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Original investigation

# Intersection of E-Cigarette Use and Gender on Transitions in Cigarette Smoking Status: Findings Across Waves 1 and 2 of the Population Assessment of Tobacco and Health Study

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## Abstract

**Introduction:** Cigarette smokers report using electronic cigarettes (e-cigarettes) to reduce or quit smoking, but findings are mixed regarding the benefit and risk of e-cigarettes in this population, and effects of gender are unknown.

**Methods:** The Population Assessment of Tobacco and Health (PATH; waves 1 and 2; adult interviews) was used to evaluate relationships among wave 1 e-cigarette use (daily, nondaily, never) and gender and their association with transitions (quit vs. current; relapse vs. former) in cigarette smoking status across waves 1 and 2 of the PATH study.

**Results:** Daily e-cigarette users had higher odds of quitting smoking (odds ratio [OR] = 1.56, 95% confidence interval [CI] = 1.12 to 2.18) compared with never e-cigarette users. Conversely, daily and nondaily e-cigarette users were at greater risk of smoking relapse (OR = 1.84, 95% CI = 1.15 to 2.94 and OR = 1.85, 95% CI = 0.99 to 3.46, respectively) compared with never e-cigarette users. Women were less likely to quit smoking compared with men independent of e-cigarette use (OR = 0.76, 95% CI = 0.59 to 0.99). In stratified analyses, daily or nondaily e-cigarette use did not increase the likelihood of quitting or relapse in women. In men, daily and nondaily e-cigarette users were at greater risk of smoking relapse (OR = 2.96, 95% CI = 1.49 to 5.86 and OR = 3.05, 95% CI = 1.29 to 7.17, respectively) compared with men who were never e-cigarette users.

**Conclusions:** Findings identify e-cigarettes as a potential aid for smoking cessation but also as a potential risk for smoking relapse in men only. Overall, women were less likely to quit smoking, and e-cigarette use did not impact their ability to quit or to stay quit.

**Implications:** Cigarette smokers report using e-cigarettes to reduce or quit smoking, but findings are mixed regarding the benefit and risk of e-cigarettes in this population. Using data from the newly available PATH (waves 1 and 2; adult interviews), our findings identify e-cigarettes as a potential aid for smoking cessation but also identify e-cigarettes as a potential risk for smoking relapse in men only. These findings may have implications for the regulation of e-cigarettes by the Food and Drug Administration and the benefit–cost ratio of e-cigarette use in smokers.

## Introduction

Cigarette smoking in the United States has declined considerably over the past decade<sup>1</sup> but remains the leading cause of preventable morbidity and mortality.<sup>2</sup> Of US adults, 15.5% are current cigarette smokers.<sup>1</sup> The burden of cigarette smoking and secondhand smoke exposure is approximately 480 000 US deaths per year.<sup>2</sup> However, a recent report suggests that smoking-related mortality may actually be closer to 556 000 deaths after accounting for associations with causes not previously established as attributable to smoking (eg, renal failure, hypertensive heart disease, various respiratory diseases).<sup>3</sup> Previous estimates indicate that 68.8% of current smokers want to stop smoking completely, with 52.4% of current and former smokers having made at least a single quit attempt in the past year.<sup>4</sup> Somewhat encouraging is an increase in smokers who quit smoking from 2005 to 2016 (50.8% to 59.0%).<sup>1</sup> Given the significant health risks, it is important to identify effective harm reduction and cessation strategies for cigarette smoking.

