

Patterns of Youth Cigarette Experimentation and Onset of Habitual Smoking



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Introduction: Although research suggests that youth e-cigarette experimentation is associated with later combustible cigarette experimentation, it is unclear how this relates to habitual smoking. This study assesses how minors' patterns of combustible cigarette and e-cigarette experimentation relate to habitual smoking at ages 18–21 years.

Methods: Between November 2016 and May 2017, a cross-sectional, online survey of current and retrospective cigarette use was fielded among individuals aged 18–21 years who had tried combustible cigarettes or e-cigarettes ($n=1,424$). Logistic regressions tested how experimentation patterns prior to age 18 years related to two indicators of current habitual smoking: daily smoking and current established smoking (past 30-day use among those who had smoked ≥ 100 cigarettes).

Results: Respondents who first tried combustible cigarettes or e-cigarettes as minors ($n=1,096$) were more likely to be current established users (64%) than those who first experimented at ages 18–21 years (41%). Experimentation patterns in individuals aged <18 years beginning with combustible cigarettes were the most predictive of later smoking. Relative to those who first experimented at ages >17 years ($n=328$), trying only combustible cigarettes as a minor yielded a 175% increase in one's odds of being an established smoker (AOR=2.75, 95% CI=1.99, 3.79) and a 161% increase for daily smoking (AOR=2.61, 95% CI=1.75, 3.90). Trying combustibles and then e-cigarettes yielded sizable increases in both habitual smoking measures, whereas trying e-cigarettes before combustibles yielded smaller effects. Trying only e-cigarettes as a minor yielded a 78% decrease in both outcomes, relative to those who did not try either product as minors.

Conclusions: Minors who tried combustible cigarettes were more likely to be habitual smokers at ages 18–21 years than those who tried e-cigarettes alone.

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INTRODUCTION

The popularity of e-cigarettes raises concerns about their impact on youth smoking (i.e., combustible cigarette use). Observational studies show that minors who try e-cigarettes are more likely to go on to try combustible cigarettes, with the OR for having ever used combustible cigarettes estimated at 3.62 for those who had versus had not tried e-cigarettes at baseline.^{1–20} However, these studies have not addressed whether trying e-cigarettes results in habitual smoking; analyses typically consider ever or recent use (i.e., past 30-day) as outcomes, which may conflate experimentation with regular use. As the mortality effects of smoking seem negligible for those who quit prior to age 25 years,^{21,22}

experimentation alone would not be expected to increase smoking-related mortality.

This study assesses how patterns of experimentation among minors—products tried and order of use—relate to habitual smoking in later adolescence (ages 18–21 years). This age group marks a critical period for study, as the transition from experimentation and initiation to either

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cessation or tobacco habituation often occurs during emerging adulthood.¹⁶ Two indicators are used to capture habitual use: daily smoking and current established smoking (past 30-day use among those with a lifetime consumption of at least 100 cigarettes). Indeed, most combustible cigarette ever-tryers do not proceed to lasting habitual smoking: of individuals aged 25 years who ever tried a combustible cigarette, 36% had smoked 100 combustible cigarettes in their life, with 66% of this subgroup reporting current smoking.²³ Understanding how minors' experimentation patterns relate to their likelihood of habitual smoking would enable better allocation of resources to reduce habitual smoking as well as associated morbidity and mortality.

Investigating how minors' combustible and electronic cigarette experimentation patterns relate to later habitual smoking requires longitudinal or retrospective data on smoking and vaping (i.e., e-cigarette use) specifying both the age at and order of experimentation (i.e., e-cigarettes tried before or after combustible cigarettes). Such data were not available with the requisite detail for a nationally representative sample. Existing surveys like the Population Assessment of Tobacco and Health lack tiebreakers to clarify which product was tried first when respondents tried both at the same age. Thus, new data were collected on current and retrospective smoking and vaping from a national sample of individual ever-tryers aged 18 to 22 years (i.e., individuals who had tried at least one puff of a combustible cigarette, e-cigarette, or both). Focusing on respondents aged 18 to 21 years ($n=1,424$) allows the sample to capture most smoking experimentation and onset of habitual smoking. Specifically, most ever-smokers try their first combustible cigarette as minors, and the median regular smoker initiated regular use at age 17 or 18 years, depending on the data set.²⁴ Thus, with recalled experimentation information, this age range offers a reasonable subgroup in which to examine the transition from experimentation to onset of habitual smoking.²⁴ Twenty-one years is the maximum age for this analysis because older respondents may not have had access to e-cigarettes as adolescents, as e-cigarettes only became broadly available in the U.S. around 2012, despite entering the market 5 years earlier.²⁵

This paper's research question is how different patterns of minors' cigarette experimentation relate to habitual smoking and vaping from ages 18 to 21 years. Hypotheses are that: (1) among those who tried both products as minors, order of experimentation matters, with a greater impact on smoking when combustible cigarettes are tried before e-cigarettes; and (2) minors' e-cigarette experimentation absent combustible cigarette experimentation is not associated with a higher likelihood of habitual smoking in late adolescence. By

analyzing how minors' experimentation patterns relate to habitual use in late adolescence, this study will identify the strongest behavioral predictors of habitual smoking so that prevention funding and resources can be directed accordingly.

