessation behavior stages in current smokers: pre-contemplation, contemplation, and preparation to quit smoking. Multinomial regression models (reference group = *pre-contemplation to quit*) regressed smoking cessation behavior stages on e-cigarette flavoring, device type, and use frequency, adjusting for sociodemographic and cigarette characteristic covariates.

Dual users who used e-cigarettes with a replaceable cartridge (Adjusted Odds Ratio (AOR) 1.69, 95% CI 1.03–2.44) or tank e-cigarettes (AOR 2.03, CI 1.20–3.44) had greater odds of being in the contemplation (vs. pre-contemplation) smoking cessation stage than adults who used disposable e-cigarettes. Dual users who used e-cigarettes between 10 and 24 days in the past month had greater odds of being in the contemplation (vs. pre-contemplation) smoking cessation stage (AOR 1.79, CI 1.20–2.69), while adults who used e-cigarettes 25 + days had greater odds of being in the preparation (vs. pre-contemplation) stage (AOR 3.00, CI 1.87–4.82) compared to those who used e-cigarettes 1–9 days in the past month.

Our findings suggest that the type of e-cigarette and the frequency of e-cigarette use affect smoking cessation behaviors among adult dual users of cigarettes and e-cigarettes.

1. Introduction

A key question in tobacco control is whether there is a role for e-cigarettes as a smoking cessation aid, as it remains to be determined under what conditions e-cigarette use might increase cigarette smoking cessation (Chang, 2020; Hartmann-Boyce et al., 2021). In a recent randomized clinical trial, smokers who received e-cigarettes as cessation aids were more likely to quit cigarette smoking than those who used nicotine replacement therapy (NRT) (18.0% vs 9.9%) (Hajek et al., 2019). However, this abstinence rate was lower than previous cessation trials using combinations of NRT, bupropion or varenicline (Vogeler et al., 2016; Shah et al., 2008). Moreover, results from observational studies are mixed regarding whether e-cigarettes are associated with intention to quit, quit attempts, and smoking cessation (Jackson et al., 2019; Johnson et al., 2019; Kalkhoran and Glantz, 2016). Previous studies suggest that examining e-cigarette frequency of use and device

characteristics is crucial to better understand the relationship between e-cigarettes and cigarette smoking cessation (Levy et al., 2018; Hitchman et al., 2015; Chen et al., 2016). Nevertheless, few studies have examined these characteristics among e-cigarette and cigarette dual users. This study aims to assess how e-cigarette frequency of use and e-cigarette product characteristics influence cigarette cessation behaviors among US adult dual users of cigarettes and e-cigarettes.

E-cigarettes have evolved continuously, and currently, a wide variety of types of e-cigarette devices are available on the market (Centers for Disease Control and Prevention, 2019). Overall, e-cigarettes can be classified as disposable e-cigarettes and e-cigarettes with a prefilled cartridge, tanks, or pod mods. Disposable e-cigarettes are not refillable, while e-cigarettes with prefilled cartridges can be used more than once. Tanks are larger devices that are rechargeable and refillable, allowing users to customize flavors or nicotine liquids. Pod mods, like JUUL, also contain a replaceable cartridge allowing users to customize

combinations of liquids, and usually deliver higher nicotine levels (Centers for Disease Control and Prevention, 2019).

E-cigarette devices may influence cessation behaviors based on how efficiently they deliver nicotine (Cobb et al., 2015). A previous study found that tank e-cigarettes devices release nicotine more efficiently than disposable e-cigarettes and e-cigarettes with a replaceable cartridge (Hajek et al., 2017). Also, pod mods deliver higher levels of nicotine. For example, a Juul pod mod can deliver as much nicotine as a package of cigarettes (Vallone et al., 2019). One of the few nationally representative studies examining the type of e-cigarette devices found that current cigarette smokers who used tanks e-cigarettes were more likely to make smoking quit attempts than current smokers who used other e-cigarette devices (Chen et al., 2016). In the UK, an online survey found that daily tank e-cigarette users were more likely to quit smoking cigarettes, but non-daily disposable e-cigarette users were less likely to quit smoking than adults who were not e-cigarette users (Hitchman et al., 2015).

