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Changes in Use Patterns Over 1 Year Among Smokers and Dual Users of Combustible and Electronic Cigarettes

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Abstract

Background: Dual use of combustible and electronic cigarettes (e-cigarettes) is a growing use pattern; more than half of e-cigarette users are dual users. However, little is known regarding the course of dual use; for example, the likelihood of discontinuation of either combustible or e-cigarettes or both.

Methods: Adult daily smokers and dual users (daily smokers who also vaped at least once per week) who did not intend to quit use of either product in the next 30 days participated in a longitudinal, observational study (N = 322, 51.2% women, 62.7% white, mean age = 42.27 [SD = 14.05]). At baseline, participants completed demographics and smoking and vaping history assessments. They also reported daily cigarette and e-cigarette use via timeline follow-back assessment and provided a breath sample for carbon monoxide assay at 4-month intervals for 1 year.

Results: Of those who completed the year 1 follow-up, 1.9% baseline smokers and 8.0% dual users achieved biochemically confirmed seven-day point-prevalence abstinence from combustible cigarettes (χ^2 = 4.57, p = .03). Of initial dual users, by 1 year 43.9% were smoking only, 48.8% continued dual use, 5.9% were vaping only, and 1.4% abstained from both products. Among baseline smokers, 92.3% continued as exclusive smokers. Baseline dual users who continued e-cigarette use were more likely to be white and report higher baseline e-cigarette dependence.

Conclusions: In this community sample, the majority of dual users transitioned to exclusive smoking. A higher percentage of dual users quit smoking than smokers, but attrition and baseline differences between the groups compromise strong conclusions. Sustained e-cigarette use was related to baseline e-cigarette dependence.

Implications: This research suggests that dual use of combustible and e-cigarettes is not a sustained pattern for the majority of dual users, but it is more likely to be a continued pattern if the user is more dependent on e-cigarettes. There was evidence that dual users were more likely to quit smoking than exclusive smokers, but this may be due to factors other than their dual use.

Introduction

As of 2016, 15.4% of US adults had tried an electronic cigarette (e-cigarette) and 3.2% adults currently used them some days or every day[1], although that prevalence rate had declined to 2.8% by 2017[2]. E-cigarette use is higher among smokers; in 2014, 15.9% of smokers were dual users of both products[3] and in 2015 and 2016 more than half of e-cigarette users were dual users (ie, also smoking combustible cigarettes[4,5]). Dual use can be motivated by a variety of factors. A qualitative study found that among 20 dual users, e-cigarette use was prompted by social restrictions and norms regarding smoking, the financial burden of smoking, and the desire to reduce smoking rather than quit[6]. Such factors are likely to continue to motivate the uptake of e-cigarette use among smokers, making it vital to obtain a better understanding of the course and outcomes of such use.

The course of dual use has great public health significance; not only might e-cigarettes confer health risks, but on-going use of combustible cigarettes, even at very low levels, certainly increases health risk[7]. As noted by CDC Director Tom Frieden, it is important to understand how e-cigarette use influences combustible cigarette use to truly understand the public health effects of e-cigarettes[8]. The National Academy of Sciences[9] found that there was no evidence regarding the long-term course of dual use and insufficient evidence regarding its short-term course.

Critical questions in this area concern the likelihood of dual users continuing their e-cigarette use and whether dual use is associated with increased or decreased likelihood of cessation of combustible cigarette use? Arguments can be made that dual use could either hasten or delay smoking cessation. For instance, it is possible that dual use might lead to a longer duration of cigarette use because the use of e-cigarettes might lessen some of the costs of smoking; for example, by reducing withdrawal where smoking is restricted[10] or by offsetting some of the monetary costs of smoking. It is also possible that dual use might promote continued smoking because individuals believe that substituting e-cigarettes for some cigarettes renders their smoking less harmful[11]. On the other hand, dual use might encourage higher quit rates for some of the same reasons that nicotine replacement therapy does so (eg, reduction of smoking urges, providing a coping response[12,13]).

Much of what we know about adult dual use comes from community surveys or cross-sectional studies. Some of this evidence suggests that dual use may help individuals reduce or quit their smoking. A population-based survey showed that smokers who used e-cigarettes for at least a month were more likely to quit smoking than were exclusive smokers[14]. These data are consistent with other population-based cross-sectional studies showing that e-cigarette users are more likely to make quit attempts and to quit smoking successfully than are smokers who do not use e-cigarettes[15,16]. Some experimental studies also support the notion that e-cigarette use may increase the likelihood of smoking cessation. For instance, Jorenby et al.[17] found that smokers using e-cigarettes during a brief cessation period (3 days) were more likely to abstain successfully than were smokers not using e-cigarettes. There have been some randomized clinical trials that show that participants randomized to use nicotine containing e-cigarettes during a quit attempt were modestly more successful at achieving long-term abstinence than were smokers using non-nicotine e-cigarettes[18] and that e-cigarettes are more effective that nicotine replacement therapy in helping smokers quit.[19] Some population based-data indicate that dual use may also decrease smoking heaviness. An internet survey of Dutch e-cigarette users found that dual users on average smoked 82% fewer cigarettes per day after they began using e-cigarettes[20]. Another internet survey of e-cigarette users found that dual use was associated with a significant decrease in smoking heaviness (on average, from 20 to 4 combustible cigarettes per day[21]).

