

Dependence on e-cigarettes and cigarettes in a cross-sectional study of US adults

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ABSTRACT

Background and aims Cigarette smoking often results in nicotine dependence. With use of electronic cigarettes as an alternative source of nicotine, it is important to assess dependence associated with e-cigarette use. This study assesses dependence among current and former adult e-cigarette users on cigarettes and e-cigarettes, compared with dependence on cigarettes. **Design** Cross-sectional data from the Population Assessment of Tobacco and Health (PATH) study from 2013–2016. Psychometrically assessed dependence was compared for cigarettes and e-cigarettes among current and former exclusive and dual users of the products and among e-cigarette users who had and had not recently stopped smoking. **Setting** A population-based representative sample of US adults. **Participants** Participants were 13 311 US adults (18+) in Waves 1–3 of PATH reporting current established smoking, current use of e-cigarettes, or stopping use of either product in the past year who were administered dependence assessments for cigarettes and/or e-cigarettes. **Measurements** A 16-item scale assessing tobacco dependence (on a 1–5 scale), previously validated for assessment and comparison of dependence on varied tobacco products, including cigarettes and e-cigarettes, with a variation assessing residual dependence among users who stopped in the past year. **Findings** Among current users, dependence on e-cigarettes was significantly lower than dependence on cigarettes, in within-subjects comparisons among dual users of both e-cigarettes and cigarettes (1.58 [SE = 0.05] vs. 2.76 [0.04], $P < 0.0001$), and in separate groups of e-cigarette users and cigarette smokers (1.95 [0.05] vs. 2.52 [0.02], $P < 0.0001$), and among both daily and non-daily users of each product. Among former users, residual symptoms were significantly lower for e-cigarettes than cigarettes, both among former dual users (1.23 [0.07] vs. 1.41 [0.06], $P < 0.001$) and among users of one product (1.28 [0.03] vs. 1.53 [0.03], $P < 0.0001$). The highest level of e-cigarette dependence was among e-cigarette users who had stopped smoking (2.17 [0.08]). **Conclusion** Use of e-cigarettes appears to be consistently associated with lower nicotine dependence than cigarette smoking.

Keywords Cigarettes, dependence, electronic cigarettes, nicotine, tobacco, youth use.

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INTRODUCTION

Electronic cigarettes (e-cigarettes) were introduced into the United States (US) ~10 years ago, and their use has increased since then, with 2.8% of adults reporting past-30-day use of e-cigarettes [1]. There is broad agreement that e-cigarettes pose less risk than cigarette smoking [2,3], and thus may have potential for harm reduction, but some have expressed concern about their potential to cause or perpetuate nicotine dependence [4]. Studies suggest that e-cigarettes are associated with less dependence than tobacco cigarettes [5,6] (although see [7]). However, these studies were based on unrepresentative samples (eg,

recruited via online vaping or smoking cessation forums; college students), and used measures that had not been validated for comparing degree of dependence between e-cigarettes and conventional cigarettes. One scale was tested for this purpose, with similar results, but on a small sample of dual users from an opt-in consumer panel [8].

The Population Assessment of Tobacco and Health (PATH) study, a large survey of a representative sample of the US adult population, enables population-based comparisons of dependence on cigarettes and e-cigarettes. PATH's dependence scale was largely drawn from the Wisconsin Inventory of Smoking Dependence Motives (WISDM) [9] and the Nicotine Dependence Syndrome Scale (NDSS)