Electronic cigarette (e-cigarette) use is rapidly increasing in US adults, with current cigarette smokers being the most likely to currently use e-cigarettes.<sup>5,6</sup> Smokers report using e-cigarettes to quit smoking, reduce smoking, and reduce risks associated with smoking.<sup>7-9</sup> As such, e-cigarettes have largely been questioned for their potential use as a tool for smoking cessation. A recent systematic review and meta-analysis of the available literature (38 studies, including population-level observational studies) determined that those who used e-cigarettes had lower odds of quitting cigarette smoking.<sup>10</sup> Survey and tobacco quitline studies report that e-cigarette use does not predict quitting smoking.<sup>11-13</sup> However, a Cochrane review determined that individuals using nicotine-containing e-cigarettes were more likely to abstain from smoking for at least 6 months compared with placebo e-cigarettes,<sup>7</sup> although findings from the Cochrane review should be considered with caution as only three randomized controlled trials were included and the quality of this evidence was rated as “low” because of the small number of trials examining e-cigarette use on smoking behavior. In a recent longitudinal study, quitting cigarette smoking and being a long-term former smoker (vs. current smoker) were strongly associated with daily e-cigarette use.<sup>9</sup> Thus, findings are equivocal across studies. Because of the relative novelty of e-cigarettes and an emerging literature base, it remains relatively unknown how e-cigarette use may affect transitions in cigarette smoking status (eg, encourage quitting or relapse).

An important gap in the literature on cigarette smoking trends is how e-cigarette use and gender may interact to impact transitions in cigarette smoking. While cigarette smoking is more prevalent in men than women,<sup>1</sup> women have more difficulty quitting smoking than men<sup>14,15</sup> and are more likely to relapse after a period of abstinence.<sup>16</sup> Gender differences in e-cigarette use are not well understood. Recent data indicate that current e-cigarette use in men and women may be comparable.<sup>9</sup> Others suggest that awareness of e-cigarettes is more prevalent among men, whereas trying e-cigarettes is more prevalent in women.<sup>17</sup> To our knowledge, no studies thus far have examined the impact of e-cigarette use and gender on cigarette smoking transitions.

The aim of this study was to examine the intersection of e-cigarette use and gender in association with “transitions” in cigarette smoking status using newly available data from a nationally representative sample of adults living in the United States (Population Assessment of Tobacco and Health [PATH]; waves 1 and 2, adult surveys). We first examined whether e-cigarette use and gender were related to transitions in (1) quitting smoking versus stable current cigarette smoking and (2) relapse to cigarette smoking versus stable

former cigarette smoking across waves 1 and 2 of the PATH study. By examining transitions in these two groups, we sought to address two questions: (1) Does e-cigarette use increase odds of quitting in current smokers? and (2) does e-cigarette use change odds of relapse in former smokers? We then examined the two-way interaction between e-cigarette use and gender on transitions in cigarette smoking status (quit vs. current; relapse vs. former).

## Methods

### Data Source

Data for this study were drawn from waves 1 and 2 of the PATH study (wave 1, 2013–2014; wave 2, 2014–2015), a collaboration between the National Institute on Drug Abuse (NIDA) within the National Institutes of Health (NIH) and the Center for Tobacco Products (CTP) within the Food and Drug Administration (FDA).<sup>18</sup> The PATH study used audio computer-assisted self-interviews available in English and Spanish to collect information on tobacco use and health in a nationally representative, longitudinal cohort study of civilian, noninstitutionalized adults and youth in the United States, ages  $\geq 12$  years ( $n = 45\,971$ ). This analysis draws from the wave 1 ( $n = 32\,320$ ) and wave 2 ( $n = 28\,362$ ) adult interviews (ages  $\geq 18$  years). Data were adjusted for oversampling relative to population proportions and were then weighted to represent the US civilian population. The study design and methodology used in the waves 1 and 2 adult interviews of the PATH study are detailed elsewhere.<sup>19</sup>

### E-Cigarette Use

Wave 1 of the PATH was used to determine e-cigarette use during the past year. E-cigarette use status was characterized by the following: “daily” users reported current use of e-cigarettes every day, “nondaily” users reported current use of e-cigarettes some days, and “never” users reported never having used an e-cigarette in the past 12 months.