Other data cast doubt on the ability of e-cigarettes to enhance smoking cessation likelihood. Some population-based longitudinal studies find that e-cigarette use is associated with a reduced likelihood of smoking cessation (eg, Al-Delaimy et al.[22]) or that there is no association between e-cigarette use and smoking cessation a year later (eg, Grana et al.[23] and Sweet et al.[24]). Weaver et al.[25] conducted a population-based cohort study of a random probability sample (N = 1248). Amongst the 858 individuals who completed 1-year follow-up, those who had used e-cigarettes at baseline had a lower likelihood of quitting smoking over the course of the year than those who had not used e-cigarettes. A second longitudinal study yielded inconclusive evidence regarding the relation of e-cigarette use with cessation likelihood[26].

The current article will characterize important combustible and e-cigarette use transitions over a 1-year period amongst dual users and smokers who do not plan to change their use patterns in the next month. Because we were interested in the associations of product use patterns with use transitions (eg, becoming abstinent), we did not want to include individuals who might discontinue their use immediately upon entry into the study. This is a longitudinal, observational study that comprised 117 exclusive smokers and 205 dual users who were contacted at 1-year follow-up.

Methods

Adult, daily smokers who were not interested in quitting smoking in the next 30 days were recruited from the greater Madison and Milwaukee, Wisconsin areas via television and social media (eg, Facebook) advertisements. Interested callers completed a telephone screen and eligible participants attended an initial study visit where they learned about the 2-year longitudinal observational study and provided written informed consent. Participants had to be at least 18 years old, able to read and write English, not currently using smoking cessation medication, and not currently in treatment for psychosis or bipolar disorder. Participants also had to be either exclusive smokers (ie, smoked ≥5 cigarettes per day for the past 6 months and had not used e-cigarettes within the last 3 months) or dual users (used nicotine-containing e-cigarettes at least once a week for the past 3 months and had no plans to quit using e-cigarettes and smoked daily for the last 3 months).

At baseline, participants completed assessments of demographics, smoking and e-cigarette history and use patterns, beliefs about cigarettes and e-cigarettes including reasons for initiating e-cigarettes, cigarette and e-cigarette dependence (eg, Fagerström Test of Cigarette Dependence [FTCD][27,28], Wisconsin Inventory of Smoking Dependence Motives [WISDM][29,30], and their parallel e-cigarette dependence measures the e-Fagerström Test for Nicotine Dependence (e-FTND) and e-WISDM), and motivation to quit using cigarettes and/or e-cigarettes. At each visit (every 4 months), participants also provided a breath sample for carbon monoxide assay and a urine sample for cotinine, 3-hydroxycotinine (3HC), and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL) assays. Cotinine is the major proximate metabolite of nicotine, and 3HC is the major metabolite of cotinine[31]. Both cotinine and the sum of cotinine+3HC have been used as biomarkers of daily nicotine intake[32]. NNAL is a metabolite of the tobacco-specific carcinogen NNK, a cause of lung and pancreatic cancer in smokers[33]. Urine cotinine, 3HC, and NNAL were measured by liquid

chromatography–mass spectrometry at the Clinical Pharmacology Laboratory at the University of California San Francisco[34,35].

Participants completed phone assessments at months 2, 6, and 10 and in-person assessments at months 4, 8, and 12. During these assessments participants reported their daily smoking and e-cigarette use. Biochemical verification of year 1 abstinence was established if participants reported seven-day point-prevalence abstinence at month 12 and had an expired carbon monoxide of less than 6 ppm.

Analytic Plan

Using measures of self-reported 30-day point-prevalence abstinence from combustible and e-cigarettes, we examined smoking and vaping behavior at month 4, month 8, and year 1. We also examined participants' transitions from baseline exclusive smoking and dual use to one of four year 1 use outcomes: smoke only, dual use, vape only, no use of combustible or e-cigarettes. To address missing year 1 self-report use data, we conducted supplementary analyses using the SPSS Multiple Imputation procedure, specifying an iterative Markov chain Monte Carlo method and using a set of variables selected a priori. These variables included sociodemographic variables (age, gender, race, and education), smoking- and vaping-related variables (FTCD score, exhaled carbon monoxide, peak smoking rate, spouse or partner smoking, spouse or partner vaping, time spent around smokers, time spent around vapers, and motivation to quit), psychiatric history, month 4 and month 8 use outcome, and group (smoker or dual user) as predictors to impute 10 datasets. These datasets were then combined to classify all participants into one of the four year 1 use outcome categories.

For baseline dual users only, we examined predictors of year 1 smoking and vaping using chi-squares and *t*-tests as well as predictors of transitions into the four year 1 use outcomes using chi-square tests and one-way analysis of variance. Potential predictors examined included demographic variables (gender, race, Hispanic ethnicity, education, income, psychiatric comorbidity), social variables (spouse/partner smoking or vaping), dependence (cigarettes/day, vapes/day, vape days/week, time to first cigarette/vape in the morning, FTCD, e-FTND, WISDM and key subscales including the Primary Dependence Motives [PDM] and Secondary Dependence Motives [SDM], e-WISDM and PDM and SDM subscales, cotinine, NNAL), e-cigarette device characteristics (device type, nicotine level), and beliefs (motivation and confidence to quit combustible and e-cigarettes ["How motivated are you to quit smoking/vaping?" and "How confident are you that you could stop vaping successfully?" on scales from 1 = Not at all to 7 = Extremely motivated/confident], how e-cigarette use changed craving for and use of combustible cigarettes). For significant predictors of the four year 1 use outcomes, we conducted post hoc analyses that only included the dual use and smoking only groups to assess significant differences between those two, most common outcomes. We opted not to predict abstinence from smoking at year 1 among the baseline smokers, given that only three participants in that group reported year 1 smoking abstinence. Using the univariate predictors that were significant in predicting continued use or transition to smoking only, we constructed a backward-elimination best-fitting model.

