

Trajectories between Cigarette Smoking and Electronic Nicotine Delivery System Use among Adults in the U.S.

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SUMMARY

Smoking causes six million deaths annually worldwide. There are controversies regarding the use of electronic nicotine delivery systems (ENDS) to help smokers quit. The purpose of this study was to examine trajectories from prior ENDS use to current cigarette use among adults in the United States. We used National Cancer Institute public data from 2018 to build two statistical models. For model 1, we examined the association between prior ENDS use (vs. never ENDS use) and current cigarette use. For model 2, we examined the association between ENDS use (current and former vs. never) and continuing to smoke among ever smokers. For both models, sociodemographic covariates included age, race and ethnicity, sex, and income and incorporated survey weights. The Health Information National Trends Survey (HINTS) data set included 3,437 participants representing all 245,360,828 people 18 and over in the United States. Compared with those who were not prior ENDS users, prior ENDS users had about 10 times the odds of being current cigarette smokers (AOR=9.74, 95% CI=5.82, 16.31). Additionally, among ever smokers, compared with those who were never ENDS users, current ENDS users were significantly more likely to be current smokers (AOR=5.69, 95% CI=2.46, 13.16). Thus, ENDS use was strongly associated with later cigarette smoking, and smokers who use ENDS were more likely to continue smoking than those who did not use ENDS. These results underscore concerns regarding ENDS and question whether ENDS represent a valuable tool to help smokers quit.

INTRODUCTION

Smoking causes six million deaths annually worldwide. This is true despite the fact that many effective means of quitting smoking exist, including nicotine replacement therapy such as the nicotine patch and nicotine gum. Effective pharmacologic means include bupropion and varenicline. However, even with these tools, smoking cessation is low (1, 2).

Therefore, other proposed tools to help smokers quit are electronic nicotine delivery systems (also called e-cigarettes or ENDS). ENDS, introduced to the market in 2003, use electricity and heat to convert liquid nicotine, propylene

glycol, flavorings such as strawberry or chocolate, and sweeteners such as glycerin into an inhalable aerosol (3). ENDS do expose users to toxins such as tar, carcinogens, and heavy metals (4). In addition, there have been recent high-profile deaths related to the use of ENDS (5). However, compared with cigarettes, ENDS seem to expose users to lower amounts of these chemicals on average (4). Therefore, some experts suggest that switching cigarette smokers to ENDS can help them transition away from smoking entirely (6).

However, other studies show that ENDS may cause non-smokers to transition to traditional cigarettes. In these studies, even people who initially had very low risk of cigarette smoking ended up being smokers after experimenting with ENDS (7–9). Importantly, these studies focused on adolescents and young adults.

One reason for these contradictory results may be that these studies examined different populations. For example, studies focusing on the trajectory from experimenting with ENDS to becoming traditional cigarette users have generally involved adolescents (7, 10). However, studies examining the trajectory away from cigarette use to ENDS use have generally involved specific populations of adults (11). So, it would be useful to examine trajectories in the same population of individuals. In addition, most studies related to ENDS have focused on adolescents, and fewer studies have involved adults for whom cessation is a priority.

Therefore, the purpose of our study was to examine trajectories from prior ENDS use to current cigarette use in an adult population. Because we focused on a population of adults, and because of the studies described above that showed efficacy of ENDS for cessation, we hypothesized that former (vs. never) ENDS use would be significantly associated with lower current cigarette use (H1). However, because there is little indication that adults transition from ENDS to traditional cigarettes, we also hypothesized that there would be no significant association between prior ENDS use and continuing to smoke cigarettes among ever smokers (H2). We hoped that examining these data would help public health and medical professionals to understand the relationship between use of ENDS and traditional cigarettes.