METHODS

Study Sample

An online survey of U.S. residents aged 18 to 22 years was administered by Qualtrics from November 2016 through May 2017, using their standing survey panel. Inclusion criteria limited the sample to ever-tryers. The survey obtained data on respondent demographics plus past and current use of both combustible and e-cigarettes. To enhance generalizability, sampling quotas were defined to match the 2015 National Health Interview Survey's weighted distribution of respondents who reported ever-use of either product, by age, sex, education, and Census region.

Qualtrics was contracted to provide data on 2,003 respondents. To anticipate potential data quality issues, they oversampled and provided full data on 2,710 respondents who met the inclusion criteria. Quality checks excluded 52 of these respondents: four were dropped for straight-lining (clicking the same answer for all multiple-choice questions in order to speed through a survey); one failed a minimum time threshold designed to prevent speeding through the survey; and an additional 47 gave mutually exclusive age responses (e.g., reporting an age at first cigarette use that was greater than their current age; reporting first e-cigarette use prior to the product's entry onto the U.S. market; reporting an age and year of birth that did not match). As sampling quotas were defined based on reported age, the last of these exclusions was critical to ensuring that the quotas were filled correctly. A further 27 observations were dropped due to concerns about duplicate responses in observations with matching IP addresses, sex, birth month, and birth year. Thus, 2,631 unique observations passed the aforementioned data quality checks. To ensure the most recent data, the contracted sample of $n=2,003$ individuals aged 18 to 22 years was populated with the latest survey-date observations until each quota was filled. Given the omission of individuals aged 22 years in this study's analysis, the analytic sample contained 1,424 ever-tryers aged 18 to 21 years. Analyses were conducted in 2018.

Measures

Dependent variables were binary indicators for current habitual use (i.e., at the survey date): daily smoking, daily vaping, current established smoking, and current established vaping. Current established use was defined as having reported both past 30-day use of the relevant product, and a lifetime consumption ≥ 100 cigarettes for combustible cigarettes and 100 uses for e-cigarettes. The 100 cigarettes requirement served to distinguish established smoking from mere recent use (i.e., past 30-day use, which could reflect experimentation).²⁶ Similarly, 100 uses provided a parallel means to capture established vaping. Dual users were included in indicators for both smoking and vaping.

Current established use and daily use were not nested indicators. For example, the reference group for daily smokers included current established smokers who did not smoke daily; whereas that for current established smokers included (a very small number of) daily smokers who had not smoked 100 cigarettes.

Henceforth, current established use is referred to as established use, for brevity.

For both combustible and e-cigarettes, respondents who reported having tried that product were asked their age at first use. Those who listed the same age for both products were asked which came first. These data were used to classify experimentation patterns prior to age 18 years into tried: (1) e-cigarettes only, (2) combustible cigarettes only, (3) combustible cigarettes then e-cigarettes, (4) e-cigarettes then combustible cigarettes, (5) both on the same day, and (6) neither.

To adjust for differences in product use by key demographic characteristics, controls included year-of-age fixed effects, as well as binary indicators for: sex, Hispanic ethnicity, and race (black, Asian, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander, with white as the reference group and respondents able to report multiple races). Whether at least one parent completed ≥ 1 year of college was included as a proxy for childhood SES. As parental tobacco use can affect youth use, regressions controlled for binary indicators of whether any parent used (1) combustible cigarettes or (2) e-cigarettes when the respondent was aged 16 years.

Statistical Analysis

First, summary statistics described respondents' demographics plus smoking and vaping as minors and at the survey date. Second, established-use frequencies were calculated, partitioned by respondents' experimentation patterns prior to age 18 years. Finally, logistic regressions examined how experimentation patterns related to indicators of habitual smoking and vaping. Unadjusted results were considered alongside those adjusting for controls.

All analyses used Stata, version 14. Yale University's IRB approved this study (HIC Protocol #1307012384).