[10], which have been extensively validated for assessing dependence in smokers, demonstrating relationships to other dependence scales, self-rated addiction, cigarette consumption, laboratory self-administration, persistence or progression of use, craving, withdrawal, and relapse [11–17]. WISDM items have also been validated in e-cigarette users [14]. An additional item was drawn from the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) criteria [18], closely mirroring an item from the Fagerstrom test for Nicotine Dependence, each of which also has evidence of validity [19,20]. Respondents completed the scale for cigarette smoking and, separately, for e-cigarette use (Table S1). Strong et al. [21] applied item response theory (IRT) methods [22] to develop a unidimensional scale that was statistically demonstrated to yield a common metric for both smoking and e-cigarette use; analyses showed no differential item functioning between the cigarette scales and the e-cigarette scales, allowing for like-for-like comparison of scores between products. Strong et al. [21] showed that the scale reliably differentiated daily versus non-daily users both for cigarettes and e-cigarettes. A variation of the items, worded to focus on post-quit experiences, assessed residual symptoms of dependence (Table S2) among people who quit cigarettes or e-cigarettes during the past year, as important symptoms of dependence may appear or persist after quitting.

Strong et al.'s [21] analysis of PATH Wave 1 data suggested that e-cigarettes produced less dependence than cigarette smoking. We extend those findings to a larger sample encompassing three PATH waves, and also distinguish different groups of users to address several questions:

- How does dependence on e-cigarettes compare to dependence on cigarettes?
 - Among users of one product or the other;
 - Among dual users, who represent a very common but distinct pattern of e-cigarette use [23,24]
- How do residual symptoms of dependence differ between recent quitters of cigarettes and/or e-cigarettes?
- What degree of e-cigarette dependence is seen among former smokers who have switched completely to e-cigarettes, who may have shifted their nicotine dependence from cigarettes to e-cigarettes?

METHODS

PATH is a nationally representative survey of tobacco use with annual waves of data collection with a four-stage, stratified probability sample of noninstitutionalized, civilian US adults (approved by the Westat Institutional Review Board) [25]. Adults (ages 18+) were screened in person. African Americans, young adults aged 18–24, and tobacco

users were oversampled. Data were collected at respondents' homes using computer-assisted self-report (in English or Spanish) [26].

Our analyses include the first three waves of the PATH data (Wave 1 September 2013 to December 2014; Wave 2 October 2014 to October 2015; and Wave 3 October 2015 to October 2016). Among screened households, the weighted wave 1 response rate was 74.0% ($n = 32\,320$). Among eligible participants, the weighted response rate for wave 2 was 83.2% ($n = 28\,362$), and wave 3 was 78.4% ($n = 28\,148$).

Study population

The analyses, based on public use datasets [27], included $n = 13\,311$ adult respondents. Table 1 defines the subgroups used in analyses.

Measures

The PATH dependence scale [21] consists of 16 items (15 using a 1–5 scale ranging from “not at all true of me” to “extremely true of me”; one dichotomous item was scored 1 or 5) (Table S1). Items were presented in random order. Following Strong et al. [21], we scored the dependence measure by averaging the relevant items.

The PATH algorithm for administering the dependence items was complex [26]. All established¹ users of e-cigarettes were administered the e-cigarette items (analyses did not distinguish among types of e-cigarettes, because the user base for some types was small, and the distinctions were not consistently made across waves of PATH data). Established cigarette smokers were administered the items about cigarettes only if they did not also use another form of tobacco (other than e-cigarettes); poly-tobacco-users were administered the items with respect to their “tobacco use” in aggregate, which is difficult to interpret and does not specifically assess cigarette dependence. Thus, the cigarette dependence measure analyses focus on established cigarette smokers who did not also use another form of tobacco (e-cigarettes excluded). The e-cigarette dependence measure was assessed on all current users of e-cigarettes. (Table S3 shows that differences between those who did and did not use other products were small, and below the threshold for meaningful differences. Thus, the focus of e-cigarette dependence measure analyses remained on users.) Dual users of both e-cigarettes and cigarettes were administered the items separately for each product (in that order), allowing within-subject comparisons of dependence scores. Additionally, individuals who stopped using e-cigarettes or cigarettes,

¹The PATH study skip patterns precluded informative analysis of ‘experimenters’ who are using a product but have not achieved established use, because the items are administered only if individuals are experimenting with at least two products, and thus only to a highly selected and small subset.

Table 1 Definitions of analysis subgroups.