Results

Of the 422 participants who were enrolled at baseline, 322 (76.3%) completed the year 1 assessment. Table 1 shows that the smokers and dual users who completed the year 1 assessment differed on multiple baseline variables including race, education, and cigarettes smoked per day, consistent with the findings published previously using the full sample[36]. With respect to attrition during the first year of this observational trial, among the dual users, women were more likely to complete the year 1 assessments than were men (87.8% vs. 74.3%, $\chi^2 = 7.34$, $p = .01$) and year 1 completers were significantly older than were noncompleters (40.57 [SD = 13.82] vs. 32.51 [SD = 11.93], $t = -4.18$, $p < .001$). There was no difference in race, ethnicity, education, psychiatric history, time to first cigarette, cigarettes per day, or vape events per day between those who did and did not complete the year 1 assessment. Similarly, among the smokers, those who completed the

Table 1. Group Differences in Demographic and Smoking Variables, *N* (%)

		Total ($N = 322$)	Smokers ($n = 117$)	Dual users ($n = 205$)	Group differences
Gender	Women	165 (51.2%)	64 (54.7%)	101 (49.3%)	$\chi^2 = .88$, $p = .35$
	Men	157 (48.8%)	53 (45.3%)	104 (50.7%)	
Race	White	202 (62.7%)	60 (51.3%)	142 (70.0%)	**$\chi^2 = 24.49$, $p < .001$**
	Black	74 (23.0%)	45 (38.5%)	29 (14.3%)	
	Other	44 (13.7%)	12 (10.3%)	32 (15.8%)	
Hispanic		17 (5.3%)	4 (3.5%)	13 (6.6%)	$\chi^2 = 1.30$, $p = .26$
Education	More than high school	199 (61.8%)	61 (52.1%)	138 (67.6%)	**$\chi^2 = 7.86$, $p = .02$**
	High school/GED	94 (29.2%)	42 (35.9%)	52 (25.5%)	
	Less than high school	28 (8.7%)	14 (12.0%)	14 (6.9%)	
Psychiatric history	Any history	172 (53.4%)	48 (41.0%)	124 (60.5%)	**$\chi^2 = 11.34$, $p = .001$**
	Depression	141 (43.8%)	41 (35.0%)	100 (48.8%)	**$\chi^2 = 5.71$, $p = .02$**
	Anxiety Disorder	90 (28.0%)	28 (23.9%)	62 (30.2%)	$\chi^2 = 1.47$, $p = .23$
	ADD/ADHD	42 (13.0%)	8 (6.8%)	34 (16.6%)	**$\chi^2 = 6.24$, $p = .01$**
Lives with partner who smokes		107 (33.2%)	40 (34.5%)	67 (32.7%)	$\chi^2 = .33$, $p = .85$
Lives with partner who vapes		39 (12.1%)	2 (1.8%)	37 (18.0%)	**$\chi^2 = 20.35$, $p < .001$**
Age (mean [SD])		42.28 (14.05)	45.27 (14.00)	40.57 (13.82)	**$t = 2.93$, $p = .004$**
Baseline cigarettes smoked/d (mean [SD])		13.68 (8.59)	15.73 (10.02)	12.52 (7.43)	**$t = 3.27$, $p = .001$**
FTND score (mean [SD])		4.36 (2.39)	4.72 (2.15)	4.16 (2.49)	**$t = 2.11$, $p = .04$**
Motivation to quit smoking (mean [SD])		3.59 (1.74)	3.40 (1.81)	3.70 (1.69)	$t = -1.50$, $p = .13$

Bolded values are statistically significant ($p < .05$).

ADD/ADHD = Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder; FTND = Fagerström Test for Nicotine Dependence; GED = General Education Development test.

year 1 assessments were more likely to be women (78.0% vs. 63.1%, $\chi^2 = 4.46$, $p = .04$) and older (45.27 [SD = 14.00] vs. 36.22 [SD = 13.28], $t = -3.86$, $p < .001$). Again, there were no differences in race, ethnicity, education, psychiatric history, time to first cigarette, or cigarettes per day with regard to completion of the year 1 assessment. See Table 2 for additional baseline e-cigarette use characteristics among dual users.[36]

Product Use and Transitions Over 1 Year

Biochemically confirmed seven-day point-prevalence combustible cigarette abstinence at year 1 ($n = 279$) was achieved by 2 (1.9%) baseline smokers and 14 (8.0%) dual users ($\chi^2 = 4.57$, $p = .03$). However, self-reported 30-day point-prevalence abstinence ($n = 322$) from combustible cigarettes did not significantly differ between the two use groups: 3 (2.6%) baseline smokers and 15 (7.3%) dual users ($\chi^2 = 3.19$, $p = .07$). Analysis of the multiply imputed dataset yielded a somewhat smaller difference between the two groups with regard to 30-day abstinence (6.7% abstinence among baseline smokers, 9.5% abstinence among dual users). With respect to e-cigarette use, by year 1 6.0% of the baseline smokers and 54.6% of baseline dual users reported vaping within the last 30 days ($\chi^2 = 75.67$, $p < .001$). Results were consistent when using the multiply imputed dataset (12.9% among baseline smokers and 53.5% among dual users).

