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Original Investigation

# Electronic Nicotine Product Cessation and Cigarette Smoking: Analysis of Waves 3 and 4 From the PATH Study

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## Abstract

**Introduction:** Identifying predictors of electronic nicotine product (ENP) cessation can inform ENP cessation interventions. High rates of cooccurring ENP and cigarette (dual) use and transitions between these products underscore the importance of considering cigarette smoking status when assessing and addressing ENP cessation.

**Aims and Methods:** We analyzed waves 3 (W3) and 4 (W4) of the Population Assessment of Tobacco and Health (PATH) study to identify (1) W3 socio-demographics, tobacco and ENP use characteristics, and psychosocial correlates of W3 cigarette smoking status (non-smoker, former, and current) among W3 adult ENP users, and (2) W3 predictors of W4 combined ENP and cigarette smoking abstinence relative to use of one or both products.

**Results:** At W3, 65.6% of ENP users concurrently smoked cigarettes. Adjusted multinomial regression results indicated that different W3 socio-demographics, tobacco and ENP use characteristics, and psychosocial correlates were significantly associated with distinct W3 cigarette use profiles. At W4, 9.9% of individuals were abstinent from both products. These individuals were less likely to: (1) be current smokers (vs. non-smokers) or be advised to quit using tobacco, compared with cigarette only or dual users, and (2) use ENPs daily or live in a household allowing ENP use, compared with ENP only or dual users ( $p < .05$ ).

**Conclusions:** ENP cessation approaches need to be tailored to the distinct cigarette use profiles of ENP users. Dual users and daily ENP users may require more intensive interventions to achieve the cessation of both products. Supportive physical environments, such as home vape-free policies, may facilitate ENP cessation.

**Implications:** This analysis contributes to advancing the nascent literature on predictors of electronic nicotine product (ENP) cessation, which can guide the development of ENP cessation interventions by indicating which populations, psychosocial and environmental constructs, and cooccurring behaviors interventions should target. This research also highlights the importance of considering cigarette smoking status when designing ENP cessation interventions and defining intervention outcomes.

## Introduction

The use of electronic nicotine products (ENPs) has emerged as a major public health problem in the United States. ENPs are the second most commonly used tobacco product among U.S. adults, with an estimated 10.9 million current users.<sup>1</sup> Particularly concerning is the dramatic increase in the use of these products in young adults. For instance, among young adults, the prevalence of current (every day or someday) ENP use increased from 2.4% in 2014<sup>2</sup> to 9.3% in 2019.<sup>1</sup> Although ENPs are considered less harmful than traditional cigarettes<sup>3,4</sup> and may be effective in supporting cessation efforts,<sup>5,6</sup> there is much unknown about their long-term health effects.<sup>7-9</sup> Additionally, recent reports of health complications from COVID-19 among youth and young adult ENP users<sup>10</sup> and evidence linking ENP use to initiation of cigarette smoking<sup>11</sup> demonstrate the potential harms of these products. As a result, medical and public health experts have called for urgent action to curb the ENP epidemic.<sup>12</sup>

Addressing both ENP prevention and cessation is critical; however, relatively few efforts have focused on ENP cessation. Identifying factors associated with quitting ENPs can inform ENP cessation approaches by indicating which populations are most in need of help and which intervention targets might optimize intervention outcomes. Social Cognitive Theory (SCT) is a widely used framework for informing health behavior change interventions, including smoking cessation interventions, and thus may have utility in informing ENP cessation interventions. According to SCT, such interventions must take into account individual factors (eg, socio-demographics), psychosocial constructs (eg, social influences, risk perception, motivation), and cooccurring risk behaviors, among other factors.<sup>13</sup>

A primary consideration for ENP cessation is the co-use of other tobacco products, particularly cigarettes. Over 50% of ENP users are estimated to also smoke cigarettes (also referred to as dual users),<sup>14</sup> and a number of analyses using PATH data<sup>15</sup> have shown that transitions between ENPs and cigarettes are common.<sup>16-18</sup> For instance, two studies found that approximately 12% of exclusive ENP users at wave (W) 1 transitioned to exclusive cigarette smoking at W2.<sup>16,17</sup> Additionally, these studies as well as another study found that, among dual users at W1, a substantial proportion quit using ENPs but became exclusive cigarette smokers at W2<sup>16,17</sup> or W3.<sup>18</sup> Thus, failing to consider cigarette smoking status when assessing ENP cessation can misleadingly indicate a positive outcome (quitting ENPs) when it may in fact represent a harmful state (smoking cigarettes).

The above studies also indicate that several tobacco and ENP use characteristics are associated with ENP cessation. One analysis of ENP users (exclusive and dual users) found that being a long-term former smoker (vs. never smoker), using ENPs daily, and using other combustible products at W1 were associated with a lower likelihood of discontinuing ENPs at W2.<sup>16</sup> Another study among dual users found that younger age of first exposure to tobacco products and greater nicotine dependence at W1 were associated with a reduced risk of quitting both products (vs. remaining dual users) at W3.<sup>18</sup> Thus, ENP cessation intervention research must address the broader context of tobacco use behaviors in driving intervention messages and in defining intervention outcomes.