Category	Definition
Current established smoker ^a	Smoked >100 cigarettes lifetime AND now smokes every day or some days
Current established e-cigarette user ^b	Ever used e-cigarettes “fairly regularly” AND now uses them every day or some days
Current dual user	Meets both above definitions
Former user	Was an established user AND stopped using in the past year
Former dual user	Meets Former User definition for both cigarettes and e-cigarettes
Daily smoker/user	Reports smoking/using at least 27 days in past 30 days
Non-daily smokers/user	Reports smoking/using less than 27 days in past 30 days

^aCould not be using any other tobacco products (e-cigarettes excluded). ^bThis was further stratified (Tables S3–S5) by separating those who did and did not indicate currently using other tobacco products (traditional cigars, cigarillos, filtered cigars, pipe tobacco, hookah, smokeless tobacco, snus, and dissolvable tobacco); those indicating dual use of e-cigarettes and cigarettes are reported under dual user.

respectively, in the past year were administered variant items referring to their current residual dependence-related experiences (e.g., “I still have urges to [smoke cigarettes] [use e-cigarettes]”; see Table S2).

PATH respondents reported demographic data. Current smokers and e-cigarette users were asked how many days per month they smoked/used e-cigarettes. Smokers reported cigarettes per day. Although PATH asked about quantity of consumption for e-cigarettes, the data did not allow for aggregation, or comparison to cigarettes consumption (see Supplement 1). The public-use PATH data also did not allow for detailed computation of duration of use, though it was possible to assess this crudely in a subset of smokers (see Supplement 2).

Statistical analysis

Analyses compared dependence on cigarettes to dependence on e-cigarettes, both among dual users, who were assessed for both products, allowing for within-subject comparisons, and between exclusive smokers and exclusive e-cigarette users, providing between-subject comparisons. Because daily use has a substantial influence on dependence [21,28], and is more common for smoking than for e-cigarette use [29], to compare like with like, we also compared subsets who were either daily users of both or non-daily users of both. Analyses also compared residual dependence among former smokers and former e-cigarette users, both within-subjects (former users of both) and between subjects (former users of one or the other), and among those who stopped using both. PATH data did not distinguish daily use prior to quitting. Finally, analyses compared dependence on e-cigarettes among current users who had quit smoking, compared to those who were currently also smoking.

Analyses used generalized linear models that account for the inclusion of multiple observations from some respondents (PROC GENMOD, with a REPEATED statement, SAS version 9.4), and were weighted per PATH

methodology [26] to generate nationally representative estimates. Our primary analyses adjusted for age, sex, ethnicity, and education, and PATH wave; unadjusted analyses are shown in Table S5. These analyses were not pre-registered on a publicly available platform, so should be considered exploratory.

RESULTS

Table 2 shows the sample sizes and descriptive characteristics of the samples included in the analyses.

Analyses of the PATH dependence scales

The dependence scores for both cigarettes and e-cigarettes covered the full range from 1 to 5, and had very high reliability (Cronbach's $\alpha \geq 0.95$) for both cigarette and e-cigarette assessments, and were systematically related to other measures of dependence, such as time to first use, self-perceived addiction, and craving (Supplement 3). Evidence suggested that differences of ~ 0.40 or more were meaningful (Supplement 4).

Current established users

Table 3 shows the mean dependence scores for the various groups analyzed.

In within-subject comparisons among current established users of *both* cigarettes and e-cigarettes (dual users), dependence was significantly lower on e-cigarettes compared to cigarettes. As shown in Fig. S1, these mean differences reflect large differences in the distribution of scores. Whereas 48% of the scores for cigarette smoking were above 3.0, the mid-point of the scale, this was true for only 8% of e-cigarette scores. The majority of e-cigarette dependence scores (64%) were 1.5 or less, suggesting denial of dependence symptoms, a range seen in <13% of the cigarette-dependence scores. Dependence on e-cigarettes was also lower than

Table 2 Demographics and tobacco use history of PATH adult samples varying by cigarette smoking and e-cigarette use.