Among participants who kept smoking at year 1 ($n = 258$), dual users at year 1 went from smoking a mean of 13.14 (SD = 7.61) cigarettes per day at baseline to 11.66 (SD = 9.38) cigarettes per day at year 1, whereas exclusive smokers at year 1 went from smoking a mean of 14.56 (SD = 9.10) cigarettes per day at baseline to 14.20 (SD = 11.25) cigarettes per day at year 1. However, among the 258 participants who were still smoking at year 1, the differences in cigarettes smoked per day between the dual users and exclusive smokers at baseline or year 1 and the change from baseline to year 1 were not statistically significant.

Table 2. Baseline E-cigarette Use Behavior Among Dual Users

E-cigarette use behavior	M (SD) or %
Vape events per day	10.0 (14.2)
Years of vaping	2.7 (2.3)
Age of vaping initiation	36.1 (13.9)
Vape days per week	5.5 (1.9)
Puffs per vaping event	2.2 (1.1)
Vaping within 30 min of waking	48
Type of e-cigarette currently using	
Refillable tank	65.3
Replaceable cartridges	19.2
Disposables	11.4
Most common e-liquid flavors	
Fruit	42.3
Menthol	19.9
No preference	9
Candy	6.6
Tobacco	6.6
Preferred nicotine content	
High nicotine (18–24 mg)	27.8
Very low nicotine (1–6 mg)	26.9
Low-to-medium nicotine (7–12 mg)	23.3
Medium-to-high nicotine (13–17 mg)	14.8
Very high nicotine (>24 mg)	4.5
No nicotine	2.7
Most common reasons for initiating e-cigarette use	
To reduce smoking or smoking urges	63
Curiosity	54
To quit smoking	53
Enjoyed the taste	44
For my health	39

We examined the transitions in use patterns every 4 months. The transition patterns amongst exclusive smokers illustrate that the vast majority maintained a pattern of exclusive smoking (see Figure 1). Although some smokers did experiment with dual use, this pattern did not persist to the subsequent 4-month assessment; almost all baseline smokers were using only combustible cigarettes at year 1 (97.4%). Among dual users, less than half sustained the pattern of both smoking and vaping over time. Figure 2 illustrates that dual use prevalence dropped steadily across the four time points. By year 1, the majority of baseline dual users had transitioned to a different use outcome. Of those transitioning out of dual use who were contacted at year 1, 86% had transitioned to exclusive smoking.

Prediction of Year 1 Use Outcomes for Dual Users

Among baseline dual users, continued smoking at year 1 was predicted by the following baseline measures (along with percentages of those continuing to smoke): smoking within 30 minutes of waking (96.4%) versus those initiating smoking later in the day (85.1%; $\chi^2 = 8.50$, $p = .004$), having no plans to quit smoking in the next year ($n = 57$; 96.5% smoking at year 1) versus having plans to quit ($n = 145$; 91.7%; $\chi^2 = 13.48$, $p = .02$), a higher FTCD score (4.31 [2.42] vs. 2.33 [2.53]; $t = 3.02$, $p = .003$), a higher WISDM PDM score (4.46 [1.43] vs. 3.36 [1.54]; $t = 2.84$, $p = .01$), lower motivation to quit smoking (3.61 [1.68] vs. 4.87 [1.41]; $t = -2.83$, $p = .01$), smoking a greater number of cigarettes per day (12.99 [7.47] vs. 6.53 [3.29]; $t = 6.41$, $p = .001$), a higher cotinine level (1193.82 [788.84] vs. 639.20 [572.90]; $t = 2.67$, $p = .01$), a higher NNAL level (344.43 [349.45] vs. 89.92 [162.37]; $t = 5.04$, $p < .001$), and higher self-rated addiction to cigarettes (75.68 [22.96] vs. 60.73 [23.88]; $t = 2.42$, $p = .02$).