### Cigarette Smoking Status

Waves 1 and 2 of the PATH were used to determine transitions in cigarette smoking status between waves. We coded the PATH data into the following categories: “Current,” current daily or nondaily cigarette smoker at wave 1 and current daily or nondaily cigarette smoker at wave 2 (ie, no change in status); “Quit,” current daily or nondaily cigarette smoker at wave 1 but not a cigarette smoker at wave 2; “Former,” former cigarette smoker at wave 1 and former cigarette smoker at wave 2 (ie, no change in status); “Relapse,” former smoker at wave 1 but a current daily or nondaily cigarette smoker at wave 2 (ie, reinitiated smoking between waves 1 and 2). To code the PATH data into “Current, Quit, Former, and Relapse” categories, we defined current smokers as having ever smoked a cigarette, even one or two puffs, smoking at least 100 or more cigarettes in their entire life, and now currently smoke every day or some days. We defined former smokers as having ever smoked a cigarette, even one or two puffs, smoking at least 100 or more cigarettes in their entire life, and now currently do not smoke at all.

### Analysis

Data were analyzed using PROC SURVEYLOGISTIC in SAS, version 9.4 (SAS v9.4, SAS Institute Inc, Cary, NC). This procedure allowed for incorporating the stratification, clustering (ie, primary sampling unit), and unequal weighting of the sampling design.

Binary logistic regression analysis was used to examine associations between wave 1 e-cigarette use status and gender with transitions in cigarette smoking status between waves 1 and 2 of the PATH study (quitters vs. current smokers; relapse smokers vs. former smokers). Relationships between e-cigarette use and gender were assessed in terms of odds ratios and were considered significant at  $p \leq .05$ . The effects of each variable of interest on any given outcome were interpreted relative to our chosen reference outcome (ie, never e-cigarette user, male). Separate main effects of e-cigarette use and gender and a two-way interaction between e-cigarette use and gender for quitters versus current smokers and relapse smokers versus former smokers were performed to investigate whether e-cigarette use and gender or their interaction were associated with transitions in cigarette smoking status between waves 1 and 2. Stratified analyses were completed if the interaction was significant at  $p \leq .10$ . Age, race, and education were evaluated as potential covariates and were removed from the final models if there was no impact on the pattern of results.

## Results

Sample characteristics by gender are summarized in Table 1. All chi-square analyses that were performed to examine gender differences in sample characteristics were significant at  $p < .0001$ , except for age ( $p = .42$ ) and cigarette smoking status ( $p = .09$ ). Men were more likely to quit cigarette smoking, and women were more likely to maintain stable cigarette smoking between waves 1 and 2 of the PATH study.

### Quitting Smoking Versus Stable Current Cigarette Smokers

Wave 1 e-cigarette smoking status and gender were associated with quitting cigarette smoking (see Table 2). A main effect of e-cigarette use demonstrated that wave 1 daily e-cigarette use was associated with greater odds of quitting cigarette smoking compared with never e-cigarette use. A main effect of gender demonstrated that females were less likely to quit cigarette smoking between waves 1 and 2 independent of e-cigarette use. An interaction between wave 1 e-cigarette smoking status and gender was not significant for quitters versus current cigarette smokers.

### Relapse to Cigarette Smoking Versus Stable Former Cigarette Smokers

Wave 1 e-cigarette smoking status was associated with relapse to cigarette smoking (see Table 2). A main effect of e-cigarette use demonstrated that wave 1 daily and nondaily e-cigarette use was associated with greater odds of relapsing to cigarette smoking compared with never e-cigarette use. A main effect of gender was not significant. Relapsing to cigarette smoking demonstrated a trend level significant wave 1 e-cigarette smoking status by gender two-way interaction. Male, daily e-cigarette users (odds ratio [OR] = 2.96, 95% confidence interval [CI] = 1.49 to 5.86) and male, nondaily e-cigarette users (OR = 3.05, 95% CI = 1.29 to 7.17) had increased odds of relapsing to cigarette smoking between waves 1 and 2. The stratified analysis was not significant for women.