	<i>Established smokers^a only</i>	<i>Established e-cigarette users^b</i>	<i>Established dual users of e-cigarettes and cigarettes</i>	<i>Past year former smokers only</i>	<i>Past year former users of e-cigarette only</i>	<i>Past year former dual users of e-cigarettes and cigarettes</i>
$n^c=$	9838	2337	1282	2166	1747	175
$k^d=$	19 257	3422	1673	2487	2039	181
Age (y)^e						
18–24	1609 (10.4)	1043 (32.9)	224 (11.7)	421 (11.3)	700 (29.7)	47 (21.4)
25–34	2193 (22.6)	538 (28.6)	316 (25.9)	617 (27.2)	453 (29.2)	56 (31.5)
35–44	1804 (19.4)	315 (15.3)	287 (24.3)	402 (20.0)	252 (17.3)	29 (18.5)
45–54	1955 (21.1)	220 (10.9)	222 (18.1)	306 (16.5)	174 (11.6)	18 (11.4)
55–64	1521 (17.3)	160 (8.5)	171 (14.0)	271 (15.4)	113 (8.1)	20 (12.1)
65–74	596 (7.0)	51 (3.2)	56 (5.3)	117 (7.4)	46 (3.5)	4 (4.3)
75+	158 (2.2)	10 (0.6)	6 (0.6)	32 (2.3)	9 (0.7)	1 (0.9)
Sex						
Male	4564 (49.9)	1420 (63.2)	530 (45.3)	930 (44.1)	946 (57.1)	77 (49.3)
Female	5270 (50.1)	916 (36.8)	752 (54.7)	1233 (55.9)	801 (42.9)	98 (50.7)
Ethnicity						
Non-Hispanic Caucasian	6404 (67.6)	1553 (70.5)	1006 (81.4)	1432 (69.5)	1180 (72.9)	130 (78.2)
Non-Hispanic African American	1395 (13.9)	207 (9.2)	78 (6.4)	206 (9.4)	147 (8.2)	13 (6.0)
Hispanic	1337 (12.7)	364 (12.5)	106 (6.6)	354 (15.0)	255 (11.9)	20 (9.4)
Non-Hispanic other	677 (5.7)	209 (7.8)	91 (5.6)	168 (6.0)	160 (7.0)	11 (6.3)
Education						
< High school	1786 (17.4)	305 (11.2)	165 (11.9)	232 (10.3)	238 (12.5)	12 (6.4)
High school graduate/GED	3607 (39.1)	834 (36.2)	407 (32.4)	617 (31.8)	557 (30.5)	39 (22.9)
Some college/Associates degree	3314 (31.9)	930 (40.8)	547 (42.0)	853 (34.2)	769 (45.5)	88 (49.5)
College degree or more	1061 (11.6)	243 (11.9)	159 (13.7)	461 (23.7)	176 (11.5)	35 (21.2)
Cigarettes per day						
Mean (SE)	12.41 (0.14)	N/A	11.32 (0.29)	N/A	N/A	N/A
Cigarette days per month						
Mean (SE)	25.92 (0.12)	N/A	24.55 (0.35)	N/A	N/A	N/A
E-cigarette days per month						
Mean (SE)	N/A	18.19 (0.29)	15.20 (0.46)	N/A	N/A	N/A

Due to repeated waves, only demographic characteristics from the first year a respondent was in a given category are included in this table. ^aWho did not currently use another form of tobacco. ^bDue to PATH methodology, all current established e-cigarette users were administered the e-cigarette dependence items, even if they used other tobacco products; this group is limited to those not currently smoking cigarettes. ^cNumber of respondents. ^dNumber of observations; some respondents have multiple observations due to the inclusion of three waves of data. ^eNumbers are unweighted; percentages are weighted.

dependence on smoking among daily users of each product, and among non-daily users of each (Table 3).