Previous studies that have evaluated the role of flavors on e-cigarettes and smoking cessation behaviors have produced mixed results (Friedman and Xu, 2020; Gravely et al., 2020). One recent national longitudinal study using the Population Assessment and Tobacco Health Study (PATH) found that adults who used e-cigarettes with non-tobacco flavors at baseline were more likely to quit smoking at follow up than those who used e-cigarettes with tobacco flavor (Friedman and Xu, 2020; Gravely et al., 2020). However, another study among Canadian and U.S adult smokers did not find an association between e-cigarette flavors (tobacco flavored vs non-tobacco flavored) and quit attempts (Gravely et al., 2020).

The frequency of e-cigarette use has also been investigated as a predictor of smoking cessation. Previous studies have found that a higher frequency of e-cigarette use can potentially increase smoking quit attempts. However, only a few studies have assessed this association among US adults using a nationally representative survey. A study analyzing the 2014–15 Tobacco Use Supplement to the Current Population Survey (TUS-CPS) found that current smokers who used e-cigarettes with high frequency had higher rates of smoking quit attempts compared to current smokers who did not use e-cigarettes (Levy et al., 2018). Other nationally representative studies reported that daily e-cigarette users were more likely to quit smoking than non-daily e-cigarette users (Farsalinos and Niaura, 2020; Berry et al., 2019).

Nationally representative scientific evidence on the association between e-cigarette characteristic and cigarette cessation behaviors is needed to understand potential cigarette smoking cessation strategies among dual users of cigarettes and e-cigarettes. Therefore, this study assessed how the type of e-cigarette device, e-cigarette flavors, and the frequency of e-cigarette use are associated with smoking cessation behaviors (i.e., pre-contemplation, contemplation, and preparation to quit) among dual cigarette and e-cigarette users in a nationally representative US population.

2. Methods

2.1. Source and sample of the study

We analyzed data from the 2018–2019 Tobacco Use Supplement to the Current Population Survey (TUS-CPS), which collects information on the US adult (18yearsandolder) civilian, non-institutionalized population to monitor tobacco use and assess the impact of tobacco control policies. The response rate of the TUS-CPS 2018–19 was 57.6% (Mayer et al., 2020). TUS-CPS participants responded to questions about tobacco use by using Computer Assisted Telephone Interviewing (about two-thirds of the sample) or Computer Assisted Personal Interviewing. A detailed description of the TUS-CPS 2018–19 has been published elsewhere (National Cancer Institute, 2020). TUS-CPS included questions on e-cigarette use, including frequency of use, available since 2014–15, and questions on e-cigarette device type, dependence, and flavors, available

since 2018–19. In this study, we included 1,114 dual-users of cigarettes and e-cigarettes. After excluding participants with missing values for covariates (n = 77), our main analytic sample consisted of 1,038 participants. For a sensitivity analysis, we also limited our sample to adults who had used e-cigarettes for one year or more to exclude potential experimental use. By excluding 228 adults who currently used e-cigarettes but who had not used e-cigarettes for one year or more, the sub-sample for the sensitivity analysis consisted of 810 participants. This study was exempt from the Institutional Review Board review because it was a secondary analysis of de-identified, publicly available data.

3. Measurement

3.1. Dependent variable

Current cigarette uses was defined smoking cigarettes every day or some days among adults who had smoked more than 100 cigarettes in their lifetime. Current e-cigarette use were defined e-cigarette use every day or some days regardless of the number of e-cigarettes or sessions in their lifetime Dual use was concurrent use of both products.

In addition, to evaluate the impact of including experimental current e-cigarette use in the analyses, we constructed an alternative e-cigarette use variable including only current e-cigarette use among adults who had used e-cigarettes for one year or more (used in a sensitivity analysis). Dual established current use was defined as current cigarette use and current established e-cigarette use.