RESULTS

We accessed the public use data set for the Health Information National Trends Survey (HINTS) Wave 5, Cycle 2

		Current Cigarette Use ^a	
		OR (95% CI)	AOR (95% CI) ^b
ENDS Use ^c	Never	1.00	1.00
	Former	6.27 (3.93, 9.99)	9.74 (5.82, 16.31)
Age, years	18-34	1.00	1.00
	35-49	2.77 (1.53, 5.00)	4.79 (2.41, 9.51)
	50-64	2.87 (1.62, 5.09)	6.12 (3.08, 12.18)
	65-74	1.15 (0.63, 2.11)	2.28 (1.08, 4.84)
	75+	0.90 (0.44, 1.85)	1.81 (0.73, 4.46)
Sex	Male	1.00	1.00
	Female	0.59 (0.42, 0.84)	0.56 (0.37, 0.86)
Racial/ethnic category	Caucasian	1.00	1.00
	African-American	1.66 (0.89, 3.09)	1.30 (0.67, 2.54)
	Hispanic or Latino	1.16 (0.65, 2.09)	0.73 (0.39, 1.37)
	Asian	0.91 (0.41, 2.04)	0.52 (0.15, 1.75)
	Other ^d	1.71 (0.58, 5.03)	1.81 (0.49, 6.61)
Annual Household Income	Less than \$20,000	1.00	1.00
	\$20,000 to \$34,999	0.45 (0.25, 0.78)	0.55 (0.27, 1.10)
	\$35,000 to \$49,999	0.51 (0.28, 0.90)	0.52 (0.28, 0.98)
	\$50,000 to \$74,999	0.39 (0.22, 0.72)	0.36 (0.18, 0.72)
	\$75,000 or more	0.39 (0.22, 0.67)	0.32 (0.17, 0.57)

Table 1: Trajectories from prior cigarette use to current ENDS use and prior ENDS use to current cigarette use among adults in the United States, 2018.

Abbreviations: AOR, Adjusted Odds Ratio. CI, Confidence Interval. ENDS, Electronic Nicotine Delivery Systems. OR, Odds Ratio.

Note: Bold values indicate statistical significance at the level of $\alpha = 0.05$ for logistic regression analyses.

^a Current use was defined as use in the past 30 days.

^b Adjusted for all variables in the table.

^c Prior use was defined as use in the past but not in the most recent 30 days.

^d The other category for race and ethnicity included American Indian, Alaska Native, Native Hawaiian, Other Pacific Islander, and mixed race.

(12). HINTS is an ongoing survey conducted by the National Cancer Institute (NCI). This survey, which focuses on how people get information related to cancer, has been conducted since 2003. It assesses a nationally-representative sample of United States (US) residents ages 18 and above. Wave 5, Cycle 2 was conducted in 2018. HINTS provides survey weights to help researchers adjust the sample to reflect the whole population of the United States with regard to age, gender, educational attainment, race, ethnicity, and census region.

For the purpose of this study, we focused on the variables for ENDS and cigarette use. Both variables were categorized by HINTS as current, former, or never. We also used sociodemographic variables including age, race and ethnicity, biological sex, and household income.

The final HINTS sample included 3,437 participants representing 245,360,828 people ages 18 and above. When incorporating survey weights, the sample was 50.8% female. Participants were 64.8% Caucasian, 10.8% African-American, 16.0% Hispanic or Latino, 5.2% Asian, and 3.3% in other racial and ethnic categories. The average age of the

sample was 48.8 with a standard deviation of 17.3 years. When accounting for survey weights, cigarette smoking status was 15.8% current, 20.6% former, and 63.6% never. Also accounting for survey weights, ENDS status was 3.6% current, 13.2% former, and 83.2% never.

For our main analyses, we built two statistical models. For model 1, we examined the association between prior ENDS use and current cigarette use. For this analysis, we omitted current ENDS users in order to compare prior ENDS users to never ENDS users. For model 2, we wanted to test whether use of ENDS was related to continued smoking among smokers. Therefore, we examined the association between ENDS use (never, former, or current) and continued cigarette use (as opposed to being a former user). For both models, we used all sociodemographic covariates and incorporated survey weights.

