# Electronic Nicotine Delivery Systems Use Predicts Transitions in Cigarette Smoking among Young Adults

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## Abstract

**Background:** Although cigarette smoking during young adulthood is characterized by volatility, few studies examine if use of electronic nicotine delivery systems (ENDS) impacts transitions in cigarette use behaviors across this developmental period. The purpose of this longitudinal study was to examine the role of ENDS use on three transitions in cigarette smoking among young adults; initiation, desistance, and re-uptake.

**Methods:** Participants were 5,029 18-29-year-olds (64.2% female) enrolled in one of 24 Texas colleges at baseline and involved in an eight-wave, 4.5-year study. A multi-state, continuous time Markov model was used to assess the role of current/past 30-day and ever ENDS use on three transitions, spanning at least six months 1) never to current smoking (initiation); 2) current to non-current smoking (desistance); and 3) non-current to current smoking (re-uptake). The model also contained time-invariant socio-demographic, and time-varying intrapersonal (other tobacco use, nicotine dependence, sensation seeking, depressive symptoms) and interpersonal (peer cigarette use) covariates.

**Results:** Both current and ever ENDS use increased the probability of transitioning from never to current cigarette use (initiation) and decreased the probability of transitioning from current to non-current use (desistance). Current, but not ever, ENDS use also increased the probability

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of transitioning from non-current to current use (re-uptake). Adjustment for socio-demographic, intrapersonal, and interpersonal covariates did not alter these findings.

**Discussion:** ENDS use in young adulthood increases the risk for cigarette smoking behaviors across the continuum of uptake and progression. Prevention and cessation efforts targeting both ENDS and cigarette use during young adulthood are needed.

### Keywords

vaping; smoking; college students; young adults; Markov Models; longitudinal research

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## 1.1 INTRODUCTION

Use of Electronic Nicotine Delivery Systems (ENDS) is increasingly prevalent among young adults (Dai & Leventhal, 2019). According to data from the Population Assessment of Tobacco and Health study, 17.2% of 18-to-24-year olds reported past 30-day ENDS use in 2015/2016 (Stanton et al., 2020). Young adults may use ENDS for various reasons ranging from curiosity to socializing with friends to quitting cigarette smoking (Kinouani et al., 2019). Research indicates that ENDS may help adults quit cigarette smoking (Hartmann-Boyce et al., 2020), but findings for young adults are not conclusive (Glasser, Abudayyeh, Cantrell, & Niaura, 2019). Other research indicates that ENDS use elevates risk for subsequent cigarette initiation among young adults (Khouja, Suddell, Peters, Taylor, & Munafò, 2020; Loukas, Marti, Cooper, Pasch, & Perry, 2018; Soneji et al., 2017). As such, ENDS may have a public health benefit if use results in quitting cigarettes, the tobacco product highest on the harm continuum (Abrams et al., 2018), but the benefit may be diminished if use leads to cigarette initiation or continued use (Levy et al., 2017).

The majority of studies examining the impact of ENDS use on young adults' smoking have been limited to examination of its effect on the initiation of cigarettes (Khouja et al., 2020; Loukas et al., 2018; Soneji et al., 2017). Yet, cigarette use behaviors are characterized by their volatility and by multiple transitions during young adulthood (Wetter et al., 2004), such as increased frequency of use, reduced use or quitting (i.e., desistance), and re-uptake. For example, Wetter and colleagues (2004) found that although 35% of occasional smoking college students remained occasional smokers at the end of a four-year study period, 51% quit smoking, and 14% became daily smokers. Several hypotheses have been proposed to explain how ENDS may contribute to smoking transitions, including that ENDS use may lead to nicotine addiction and "renormalizing" cigarette use, both of which may elevate risk for cigarette smoking and undermine quitting (Schneider & Diehl, 2016). Cigarettes continue to be the most common type of tobacco product used by young adults, surpassing even ENDS use on the 2019 National Health Interview survey (Cornelius, Wang, Jamal, Loretan, & Neff, 2020). A more nuanced understanding of the impact of risk factors, like ENDS use, on different stages in smoking uptake and progression are needed to inform development of smoking prevention and cessation interventions for young adults.