The stages of cigarette cessation were defined as pre-contemplation, contemplation, and preparation to quit smoking based on the Trans-theoretical model (Prochaska and Velicer, 1997). The advantage of using the Trans-theoretical model is that cessation is viewed as a process rather than as a binary outcome (DiClemente et al., 1991). Participants were assigned to the pre-contemplation stage if they responded that they had not tried to quit smoking completely in the last 12 months and did not intend to quit in the next six months. They were assigned to the contemplation to quit smoking stage if they: 1) had made a quit attempt in the last year and intended to quit but not in the next month, or 2) had plans to stop smoking but did not make a quit attempt in the last year. Participants were assigned to the preparation to quit smoking stage if they had a plan to quit smoking in the near future (intention to quit in the next month), and they had taken some action in the past year (smoking quit attempt) (DiClemente et al., 1991; Jhun and Seo, 2006).

3.2. Independent variables

The type of e-cigarette device was measured with the following question: *"Which of the following best describes the type of e-cigarette you currently use? If you use more than one type, please think of the one you use most often,"* with response options of disposable e-cigarettes, e-cigarettes with replaceable cartridges, tank, or mod system. We classified e-cigarette flavor into the four categories of menthol/mint, tobacco, sweet/spicy, and other flavors using questions on e-cigarette flavor preference. The detailed algorithm of the classification of flavor is described in Supplementary Fig. 1. E-cigarette frequency of use was assessed based on the number of days that they used e-cigarettes and categorized as 1–9, 10–25, and 25 + days in the past month.

3.3. Covariates

Similar to the e-cigarette frequency of use variable, cigarette frequency of use was measured based on the number of days that participants smoked cigarettes, categorized as 1–9, 10–25, and 25 + days in the past month. Cigarette flavor was measured with the following question: *"Do you usually smoke menthol or non-menthol cigarettes?"* Response options were menthol, non-menthol, and non-usual type, and responses were re-coded as menthol and non-menthol, with non-usual type classified as non-menthol. We included cigarette flavor as a covariate given

that menthol smokers are less likely to quit smoking (Levy et al., 2011; Foulds et al., 2010), and because the use of menthol cigarettes could be associated with our main exposures (i.e., flavors on e-cigarettes).

3.4. Sociodemographic variables

All models were adjusted for sex (male, female), age group (18–24, 25–34, 35–54, 55 and over), race/ethnicity (non-Hispanic (NH) white, NH black, Hispanic and NH other), annual household income (<$50,000, $50,000-$99,000 and more than $100,000) and education (less than high school, high school, some college, and college or more).

3.5. Statistical analyses

First, we described the sample characteristics of the 1,038 dual-user of cigarettes and e-cigarettes. Second, we estimated the proportion of participants who were in each cessation stage by each independent variable. Third, we fit multinomial logistic regression models with the different cessation stages (pre-contemplation = reference group, contemplation, and preparation to quit smoking) to examine the relationship between e-cigarette characteristics and cessation behaviors among dual users and dual established users adjusting for all relevant covariates. Fourth, we ran several sensitivity analyses using logistic regression to examine different binary indicators of intention to quit and cessation attempts (i.e., intention to quit in the next six months, intention to quit in the next month, and quit attempt in the past year). All of our analyses took into account the complex survey design of TUS-CPS. Variance estimates were calculated using the balanced repeated replication method with Fay's adjustment set to 0.4 (Judkins, 1990). All statistical analyses were conducted in Stata 16.

4. Results

In our sample, approximately 60% of dual users were male, 53% reported a family income lower than $50,000, and 76% were NH whites (Table 1). More than 40% reported primarily using tank devices, 37% replaceable e-cigarettes, 12% mod system, and 10% disposable e-cigarettes. About 29% of dual users reported using e-cigarettes with tobacco flavor, 24% menthol flavor, and 39% sweet/spicy. One-third of the sample reported using e-cigarettes more than 25 days per month.