A between-subjects analysis among individuals who either smoked cigarettes or used e-cigarettes, but not both, showed the same pattern: dependence was lower among e-cigarette users. Again, this reflected large differences in the distribution of scores, with half the e-cigarette users scoring ≤ 1.5 on the 1–5 scale, compared to 17% for cigarette smokers (Fig. S2). Scores for e-cigarette dependence were lower than those for cigarette dependence both for daily and non-daily users (Table 3).

Former users

Among former established users of both cigarettes and e-cigarettes who stopped both in the past year (i.e., former dual users), within-person comparison showed that residual dependence was significantly lower on e-cigarettes (Table 3).

A similar pattern was seen in between-person comparison of former e-cigarette users and former smokers who were not former dual users. The differences were similar, and slightly larger when the analysis was limited to those

Table 3 Comparisons of dependence on cigarettes and e-cigarettes.

Current users	Adjusted analysis ^a										
	Cigarette dependence				E-cigarette dependence				M_{CIG} M_{ECIG}	95% CI	p^b
	<i>n</i>	<i>k</i>	Mean	SE	<i>n</i>	<i>k</i>	Mean	SE			
Current non-dual users	9768	19 089	2.52	0.02	2310	3382	1.95	0.05	0.56	0.51,0.62	<0.001
Daily cigarettes or e-cigarettes	8271	15 927	2.81	0.02	1149	1671	2.22	0.07	0.58	0.51,0.65	<0.001
Non-daily cigarettes or e-cigarettes	2310	3133	1.64	0.03	1374	1694	1.56	0.06	0.08	0.02,0.15	<0.001
Current dual users (within-subjects)	1277	1664	2.76	0.04	1277	1664	1.58	0.05	1.18	1.07,1.30	<0.001
Both cigarettes and e-cigarettes daily	321	364	2.94	0.12	321	364	1.81	0.09	1.13	0.90,1.36	<0.001
Both cigarettes and e-cigarettes non-daily	155	164	2.14	0.09	155	164	1.38	0.08	0.76	0.51,1.01	<0.001
Former users											
Former non-dual users	2155	2474	1.53	0.03	1735	2022	1.28	0.03	0.25	0.20,0.31	<0.001
Former non-dual users, quit in past 6 months	1587	1779	1.61	0.04	1269	1429	1.33	0.04	0.28	0.22,0.34	<0.001
Former non-dual users, quit in past 3 months	1151	1258	1.71	0.05	870	959	1.42	0.06	0.29	0.20,0.37	<0.001
Former dual users (within-subjects)	173	179	1.41	0.06	173	179	1.23	0.07	0.19	0.02,0.35	<0.001
Current e-cigarette users, smokers vs. former smokers	E-cigarette dependence: stopped smoking ^c				E-cigarette dependence: smoking						
Current e-cigarette users ^d	428	465	2.17	0.08	1277	1664	1.58	0.05	0.59	0.47,0.72	<0.001
Daily e-cigarette use	364	399	2.31	0.10	532	628	1.92	0.08	0.39	0.25,0.53	<0.001
Non-daily e-cigarette use	64	65	1.14	0.05	854	1029	1.24	0.03	-0.11	-0.20, -0.01	<0.036

^aAdjusted analyses control for PATH wave of data collection, age, sex, ethnicity, and education; unadjusted analyses are shown in Table S1. ^bWith Bonferroni correction for 13 tests, all *P*-values except the last one in the table are still *P* < 0.001; the last is *P* = 0.47. ^cQuit in past 12 months. ^dStratified by smoking status: former smoker versus current smoker; never smokers not assessed in this analysis.

who had stopped the respective products within the past 6 months or 3 months. As expected, residual dependence scores trended higher among more recent quitters.