## Discussion

Cigarette smokers often report using e-cigarettes to reduce or quit smoking.<sup>7-9</sup> As such, the aim of the present investigation was to

**Table 1.** Sample Demographics by Gender (PATH, Wave 1 Adult  $n = 32\ 320$  and Wave 2 adult  $n = 28\ 362$ )

	Men	Women	$\chi^2$	$p$
Age (%)			1.73	.42
18–29	38.6	38.0		
30–44	24.5	25.0		
45+	36.9	36.9		
Race (%)			21.29	<.0001
Caucasian	61.4	60.1		
African American	13.3	15.0		
Hispanic or Latino	17.4	17.5		
Other	7.9	7.4		
Household income (%)			208.61	<.0001
<\$10 000	17.0	22.0		
\$10 000–\$14 999	10.0	11.7		
\$15 000–\$24 999	12.2	12.6		
\$25 000–\$34 999	11.0	11.2		
\$35 000–\$49 999	12.3	11.2		
\$50 000–\$74 999	13.5	12.0		
\$75 000–\$99 999	9.1	7.5		
\$100 000–\$149 999	8.6	7.0		
\$150 000–\$199 999	3.3	2.4		
\$200 000 or more	3.1	2.4		
Education (%)			111.45	<.0001
Less than high school or general educational development	22.0	18.1		
Completed high school	24.2	22.8		
Some college (no degree) or associate's degree	33.1	37.4		
Bachelor's degree	13.8	14.2		
Advanced degree	7.0	7.4		
Wave 1 e-cigarette use status (%)			7.23	.03
Daily	3.3	2.8		
Nondaily	12.2	11.7		
Never	84.5	85.6		
Cigarette smoking status (%) <sup>a</sup>			6.4	.09
Quit	12.2	10.7		
Current	77.0	78.9		
Relapse	5.4	5.4		
Former	5.4	5.0		

<sup>a</sup>Transitions in cigarette smoking status between waves 1 and 2 of the PATH study;

“Current,” current daily or nondaily cigarette smoker at wave 1 and current daily or nondaily cigarette smoker at wave 2 (ie, no change in status); “Quit,” current daily or nondaily cigarette smoker at wave 1 but not a cigarette smoker at wave 2; “Former,” former cigarette smoker at wave 1 and former cigarette smoker at wave 2 (ie, no change in status); “Relapse,” former smoker at wave 1 but a current daily or nondaily cigarette smoker at wave 2 (ie, reinitiated smoking between waves 1 and 2).

identify associations between e-cigarette use and gender with transitions in cigarette smoking status across waves 1 and 2 of the PATH study. Results from the present investigation provide mixed support for the relationship between e-cigarette use and transitions in cigarette smoking. In a nationally representative sample of US adults, daily e-cigarette users at wave 1 were 1.5 times more likely to quit cigarette smoking between waves 1 and 2 relative to never users. Conversely, daily and nondaily e-cigarette users at wave 1 were nearly two times more likely to relapse to cigarette smoking between waves 1 and 2 relative to never users. These epidemiological findings identify e-cigarettes as a potential aid for smoking cessation but also identify e-cigarettes as a potential risk for smoking

**Table 2.** Associations of Wave 1 E-Cigarette Use Status and Gender With Transitions in “Quit Versus Current” Cigarette Smoking Status and “Relapse Versus Former” Cigarette Smoking Status

Quit vs. current		
	OR [95% CI]	<i>p</i>
Wave 1 e-cigarette use status		.003
Daily	1.56 [1.12, 2.18] <sup>a</sup>	.01
Nondaily	0.83 [0.68, 1.02]	.07
Never	ref.	
Gender		.04
Female	0.76 [0.59, 0.99] <sup>a</sup>	
Male	ref.	
Wave 1 e-cigarette use status by gender		.82
Daily by female	1.41 [0.89, 2.22]	.14
Nondaily by female	0.81 [0.61, 1.07]	.13
Never by female	ref.	
Daily by male	1.73 [1.05, 2.84]	.03
Nondaily by male	0.85 [0.65, 1.12]	.26
Never by male	ref.	
Relapse vs. former		
	OR [95% CI]	<i>p</i>
Wave 1 e-cigarette use status		.02
Daily	1.84 [1.15, 2.94] <sup>a</sup>	.01
Nondaily	1.85 [0.99, 3.46] <sup>a</sup>	.05
Never	ref.	
Gender		.99
Female	1.00 [0.61, 1.65]	
Male	ref.	
Wave 1 e-cigarette use status by gender <sup>b</sup>		.10
Daily by female	1.15 [0.57, 2.29]	.69
Nondaily by female	1.12 [0.49, 2.60]	.78
Never by female	ref.	
Daily by male	2.96 [1.49, 5.86] <sup>b</sup>	.002
Nondaily by male	3.05 [1.29, 7.17] <sup>b</sup>	.01
Never by male	ref.	