4.1. Contemplation vs. Pre-contemplation to quit smoking

Dual users who used e-cigarettes with a replaceable cartridge and those who used tank e-cigarette devices had greater odds of being in the contemplation smoking cessation stage rather than the pre-contemplation staged compared to those who used disposable e-cigarettes (Table 2: Adjusted Odds Ratio (AOR) $_{Cartridge\ VS\ Disposable}$ = 1.69, 95% CI 1.04–2.77; AOR $_{Tank\ VS\ Disposable}$ = 2.03, 95% CI 1.20–3.44). Participants who used e-cigarettes between 10 and 24 days in the past month compared with those who used e-cigarettes 1–9 days had greater odds of being in the contemplation smoking cessation stage rather than the pre-contemplation stage (AOR = 1.79, 95% CI 1.20–2.69). There was no association between the use of specific e-cigarette flavors and being in the contemplation stage.

4.2. Preparation vs. Pre-contemplation to quit smoking

Participants who used e-cigarettes with higher frequency had greater odds of being in the preparation stage than the pre-contemplation stage (Table 2: AOR $_{E-cigarette\ use\ 10-24\ vs.\ 1-9\ days\ in\ the\ last\ month}$ = 3.73 CI 95% 2.15–6.47, and AOR $_{E-cigarette\ use\ 25+\ vs.\ 1-9\ days\ in\ the\ past\ month}$ = 3.00 CI 95% 1.87–4.81). We found no associations between the type of e-cigarette devices nor the e-cigarette flavors and being in the preparation to quit stage. Results of the multinomial model using a more stringent e-cigarette use definition restricted to adults who currently used e-cigarette and had used e-cigarettes for one year or more were similar compared to the main model (Supplementary Table 1).

Results from the sensitivity analyses using binary outcomes (i.e., intention to quit in the next six months, intention to quit in the next month, and quit attempt in the past year) were generally in the same direction as the findings reported here (Supplementary Table 2).

5. Discussion

Using a large, nationally representative survey of tobacco use behaviors in the US, we found that, among dual cigarette and e-cigarette users, frequent use (10–25 days per month) of e-cigarettes increased the odds of being in the stages of contemplation and preparation to quit smoking rather than the pre-contemplation stage compared to adults who used e-cigarettes less frequently. This finding is consistent with an analysis of the earlier 2014 TUS-CPS data (Levy et al., 2018), as well as data from different analytic samples of current smokers and recent former smokers (Farsalinos and Niaura, 2020; Amato et al., 2016; Biener

Table 1

Characteristics of the analytic sample of e-cigarette and cigarette dual users, Tobacco Use Supplement to the Current Population Survey, 2018–19 (N = 1,038).

	%(n)
E-cigarette variables (independent variables)	
E-cigarette device	
Disposable	10.3 (110)
An e-cigarette with replaceable cartridges	36.8 (374)
Tank	41.1 (440)
Pod mod	11.9 (114)
Flavors on e-cigarettes	
Tobacco	28.5(338)
Menthol	24.1(220)
Sweet/spice	38.9 (396)
Other	8.4 (94)
Frequency of e-cigarette use	
1–9 days in the past month	37.7 (429)
10–24 days in the past month	27.4 (265)
25 + days in the past month	34.5 (344)
Age	
18–24 years	17.9 (116)
25–34 years	28.6 (257)
35–55 years	33.4 (395)
55 or more years	16.8 (270)
Sex	
Female	41.5 (479)
Male	58.5 (559)
Race/Ethnicity	
NH whites	76.7 (863)
NH blacks	5.2 (39)
Hispanic	10.7 (70)
NH other	7.3 (66)
Education	
College or more	11.9 (114)
Some college	41.1 (440)
High school	36.8 (374)
Less than high school	10.3 (110)
Family income	
$100,000 or more	53.1 (581)
$50,000-$99,999	30.1 (308)
<$50,000	16.8 (149)
Cigarette variables (Covariates)	
Flavor on cigarettes	
Non-menthol	65.8 (725)
Menthol	34.2 (313)
Frequency of cigarette use	
1–9 days in the past month	12.3 (105)
10–24 days in the past month	18.8 (175)
25 + days in the past month	68.9 (758)
Cessation behaviors (study outcome)	
Pre-contemplation to quit smoking	26.5 (288)
Contemplation to quit smoking	49.3 (519)
Preparation to quit smoking	24.1 (231)

Table 2

Correlates of cessation behaviors among US adult dual users. TUS-CPS 2018–19 (n = 1,038) (Reference = pre-contemplation).