E-cigarette dependence among current versus former smokers

Among the groups examined, the highest level of e-cigarette dependence was reported by current e-cigarette users who had been established cigarette smokers but who had quit smoking in the past year. Their rated dependence on e-cigarettes was higher than that reported among e-cigarette users who were still smoking. (Results were similar for those who had quit within the past 6 months or 3 months; data not shown.) However, their e-cigarette dependence was significantly lower than the cigarette dependence of current smokers, whether the smokers currently used e-cigarettes, had quit e-cigarettes (data not shown), or never used e-cigarettes. The pattern that e-cigarette dependence was higher among those who had stopped smoking cigarettes held for daily e-cigarette users, but was reversed for non-daily e-cigarette

users, where those who were still smoking showed higher (but still low) e-cigarette dependence.

DISCUSSION

The PATH data for the first time allows direct comparison of dependence on cigarettes and on e-cigarettes on the same metric in a large representative population sample. The present analyses compared dependence on cigarettes and dependence on e-cigarettes across a variety of populations varying by current and historical product use. In every comparison, e-cigarette use was associated with significantly less dependence than cigarette smoking. This applied both to within-subject comparisons among the individuals who were currently using both products, as well as to between-person comparisons of individuals who were using one or the other. The differences were substantial, as seen in the distribution of scores: although few e-cigarette users scored as highly dependent on e-cigarettes, most smokers were highly dependent on cigarettes. The mean differences observed among current users, though numerically small, were deemed meaningful (see Supplement 4), with the exception of scores among

non-daily users, where even the cigarette smokers obtained very low scores near the scale's floor, indicating denial of dependence, making observation of meaningful declines difficult. E-cigarette dependence was also lower than cigarette dependence among those who recently stopped using each product, but even the former smokers indicated little or no residual dependence, again making it difficult to observe larger differences. Most striking is the consistency of the findings across multiple subpopulations of users, whether stratified by daily versus non-daily use, or by current or former usage, and whether analyzed within-persons or between persons. In every case, dependence was significantly lower on e-cigarettes than on cigarettes, usually meaningfully so.

Interestingly, among e-cigarette users, the highest rated e-cigarette dependence was seen among the e-cigarette users who had recently quit smoking, especially among those using e-cigarettes daily. This is consistent with the idea that smokers might transition to exclusive e-cigarette use by transferring their dependence to e-cigarettes instead. It could also be due to the fact that stopping smoking completely and transitioning to e-cigarettes is most likely when e-cigarettes are used more regularly and in greater amounts [30,31], which might be associated with greater dependence. This is consistent with the observation that the daily e-cigarette users show higher e-cigarette dependence when they have quit smoking. In any case, even in this group, who had transitioned from smoking to e-cigarettes, dependence on e-cigarettes was less severe than dependence on cigarettes among continuing daily smokers.

Although not a focus of our analyses, the data also show that e-cigarette use tends to occur among smokers who show more cigarette dependence. Although the data are cross-sectional, they suggest one factor that may influence uptake of e-cigarettes.

Altogether, the data suggest that some dependence on e-cigarettes does occur, which is not surprising for devices that deliver nicotine. Health authorities have pointed out that it is not nicotine or nicotine dependence, per se, that causes the vast harms of cigarette smoking, but rather the exposure to toxins in cigarette smoke [2,3,32,33]. Indeed, harm reduction advocates have argued that, from a harm reduction perspective, some degree of dependence potential may even be necessary if e-cigarettes are to compete successfully with cigarettes to displace smoking and reduce risk [34,35], and some harm reduction products have even been criticized for not having high enough abuse liability [36]. Thus, some continued dependence may be a favorable and even necessary trade-off against the expected reduction in physical harm from e-cigarettes.