Amongst baseline dual users, the following baseline variables predicted continued use of e-cigarettes at year 1: white race compared to black or other race (64.1% vs. 20.7% vs. 43.8%; $\chi^2 = 20.13$, $p < .001$), household income equal to or greater than $25 000 (65.5% vs. 49.1%; $\chi^2 = 5.19$, $p = .02$), using a rechargeable battery versus a non-rechargeable battery (58.8% vs. 30.8%; $\chi^2 = 3.89$, $p = .049$), living with a vaper (65.5% vs. 49.6%; $\chi^2 = 4.17$; $p = .04$), vaping within 30 minutes of waking (73.1% vs. 45.7%; $\chi^2 = 13.74$, $p < .001$), a lower WISDM SDM score (3.93 [1.15] vs. 4.30 [1.23]; $t = -2.20$, $p = .03$), a higher e-WISDM total score (33.10 [13.03] vs. 26.68 [12.36]; $t = 2.88$, $p = .01$), a higher e-WISDM PDM score (2.89 [1.48] vs. 2.05 [1.26]; $t = 3.61$, $p < .001$), a higher e-WISDM SDM score (3.08 [1.14] vs. 2.64 [1.13]; $t = 2.21$, $p = .03$), higher self-rated addiction to e-cigarettes (46.79 [28.22] vs. 30.50 [22.11]; t = 3.82, $p < .001$), lower confidence in ability to quit vaping (4.61 [2.02] vs. 5.44 [1.76]; $t = -2.44$, $p = .02$), lower motivation to quit vaping (2.29 [1.56] vs. 3.14 [2.14]; $t = -2.48$, $p = .02$), vaping on more days/week (5.93 [1.85] vs. 4.58 [2.09]; $t = 3.98$, $p < .001$), and more vapes/day (11.42 [15.56] vs. 6.34 [6.37]; $t = 2.75$, $p = .01$).

Finally, we examined predictors of transitions from dual use to either smoke only, vape only, or no use at year 1. There were no differences in year 1 use outcome by gender, Hispanic ethnicity, education, income, psychiatric comorbidity, or spouse/partner smoking. However, race, a variety of combustible and e-cigarette dependence measures, motivation to quit vaping and smoking, changes in smoking as a result of vaping, and use of an e-cigarette with a rechargeable battery were baseline predictors of year 1 use outcome

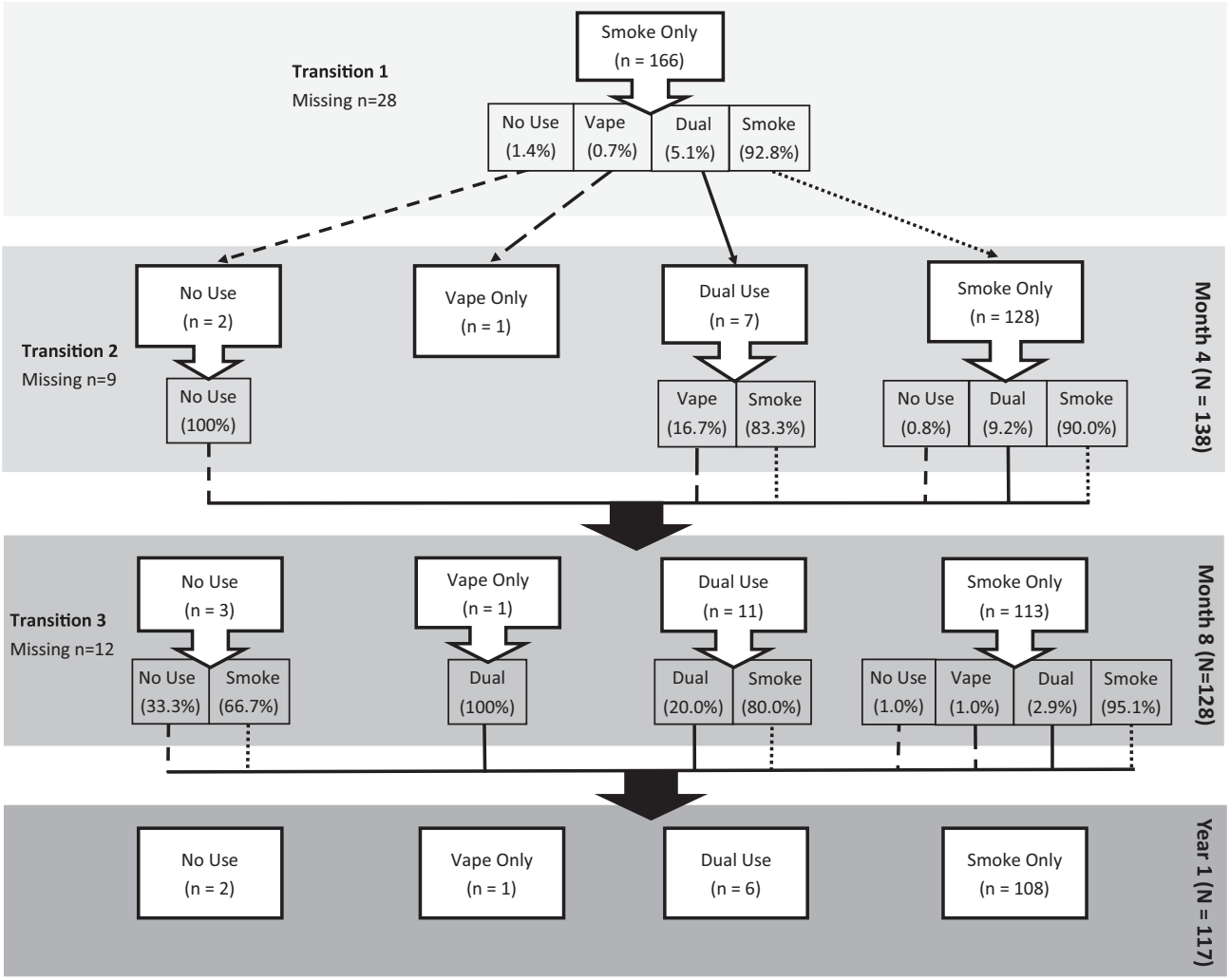

Figure 1. Transitions from baseline to year 1 for baseline exclusive smokers.

category (see Table 3). When we identified the best-fitting model to predict the two most common outcomes among baseline dual users (ie, maintaining dual use or transitioning to smoking only), the logistic regression revealed that race, WISDM SDM, and e-WISDM SDM predicted year 1 use status. Specifically, being white, lower WISDM SDM, and higher e-WISDM SDM were related to increased likelihood of continued dual use.