With regard to socio-demographic characteristics, higher education has been shown to correlate with a higher likelihood of ENP cessation.<sup>19</sup> Psychosocial characteristics associated with the likelihood of quitting ENPs include reasons for using ENPs. One study found that those who used ENPs for non-goal oriented reasons such

as curiosity were more likely to quit than those who used it for goal oriented reasons such as quitting smoking.<sup>19</sup> However, reasons for discontinuing ENPs vary based on smoking status, further underscoring the need to address cigarette smoking when developing ENP cessation interventions.<sup>20-24</sup> Never or non-smokers most commonly cite health concerns and cost for discontinuing ENPs.<sup>20,21</sup> Former smokers commonly cite health concerns and not needing ENPs to stay quit as the main reasons for discontinuation.<sup>20-22,24</sup> For dual users, the primary reason for quitting ENPs is because they are perceived to be less satisfying than cigarettes.<sup>20-22,24</sup>

As cigarette smoking status plays a prominent role in ENP cessation, understanding how distinct cigarette use groups differ in terms of socio-demographics, tobacco and ENP use, and psychosocial characteristics can inform tailored ENP cessation approaches. Additionally, given the limited research on ENP cessation, and transitions between ENP and cigarette use, further research, particularly longitudinal research, is needed to identify a range of factors predicting combined ENP and cigarette smoking abstinence that might indicate promising targets for ENP cessation interventions. To date, a handful of studies have examined factors associated with ENP cessation,<sup>16,18,19</sup> but several gaps remain. Two of these studies included cigarette smoking as a covariate and not as part of the outcome measure<sup>16,19</sup> and only one study examined predictors of transitions to complete tobacco/nicotine product cessation.<sup>18</sup> These studies have also largely focused on socio-demographics and tobacco use characteristics and there is limited research on the association between psychosocial and environmental characteristics, and ENP cessation in a nationally representative sample. Finally, while two of these studies analyzed data from earlier waves of the PATH study (W1-W2<sup>16</sup> and W1-W3<sup>18</sup>), the landscape of ENPs underwent significant changes around this period. W2 data collection ended and W3 data collection began in 2015, just as novel fourth-generation ENPs such as JUUL entered the market.<sup>25</sup> Therefore, cigarette use patterns among ENP users and predictors of ENP cessation could have changed. Additionally, there were changes to the PATH study methodology across W1, W2, and later waves. For instance, in W1 and W2, some questions such as plans to quit ENPs were asked only to dual and poly users of tobacco who also used ENPs. However, in W3 and W4, these questions were asked to all current established ENP users. Similarly, W1 and W2 did not specifically assess household rules about using ENPs, but subsequent waves did. Thus, the current analysis builds on previous analyses of PATH data<sup>16,18</sup> and leverages the most recent waves (W3 and W4) to: (1) identify W3 socio-demographics, tobacco and ENP use characteristics, and psychosocial correlates of distinct W3 cigarette use profiles (ie, current, former, and non-smokers) among W3 ENP users, and (2) identify W3 predictors of combined ENP and cigarette smoking abstinence relative to use of one or both products at W4 among W3 ENP users.

## Methods

### Data Source

PATH is a nationally representative longitudinal cohort study of tobacco use in the U.S. civilian, non-institutionalized population. Details of the design and methodology of the PATH study have been published elsewhere.<sup>15</sup> Briefly, the PATH survey used a four-stage stratified area probability sampling design whereby smaller geographic segments were sampled from a stratified sample of geographical primary sampling units (PSUs). Within each geographic segment, residential addresses were sampled and adults were included from

households corresponding to the selected residential addresses. Sampling rates varied by age, race, and tobacco-use status. W3 data was collected between October 2015 and 2016 and W4 data was collected between December 2016 and January 2018.

### Sample

The analytic sample for aim 1 included current established ENP users at W3 with complete data on all W3 variables. The PATH study defines (1) ENPs to include e-cigarettes, vape pens, personal vaporizers and mods, e-cigars, e-pipes, e-hookahs and hookah pens, and (2) current established ENP users as those who have ever used ENPs fairly regularly and currently use them every day or some days. The W3 sample consisted of 28 148 adults, of whom 26 316 were not current established ENP users and 61 were missing data on one or more variables used to define current established ENP use. Of the 1771 ENP users, 32 were missing data on one or more variables used to define cigarette smoking status and 203 were missing data on one or more W3 covariates, resulting in a sample size of 1536.

An additional criterion for the aim 2 analytic sample was non-missing W4 ENP and cigarette use status. Of the 1536 adults in the aim 1 sample, 228 were missing data on W4 ENP and or cigarette use, resulting in a sample size of 1308 for aim 2. This analysis was determined to be non-human subjects research by the George Washington University IRB.

### Measures

**Aim 1 Outcome:** W3 cigarette smoking status among W3 ENP users. This was treated as a three-level categorical variable: (1) current smokers (ie, those who reported smoking at least one cigarette in the past 30 days), (2) former smokers (ie, those who reported no smoking in the past 30 days but smoking 100 cigarettes or more in their lifetime), and (3) non-smokers (ie, those reporting no smoking in the past 30 days and smoking less than 100 cigarettes in their lifetime). The 100-cigarette lifetime threshold was used to discriminate between former established and casual smokers<sup>26</sup> and has been used in previous analyses of PATH data<sup>16,17</sup> as well as large national surveys such as the National Health Interview Survey.<sup>27</sup>

**Aim 2 Outcome:** W4 combined ENP and cigarette use status among W3 ENP users. The dependent variable for Aim 2 was categorized as none (ie, abstinent from both ENPs and cigarettes), use of ENPs only, use of cigarettes only, and use of both products within the past 30 days.

### Independent Variables at W3

**Socio-demographics:** included age (18–24, 25–44, and 45 years or older), gender (male/female), race-ethnicity (non-Hispanic White and other), household income (<\$10 000, \$10 000–49 999, and \$50 000 or more), education (less than high school, completed GED or high school and completed some college or higher), employment (don't currently work, work part-time and work full time), and marital status (never married, married, widowed/divorced/separated).

**Other tobacco products and substance use:** were operationalized as past 30-day use (yes/no) of combustible and non-combustible tobacco products (cigars, cigarillos, pipes, hookah, smokeless tobacco, snus) and marijuana. Combustible and non-combustible tobacco products were combined owing to small sample sizes for the latter.