Evidence indicates that ENDS use may impact increased frequency of cigarette use and quitting. One study of young adult non-daily smokers indicated that more frequent use of ENDS six months prior to entry into the study predicted more frequent cigarette use over

the next year (Doran et al., 2017). Another study indicated that ENDS use was negatively associated with past cigarette cessation attempts among college students (Peltier et al., 2020), but two studies showed that the use of ENDS for the purpose of quitting smoking was not associated with cigarette smoking status, either concurrently among a sample of adolescents and college students (Camenga, Kong, Cavallo, & Krishnan-Sarin, 2017) or across a 12-month period among a sample of young adults (Selya, Dierker, Rose, Hedeker, & Mermelstein, 2018). In contrast, another study showed that use of ENDS for quitting smoking was associated with an increased likelihood of being a non-smoker 6-months and 12- months later among college students (Mantey, Cooper, Loukas, & Perry, 2017). Thus, ENDS use may contribute to cigarette initiation and increases in frequency of use among young adults, but the role of ENDS in quitting is mixed. Importantly, the large majority of studies examine the role of ENDS use on one transition (e.g., initiation or quitting) without capturing the dynamic nature of cigarette use behaviors across young adulthood.

The present longitudinal study aimed to extend existing research by simultaneously examining the role of ENDS use on not one, but three transitions in cigarette smoking behaviors (initiation, desistance, re-uptake) among a sample of 18-to-29-year-old young adults initially recruited from colleges. Although college students report a lower prevalence of cigarette smoking than non-college students, Monitoring the Future data indicate that they have a higher prevalence of ENDS use (Schulenberg et al., 2019, 2020), underscoring the need for research on the role of ENDS in college students' cigarette transitions. We used multi-state, continuous time Markov models to examine three transitions across three "states" of cigarette smoking; never, current (i.e., past 30-day) and non-current (i.e., ever, but not current) use (see Figure 1). The three transitions across these three states were from: 1) never cigarette smoking to current cigarette smoking, referred to as initiation; 2) current cigarette smoking to non-current smoking, referred to as desistance; and 3) non-current cigarette smoking to current cigarette smoking, referred to as re-uptake. Transitions were assessed across intervals of at least six months, the shortest length of time between adjacent study assessments/waves. Research on the impact of ENDS use on cigarette smoking has been limited to unidirectional models that allow examination of only one transition at a time and in only one direction. Markov models capture the dynamic nature of cigarette use by simultaneously modeling multiple transitions, some of which are in the opposite direction, such as desistance and re-uptake (see Figure 1). We examined the impact of current and ever ENDS use on the three transitions while controlling for socio-demographic, intrapersonal (other tobacco use, nicotine dependence, sensation seeking, and depressive symptoms) and interpersonal (peer cigarette use) covariates known to be associated with young adults' cigarette use (Petraitis, Flay, & Miller, 1995; Weinberger et al., 2017).

## 2.1 MATERIAL & METHODS

### 2.2 Participants

Participants were 5,029 young adults from the Marketing and Promotions across Colleges in Texas project (Project M-PACT), a longitudinal, web-based, study that assessed tobacco use across a 4.5-year period from 2014-2019. Project M-PACT followed a cohort of 5,482 18-29-year-olds, recruited in fall 2014/spring 2015 from 24 Texas colleges (12 four-year and

12 two-year) in the five counties surrounding Austin, Dallas/Fort Worth, Houston, and San Antonio.