	Contemplation to quit			Preparation to quit		
	%	Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)	%	Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
E-cigarette variables (independent variables)						
E-cigarette device						
Disposable	40.1%	1.00	1.00	23.5%	1.00	1.00
An e-cigarette with replaceable cartridges	51.0%	**1.65* (1.02–2.7))**	**1.69* (1.04–2.77)**	21.1%	1.17 (0.64–2.14)	1.22 (0.65–2.32)
Tank	52.4%	**2.00* (1.22–3.26)**	**2.03* (1.20–3.44)**	23.8%	1.54 (0.81–2.92)	1.41 (0.72–2.75)
Pod mod system	41.3%	1.60 (0.80–3.18)	1.87 (0.86–4.06)	35.3%	**2.33* (1.08–5.00)**	1.99 (0.81–4.90)
Flavors on e-cigarettes						
Tobacco	49.6%	1.00	1.00	24.2%	1.00	1.00
Menthol	51.2%	1.10 (0.70–1.73)	1.19 (0.70–2.01)	24.3%	1.07 (0.63–1.82)	0.89 (0.46–1.69)
Sweet/spice	46.9%	0.89 (0.62–1.26)	0.86 (0.58–1.28)	25.2%	0.98 (0.62–1.54)	0.75 (0.46–1.24)
Other	53.9%	1.03 (0.57–1.83)	1.06 (0.61–1.85)	18.4%	0.72 (0.33–1.54)	0.70 (0.32–1.54)
Frequency of e-cigarette use						
1–9 days in the past month	51.2%	1.00	1.00	14.6%	1.00	1.00
10–24 days in the past month	52.5%	**1.68* (1.12–2.53)**	**1.79* (1.20–2.69)**	26.7%	**3.00*** (1.73–5.19)**	**3.73*** (2.15–6.48)**
25 + days in the past month	44.8%	1.32 (0.93–1.87)	1.25 (0.83–1.87)	32.5%	**3.35*** (2.11–5.30)**	**3.00*** (1.87–4.82)**
Sociodemogrqaphic Variables						
Age						
18–24 years	41.3%	1.00	1.00	27.9%	1.00	1.00
25–34 years	45.9%	1.25 (0.73–2.11)	1.36 (0.77–2.41)	26.7%	1.08 (0.61–1.91)	1.39 (0.72–2.67)
35–55 years	54.3%	**1.75* (1.07–2.86)**	**2.05* (1.20–3.49)**	22.5%	1.08 (1.07–2.86)	1.60 (0.79–3.26)
55 or more years	53.1%	1.45 (0.88–2.38)	1.71 (0.95–3.06)	19.7%	0.80 (0.45–1.42)	1.22 (0.60–2.47)
Sex						
Female	49.6%	1.00	1.00	28.5%	1.00	1.00
Male	49.1%	**0.72* (0.54–0.99)**	**0.70* (0.51–0.96)**	21.0%	**0.54** (0.37–0.78)**	**0.42*** (0.28–0.63)**
Race/Ethnicity						
NH whites	49.0%	1.00	1.00	24.3%	1.00	1.00
NH blacks	53.7%	1.03 (0.45–2.37)	1.02 (0.47–2.24)	17.9%	0.79 (0.25–1.94)	0.61 (0.19–1.97)
Hispanic	40.3%	0.75 (0.39–1.46)	0.82 (0.43–1.56)	30.6%	1.16 (0.58–2.31)	1.18 (0.54–2.59)
NH other	63.2%	1.76 (0.86–3.60)	1.62 (0.76–3.45)	17.2%	0.96 (0.39–2.37)	1.00 (0.39–2.56)
Education						
College or more	55.6%	1.00	1.00	17.2%	1.00	1.00
Some college	46.6%	0.87 (0.53–1.43)	0.89 (0.54–1.49)	27.3%	1.65 (0.91–3.00)	1.75 (0.87–3.52)
High school	50.4%	0.97 (0.68–1.58)	1.07 (0.67–1.72)	24.2%	1.50 (0.80–2.81)	1.91 (0.94–3.91)
Less than high school	44.9%	0.70 (0.37–1.34)	0.93 (0.47–1.87)	23.9%	1.21 (0.53–2.70)	2.05 (0.85–4.95)
Family income						
$100,000 or more	44.5%	1.00	1.00	26.0%	1.00	1.00
$50,000-$99,999	48.1%	1.17 (0.71–1.91)	1.09 (0.65–1.83)	24.5%	1.02 (0.57–1.80)	0.83 (0.43–1.59)
<$50,000	51.5%	1.35 (0.87–2.11)	1.34 (0.84–2.14)	23.3%	1.05 (0.61–1.79)	0.83 (0.43–1.58)
Cigarette variables (Covariates)						
Flavor on cigarettes						
Non-menthol	50.4%	1.00	1.00	23.4%	1.00	1.00
Menthol	47.3%	0.91 (0.68–1.22)	0.85 (0.58–1.24)	25.6%	1.06 (0.71–1.58)	1.13 (0.70–1.83)
Frequency of cigarette use						
1–9 days in the past month	43.4%	1.00	1.00	34.4%	1.00	1.00
10–24 days in the past month	43.3%	1.44 (0.70–3.00)	1.35 (0.61–3.02)	41.3%	1.72 (0.86–3.49)	1.63 (0.73–3.63)
25 + days in the past month	52.0%	0.88 (0.49–1.56)	0.66 (0.36–1.23)	17.6%	**0.37** (0.21–0.69)**	**0.29*** (0.14–0.56)**