**ENP use characteristics:** included frequency of use (daily vs. non-daily) and whether the device was rechargeable (yes vs. no/don't know).

**Psychosocial and physical factors:** psychosocial factors included (1) home rules about using ENPs (not allowed, allowed in some places or at some times, and not allowed anywhere or anytime), (2) whether important referents used ENPs (yes vs. no/unsure), (3) perceived harm of using ENPs to health, which was measured on a five-point Likert scale, with response options ranging from not at all harmful to extremely harmful and higher scores indicative of greater perceived harm, (4) readiness to quit using ENPs, defined as planning to quit using ENPs within the next six months (yes/no), and (5) receipt of advice to quit using tobacco from a healthcare provider (yes/no). Physical factors included the presence of respiratory difficulties, that is wheezing and/or dry cough in the past 12 months (yes/no).

### Data Analysis

We first examined bivariate associations between the independent variables and both dependent variables (W3 cigarette smoking status and W4 dual product use status) using chi-square tests for categorical variables and Student's t-test for continuous variables. We also examined bivariate associations among independent variables to assess correlations between predictors and determine which predictors to include in the regression models. Because of high correlations, we chose to omit marital status (correlated with age), employment, and education (correlated with income) in the regression models. The variable indicating whether important referents used ENPs was also excluded from the regression models, as it was not significantly associated with either of the dependent variables at the bivariate level. To identify W3 correlates of W3 cigarette smoking status, we conducted a multinomial logistic regression analysis to estimate adjusted relative risk ratios for all combinations of smoking status (non-smoker vs. former smoker, current smoker vs. former smoker, current smoker vs. non-smoker). Similarly, to identify W3 predictors of W4 combined ENP and cigarette smoking abstinence, we used multinomial logistic regression to estimate adjusted relative risk ratios comparing those abstinent from both products to those using ENPs only, cigarettes only, and both products. Due to the complex survey design, analyses of PATH data require the use of sample weights to account for differential probabilities of selection, non-response rates, and deficiencies in the sampling frame, and replicate weights to correctly calculate standard errors of statistics. W3 single wave weights were used for cross-sectional W3 analyses (aim 1) and W4 all wave weights were used for longitudinal (aim 2) analyses. All analyses used the balanced repeated replications method for variance estimation with Fay's adjustment of 0.3. For descriptive analyses, weighted percentages and logit transformed confidence intervals were calculated. A *p*-value of .05 was considered statistically significant. No adjustments were made for multiple comparisons. All analyses were conducted using Stata version 14.

### Results

Characteristics of the aim 1 sample are presented in [Table 1](#). Among this sample of 1536 ENP users at W3, the majority was male (56.1%), non-Hispanic White (76.8%), had completed some college or more (56.6%), and worked full time (50.9%). A sizeable proportion was between the ages of 25–44 years (45.4%), had a household income between \$10 000 and \$49 999 (49.7%), and was never married (42.6%). At W3, 6.8% of ENP users were non-smokers, 27.6% were former smokers, and 65.6% were current smokers (dual users). The majority did not use other combustible or non-combustible