### 2.3 Procedure

Students from the 24 colleges were recruited with an email describing the study and inviting them to complete an eligibility survey. Students were required to be 18-29 years old and full-or part-time degree- or certificate-seeking undergraduate students attending a participating 4-year college or a vocational/technical program at a 2-year college. Of the 13,714 students who were eligible to participate, 5,482 (40%) provided informed consent and completed the baseline survey. Follow-up web-based surveys were administered every six months until spring 2018 and then a yearly survey was administered in spring 2019. In fall 2017, we administered an abbreviated survey that was not used for the present study because it included only limited current tobacco use data. Thus, the present study used data from eight study waves (with six months between the first six waves and one year between the remaining two waves) spanning a 4.5-year period from 2014-2019. Participants received a $10 e-gift card incentive at Wave 1 and Wave 2, and a $20 e-gift card incentive for the remaining six waves, and there were drawings at each wave to win additional e-gift cards. Retention rates for the follow-up waves ranged from 70% (at the final wave) to 81% at (Wave 4) of the 5,482 participants. The research protocol was approved by the Institutional Review Board of the university leading the study.

Only participants who had at least two waves of data and data for all study variables were included in the present study (n=5,029; 92.7% of all possible participants). Of the 5,029 participants, 57.8% participated at all eight waves. The 5,029 participants were 18-29 years old at baseline in 2014-2015, most were female (64%), and non-Hispanic, white (36%) or Hispanic (31%), and the majority (93%) attended a 4-year (vs. a 2-year) college at baseline. Table 1 shows the baseline socio-demographic characteristics for the overall sample and for the three cigarette use states/categories at baseline. Although we present the socio-demographic characteristics of the 5,029 participants for descriptive purposes, it is important to note that the primary unit of analysis for Markov models is observations. Observations are the transitions that occurred from one wave to the adjacent wave of available data, which spanned at least six months. As such, analyses are based on 28,659 transitions from the 5,029 participants across the eight study waves.

### 2.4 Measures

**Outcome Variables.—**The three cigarette transitions (initiation, desistance, re-uptake) were based on three mutually exclusive cigarette use states of never, current, and non-current cigarette use, assessed at all eight waves. The dichotomous cigarette use states served as the outcome variables and were defined at each wave based on two items, ever cigarette use and past 30-day cigarette use. Participants who selected the response, "I have never smoked a cigarette, even 1 or 2 puffs" on the ever use item were considered never smokers and those who reported using cigarettes on at least one day to the question, "On how many of the past 30 days did you smoke cigarettes?" were considered current smokers. Participants who reported ever smoking, but who did not use cigarettes in the past 30-days were considered non-current smokers.

**Exposure Variables.**—Current and ever ENDS use were time-varying and assessed at all eight waves. Current ENDS use was assessed with one item, "During the past 30 days, have you used any ENDS product (i.e. an e-cigarette, vape pen, or e-hookah), even one or two puffs, as intended (i.e. with nicotine cartridges and/or e-liquid/e-juice)?" Participants who indicated using ENDS on at least one day in the past 30 were current ENDS users (coded '1') and all others were non-current ENDS users (coded '0'). Ever ENDS use was assessed with one item asking participants if they "ever used an ENDS product (i.e. an e-cigarette, vape pen, JUUL/ pod vape, e-hookah, or mod) as intended (i.e. with nicotine cartridges and/or e-liquid/e-juice), even one or two puffs"; ever users were coded '1' and all others were coded '0'.

**Socio-Demographic Covariates.**—Four socio-demographic variables, all assessed at Wave 1, were included in the model; sex ('0'=female/'1'=male), age in years (centered at 18), race/ethnicity (coded as White, Hispanic/Latino, African American, Asian, and other), and type of college attended ('0'=2-year/'1'=4-year).