RESULTS

Table 1 presents sample demographics, current smoking and vaping, and experimentation patterns prior to age 18 years. The sample was 59.9% male and 81.5% white. Seventy-seven percent of respondents experimented with either combustible or e-cigarettes as a minor. Of these, about 83% started with combustible cigarettes. The average age at first combustible cigarette use (15 years) was lower than that for e-cigarettes (17 years). At age 16 years, 51% of respondents had at least one parent who smoked, whereas only 8.5% had a parent who vaped.

Considering current use, the largest subgroup consisted of those who used neither product habitually (41%), followed by habitual smokers who were not habitual vapers (34%), then dual users (16%), and finally habitual vapers who were not habitual smokers (9%).

Table 2 describes the general relationship between experimentation prior to age 18 years (in columns) and established use at the survey date (in rows). Respondents who experimented with either combustible or e-cigarettes as minors were more likely to be established users than

Table 1. Summary Statistics for Respondents Aged 18–21 Years

Variable	Data
Survey year, M (SD)	2016.3 (0.44)
Age, years, M (SD)	19.7 (1.10)
Age at first cigarette use, years, M (SD)	
CC	15.3 (2.82)
EC	17.3 (1.74)
Parental cigarette use when respondent was aged 16 years, %	
At least 1 parent smoked	50.9
At least 1 parent vaped	8.5
No parent smoked or vaped	46.6
Pre-age-18 years experimentation pattern, %	
Neither	23.0
CC only	34.3
CC then EC	29.7
EC then CC	6.5
EC only	6.0
Both on same day	0.5
Current established use (mutually exclusive categories), %	
None	41.2
Smoker only	34.3
Vaper only	8.9
Dual user	15.6
Current daily smoker, %	25.7
Current daily vaper, %	8.3
Male, %	59.9
Race, %	
White	81.5
Black	11.3
Asian	4.8
American Indian/Alaska Native	5.0
Native Hawaiian/Other Pacific Islander	1.6
Hispanic ethnicity, %	15.6
Either parent completed 1 year or more of college, %	60.2
<i>n</i>	1,424

Note: Survey data means are presented for respondents aged 18–21 years, with SDs given for non-binary variables. As respondents are able to report multiple races, race prevalences do not add to 100. The term *current* refers to behaviors at the respondent's survey date. "Current established use" is indicated if the respondent reported both having used the product in the prior 30 days and a lifetime consumption exceeding 100 cigarettes for CCs (Have you smoked traditional cigarettes at least 100 times in your entire life?) and 100 uses for ECs (Have you used e-cigarettes at least 100 times in your entire life?). CC, combustible cigarette; EC, electronic cigarette.

those who first used at ages ≥ 18 years (64.1% vs 40.9%, respectively). Still, early experimentation did not necessarily lead to habitual use: 35.9% of those who tried a combustible or electronic cigarette as minors were not current established users as of their survey date. Thus,

Table 2. Current Established Use by Pre-age-18 Years Experimentation

Current established use?	Tried combustible or electronic cigarettes as minors?			
	Yes		No	
	n	% (95% CI)	n	% (95% CI)
Yes	703	64.1 (61.2, 67.0)	134	40.9 (35.5, 46.4)
No	393	35.9 (33.0, 38.8)	194	59.1 (53.6, 64.5)

Note: Dividing the sample into those who did versus did not try CCs or ECs as minors, this table displays the percentage of each subgroup who were versus were not current established users of either product when surveyed. Corresponding counts and 95% CIs are also given. "Current established use" refers to those who report current established smoking and/or current established vaping. CC, combustible cigarette; EC, electronic cigarette.

understanding which experimentation patterns among minors most strongly predict later habitual use is critical.

Table 3 summarizes different types of current established use by respondents' experimentation patterns prior to age 18 years. Those who tried combustibles first as minors accounted for 64.0% of the full sample, 79.5% of exclusive smokers, 76.1% of dual users, and more than half of exclusive vapers. By contrast, respondents who tried e-cigarettes first comprised 12.5% of the sample, 3.8% of exclusive smokers, 10.8% of dual users, and 26.8% of exclusive vapers. Two-sample tests of proportions verify that those who tried combustible cigarettes first were significantly more likely to be exclusive smokers ($p < 0.001$) than those who experimented with e-cigarettes first, though the same was not true for dual users ($p = 0.11$).

Logistic regressions examined which experimentation patterns were most likely to result in habitual smoking (i.e., smoker or dual user) and vaping (i.e., vaper or dual user) at the respondent's survey date. Dual use was not examined as a separate outcome due to the small sample size and reduced statistical power when treating these as three mutually exclusive outcomes. Two indicators of habitual use were considered: established use and daily use.