A limitation of these analyses is that they are based on cross-sectional data; analyses considering the trajectory of dependence over time would add to the picture presented here. As in any observational study, the smokers,

e-cigarette users, and dual users may differ in other ways that shaped their current use patterns; for example, those smokers who, for whatever reason, develop less dependence on e-cigarettes may be less able to switch completely to vaping, and thus become dual users, while smokers who are more dependent might, in turn, have more difficulty switching completely to e-cigarettes. As cigarettes have been available for much longer than e-cigarettes, duration of use is a confounding factor; it is possible that e-cigarette dependence could increase over time as users accumulate years of use. The analyses did not address dependence on particular kinds of e-cigarettes or e-liquids, which may differ in their effectiveness at delivering nicotine; subsequent analyses should consider how these variations affect dependence. Another limitation, deriving from PATH's design, is that a cigarette dependence measure was available only for those smokers who did not also use another (non-e-cigarette) tobacco product, which excluded one of five smokers, who might plausibly differ in dependence. However, among e-cigarette users, we were able to contrast 'pure' e-cigarette users with those also using other tobacco products, and saw only small differences, with both groups showing lower dependence than did 'pure' cigarette smokers. Findings about residual dependence in former smokers and e-cigarette users should be considered with caution, as this assessment was not validated in the Strong et al. [21] PATH analyses. These data also address only adult smokers and e-cigarette users, whereas there is considerable interest in the experience of youth who smoke and/or use e-cigarettes. Finally, at the low end of the scale, the dependence scores were likely subject to floor effects; e.g., with former smokers and current non-daily smokers scoring at dependence levels close to strong denial of dependence-related experience, it may be difficult, both statistically and psychologically, to show further decreases.

Strengths of the analyses include the psychometric strengths of the IRT-based PATH dependence scale, especially its statistically demonstrated ability to validly compare dependence across products. Other strengths include the large and nationally representative sample provided by the PATH survey, and the ability to do comparisons among diverse subsamples stratified by patterns of use.

In sum, multiple analyses showed that, whether they were using one or both products, users were less dependent on e-cigarettes than on traditional combusted cigarettes. These findings were consistent with previous studies [5,6], and suggest that e-cigarettes may have less potential than conventional combusted cigarettes to produce dependence, suggesting that individuals who switch from smoking to e-cigarettes may reduce their nicotine dependence as well as their health risks. This, in turn suggests that smokers who transition from cigarettes to e-cigarettes may find it easier to subsequently transition off e-cigarettes should they try to do so. Further research

is needed on the trajectories of use and dependence among e-cigarette users.

Declaration of interests

At the time the analysis was conducted, Pinney Associates, Inc., provided consulting services on tobacco harm minimization (including smokeless tobacco and vapor products) to R.J. Reynolds Vapor Company, and RAI Services Company, all of which are subsidiaries of Reynolds American Inc. Currently, Pinney Associates, and both authors, consult to JUUL Labs, Inc. regarding e-cigarettes and harm reduction. S.S. also owns an interest in intellectual property for a novel nicotine medication that has not been developed.

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Author contributions

S.S. and M.A.S. had full access to all of the data in the study, which is available for public use, and take responsibility for the accuracy of the data analysis. S.S. conceptualized the project and wrote the majority of the manuscript. M.A.S. performed the data analysis and wrote portions of the manuscript.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 PATH dependence scale items for current users of cigarettes or e-cigarettes

Table S2 PATH dependence scale items for former past 12-month users of cigarettes or e-cigarettes

Table S3 E-cigarette dependence among currently established e-cigarette users, comparing those also using other tobacco products versus e-cigarettes only (none were smoking cigarettes)

Supplement 1 PATH assessment of patterns of use

Supplement 2 Relationship between duration of regular smoking and cigarette dependence

Table S4 Cigarette dependence among current cigarette smokers, based on crude duration of regular use

Table S5 Unadjusted comparisons of dependence on cigarettes and e-cigarettes

Supplement 3 Validation of the PATH dependence measure

Table S6 Correlations between the PATH dependence scale and other dependence indicators

Supplement 4 Estimating meaningful differences on the PATH dependence measure

Table S7 Estimating meaningful differences on the PATH dependence measure

Figure S1 Distribution of cigarette and e-cigarette dependence scores among current dual users

Figure S2 Distribution of cigarette and e-cigarette dependence scores among current non-dual users