**Intrapersonal Covariates.**—Four time-varying intrapersonal covariates were assessed at all eight waves; number of other tobacco products used, nicotine dependence, sensation seeking, and depressive symptoms. The number of other tobacco products used was a sum of three products used in the past 30 days: cigars/little cigars, cigarillos, hookah, and smokeless tobacco/snus. Scores ranged from '0' (none) to '3' (used all products in the past 30 days). Nicotine dependence was assessed with two items asking participants how soon after waking up they typically use their first ENDS product or smoke a cigarette (Heatherton, Kozlowski, Frecker, & Fagerström, 1991). Non-users and those reporting using their first product after 30 minutes of waking were coded '0' and those using an ENDS or smoking a cigarette within 30 minutes of waking were coded '1'. Sensation seeking was assessed using the four-item Brief Sensation-Seeking Scale (e.g., "I would like to explore strange places,") (Stephenson, Hoyle, Palmgreen, & Slater, 2003). Participants were asked the extent to which they agreed with each statement on a five-point scale ranging from '1' ("strongly disagree") to '5' ("strongly agree"). The four items were averaged and higher scores reflected higher sensation seeking. Depressive symptoms were assessed with the Center for Epidemiological Studies Depression Scale-10 (CES-D-10) (Andresen, Malmgren, Carter, & Patrick, 1994). The CES-D-10 assesses 10 symptoms of depression (e.g. "I was bothered by things that don't usually bother me") in the past seven days. Response options ranged on a three-point scale from '0' ["rarely (less than 1 day)"] to '3' ["most of the time (5-7 days)"]. The ten items were summed and then standardized in a z score, and higher scores reflected more depressive symptoms.

**Interpersonal Covariate.**—One time-varying interpersonal covariate, peer cigarette use, was assessed at all eight waves with one item, "How many of your close friends smoke/use cigarettes." Response options ranged on a five-point scale from '0' ("none") to '4' ("all").

## 2.5 Data Analysis

A multi-state, continuous time Markov model was used to examine longitudinal patterns in transitions between the three cigarette use states of never, current, and non-current use

(see Figure 1), and determine the role of current and ever ENDS use in transitions between the states. Because time is continuous in Markov models, the timing of observations can occur at uneven intervals, such as when participants are missing data at one or more study waves. States at any given wave are conditional only on the prior wave. As such, transitions are assessed between adjacent waves of available data (e.g., from Wave 1 to Wave 3, if missing Wave 2). For this study, transitions were only permitted between the same state (i.e., stable state) and adjoining states. Thus, a participant could either remain in the same state or could transition from never use to current use, current to non-current use, or non-current to current use. However, transitions from the two use states to never use were not permissible, as participants could not be considered never users once they had reported ever or current cigarette use (see Figure 1). Initial transition intensities were generated automatically for the allowed model transitions and bidirectional transitions were permitted such that participants could transition from current to non-current cigarette use states and from non-current to current cigarette use states.

Unadjusted and adjusted multi-state Markov models were fit using the R msm package (Jackson, 2011). The primary exposure variables were time-varying current ENDS use and ever ENDS use. The adjusted multivariable model contained four Wave 1 time-invariant covariates (participant's sex, age, race/ethnicity, 4-year versus 2-year college attendance) and five time-varying covariates (number of other tobacco products used, nicotine dependence, sensation seeking, depressive symptoms, peer cigarette use).

### 2.6   Attrition Analyses

Separate logistic regression analyses were conducted to assess if participants included in the present study (n=5,029) differed from those excluded (n=453) on the four Wave 1 socio-demographic covariates (sex, age, college type, and race/ethnicity) and on Wave 1 current and ever ENDS use. Participants who were excluded from the study were significantly more likely than those included to be male, older, attending a 2-year college, and an ever ENDS user; they were less likely to be excluded if they were Asian American (versus non-Hispanic, white). However, the observed effect sizes were small, indicating that excluded participants differed minimally from included participants.

### 3.1   RESULTS

Descriptive analyses were conducted first to examine the transition probabilities for all three cigarette states (see Table 2). There was a total of 28,659 transitions from the 5,029 participants across the eight study waves. Overall, the highest probabilities were those capturing no transitions (i.e., stability) in the three states from one wave to the adjacent wave. The never use state was highly stable across the 4.5-year period (96%), as participants who were never users at the start of the study largely remained never users, with few instances of transitions to current use or to non-current use in the subsequent assessment. In contrast, current use and non-current use states were less stable. Among instances of the current use state, the majority (66%) were stable, whereas 34% were transitions to the non-current use state (desistance). Similarly, among instances of the non-current use state, the majority (88%) were stable, whereas 12% were transitions to the current use state

(re-uptake). Thus, while it was more common for a current cigarette user to transition to the non-current use state, non-current to current cigarette use transitions still occurred.