Table 4 presents regressions with and without adjustment for respondent demographics as well as parental combustible and electronic cigarette use when the respondent was aged 16 years. Findings were similar between unadjusted and adjusted regressions, so only the latter are discussed here. Note that the reference group for experimentation patterns was ever-tryers who did not try either product as minors.

Compared with those who did not try either product until ages ≥ 18 years, having tried only combustible cigarettes as a minor was associated with a 175% increase in the odds of being an established smoker (AOR=2.75, 95% CI=1.99, 3.79) and a 161% increase in the odds of being a daily smoker (AOR=2.61, 95% CI=1.75, 3.90). Having tried only e-cigarettes as a minor was associated with a 78% decrease in one's odds of habitual smoking

at ages 18–21 years using either smoking measure (Established Smoking AOR=0.22, 95% CI=0.10, 0.50, Daily Smoking AOR=0.22, 95% CI=0.06, 0.77).

Considering those who tried both products as minors, order of experimentation mattered. Experimenting with combustible cigarettes first and then e-cigarettes was associated with a statistically significant 312% increase in the odds of established smoking (AOR=4.12, 95% CI=2.89, 5.87) and a 214% increase in the odds of daily smoking (AOR=3.14, 95% CI=2.05, 4.81). By contrast, trying e-cigarettes and then combustible cigarettes yielded an 89% increase for established smoking (AOR=1.89, 95% CI=1.09, 3.27) and a statistically insignificant decrease for daily smoking. AORs for "combustible then e-cigarettes" and its inverse were statistically different ($p < 0.01$; Table 4 Wald tests for $\beta_{CC \text{ then } EC} = \beta_{EC \text{ then } CC}$).

Considering e-cigarette use, analyses found that experimentation with only one product as a minor yielded statistically insignificant coefficients for both measures of habitual vaping. However, having tried both combustible and e-cigarettes was associated with increased odds of established vaping, with a greater impact from trying e-cigarettes first (AOR=4.36, 95% CI=2.47, 7.69) versus combustibles first (AOR=2.60, 95% CI=1.74, 3.87). For daily vaping, trying e-cigarettes before combustible cigarettes yielded a statistically significant increase (AOR=2.35, 95% CI=1.03, 5.36), whereas trying combustibles first did not (AOR=1.64, 95% CI=0.90, 2.98).

For both smoking and vaping, parental use of a given product when the respondent was aged 16 years was associated with a $>80\%$ increase in the odds that the respondent would be an established user of that same product in late adolescence. For daily use, parental smoking yielded a 146% increase in the odds of daily smoking (AOR=2.46, 95% CI=1.84, 3.29), whereas parental vaping did not yield a statistically significant impact on daily vaping. In all cases, ORs for the cross-product effects were statistically insignificant.

Table 3. Current Established Smoking and Vaping, by Experimentation Patterns Prior to Age 18 Years

Variable	Smoker only (n=488)		Dual user (n=222)		Vaper only (n=127)		No established use (n=587)		Total (n=1,424)	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
No experimentation as a minor	79	16.2 (13.0, 19.8)	29	13.1 (0.09, 0.18)	26	20.5 (13.8, 28.5)	194	33.0 (29.3, 37.0)	328	23.0 (20.9, 25.3)
Experimentation as a minor										
Tried CCs first	388	79.5 (75.7, 83.0)	169	76.1 (69.9, 81.6)	67	52.8 (43.7, 61.7)	287	48.9 (44.8, 53.0)	911	64.0 (61.4, 66.5)
CC only	221	45.3 (40.8, 49.8)	71	32.0 (25.9, 38.6)	29	22.8 (15.9, 31.1)	167	28.4 (24.8, 32.3)	488	34.3 (31.8, 36.8)
CC then EC	167	34.2 (30.0, 38.6)	98	44.1 (37.5, 50.9)	38	29.9 (22.1, 38.7)	120	20.4 (17.3, 23.9)	423	29.7 (27.3, 32.2)
Tried ECs first	19	3.8 (2.4, 6.0)	24	10.8 (7.1, 15.6)	34	26.8 (19.3, 35.4)	101	17.2 (14.2, 20.5)	178	12.5 (10.8, 14.3)
EC then CC	11	2.3 (1.1, 3.9)	23	10.4 (6.7, 15.1)	18	14.2 (8.6, 21.5)	41	7.0 (5.1, 9.4)	93	6.5 (5.3, 7.9)
EC only	8	1.6 (0.7, 3.2)	1	0.5 (0.0, 2.5)	16	12.6 (7.3, 19.7)	60	10.2 (7.9, 13.0)	85	6.0 (4.8, 7.3)
Tried both on same day	2	0.4 (0.0, 1.5)	0	0 (—)	0	0 (—)	5	0.9 (0.2, 2.0)	7	0.5 (0.2, 1.0)
Total (any use as minor)	409	84.8 (80.2, 87.0)	193	86.9 (81.8, 91.1)	101	79.5 (71.5, 86.2)	393	67.0 (63.0, 70.7)	1,096	77.0 (74.7, 79.1)