In the analysis that included all variables, compared with those who were never ENDS users, those who were former ENDS users had about 10 times the odds of being current cigarette smokers (AOR=9.75, 95% CI=5.82, 16.33). Therefore, H1 was not supported. Certain sociodemographic

		Remain Cigarette Use ^a	
		OR (95% CI)	AOR (95% CI) ^b
ENDS Use ^c	Never	1.00	1.00
	Former	3.27 (2.02, 5.28)	3.01 (1.69, 5.34)
	Current	5.33 (2.54, 11.20)	5.69 (2.46, 13.16)
Age, years	18-34	1.00	1.00
	35-49	1.08 (0.54, 2.16)	1.56 (0.70, 3.50)
	50-64	0.83 (0.43, 1.61)	1.44 (0.66, 3.12)
	65-74	0.24 (0.12, 0.47)	0.38 (0.16, 0.88)
	75+	0.17 (0.08, 0.38)	0.27 (0.10, 0.74)
Sex	Male	1.00	1.00
	Female	0.61 (0.43, 0.88)	0.58 (0.37, 0.90)
Racial/ethnic category	Caucasian	1.00	1.00
	African-American	2.47 (1.19, 5.13)	1.75 (0.80, 3.83)
	Hispanic or Latino	2.57 (1.37, 4.79)	1.50 (0.77, 2.94)
	Asian	1.48 (0.54, 4.09)	0.95 (0.28, 3.20)
	Other ^d	2.72 (0.99, 7.49)	1.48 (0.49, 4.56)
Annual Household Income	Less than \$20,000	1.00	1.00
	\$20,000 to \$34,999	0.44 (0.23, 0.83)	0.51 (0.24, 1.10)
	\$35,000 to \$49,999	0.63 (0.34, 1.17)	0.59 (0.30, 1.16)
	\$50,000 to \$74,999	0.34 (0.19, 0.64)	0.36 (0.18, 0.74)
	\$75,000 or more	0.38 (0.22, 0.67)	0.29 (0.15, 0.56)

Table 2: Factors related to remaining a cigarette smoker among ever smokers, 2018.

Abbreviations: AOR, Adjusted Odds Ratio. CI, Confidence Interval. ENDS, Electronic Nicotine Delivery Systems. OR, Odds Ratio.

Note: Bold values indicate statistical significance at the level of $\alpha = 0.05$ for logistic regression analyses.

^a Current use was defined as use in the past 30 days.

^b Adjusted for all variables in the table.

^c Prior use was defined as use in the past but not in the most recent 30 days.

^d The other category for race and ethnicity included American Indian, Alaska Native, Native Hawaiian, Other Pacific Islander, and mixed race.

variables were related to cigarette and ENDS use in this model. Compared with people 18-34, those ages 35-74 were significantly more likely to be current cigarette smokers (**Table 1**). Compared with males, females were about half as likely to be current cigarette smokers (AOR=0.56, 95% CI=0.37, 0.86). Wealthier individuals were less likely to be cigarette smokers (**Table 1**). There were no significant associations between race and ethnicity and current cigarette use.

Among ever smokers, when covariates were included, compared with those who were never ENDS users, smokers who were former ENDS users had about 3 times the odds of remaining as cigarette smokers (AOR=3.01, 95% CI=1.70, 5.35). Furthermore, compared with those who were never ENDS users, those who were current ENDS users had about 6 times the odds of remaining as cigarette smokers (AOR=5.72, 95% CI=2.47, 13.24). Therefore, H2 was not supported. In this model, remaining a cigarette user was also associated with lower odds of being older, female, and wealthier (**Table 2**). There were no significant associations between race and ethnicity and remaining a cigarette smoker.

DISCUSSION

This nationally representative study that used NCI HINTS data had two major findings. First, this study found that being a former ENDS user, as opposed to never using ENDS, was strongly associated with being a current cigarette smoker. Second, we found that, among ever cigarette smokers, compared with being a never ENDS user, being a former or current ENDS user was strongly associated with continuing to smoke cigarettes.