Results from unadjusted and adjusted multi-state Markov models examining the impact of current and ever ENDS on the three cigarette use transitions are reported in Table 3. Adding the covariates to the multivariable model did not change the findings from the unadjusted models. After adjusting for the covariates, current ENDS use increased the probability of transitioning from never to current cigarette use (initiation) by 2.69 times and from non-current to current cigarette use (re-uptake) by 1.92 times, and decreased the probability of transitioning from current to non-current cigarette use (desistance) by 1.59 times. Ever ENDS use also increased the probability of transitioning from never to current cigarette use (initiation) by 2.16 times and decreased the probability of transitioning from current to non-current cigarette use (desistance) by 1.85 times, but did not impact transitions from non-current to current cigarette use (re-uptake).

Examination of the covariates indicated that the cigarette use transitions were associated primarily with the intrapersonal and interpersonal covariates. However, among the socio-demographic covariates, males were less likely than females to transition from current to non-current use (desistance) and more likely to transition from non-current to current use (re-uptake), and older young adults were less likely than younger young adults to transition from current to non-current use (desistance) and from non-current to current use (re-uptake). Relative to non-Hispanic, White young adults, African American/Black young adults were less likely to transition from non-current to current use (re-uptake) and Asian American young adults were more likely to transition from current to non-current use (desistance). Regarding the intrapersonal and interpersonal factors, number of other tobacco products used, depressive symptoms, and peer cigarette use all increased the probability of transitioning from never to current cigarette use (initiation) and from non-current to current use (re-uptake), and nicotine dependence and peer cigarette use decreased the probability of transitioning from current to non-current use (desistance). Sensation seeking also increased the probability of transitioning from never to current cigarette use (initiation) and from non-current to current use (re-uptake) and, unlike the other covariates it also increased the probability of transitioning from current to non-current use (desistance).

## 4.1   DISCUSSION

Cigarette smoking in young adulthood is dynamic and characterized by multiple transitions, ranging from initiation to quitting. Yet, relatively little is known about the role of ENDS use in cigarette use transitions across this developmental period. Findings extend existing research by showing that current ENDS use increased the likelihood of cigarette initiation and re-uptake, and decreased the likelihood of desistance. With the exception of re-uptake, the same findings were observed for ever ENDS use, suggesting any ENDS use may be problematic when it comes to increasing the risk for cigarette smoking among young adults, across the entire continuum of uptake and progression. It is notable that the impact and magnitude of ENDS use on subsequent cigarette use transitions continued to be significant and did not diminish markedly, even after inclusion of covariates known to increase risk for

smoking among young adults, such as depressive symptoms, sensation seeking, and peer cigarette use (Petraitis et al., 1995; Weinberger et al., 2017).

Consistent with contemporary research (Hair et al., 2017; Hair et al., 2018; Soneji et al., 2017), most young adult college students did not use cigarettes and the most common pattern was stable never use across the 4.05-year period. Transitions from never to current use were comparatively low, but students initiated cigarette smoking during this developmental period and stability in current cigarette use was more common than transitions to desistance. Stability in non-current cigarette use was also more common than transitions to current use (i.e., re-uptake), but re-uptake occurred in some instances. These findings confirm research indicating that cigarette smoking in young adulthood can be both stable *and* dynamic, characterized by multiple transitions that may include initiation, desistance, and re-uptake (Taylor et al., 2020). Findings also are consistent with studies showing that smoking is persistent for some young adults, with prior research indicating that smoking patterns are established between the ages of 20 and 22 years (Hair et al., 2017). These findings indicate that both prevention and cessation efforts are necessary during young adulthood. Although there are a number of cigarette smoking and ENDS cessation interventions for young adults (Graham, Jacobs, & Amato, 2020; Villanti et al., 2020), there are few contemporary efforts aimed at preventing tobacco initiation and re-uptake for this population (Villanti, Niaura, Abrams, & Mermelstein, 2018). Future research is needed to fill this gap.