**Table 1.** Weighted Sample Characteristics of ENP Users by Cigarette Smoking Status, PATH Study Wave 3: 2015–2016

Variable	Total (unweighted N = 1536)	W3 cigarette smoking status			p
		Non-smoker (unweighted N = 128)	Former smoker (unweighted N = 370)	Current smoker (unweighted N = 1038)	
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	
Socio-demographic factors		6.8 (5.5, 8.4)	27.6 (25.1, 30.3)	65.6 (62.8, 68.3)	
Age					
18–24 years	23.8 (21.5, 26.3)	72.6 (59.8, 82.6)	10.6 (8.0, 13.9)	24.3 (21.7, 27.1)	
25–44 years	45.4 (42.6, 48.3)	17.7 (10.1, 29.0)	46.9 (40.7, 53.1)	47.7 (44.2, 51.2)	
45 years or older	30.8 (28.1, 33.6)	9.7 (3.8, 22.6)	42.5 (36.2, 49.0)	28.0 (25.1, 31.2)	<.0001
Male	56.1 (53.1, 59.1)	56.2 (45.1, 66.6)	57.2 (50.7, 63.5)	55.6 (52.5, 58.7)	.8872
Non-Hispanic White	76.8 (74.3, 79.1)	55.3 (44.7, 65.5)	82.8 (77.9, 86.7)	76.5 (73.5, 79.2)	<.0001
Household income					
<\$10 000	15.0 (13.3, 16.8)	21.8 (13.8, 32.6)	6.7 (4.5, 9.8)	17.8 (15.6, 20.3)	
\$10 000–49 999	49.7 (46.9, 52.5)	45.4 (35.1, 56.1)	46.3 (40.5, 52.2)	51.5 (48.1, 54.9)	
\$50 000+	35.3 (32.6, 38.2)	32.8 (23.6, 43.6)	47.0 (41.5, 52.7)	30.7 (27.3, 34.3)	<.0001
Education					
Less than high school	10.3 (8.8, 12.1)	10.1 (5.5, 17.8)	8.6 (6.1, 12.0)	11.1 (9.2, 13.4)	
GED or high school	33.1 (30.3, 36.0)	36.2 (26.1, 47.8)	30.1 (25.1, 35.8)	34.0 (30.4, 37.9)	
Some college or more	56.6 (53.5, 59.6)	53.7 (42.8, 64.2)	61.3 (55.7, 66.5)	54.9 (51.0, 58.7)	.3353
Employment					
Don't work	30.7 (27.9, 33.6)	21.7 (14.6, 31.0)	29.6 (25.0, 34.6)	32.1 (28.8, 35.5)	
Work part time	18.4 (16.4, 20.6)	34.7 (26.1, 44.4)	12.9 (9.5, 17.3)	19.1 (16.78, 21.7)	
Work full time	50.9 (48.0, 53.8)	43.7 (33.8, 54.0)	57.5 (52.0, 62.8)	48.8 (45.3, 52.4)	<.0001
Marital status					
Never married	42.6 (39.7, 45.7)	76.9 (66.1, 85.1)	29.8 (24.0, 36.4)	44.4 (41.2, 47.7)	
Married	35.4 (32.6, 38.3)	17.1 (10.6, 26.5)	49.2 (42.6, 55.8)	31.6 (28.4, 35.0)	
Widowed/divorced/separated	22.0 (19.5, 24.6)	6.0 (1.7, 18.6)	21.0 (16.6, 26.2)	24.0 (21.0, 27.3)	<.0001
Tobacco and substance use characteristics					
Use other tobacco products	29.9 (27.4, 32.6)	37.3 (29.1, 46.4)	13.1 (9.6, 17.7)	36.2 (33.3, 39.2)	<.0001
Use marijuana	26.5 (23.9, 29.3)	32.7 (23.5, 43.5)	16.9 (12.8, 22.0)	29.9 (26.8, 33.1)	.0001
ENP use characteristics					
Use ENPs daily	48.0 (44.8, 51.3)	23.9 (16.2, 34.0)	78.8 (73.3, 83.3)	37.5 (33.8, 41.4)	<.0001
ENP is rechargeable	89.7 (87.6, 91.4)	84.6 (75.2, 90.9)	94.9 (91.6, 97.0)	87.9 (85.3, 90.2)	.0011
Psychosocial and physical factors					
ENP home rules					
Not allowed	28.3 (25.5, 31.2)	48.8 (37.6, 60.1)	22.4 (18.1, 27.4)	28.6 (25.3, 32.2)	
Partially allowed	24.3 (21.6, 27.2)	25.6 (17.2, 36.3)	23.7 (18.9, 29.3)	24.5 (21.3, 27.9)	
Fully allowed	47.4 (44.6, 50.3)	25.6 (17.9, 35.2)	53.9 (48.1, 59.7)	47.0 (43.8, 50.2)	<.0001
Important others use ENPs	47.8 (44.6, 50.9)	44.1 (33.6, 55.2)	52.1 (45.8, 58.3)	46.3 (42.4, 50.2)	.2258
Perceived harm of ENPs, M (95% CI)	2.55 (2.50, 2.60)	2.43 (2.18, 2.68)	2.40 (2.31, 2.49)	2.63 (2.57, 2.68)	.0002
Readiness to quit ENPs	17.6 (15.4, 20.1)	21.5 (13.8, 31.9)	11.3 (8.6, 14.8)	19.9 (17.1, 23.0)	.0010
Advised to quit tobacco	28.5 (26.0, 31.1)	5.6 (3.1, 9.8)	15.5 (12.1, 19.7)	36.3 (32.9, 39.8)	<.0001
Respiratory symptoms in last 12 months	41.5 (38.4, 44.6)	29.6 (19.9, 41.7)	30.4 (24.1, 37.6)	47.3 (44.0, 50.7)	<.0001

Bold values indicate  $p < .05$ .

tobacco products (70.1%) or marijuana (73.5%). A slight majority (52%) were non-daily users of ENPs, and most (89.7%) used rechargeable devices.

### W3 Smoking Status Among W3 ENP Users

Table 1 also provides bivariate analyses results regarding W3 correlates of smoking status (ie, non-smoker, former, current) among W3 ENP users.

In the adjusted multivariable multinomial logistic regression model examining correlates of W3 smoking status among W3 ENP users (Table 2), compared with *former smokers*, *current smokers* were more likely to be younger, use other tobacco products (aRRR = 2.46), use marijuana (aRRR = 1.47), received advice

to quit using tobacco (aRRR = 3.24), and experienced respiratory symptoms in the last 12 months (aRRR = 1.76); however, *current smokers* were less likely than *former smokers* to have a household income  $\geq$ \$10 000, use ENPs daily (vs. non-daily; aRRR = 0.22), and use a rechargeable ENP (aRRR = 0.47).

Compared with *non-smokers*, *current smokers* were more likely to be non-Hispanic White (vs. other; aRRR = 2.31), use other tobacco products (aRRR = 1.70), use ENPs daily (vs. non-daily; aRRR = 1.90), live in a home where ENP use was fully allowed (vs. not allowed; aRRR = 2.01), perceive ENPs to be more harmful (aRRR = 1.43), and received advice to quit using tobacco (aRRR = 6.23), but less likely to be between 18 and 24 years (vs. 45 years or older; aRRR = 0.14).

**Table 2.** Adjusted Multinomial Logistic Regression Results of Cigarette Use Profiles for ENP Users, PATH Study Wave 3: 2015–2016 (Unweighted  $N = 1536$ )