Discussion

Perhaps the most striking finding of this research is the flux of nicotine product use amongst the individuals who were dual users at baseline. Of the original 256 dual users at baseline, 205 completed the year 1 assessment and less than half of these (n = 100) continued their dual use. Unfortunately, the majority of those who discontinued dual use reverted to exclusive smoking; about 86% were exclusive smokers. The current sample is small and therefore the amount of flux across time could be questioned, although the patterns were similar when missing year 1 data was addressed using multiple imputation. However, the level of flux observed is consistent with that observed in other longitudinal observational studies (eg, Zhuang et al.[37]), including the population-based Population Assessment of Tobacco and Health (PATH) study. Among the dual users at Wave 1 in the PATH study, at Wave 2 44.3% continued dual use, 43.5% were exclusive smokers, 5.1% used e-cigarettes exclusively, and 7.0% were not using either product[38]. Thus, one lesson offered by these data is that concerns about the risks of dual use (eg, potential harms of e-cigarettes, prolonging use of combustible tobacco) should be weighed against the evidence that for many individuals dual use is a fairly transitory state. This may be due to the fact that more than half of the dual users reported initiating e-cigarette use to quit smoking (53%) or to reduce my smoking or smoking urges (63%) (even though they had no immediate plans to quit). If these goals were not met, or were no longer goals, this could be one reason for discontinuing e-cigarette use. It is important to bear in mind that the level of flux observed occurred despite the fact that the inclusion criteria for participation were designed to discourage participation by individuals using e-cigarettes on a short-term, experimental basis: that is, dual users must have used nicotine-containing e-cigarettes at least once a week for the past 3 months and had no plans to quit using them. Yet, within 4 months of induction into the study, 81 of 209 individuals (39%) were no longer dual users (Figure 2).

This research also suggests that dual users are more likely to attain biochemically confirmed abstinence from smoking at 1-year