Consistent with expectations and existing research (Khouja et al., 2020; Loukas et al., 2018; Soneji et al., 2017), ENDS use elevated risk for cigarette initiation. Although ENDS are low on the tobacco harm continuum, their role in cigarette initiation is concerning because cigarettes are among the most harmful tobacco products (Abrams et al., 2018). Research is just beginning to explore why/how ENDS use may contribute to cigarette initiation, with one recent qualitative study indicating that college students report transitioning from ENDS to cigarettes because cigarettes are more commonly available for sharing with peers, such as at parties, are more useful as a coping mechanism, and are more convenient and less expensive to access (Hiler et al., 2020). Additional research examining if one or more of these reasons leads to persistent cigarette use is needed to determine who becomes a regular smoker and who eventually quits using cigarettes.

Further findings indicated that ENDS use may undermine smoking desistance and potential reductions in use or quitting. Research is mixed regarding the role of ENDS in smoking desistance among young adults, with some studies showing that the use of ENDS for the purpose of quitting smoking is not associated with subsequent smoking status (Camenga et al., 2017; Selya et al., 2018) and at least one showing that it is associated with an increased likelihood of being a non-smoker up to 12 months later (Mantey et al., 2017). It is important to note that participants who did not stop smoking cigarettes may have maintained ENDS use, becoming dual users of ENDS and cigarettes, a pattern that is common among young adults (Stanton et al., 2020). Findings from the Truth Initiative Young Adult Cohort Study (Niaura et al., 2019) indicate that dual use of ENDS and at least one combustible product is also dynamic during young adulthood, and that dual users are most likely to transition to combustible product use three years later rather than to maintain dual use or to transition

to ENDS or non-current use. Taken together, findings indicate that ENDS use either alone or in combination with other combustible products may increase risk for continued cigarette smoking.

The finding that ENDS use elevated risk for the re-uptake of cigarettes is unique as relatively little research examines factors impacting transitions from non-current to current cigarette use among young adults. There is evidence that ENDS use elevates risk for relapse among adult former smokers (Azagba, Qeadan, Shan, Latham, & Wolfson, 2020) who may find ENDS are not a satisfying alternative to cigarettes. However, many young adults are not using ENDS to quit smoking (Kinouani et al., 2019). Young adults report using ENDS for various other reasons including out of curiosity, for experimentation or socialization purposes (Ickes et al., 2019; Saddleson et al., 2016). As such, young adults who use ENDS for these or other reasons may be open to using other nicotine-containing products (Coleman et al., 2015), including cigarettes, which they may use intermittently and only in certain contexts, such as when socializing and drinking alcohol (Schane, Glantz, & Ling, 2009). Thus, although smoking may be persistent for some young adult smokers, it is likely intermittent and volatile for others, particularly college students who may be experimenting with cigarettes or using in distinct contexts such as when drinking alcohol in social situations (Schane et al., 2009). Nonetheless, findings extend existing research by indicating that ENDS use not only elevates risk for initiation but also for continued cigarette use during young adulthood, which is concerning given that this is the developmental period when lifelong use is established (Ling & Glantz, 2002).

The present study is not without limitations. First, participants were drawn from 24 Texas colleges. Although the sample was large and racially/ethnically diverse, findings may not generalize to other young adult populations. College students are more likely than their non-college peers to use ENDS, but they are less likely to use cigarettes (Schulenberg et al., 2020); thus, additional research with non-college young adults is needed to replicate study findings. Second, this study improves upon others by capturing a range of smoking transitions across at least six month intervals within a 4.5-year period spanning young adulthood, from initiation to desistance (Hyland et al., 2020). However, transitions were based on smoking states (i.e., never; current; non-current) that were defined by ever and past 30-day cigarette smoking. As such, it is not possible to determine if and for whom ENDS use will lead to regular cigarette use, a question that needs to be addressed to fully understand the consequences of ENDS use.