Variable	Current smoker vs. former smoker		Current smoker vs. non-smoker		Non-smoker vs. former smoker	
	aRRR (95% CI)	<i>p</i>	aRRR (95% CI)	<i>p</i>	aRRR (95% CI)	<i>p</i>
Socio-demographic factors						
Age (vs. $\geq 45$ years)	Ref		Ref		Ref	
25–44 years	1.70 (1.13, 2.56)	.011	1.24 (0.36, 4.20)	.732	1.38 (0.38, 4.96)	.621
18–24 years	3.18 (1.93, 5.24)	<.0001	0.14 (0.04, 0.48)	.002	22.21 (5.99, 82.40)	<.0001
Male (vs. female)	0.89 (0.64, 1.24)	.481	1.68 (0.99, 2.86)	.054	0.53 (0.29, 0.97)	.039
Non-Hispanic White (vs. other)	0.89 (0.58, 1.35)	.567	2.31 (1.37, 3.90)	.002	0.38 (0.19, 0.77)	.008
Household income (vs. $< \$10\,000$ )	Ref		Ref		Ref	
\$10 000–49 999	0.48 (0.29, 0.80)	.005	1.12 (0.52, 2.41)	.769	0.43 (0.17, 1.10)	.078
\$50 000+	0.34 (0.20, 0.58)	<.0001	0.68 (0.30, 1.57)	.366	0.50 (0.19, 1.29)	.147
Tobacco and substance use characteristics						
Use other tobacco products	2.46 (1.55, 3.90)	<.0001	1.70 (1.05, 2.75)	.032	1.45 (0.80, 2.61)	.214
Use marijuana	1.47 (1.00, 2.17)	.05	1.24 (0.71, 2.17)	.441	1.19 (0.61, 2.31)	.612
ENP use characteristics						
Daily (vs. nondaily user)	0.22 (0.15, 0.31)	<.0001	1.90 (1.02, 3.53)	.044	0.11 (0.06, 0.22)	<.0001
Rechargeable device	0.47 (0.26, 0.86)	.015	1.23 (0.51, 2.97)	.646	0.38 (0.14, 1.07)	.067
Psychosocial and physical factors						
ENP home rules (vs. not allowed)	Ref		Ref		Ref	
Partially allowed	0.97 (0.62, 1.52)	.893	1.21 (0.60, 2.45)	.593	0.80 (0.36, 1.77)	.579
Fully allowed	1.07 (0.70, 1.62)	.753	2.01 (1.06, 3.80)	.033	0.53 (0.25, 1.12)	.097
Perceived harm of ENPs	1.02 (0.88, 1.18)	.834	1.43 (1.01, 2.02)	.044	0.71 (0.50, 1.02)	.064
Readiness to quit ENPs	1.35 (0.90, 2.02)	.147	0.91 (0.46, 1.80)	.780	1.49 (0.69, 3.20)	.308
Advised to quit tobacco	3.24 (2.19, 4.80)	<.0001	6.23 (3.00, 12.92)	<.0001	0.52 (0.23, 1.17)	.113
Respiratory symptoms in last 12 months	1.76 (1.19, 2.60)	.005	1.21 (0.67, 2.19)	.516	1.45 (0.70, 3.02)	.318

Bold values indicate  $p < .05$ .

Finally, relative to *former smokers*, *non-smokers* were more likely to be between 18 and 24 years (vs. 45 years or older; aRRR = 22.21) but less likely to be male (vs. female; aRRR = 0.53), non-Hispanic White (vs. other; aRRR = 0.38), and use ENPs daily (vs. non-daily; aRRR = 0.11).

#### W4 Combined ENP and Cigarette Smoking Abstinence Among W3 ENP Users

Characteristics of the W4 sample were largely similar to that of the W3 sample (Table 3). Comparisons of characteristics of W3 and W4 participants indicated that those lost to follow-up at W4 were significantly younger, more likely to live in a home where ENP use was not allowed at all, and less likely to be interested in quitting ENPs (results not shown). Table 3 provides bivariate analyses results regarding W3 correlates of W4 combined ENP and cigarette use status (ie, none, ENPs only, cigarettes only, both) among W3 ENP users.

A greater proportion of W3 non-smokers were more likely to be abstinent from both products at W4 (29.3%) than W3 former (15.6%) and current (5.5%) smokers. In adjusted multivariable analyses of W4 combined ENP and cigarette smoking abstinence (Table 4), compared with those *abstinent from both products*: those using *ENPs only* were more likely to have used ENPs daily (vs. nondaily; aRRR = 5.81) and lived in a home where the use of ENPs was partially or fully allowed at W3. Compared with those *abstinent from both products*, those using *cigarettes only* were more likely to have been current smokers (vs. non-smokers; aRRR = 16.77) and been advised to quit using tobacco (aRRR = 2.83) at W3. Finally, compared with those *abstinent from both products*, those using *both products* were also more likely to have been current smokers (vs. non-smokers; aRRR = 8.15), used ENPs daily (vs. non-daily;

aRRR = 3.30), lived in a home where ENP use was fully allowed (vs. not allowed; aRRR = 2.16), and been advised to quit using tobacco (aRRR = 2.52), but were less likely to have been ready to quit using ENPs (aRRR = 0.53) at W3.

#### Discussion

By using data from the most recent waves of the PATH study (W3 and W4), this analysis offers the most current evidence regarding a wide range of predictors of combined ENP and cigarette smoking abstinence, and correlates of cigarette smoking status in a large, nationally representative sample of U.S. adult ENP users. Similar to previous analyses, we found that the majority of ENP users (65.6%) concurrently smoked cigarettes (ie, were dual users).<sup>14,16</sup> We also found that ENP users differed in socio-demographics, tobacco and substance use patterns, and psychosocial characteristics based on their cigarette smoking status.

Socio-demographic correlates of W3 cigarette smoking status included age, race/ethnicity, gender and household income, and the patterns of associations we found are consistent with findings from previous studies. For instance, former smokers were more likely to be older than current smokers and non-smokers,<sup>20,24,28–30</sup> current and former smokers were more likely to be non-Hispanic White,<sup>20,29</sup> and former smokers and non-smokers were more likely to have a higher income than current smokers.<sup>24,28,29</sup>

W3 current smokers were more likely to use other combustible or non-combustible tobacco products than W3 former or non-smokers, and W3 current smokers were more likely than W3 former smokers to use marijuana, similar to results from other analyses.<sup>20,29</sup> ENP use characteristics also differed markedly by smoking status.