*p value < 0.05, ** p value < 0.005, *** p value < 0.001

and Hargraves, 2015).

We also found that the use of tank e-cigarette devices was associated with higher odds of being in the contemplation versus the pre-contemplation stage compared to the use of disposable e-cigarette devices. This result is somewhat consistent with previous US and UK literature (Hitchman et al., 2015; Chen et al., 2016). Hitchman and collaborators analyzed the association between type of e-cigarette device and frequency of use and smoking cessation among UK adults, and they found that the daily users of tank e-cigarettes were more likely to stop smoking compared to adults who were not e-cigarette users (Chen et al., 2016). Chen and collaborators examined the association between the type of device and smoking quit attempts among US adults, and they reported that e-cigarette users who used open systems including tanks devices were more likely to intend to quit smoking that those who used disposable e-cigarettes (Chen et al., 2016).

Although the use of pod mod devices was not statistically significantly associated with higher odds of cessation behaviors, the results were in the same direction as the association of tank e-cigarettes devices

with cessation behaviors. Pod mod devices, such as JUUL, and tank devices are the type of e-cigarettes with the highest capability to deliver nicotine (Hajek et al., 2017; Vallone et al., 2019; Hajek et al., 2020). Our findings suggest that devices with the highest nicotine delivery are associated with cessation outcomes. Additional longitudinal research is needed to better understand the role of the type of e-cigarettes in cessation outcomes.