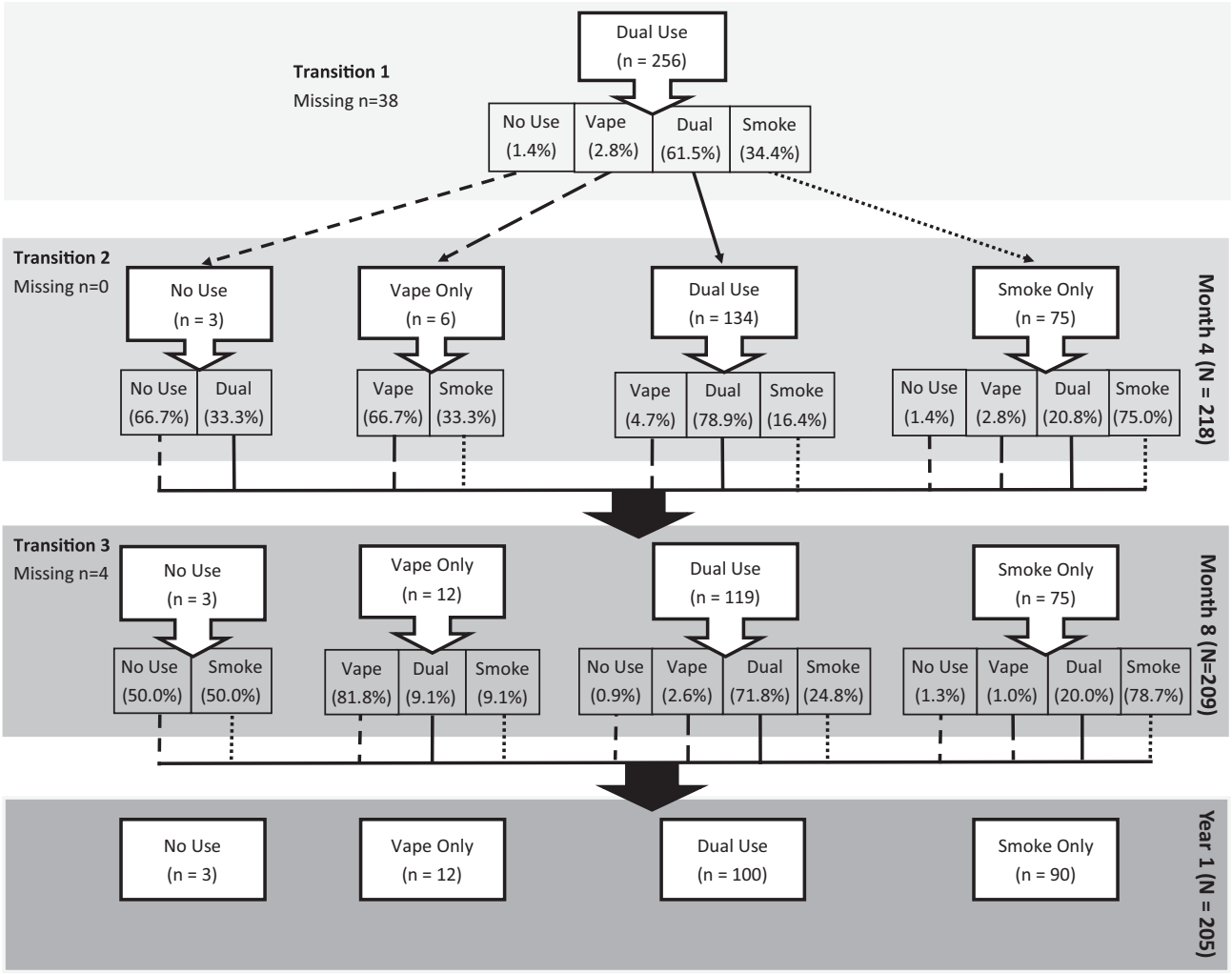

Figure 2. Transitions from baseline to year 1 for baseline dual users.

follow-up (8%) than are exclusive smokers (1.9%). This finding agrees with other evidence that dual use is often associated with a greater likelihood of successful cessation (eg, Zhu et al.[15] and Young-Wolff et al.[39]). However, this finding must be viewed with caution because of the limitations of this study. First, the sample size is relatively small and there was meaningful nonascertainment at year 1 (almost one-quarter of the sample did not complete the year 1 follow-up). Second, the 1-year follow-up does not necessarily reflect long-term cessation as biochemically confirmed abstinence was based on no reported smoking in the previous 7 days at year 1 (self-reported follow-up data do suggest considerable stability in post-transition product use, however). Third, the sample is not necessarily representative of smokers or dual users in general given the participation inclusion and exclusion criteria. And, finally, participants were not randomized to dual use or exclusive smoking status. Therefore, the dual users and exclusive smokers differed on numerous baseline variables that could have accounted for the differential cessation outcomes observed (eg, cigarette dependence, age, race, education, psychiatric history; see Table 1). Some of these differences may be due to the use of e-cigarettes (eg, smoking fewer cigarettes per day might have reduced cigarette dependence) but many reflect the fact that different types of people adopted the two use patterns: dual users were more likely to be white, have more education, and have a greater likelihood of psychiatric comorbidity. Owing to the various meaningful initial differences between dual users and smokers it is impossible to conclude with assurance that dual use per se played a causal role in the transition to nonsmoking, or that e-cigarette use was responsible for many dual users resuming a pattern of exclusive smoking by year 1 follow-up. Who decides to use e-cigarettes may be as or more important than the effects of e-cigarettes per se in determining product use patterns over time.

Some observations though are consistent with the notion that e-cigarette use and its consequences play a causal role in cessation. In particular, dual users appeared to be more likely to transition to vape-only status (ie, quit smoking while using e-cigarettes) if they had higher baseline scores on the e-cigarette dependence measures (Table 2). However, the small number of individuals who transitioned to vape only status limits inference.

The only product use transition at year 1 that involved meaningfully large samples was the comparison of those who did and did not transition back to exclusive smoking. What factors appeared to sustain versus derail e-cigarette use amongst dual users? Certainly race seemed to play a role. Although the majority of whites maintained dual use, three-quarters of black dual users reverted back to

Table 3. Significant Predictors[a] of Year 1 Use Outcome Categories Among Baseline Dual Users