**Table 3.** Weighted Sample Characteristics of Wave 3 ENP Users by Wave 4 Combined ENP and Cigarette Use Status, PATH Study Waves 3 and 4: 2015–2018

Variable	Total (unweighted N = 1308)	W4 combined ENP and cigarette use status				p
		None (unweighted N = 136)	ENPs only (unweighted N = 333)	Cigarettes only (unweighted N = 400)	Both (unweighted N = 439)	
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	
Socio-demographic factors		9.9 (7.9, 12.5)	27.7 (25.0, 30.5)	30.0 (27.0, 33.1)	32.4 (29.4, 35.6)	
Age						
18–24 years	23.0 (20.5, 25.6)	29.0 (21.1, 38.5)	19.8 (16.0, 24.4)	24.5 (20.0, 29.6)	22.4 (18.8, 26.4)	
25–44 years	47.0 (43.7, 50.3)	43.9 (34.3, 54.1)	43.9 (37.3, 50.6)	50.2 (43.8, 56.6)	47.6 (41.8, 53.5)	
45 years or older	30.0 (27.2, 33.1)	27.0 (17.9, 38.7)	36.3 (30.1, 43.0)	25.3 (20.6, 30.7)	30.0 (25.2, 35.3)	.1250
Male	56.1 (52.8, 59.3)	48.9 (36.9, 61.1)	60.8 (54.0, 67.1)	57.2 (51.9, 62.4)	53.2 (48.1, 58.2)	.1690
Non-Hispanic White	77.3 (74.6, 79.7)	68.5 (58.3, 77.2)	83.0 (78.5, 86.7)	74.6 (69.8, 78.9)	77.5 (72.3, 81.9)	.0121
Household income						
<\$10 000	15.3 (13.3, 17.6)	16.3 (10.7, 24.1)	9.0 (6.2, 12.7)	21.2 (17.3, 25.6)	15.0 (11.8, 18.9)	
\$10 000–49 999	50.2 (47.1, 53.4)	50.2 (40.2, 60.1)	48.1 (41.7, 54.6)	55.7 (50.7, 60.5)	47.0 (41.7, 52.4)	
\$50 000+	34.5 (31.2, 37.9)	33.5 (24.8, 43.5)	42.9 (36.3, 49.7)	23.1 (18.6, 28.4)	38.0 (32.8, 43.5)	<.0001
Education						
Less than high school	10.0 (8.3, 12.0)	6.6 (3.0, 13.9)	7.6 (4.9, 11.5)	11.9 (8.9, 15.8)	11.4 (8.3, 15.4)	
GED or high school	33.0 (30.0, 36.2)	31.4 (21.9, 42.9)	30.5 (24.2, 37.7)	34.8 (29.7, 40.3)	33.9 (28.4, 40.0)	
Some college or more	57.0 (53.9, 60.0)	62.0 (51.9, 71.2)	61.9 (54.8, 68.6)	53.3 (47.6, 58.9)	54.7 (49.1, 60.2)	.3228
Employment						
Don't work	30.9 (28.0, 34.0)	29.4 (21.5, 38.8)	26.5 (21.2, 32.7)	34.8 (29.2, 40.7)	31.5 (27.0, 36.4)	
Work part time	19.1 (16.6, 21.9)	19.9 (12.7, 29.7)	18.7 (14.2, 24.1)	17.0 (13.3, 21.4)	21.3 (17.0, 26.4)	
Work full time	50.0 (46.5, 53.4)	50.7 (41.2, 60.1)	54.8 (47.8, 61.6)	48.3 (42.6, 54.1)	47.2 (42.7, 51.7)	.3229
Marital status						
Never married	42.7 (39.5, 46.0)	44.3 (35.1, 53.9)	38.5 (32.6, 44.8)	43.9 (39.1, 48.8)	44.8 (39.6, 50.1)	
Married	35.2 (32.3, 38.2)	34.5 (26.1, 44.1)	41.7 (35.8, 47.8)	34.4 (29.3, 39.8)	30.6 (26.3, 35.3)	
Widowed/divorced/ separated	22.1 (19.5, 24.9)	21.2 (13.0, 32.6)	19.8 (15.2, 25.4)	21.8 (17.6, 26.6)	24.6 (20.5, 29.2)	.1908
Tobacco and substance use characteristics						
Smoking status						
Non-smoker	6.7 (5.3, 8.4)	19.6 (13.1, 28.4)	11.2 (8.0, 15.5)	1.9 (1.1, 3.5)	3.2 (1.9, 5.3)	
Former smoker	28.3 (25.7, 31.0)	44.3 (33.4, 55.8)	64.0 (58.0, 69.6)	5.5 (3.4, 8.8)	13.9 (10.3, 18.4)	
Current smoker	65.1 (62.2, 67.8)	36.1 (26.8, 46.6)	24.8 (19.9, 30.4)	92.6 (89.4, 94.8)	83.0 (78.5, 86.7)	<.0001
Use other tobacco products	29.4 (26.6, 32.3)	29.3 (21.4, 38.7)	17.7 (12.9, 23.9)	35.8 (31.0, 41.1)	33.5 (29.1, 38.2)	<.0001
Use marijuana	26.2 (23.3, 29.3)	25.8 (17.0, 37.1)	17.7 (13.5, 22.8)	30.1 (25.1, 35.6)	30.0 (24.9, 35.6)	.0040
ENP use characteristics						
Use ENPs daily	48.8 (45.4, 52.2)	29.5 (21.3, 39.2)	76.7 (70.8, 81.7)	25.5 (20.3, 31.5)	52.5 (46.9, 58.0)	<.0001
ENP is rechargeable	90.0 (87.7, 91.9)	85.1 (76.6, 90.9)	94.4 (90.9, 96.6)	85.2 (80.8, 88.7)	92.1 (87.9, 95.0)	.0008
Psychosocial and physical factors						
ENP home rules						
Not allowed	27.3 (24.4, 30.4)	47.2 (37.3, 57.3)	19.2 (15.1, 24.1)	31.5 (25.8, 37.8)	24.2 (19.4, 29.7)	
Partially allowed	24.6 (21.8, 27.7)	20.4 (13.3, 30.1)	24.6 (20.3, 29.6)	28.1 (22.8, 34.0)	22.7 (19.0, 27.0)	
Fully allowed	48.1 (45.0, 51.2)	32.4 (22.7, 43.8)	56.2 (49.7, 62.4)	40.4 (34.9, 46.2)	53.1 (48.4, 57.7)	<.0001
Important others use ENPs	48.4 (44.8, 51.9)	44.7 (33.4, 56.5)	50.0 (43.8, 56.2)	43.8 (38.0, 49.8)	52.3 (46.6, 57.9)	.1926
Perceived harm of ENPs, M (95% CI)	2.54 (2.48, 2.60)	2.57 (2.37, 2.78)	2.32 (2.20, 2.44)	2.82 (2.70, 2.94)	2.48 (2.36, 2.59)	<.0001
Readiness to quit ENPs	16.1 (14.0, 18.5)	22.6 (15.9, 31.1)	9.2 (6.3, 13.1)	23.6 (18.9, 29.2)	13.1 (10.2, 16.8)	<.0001
Advised to quit tobacco	28.4 (25.7, 31.3)	12.9 (7.4, 21.4)	15.1 (11.2, 20.0)	39.6 (34.5, 44.9)	34.2 (29.2, 39.5)	<.0001
Respiratory symptoms in last 12 months	41.3 (38.0, 44.6)	35.0 (24.9, 46.6)	31.7 (25.4, 38.8)	49.4 (44.6, 54.3)	43.8 (38.8, 48.8)	.0003