Our study is consistent with previous studies that found an association between regular e-cigarette use and smoking cessation (Levy et al., 2018; Farsalinos and Niaura, 2020; Giovenco and Delnevo, 2018), but with some variations by device type and frequency. For instance, we found that e-cigarette device type was statistically significantly associated with contemplation but not preparation to quit. This is somewhat consistent with one PATH study that found that the use of rechargeable devices vs. disposable devices was associated with quitting smoking in the short term but not in the long term (Glasser et al., 2021). In addition, while we found that higher frequency of e-cigarette use is associated with higher odds of contemplation and preparation to quit; these effects

were stronger for those who used e-cigarettes between 10 and 24 days compared to those who used e-cigarettes 25 + days in the past 30 days. Levy et al, in contrast, found a monotonic increase in the odds of quit attempts and quit success with increasing frequency of e-cigarette use using TUS-CPS 2013–2014 data (Levy et al., 2018). Other studies have also found that daily vs. non-daily use of e-cigarette is associated with smoking quit attempts (Farsalinos and Niaura, 2020; Giovenco and Delnevo, 2018). Future studies are necessary to further elucidate the way that the type of e-cigarettes, frequency, duration, and intensity of use of e-cigarettes differentially affect smoking cessation outcomes.

Finally, we did not find an association between the use of e-cigarette flavors and any cessation behavior. Prior research indicates that flavors are associated with the initiation of cigarette and e-cigarette use among youth and young adults (Villanti et al., 2017), but it is unclear if flavors improve cessation outcomes. Our cross-sectional analysis did not find an association between e-cigarettes with non-tobacco flavors and contemplation or preparation to quit relative to use of tobacco-flavored e-cigarettes. In contrast, a recent longitudinal PATH study found that adults who used non-tobacco flavors at wave 2 were more likely than adults who used e-cigarettes with tobacco flavor to quit smoking at follow-up (waves 3 and 4) (Friedman and Xu, 2020). Besides differences in study type (cross-sectional vs. longitudinal), varying use definitions and questions about e-cigarette flavors between PATH and TUS-CPS might explain these discrepant findings. More research is needed to understand the role of e-cigarettes flavors in cessation outcomes. Moreover, efforts to standardize questions and definitions on flavored tobacco products in national health surveys are needed.

This study has several limitations. The cross-sectional nature limits the analysis to non-causal associations. As such, reverse causality cannot be ruled out (e.g., participants in cessation stages increased the frequency of e-cigarette use). In addition, we did not adjust our models for reasons of e-cigarette use (i.e., to help quit smoking cigarettes or to use in places where smoking cigarettes is not allowed) because they are strongly correlated with our cessation outcomes (Supplementary Table 3). Interestingly, while the proportion of e-cigarette users reporting using them to help quit cigarettes increases with cessation stage (from pre-contemplation to preparation), the proportion reporting using them in times or in places where smoking is not allowed decreases with cessation stage (Supplementary table 3). Future research should investigate the interplay of reasons for e-cigarettes use and eventual cigarette smoking cessation. Still, some possible confounders such as friends or family members who smoke, reasons of smoking, or having a chronic condition were not included because there was no information on these variables in the TUS-CPS survey. Despite these limitations, this study is among the first to explore how e-cigarettes product characteristics could influence cessation behaviors among dual users using a nationally representative survey. Finally, our study sample was restricted to dual users; future studies should examine other indicators of reduction in use on the path to cessation, including reduced frequency or intensity of cigarettes use, using longitudinal samples.

6. Conclusion

Our results suggest that the type of e-cigarette devices and the frequency of use could be determinants of smoking cessation behaviors among U.S adult dual users of cigarettes and e-cigarettes. Although there is a potential role for e-cigarettes in smoking cessation, regulation of e-cigarette devices should consider the type of e-cigarettes, the amount of nicotine, and the flavors of e-cigarette devices. At the same time, the regulatory framework must prevent harm to youth and young adults from e-cigarette initiation.

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8. Contributors

Luis Zavala-Arciniega, **Nancy L. Fleishcer** and **Rafael Meza** conceptualized the study. **Luis Zavala-Arciniega** curated the data and conducted the formal analyses. **Luis Zavala-Arciniega**, **Jana L. Hirschtick**, **Nancy L. Fleischer** and **Rafael Meza** drafted the original manuscript. All authors contributed to the study design, and interpretation of the results. All authors approved the final version of this manuscript.

Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2022.101748.

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