The former finding suggests that initially using ENDS and then transitioning to cigarettes is a common pattern. There are multiple reasons why we might see this pattern. First, ENDS expose users to nicotine, a highly addictive drug, in a palatable form. Once users are sensitized to nicotine and build tolerance, they may seek it out in stronger forms, including cigarettes. Second, once users are accustomed to the behavioral aspects of ENDS use—such as holding the implement and bringing it to their lips—they are more likely to transfer those same habits to cigarette smoking. Third, ENDS use may come along with social situations that may pressure users into cigarette smoking. This pattern of ENDS

use transitioning to cigarette use has been found in prior studies (7, 9, 10). However, this study adds to that body of work because of its focus on adults. Most prior studies have focused on adolescence, but our sample included young adults, middle-aged individuals, and the elderly.

These findings support the recent steps taken by the Food and Drug Administration (FDA) to regulate ENDS (13). For instance, in 2016 the FDA made it illegal to sell ENDS products to people under 18, and they enforce this policy by issuing warning letters and penalizing stores that sell these products to minors. In addition, the FDA conducts inspections of ENDS stores and manufacturers. The FDA also requires labeling of ENDS products with ingredients and a nicotine warning.

We also found that, among ever cigarette users, there was a strong relationship between being an ENDS user and remaining a cigarette smoker. This suggests that ENDS may not represent a cessation tool to quit smoking. In fact, their use may inhibit the ability to stop smoking. The data around ENDS as a cessation tool have been mixed. One randomized, controlled trial conducted in New Zealand, found that ENDS were no better than the nicotine patch for cessation (6). More recently, however, a study in England found that ENDS was better than nicotine replacement therapy for cessation (14). However, the benefit was relatively weak, and this study did not compare ENDS to more established cessation tools such as bupropion or varenicline. However, a randomized, controlled study recently showed those who were assigned to ENDS use and counseling for cessation were far less successful than those assigned to counseling only. In particular, 10.1% of the smokers who were randomized to use e-cigarettes for cessation had quit smoking after 6 months compared to 26.6% of smokers who were assigned to no specific treatment (15).

Our findings were most consistent with this latter study. There are several reasons why use of ENDS may counterintuitively reduce the likelihood of cessation. One reason is that they may propagate a cycle of nicotine addiction instead of encouraging complete cessation. Unlike nicotine patches, for instance, which are simply stuck on the body, ENDS use involves actions and patterns similar to traditional cigarette use. This can include a similar daily routine as smoking, such as using the implement once an hour. It also involves holding onto and dragging from the implement in a similar way. Indeed, studies show that many ENDS users become dual users of ENDS and cigarettes (16).

The most important limitation of this study is that, because of the study design, it cannot determine causality. For example, just because someone is a former ENDS user and now smokes cigarettes, this does not mean that the initial ENDS use necessarily caused the smoking. It will be useful for future studies to use longitudinal designs to more carefully examine trajectories to help us determine causality. Another limitation was the wording of the tobacco and nicotine questions in the HINTS survey. For example, for the question

determining cigarette use, participants were asked if they had smoked 100 cigarettes in their lifetime, but the ENDS question asked if they had used an ENDS product at all. This was due to the fact that ENDS is still a newer behavior with less defined assessment tools. Over time, large studies such as HINTS likely will develop more standardized methods of measuring ENDS use.

In any large, self-report study, there is the risk of dishonesty. Because the HINTS survey did not use biochemical validation, we cannot determine the validity of participants' responses. However, it is unlikely that the participants were dishonest, because ENDS and cigarettes are legal, and the study was conducted anonymously. Still, future studies might employ biochemical validation to confirm the integrity of the participants' responses.

In conclusion, despite these limitations, this study helps add to the literature because it showed that there are associations between being a former ENDS user and a current cigarette smoker, as well as showing that there is a strong association between ENDS use and continuing to smoke cigarettes among ever smokers. It is important to continue researching this topic using both qualitative and quantitative methodologies.

MATERIALS AND METHODS

Data Source and Participants

For this study we conducted a secondary analysis of HINTS data. The HINTS survey is a project of the National Cancer Institute. It has been conducted 13 times since 2003. HINTS uses a cross-sectional model to survey participants about topics related to cancer and health information. For this study we used HINTS 5 Cycle 2, collected from January through May of 2018 (12).