## 5.1 CONCLUSIONS

Notwithstanding limitations, the present study extends our limited understanding of the transitions in cigarette smoking behaviors during young adulthood in the contemporary tobacco marketplace that includes ENDS products. Findings have implications for intervention efforts. Although the majority of participants did not smoke cigarettes, there were new users of cigarettes during this developmental period and cigarette use behaviors were both dynamic and stable. Moreover, ENDS use elevated risk for cigarette initiation and continued use, while it decreased the likelihood of desistance. These findings indicate that both prevention and cessation efforts are needed for young adults, and that both cigarette

smoking and ENDS use should be addressed given the potential for dual use, and the importance of the latter in increasing the risk for the former across the continuum of uptake and progression.

## Role of Funding Source:

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## HIGHLIGHTS

- There were numerous cigarette transitions, but stable never use was most prevalent.

- The role of ENDS in cigarette use transitions across young adulthood is not known.

- ENDS use elevated risk of smoking initiation and decreased probability of desistance.

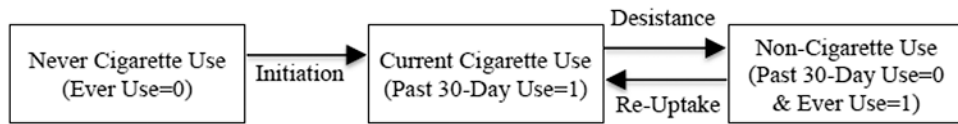- ENDS use elevated risk for the re-uptake of smoking after a period of non-use.

**FIGURE 1.**
Examining three transitions in cigarette smoking behaviors (initiation, desistance, and re-uptake) across three states

**TABLE 1**

Wave 1 sociodemographic characteristics for the overall sample and categorized by baseline/wave 1 cigarette use state

|  | Overall (n=5,029) | Never Cigarette Use (n=2,618) | Current Cigarette Use (n=1,021) | Non-Current Cigarette Use (n=1,390) |
|---|---|---|---|---|
| Mean age in years (SD) | 20.96 (2.33) | 20.24 (1.64) | 21.62 (2.70) | 21.83 (2.66) |
| Male sex | 35.8% | 32.2% | 47.6% | 34.0% |
| 4- vs. 2-year college enrollment | 92.8% | 93.8% | 91.3% | 91.9% |
| Race/ethnicity |  |  |  |  |
| Non-Hispanic, White | 36.1% | 32.0% | 40.8% | 40.4% |
| Hispanic/Latinx | 31.0% | 27.3% | 34.7% | 35.0% |
| Black/African American | 8.1% | 10.0% | 5.6% | 6.4% |
| Asian | 17.4% | 23.1% | 10.9% | 11.2% |
| Other race/ethnicity | 7.5% | 7.6% | 8.0% | 6.9% |

**TABLE 2**

Total number of transitions (row %) between consecutive ENDS use states

| | Transition to state | | |
|---|---|---|---|
| **Transition from state** | **Never** | **Current** | **Non-Current** |
| Never | 13,389 (96%) | 173 (1%) | 356 (3%) [*] |
| Current | Not Applicable [**] | 3218 (66%) | 1630 (34%) |
| Former | Not Applicable [**] | 1184 (12%) | 8709 (88%) |

[*] Represents transitions from never cigarette use to ever (but not current) cigarette use; this transition was not included in the multi-state Markov model addressing the study hypotheses.

[**] Transitions from current use or former use to never use were not allowed.