	Dual use	Smoke only	Vape only	No use	
	n = 100	*n* = 90	*n* = 12	*n* = 3	Statistic (*p* value)
Demographic constructs					
Race[b] (%)					$\chi^2 = 22.71$, $p = .001$
White (*n* = 142)	80.8	55.1	91.7	66.7	
Black (*n* = 29)	5.1	24.7	8.3	33.3	
Other (*n* = 32)	14.1	20.2	0.0	0.0	
Social constructs					
Spouse/partner vapes[b]	25.0	11.1	8.3	33.3	$\chi^2 = 14.34$, p = .03
Cigarette dependence					
Smoke within 30 min of waking (%)	71.0	68.9	33.3	33.3	$\chi^2 = 8.59$, $p = .04$
FTND (mean [SD])	4.36 (2.55)	4.24 (2.31)	2.25 (2.70)	2.67 (2.08)	$F = 3.06$, $p = .03$
WISDM PDM (mean [SD])	4.50 (1.57)	4.42 (1.27)	3.15 (1.47)	4.23 (1.81)	$F = 3.19$, $p = .03$
WISDM SDM (mean [SD])	4.00 (1.16)	4.26 (1.23)	3.39 (0.94)	5.49 (0.79)	$F = 3.65$, $p = .01$
WISDM Total (mean [SD])	45.99 (13.40)	47.49 (12.54)	36.31 (11.51)	55.36 (12.56)	$F = 3.16$, $p = .03$
Cigarettes/day (mean [SD])	12.88 (7.59)	13.12 (7.38)	6.00 (3.16)	8.67 (3.51)	$F = 3.77$, $p = .01$
Cotinine[b] (mean [SD])	1307.66 (894.15)	1064.45 (629.22)	724.20 (609.21)	299.22 (198.82)	$F = 4.21$, $p = .01$
Cigarette beliefs					
Motivation to quit smoking (mean [SD])	3.75 (1.62)	3.44 (1.73)	4.83 (1.53)	5.00 (1.00)	$F = 3.20$, $p = .02$
E-cigarette dependence					
e-WISDM PDM[b] (mean [SD])	2.82 (1.42)	2.08 (1.27)	3.43 (1.85)	1.44 (0.62)	$F = 4.70$, $p = .004$
e-WISDM Total[b] (mean [SD])	32.60 (13.06)	26.63 (12.50)	36.60 (12.81)	27.92 (11.67)	$F = 3.10$, $p = .03$
Self-rated addiction to e-cigarettes[b] (mean [SD])	45.02 (28.08)	30.75 (22.34)	59.00 (27.23)	24.50 (20.51)	$F = 5.26$, $p = .002$
Days/week vaping (mean [SD])	5.94 (1.79)	4.60 (2.04)	5.83 (2.33)	4.00 (4.24)	$F = 5.28$, $p = .002$
Vape within 30 min of waking[b] (%)	41.0	20.0	66.7	0.0	$\chi^2 = 17.48$ $p = .001$
E-cigarette beliefs					
Since starting e-cigarette use, your combustible use has (%)					$\chi^2 = 23.24$, $p = .001$
Increased or stayed the same	33.3	54.2	16.7	50.0	
Decreased somewhat	41.7	31.3	8.3	50.0	
Decreased dramatically	25.0	14.6	75.0	0.0	
Since starting e-cigarette use, your craving for cigarettes has (%)					$\chi^2 = 19.24$, $p = .004$
Increased or stayed the same	41.7	58.3	16.7	50.0	
Decreased somewhat	39.3	33.3	25.0	0.0	
Decreased dramatically	19.0	8.3	58.3	50.0	
Confident in ability to quit vaping (mean [SD])	4.69 (2.02)	5.38 (1.77)	4.08 (2.02)	7.00 (0.00)	$F = 2.79$, $p = .04$
Motivation to quit vaping[b] (mean [SD])	2.25 (1.54)	3.19 (2.16)	2.58 (1.73)	2.00 (1.41)	$F = 2.90$, $p = .04$
E-cigarette characteristics					
Rechargeable battery (%)	97.0	90.2	91.7	50.0	$\chi^2 = 9.45$, $p = .02$

FTND = Fagerström Test for Nicotine Dependence; PDM = Primary Dependence Motives; SDM = Secondary Dependence Motives; WISDM = Wisconsin Inventory of Smoking Dependence Motives.

[a]Predictors that were examined and not significantly related to predicting one of the four year 1 use outcome categories included: gender, Hispanic ethnicity, income, psychiatric history, goals for future cigarette and e-cigarette use, a spouse who smokes or vapes, living with someone (not a spouse) who smokers or vapes, type of e-cigarette and whether it is a "mod," e-liquid nicotine concentration, e-liquid flavors, NNAL level, motivation to quit smoking, age of first cigarette, age began daily smoking, number of vape events per day, time to first cigarette, e-WISDM SDM score, e-cigarette cost per week, initial cost of e-cigarette, use of e-cigarettes when smoking is prohibited, number of puffs per vaping session, age of first vape, age began vaping daily.

[b]Indicates a significant predictor in a post hoc analysis that examined only year 1 smoke only and dual use groups.

exclusive smoking. If it is indeed the case that e-cigarette use can facilitate smoking cessation, then the disinclination of blacks to continue e-cigarette use could ultimately add to differences in smoking prevalence and thereby enhance health inequity. Interestingly, level of cigarette dependence did not distinguish those who returned to exclusive smoking; both dual users and exclusive smokers at year 1 had fairly high scores on all baseline measures of cigarette dependence—substantially higher than those who quit smoking completely by year 1. A relatively strong and consistent difference amongst the continuing dual users versus the year 1 exclusive smokers was that the former had developed higher levels of e-cigarette dependence and were more likely to use a rechargeable device, which is associated with delivery of more nicotine than non-rechargeable devices. This is consistent with the notion that adequate substitution of a modified risk tobacco product for combustible cigarettes depends upon the former's ability to develop a competing dependence[9]. Interestingly, those who became exclusive smokers at year 1 had, at baseline, rated themselves as relatively more confident in their ability to quit e-cigarette use. This may reflect their recognition that their dependence on e-cigarettes was low.

In sum, this longitudinal cohort study of smokers and dual users who were initially not interested in changing their use patterns shows that amongst dual users assessed at 1-year follow-up, slightly fewer than half had maintained their pattern of dual use; the majority of

those who discontinued dual use transitioned to exclusive smoking. The data also show that over the course of 1 year, those who were dual users at baseline were more likely to have stopped smoking completely than were those who were exclusive smokers at baseline. However, the sample sizes were modest and dual users differed from exclusive smokers on multiple variables at baseline challenging causal inference. Compared to exclusive smokers, dual users were more likely to be white, more educated, younger, and have a history of psychiatric diagnosis. Finally, discontinuation of dual use was especially common among blacks whereas sustained dual use was associated with relatively strong dependence on e-cigarettes at baseline. These data provide insight into the changes in use patterns over the course of a year, but they do not provide any clear insight into the net public health benefit of e-cigarettes.

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Declaration of Interests

The authors have no conflicts of interest to declare.

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