Table 2 presents covariate-adjusted ORs.

CI = confidence interval; OR = odds ratio; ref. = reference category.

<sup>a</sup>Main effects were significant at  $p \leq .05$ .

<sup>b</sup>Stratified analyses were completed if the interaction was at  $p \leq .10$ .

The overall two-way interaction for “relapse versus former” cigarette smoking status was trend level significant at  $p = .10$ . Stratified analyses for daily by male and nondaily by male were significant at  $p = .002$  and  $p = .01$ , respectively.

relapse. Interestingly, our results are highly consistent with a recently published report in Kaiser Permanente Northern California (KPNC) patients demonstrating that electronic nicotine delivery systems (ENDS) were associated with greater odds of quitting cigarette smoking in current smokers (OR = 1.17) but also associated with greater odds of cigarette smoking relapse in former smokers (OR = 1.53).<sup>20</sup>

Given that the intention to quit cigarette smoking is higher among e-cigarette users than nonusers,<sup>8</sup> it is possible that e-cigarettes increase the motivation to reduce or quit cigarette smoking or those who have increased motivation to quit are more likely to turn toward e-cigarettes as an intervention. Our results indicate that daily e-cigarette use increased odds of quitting cigarette smoking. This is consistent with some previous reports,<sup>7,9,20,21</sup> but results are mixed.<sup>10-13</sup> A recent investigation using the PATH dataset determined that current cigarette smokers who initiated daily e-cigarette

use between waves 1 and 2 were more likely to reduce cigarette use or quit cigarette smoking relative to nonusers.<sup>21</sup> Furthermore, results from longitudinal data and a Cochrane review of clinical trials suggest that e-cigarette use may be positively associated with quit attempts and smoking abstinence in current cigarette smokers.<sup>7,9,22</sup> However, a recent meta-analysis concluded that e-cigarette use was associated with significantly less quitting among smokers.<sup>10</sup> It may be that e-cigarettes are only successful tools for reducing or quitting cigarette smoking in smokers highly motivated to quit. In the aforementioned Cochrane review<sup>7</sup> and meta-analysis,<sup>10</sup> associations between e-cigarette use and smoking cessation were assessed in current smokers regardless of their motivation to quit. Several randomized controlled trials are currently underway to further investigate the effect of e-cigarettes (vs. control) on long-term abstinence rates in current smokers.<sup>7</sup>

We also demonstrated that daily and nondaily e-cigarette use increased odds of relapsing to cigarette smoking. To our knowledge, only one other study has shown that e-cigarette use was associated with relapse to smoking among former smokers.<sup>20</sup> Young-Wolff et al.<sup>20</sup> analyzed electronic health records from 7926 documented ENDS users and 7926 matched patients without ENDS use at KPNC, a nonprofit healthcare delivery system. It is possible that e-cigarette use reinstated cigarette smoking behavior and may account for similar results between this study and that of Young-Wolff et al.<sup>20</sup> E-cigarettes may act as a robust cue to increase cigarette smoking.<sup>23</sup> In young (age 18–35 years) daily smokers, passive exposure to e-cigarette use or visual imagery has been found to increase the urge to smoke cigarettes.<sup>23-25</sup> It is also possible that former smokers who use e-cigarettes are different from nonvapers in such a way that makes them more vulnerable to relapse.