Bold values indicate  $p < .05$ .

W3 former smokers were more likely than W3 non-smokers or current smokers to use ENPs daily and were also more likely than W3 current smokers to use a rechargeable device. This is likely due to the fact that among former smokers, a primary reason for using ENPs is to quit smoking.<sup>20–22,24</sup> Therefore, former smokers might invest in a rechargeable device as a cessation aid and may perceive the

need to use ENPs more frequently to remain abstinent from cigarette smoking.<sup>24</sup>

W3 current smokers were also more likely to receive advice to quit using tobacco products than W3 former or non-smokers. This is similar to results from another study, which found that cigarette smokers were more likely to receive advice to quit compared with

**Table 4.** Adjusted Multinomial Logistic Regression Results of Wave 4 Combined ENP and Cigarette Smoking Abstinence for Wave 3 ENP Users, PATH Study Waves 3 and 4: 2015–2018 (Unweighted *N* = 1308)

Variable	ENPs only vs. none		Cigarettes only vs. none		Both vs. none	
	aRRR (95% CI)	<i>p</i>	aRRR (95% CI)	<i>p</i>	aRRR (95% CI)	<i>p</i>
Socio-demographic factors						
Age (vs. ≥45 years)	Ref		Ref		Ref	
25–44 years	0.78 (0.38, 1.63)	.514	1.14 (0.54, 2.40)	.738	0.85 (0.40, 1.77)	.655
18–24 years	0.85 (0.36, 2.01)	.710	1.08 (0.46, 2.52)	.865	0.83 (0.38, 1.81)	.633
Male (vs. female)	1.98 (0.98, 3.99)	.056	1.75 (0.89, 3.42)	.102	1.35 (0.70, 2.62)	.371
Non-Hispanic White (vs. other)	1.36 (0.73, 2.53)	.328	1.11 (0.63, 1.96)	.722	1.00 (0.54, 1.84)	.992
Household income (vs. <\$10 000)	Ref		Ref		Ref	
\$10 000–49 999	1.42 (0.65, 3.14)	.376	0.90 (0.43, 1.86)	.770	0.99 (0.48, 2.07)	.986
\$50 000+	1.49 (0.60, 3.68)	.383	0.68 (0.28, 1.64)	.387	1.44 (0.59, 3.50)	.414
Tobacco and substance use characteristics						
Smoking status (vs. non-smoker)	Ref		Ref		Ref	
Former smoker	0.63 (0.26, 1.51)	.295	0.90 (0.32, 2.52)	.839	0.73 (0.27, 1.96)	.531
Current smoker	0.63 (0.27, 1.50)	.297	<b>16.77 (7.25, 38.77)</b>	<b>&lt;.0001</b>	<b>8.15 (3.69, 18.02)</b>	<b>&lt;.0001</b>
Use other tobacco products	0.82 (0.42, 1.61)	.565	1.00 (0.54, 1.84)	.998	1.18 (0.65, 2.13)	.589
Use marijuana	0.67 (0.34, 1.30)	.232	1.02 (0.56, 1.87)	.942	1.11 (0.57, 2.17)	.755
ENP use characteristics						
Daily (vs. nondaily user)	<b>5.81 (3.17, 10.64)</b>	<b>&lt;.0001</b>	1.30 (0.66, 2.56)	.449	<b>3.30 (1.76, 6.21)</b>	<b>&lt;.0001</b>
Rechargeable device	1.99 (0.99, 4.02)	.054	1.24 (0.62, 2.48)	.544	1.91 (0.97, 3.74)	.060
Psychosocial and physical factors						
ENP home rules (vs. not allowed)	Ref		Ref		Ref	
Partially allowed	<b>2.48 (1.26, 4.91)</b>	<b>.009</b>	1.90 (0.95, 3.78)	.069	1.86 (0.98, 3.53)	.056
Fully allowed	<b>2.48 (1.22, 5.04)</b>	<b>.013</b>	1.74 (0.83, 3.61)	.138	<b>2.16 (1.06, 4.44)</b>	<b>.035</b>
Perceived harm of ENPs	0.98 (0.71, 1.34)	.889	1.30 (0.98, 1.72)	.066	1.04 (0.76, 1.43)	.795
Readiness to quit ENPs	0.57 (0.30, 1.11)	.097	0.82 (0.43, 1.57)	.551	<b>0.53 (0.29, 0.96)</b>	<b>.037</b>
Advised to quit tobacco	1.35 (0.63, 2.90)	.435	<b>2.83 (1.39, 5.78)</b>	<b>.005</b>	<b>2.52 (1.27, 5.01)</b>	<b>.009</b>
Respiratory symptoms in last 12 months	0.83 (0.46, 1.51)	.541	1.15 (0.62, 2.12)	.653	0.96 (0.56, 1.67)	.894