**TABLE 3**

Hazard ratios (HRs) and confidence intervals (CIs) for current and ever ENDS use, and for socio-demographic, intrapersonal, and interpersonal covariates predicting transitions in three states of cigarette use (never, current/past 30-day, and non-current)

| Exposure Variables and Covariates | Transitions | Unadjusted Models[a] | Adjusted Model |
|---|---|---|---|
| | | **Hazard Ratios (95 % CI)** | |
| Past 30-day ENDS use | Never to Current Use | 4.56 (3.51-5.91) | 2.69 (1.95-3.72) |
| | Current to Non-Current Use | 0.86 (0.77-0.96) | 0.63 (0.53-0.75) |
| | Non-Current to Current Use | 2.25 (1.94-2.60) | 1.92 (1.50-2.45) |
| Ever ENDS Use | Never to Current Use | 2.32 (1.95-2.76) | 2.16 (1.79-2.62) |
| | Current to Non-Current Use | 0.86 (0.78-0.95) | 0.54 (0.47-0.63) |
| | Non-Current to Current Use | 0.88 (0.77-1.00) | 1.14 (0.92-1.40) |
| Male Sex | Never to Current Use | | 1.17 (0.98-1.41) |
| | Current to Non-Current Use | | 0.82 (0.73-0.92) |
| | Non-Current to Current Use | | 1.21 (1.05-1.40) |
| Baseline Age | Never to Current Use | | 0.96 (0.91-1.02) |
| | Current to Non-Current Use | | 0.93 (0.91-0.95) |
| | Non-Current to Current Use | | 0.94 (0.92-0.97) |
| Hispanic | Never to Current Use | | 1.23 (0.98-1.53) |
| | Current to Non-Current Use | | 1.14 (1.00-1.29) |
| | Non-Current to Current Use | | 1.04 (0.89-1.21) |
| African-American/Black | Never to Current Use | | 0.88 (0.63-1.22) |
| | Current to Non-Current Use | | 1.16 (0.91-1.48) |
| | Non-Current to Current Use | | 0.48 (0.34-0.69) |
| Asian-American | Never to Current Use | | 0.98 (0.77-1.25) |
| | Current to Non-Current Use | | 1.32 (1.10-1.58) |
| | Non-Current to Current Use | | 1.03 (0.82-1.29) |
| Other race or ethnicity | Never to Current Use | | 0.91 (0.64-1.30) |
| | Current to Non-Current Use | | 1.00 (0.81-1.24) |
| | Non-Current to Current Use | | 0.86 (0.66-1.12) |
| Four-year college | Never to Current Use | | 1.22 (0.83-1.81) |
| | Current to Non-Current Use | | 1.05 (0.85-1.30) |
| | Non-Current to Current Use | | 1.00 (0.78-1.29) |
| # of other products used | Never to Current Use | | 2.13 (1.80-2.52) |
| | Current to Non-Current Use | | 0.96 (0.88-1.05) |
| | Non-Current to Current Use | | 1.60 (1.43-1.79) |
| Nicotine dependence | Never to Current Use | | 0.97 (0.23-4.11) |
| | Current to Non-Current Use | | 0.42 (0.34-0.53) |
| | Non-Current to Current Use | | 0.88 (0.60-1.29) |
| Sensation seeking | Never to Current Use | | 1.22 (1.10-1.35) |
| | Current to Non-Current Use | | 1.07 (1.01-1.14) |

| Exposure Variables and Covariates | Transitions | Hazard Ratios (95 % CI) | |
|---|---|---|---|
| | | Unadjusted Models[a] | Adjusted Model |
| | Non-Current Use to Current | | 1.17 (1.08-1.27) |
| Depressive symptoms | Never to Current Use | | 1.13 (1.04-1.23) |
| | Current to Non-Current Use | | 0.95 (0.90-1.00) |
| | Non-Current Use to Current | | 1.10 (1.03-1.17) |
| Peer cigarette use | Never to Current Use | | 1.42 (1.29-1.57) |
| | Current to Non-Current Use | | 0.68 (0.64-0.72) |
| | Non-Current Use to Current | | 1.24 (1.15-1.34) |

[a] Two separate unadjusted models were conducted, one for current ENDS use, and one for ever ENDS use.