In our study, women were less likely to quit smoking between waves 1 and 2 of the PATH study compared with men. This is expected as women have more difficulty quitting smoking than men.<sup>14,15</sup> We also demonstrated that men who were daily or nondaily e-cigarette users at wave 1 were three times more likely to relapse to cigarette smoking between waves 1 and 2 compared with men who were never e-cigarette users. The stratified analysis was not significant for women, such that e-cigarette use did not impact their ability to quit or to stay quit. This finding likely suggests that men are at higher risk than women of relapsing to smoking following daily or nondaily e-cigarette use. It is important to interpret this result with some caution given that the overall interaction was significant at trend level only. Future research is needed to elucidate gender differences in e-cigarette use and how e-cigarette consumption may translate to cigarette smoking behavior.

Notably, results were consistent across daily and nondaily use of e-cigarettes for smoking relapse. Daily and nondaily e-cigarette users were two times more likely to relapse to cigarette smoking, and men who were daily or nondaily e-cigarette users were three times more likely to relapse to cigarette smoking. These findings indicate that even nondaily, intermittent e-cigarette use may be harmful to former smokers trying to maintain abstinence from smoking. Consistent with this hypothesis, Berry et al. demonstrated that nondaily e-cigarette use was not associated with cigarette smoking reduction or quitting smoking in current smokers initiating e-cigarette use between waves 1 and 2 of the PATH study.<sup>21</sup>



## Limitations

While this study presents current data on e-cigarette use and gender in association with cigarette smoking status, limitations of this study must be addressed. First, study findings were limited to data collected in US adults and may not generalize to adults from other countries. Future work should examine these relationships in other national and international longitudinal datasets. Relatedly, data analysis was limited to variables collected at the two assessment time-points (wave 1, 2013–2014 and wave 2, 2014–2015). As these data suggest time-varying effects of e-cigarette use on cigarette smoking, it may be informative to examine this relationship longitudinally at multiple time points. Third, e-cigarette use and cigarette smoking behavior were self-reported and may be subjected to response bias or under-reporting. Fourth, because e-cigarettes are relatively novel, it is possible that individuals may have misinterpreted or were uncertain about questions related to e-cigarette use. However, the PATH study questionnaire provided a description of e-cigarettes as well as images of e-cigarettes, cartridges, and juice prior to the questions regarding e-cigarette use. Fifth, the number of daily e-cigarette users in this dataset was relatively small (3% of entire sample and 20% of all e-cigarette users) compared with nondaily (12% of entire sample and 80% of all e-cigarette users) and never e-cigarette users (85% of entire sample) and may account for findings that nondaily users generally have lower odds of quitting smoking.<sup>10</sup> Finally, motivation to quit was not specifically assessed in the present datasets, and this would provide valuable information regarding the utility of e-cigarettes as an intervention.

## Conclusions

Results from the present investigation support e-cigarettes as a potential aid for smoking cessation but also identify e-cigarettes as a potential risk for smoking relapse in men only. Women were less likely to quit smoking, and e-cigarette use did not impact on their ability to quit or to stay quit. Overall, these PATH results are consistent with Young-Wolff et al.'s recent report<sup>20</sup> using data from the KPNC health care system. The similarities in results across two datasets emphasize that e-cigarettes pose a potential risk to former cigarette smokers and potential benefit to cigarette smokers trying to quit. These findings may have implications for the regulation of e-cigarettes by the FDA. The FDA recently reported that their strategy to reduce the use of cigarettes is to (1) reduce the nicotine content of cigarettes and (2) consider the role of other tobacco products as a harm reduction approach.<sup>26</sup> The same report notes that e-cigarettes could deliver nicotine while reducing the harm associated with combustible cigarettes.<sup>26</sup> Because results from the present investigation document the potential of e-cigarettes to both increase and decrease risk of smoking, more research is needed to inform regulatory policy on the use of e-cigarettes for smoking cessation. It may be important to develop guidelines regarding time-limited use of e-cigarettes as a smoking cessation aid as they may become iatrogenic over time. Optimal length of the course of e-cigarette replacement therapy will be an important question for future research. It will be necessary for future work to assess the safety and benefit–cost ratio of e-cigarette use in smokers.

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## Declaration of Interests

None declared.

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