Bold values indicate *p* < .05.

non-cigarette tobacco product users.<sup>31</sup> Several factors could account for this difference, including lack of routine screening for other tobacco products in clinical settings, lack of guidance for providers on ENP cessation, and ambivalence among healthcare providers about the efficacy of ENPs as a smoking cessation aid.<sup>32,33</sup> Similar to other studies, we also found that dual users were more likely than former smokers to experience respiratory difficulties such as wheezing and/or dry cough.<sup>34–36</sup>

Longitudinal predictors of combined ENP and cigarette smoking abstinence largely mirrored findings from previous analyses of PATH data on predictors of ENP discontinuation.<sup>16–18</sup> We also found that socio-demographic characteristics did not predict combined ENP and cigarette smoking abstinence but some tobacco and ENP use characteristics did. Thus, the introduction of newer ENPs such as JUUL does not appear to have changed predictors of ENP cessation. Given that W3 dual users were more likely than W3 non-smokers to use cigarettes only or both products (vs. be abstinent from both products) at W4, and W3 dual users were also more likely than W3 former or non-smokers to use other combustible or non-combustible tobacco products, dual users merit particular attention for interventions, specifically around quitting all tobacco products, because of their high-risk status. This also implies that interventions that successfully promote ENP cessation without attention to smoking or other tobacco product use may not substantially change a user's risk. In terms of ENP use characteristics, daily users at W3 were more likely to use ENPs only or both products (vs. be abstinent from both products) at W4. ENP cessation interventions could encourage and assist daily ENP users with cutting down their frequency to facilitate ENP cessation.

Among psychosocial factors, living in a home freely allowing ENP use at W3 was associated with a greater likelihood of using ENPs only or both products (vs. being abstinent from both products) at W4. Household vaping restrictions are associated with lower vaping prevalence and frequency.<sup>37</sup> Therefore, more efforts are needed to encourage vape-free homes, for instance by emphasizing the potential harms associated with secondhand exposure to aerosols from ENPs.<sup>38</sup> Receiving advice to quit tobacco products at W3 was associated with a greater likelihood of using cigarettes only or both products (vs. being abstinent from both products) at W4. However, this could possibly reflect confounding by smoking status, as current smokers are more likely to receive advice to quit using tobacco and less likely to be abstinent from both products. Finally, readiness to quit using ENPs at W3 was associated with a greater likelihood of abstinence from both products (vs. using both products) at W4, and could serve as a potential target for behavioral ENP cessation interventions for dual users.

These findings illustrate the utility of an SCT framework to inform ENP cessation interventions. Interventions need to be tailored to the complex and heterogeneous profiles of cooccurring risk behaviors and substance use patterns among ENP users. Interventions targeting dual users will need to address cigarette smoking as well as other combustible and non-combustible tobacco product and marijuana use. As a result, dual or poly users might require more intensive behavioral support and pharmacotherapy. Psychosocial intervention targets may also differ across different cigarette use groups. For instance, former smokers use ENPs more frequently to remain abstinent from cigarette smoking, and common reasons for quitting ENPs among former smokers include

safety concerns and not needing ENPs to stay quit.<sup>20,21,24</sup> Thus, ENP cessation approaches tailored to former smokers could emphasize the risks of ENPs, encourage them to cut down on the frequency of use, and build self-efficacy to stay quit, while interventions for dual users may need to increase readiness to quit both products. Supportive social and physical environments, such as vape-free environments could potentially facilitate ENP cessation.

### Strengths and Limitations

Limitations of this analysis include self-report of ENP and cigarette use and small sample sizes for some groups, which is reflected in the wide confidence intervals for some estimates. Additionally, observations that were excluded for missing data may have been associated with the outcomes of ENP and cigarette use, resulting in reduced statistical power and potentially biased estimates. The observational nature of the data precludes us from making any causal conclusions, particularly for W3 analyses, which are cross-sectional. However, strengths of this analysis are the inclusion of a wider range of variables than previous analyses, including psychosocial and environmental variables, and the use of a nationally representative sample, which enhances the generalizability of findings. Given the dearth of research on ENP cessation, these findings can inform the development of ENP cessation interventions.

### Conclusions

Current, former, and non-smoking ENP users differ in socio-demographic, tobacco use, and psychosocial characteristics. Therefore, ENP cessation approaches need to be tailored to the distinct cigarette use profiles of ENP users. Dual users and daily ENP users may require intensive approaches to support abstinence from both products. Promoting the adoption of vape-free policies in homes could create supportive environments that facilitate ENP and cigarette smoking abstinence.

### Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

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### Declaration of Interests

None declared.

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