HINTS 5 Cycle 2 used a paper questionnaire mailed to random houses from the United States Postal Service list of residential houses. Then, the adult the survey was given to was selected using the next birthday method. This method chooses the next person to have a birthday in that household. HINTS only included adults. This means that it excluded people under 18 years of age. It also excluded institutionalized individuals and military personnel serving overseas.

HINTS created survey weights to adjust the sample to reflect the whole population of the United States. For example, if the proportion of females in the sample was smaller than the proportion of females in the US, the weights would help overweight the females' responses. The survey weights also adjusted for non-response. Demographic variables that were used to create the survey weights included age, gender, educational attainment, race and ethnicity, and census region.

The HINTS study received Institutional Review Board (IRB) approval from the National Institutes of Health. For the current analysis, we did not require additional IRB approval because we only conducted secondary analyses and did not collect additional primary data.

Measures

HINTS categorizes people into being current, former, or never smokers. In order to define the participants' smoking status, they were asked two questions: "Have you smoked at least 100 cigarettes in your entire life?" (with responses of yes and no) and "Do you now smoke cigarettes every day, some days, or not at all?" (with responses of everyday, some days, or not at all). Current smokers were defined as those who answered either "everyday" or "some days" to the latter question. Former smokers were defined as those who answered "yes" to having smoked 100 cigarettes in their lifetime and "not at all" to the latter question. Never smokers were defined as those who answered "no" and "not at all" respectively.

In order to define the participants' ENDS use status, they were also asked two questions: "Have you ever used an e-cigarette, even one or two times?" (with responses of yes and no) and "Do you now use an e-cigarette every day, some days, or not at all?" (with responses of everyday, some days, or not at all). Current ENDS users were defined as those who answered either "everyday" or "some days" to the latter question. Former ENDS users were defined as those who answered "yes" to having tried ENDS before and "not at all" to the latter question. Never ENDS users were defined as those who answered "no" to the former question and "not at all" to the latter question.

We used four demographic variables: age, gender, race, and annual household income. HINTS categorizes age into five predetermined categories: 18-34, 35-49, 50-64, 65-74, and 75+. For gender, respondents self-reported as being either male or female. For the question regarding race and ethnicity, there were six options, and participants were allowed to select as many as they liked: Hispanic, White, African-American or Black, Native American or Native Alaskan, Asian, and Pacific Islander. We collapsed these into five mutually-exclusive categories: Hispanic, White, Black, Asian, as well as "other," which included Native American, Native Alaskan, Pacific Islander, and mixed race. We created this "other" category because there were too few American Indians and Pacific Islanders to have their own categories, and we did not want our models to be unstable due to small cell sizes. For household income, participants were asked "What is your combined annual income, meaning the total pre-tax income from all sources earned in the past year?" They responded in 5 categories: Less than \$20,000, \$20,000 to \$34,999, \$35,000 to \$49,999, \$50,000 to \$74,999, and \$75,000 or more.

Analysis

To determine the association between being a former ENDS user and a current cigarette smoker we used logistic regression. This is because our dependent variable, current cigarette smoking, is dichotomous. Our primary independent variable for this analysis was former (vs. never) ENDS use. For this analysis we did not include current ENDS users because we wanted to directly compare former ENDS use to never ENDS use.

To determine the association between being a current

or former ENDS user and continuing to smoke we also used logistic regression. For this analysis we did not include never cigarette users so current cigarette use effectively meant continuing to smoke.

We included in our primary models all relevant demographics, including age, gender, race, and annual household income. We included survey weights in all of our primary models. We also conducted secondary models to examine the robustness of our results. For example, we conducted analyses without survey weights. We also conducted logistic regression analyses that only included control variables that were significantly associated with the outcome variables at $P < 0.15$. Because the results of these secondary analyses were similar to the primary analyses, we only include results from primary analyses in this report.

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