Note: Using survey data on respondents ages 18–21 years, the table displays the respondent count for each category of current established use (on survey date), partitioned by respondents' pre-age-18 years experimentation patterns. The percentage of the current use column accounted for by each experimentation pattern is also given. Dual users are current established users of both ECs and CCs. CC, combustible cigarette; EC, e-cigarette.

DISCUSSION

Using newly collected data, this study presents important evidence on the relationship between minors' combustible and electronic cigarette experimentation patterns and subsequent habitual smoking and vaping. Analyses yield three key findings: (1) Thirty-six percent of those who experimented with either product as minors reported no current established smoking or vaping. (2) Consistent with the initial hypotheses, experimentation patterns that began with combustible cigarettes were the most predictive of later habitual smoking. (3) Among ever-tryers, experimentation with e-cigarettes alone prior to age 18 years was associated with a reduced likelihood of habitual smoking in late adolescence, relative to individuals who did not experiment with either product until aged 18 years or later. As more than 50% of habitual smoking in the U.S. begins by age 18 years,¹⁷ these findings suggest that efforts to prevent lasting smoking habits should focus on those who experiment with combustible cigarettes as minors, more than on minors who try only e-cigarettes.

These findings have implications for smoking-prevention efforts. Specifically, habitual smoking is the main cause of tobacco-related morbidity and mortality. The fact that youth combustible cigarette use is a stronger predictor of habitual smoking than youth vaping alone suggests that new efforts to reduce e-cigarette use should not take resources away from effective smoking-prevention programs.

An additional result deserves further discussion. Analyses showed a strong association between parental use of a given product when a respondent was aged 16 years and that respondent's established use of the same product in late adolescence. However, parental vaping when a respondent was aged 16 years had a small and statistically insignificant association with respondent smoking at the survey date. The same was true for parental smoking and respondent vaping. This result suggests that interventions that encourage parents who are resistant to quitting smoking to switch to e-cigarettes should be tested for their effects on youth smoking, particularly as smoking appears to pose larger health risks than vaping.^{2,27–29}

Limitations

Building on the existing literature on youth tobacco experimentation, this study considers how different experimentation patterns among minors relate to onset of habitual use. This is possible only with collection of new data on age and order of first use of combustible and e-cigarettes. Nonetheless, these data have limitations. First, sample selection bias is a concern with online surveys (e.g., online samples often have greater

Table 4. Minors' Experimentation and Habitual Use of Combustible and Electronic Cigarettes at Ages 18–21 Years

Variable	Current established smoking		Daily smoking		Current established vaping		Daily vaping	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Experimentation pre-age-18 years, OR (t-statistic)								
EC only	0.2412** (-3.827)	0.2208** (-3.621)	0.2243* (-2.455)	0.2180* (-2.367)	1.2409 (0.699)	1.3294 (0.863)	0.3352 (-1.460)	0.3265 (-1.445)
CC only	3.0348** (7.429)	2.7480** (6.154)	3.1604** (6.203)	2.6122** (4.701)	1.2793 (1.328)	1.2283 (1.027)	1.1411 (0.473)	1.0130 (0.042)
CC then EC	3.4165** (7.946)	4.1181** (7.833)	3.0979** (5.969)	3.1391** (5.245)	2.3521** (4.731)	2.5974** (4.703)	1.5739 (1.661)	1.6370 (1.610)
EC then CC	1.1739 (0.654)	1.8884* (2.268)	0.4990 (-1.640)	0.7292 (-0.695)	3.9136** (5.333)	4.3622** (5.086)	2.4649* (2.476)	2.3495* (2.032)
Both on same day	0.8148 (-0.242)	0.9229 (-0.081)	2.4522 (1.053)	3.5997 (1.294)	Dropped ^a	Dropped ^a	Dropped ^a	Dropped ^a
Parental use, OR (t-statistic)								
Parent smoked when respondent was aged 16 years	—	1.9554** (5.308)	—	2.4574** (6.064)	—	1.1523 (1.009)	—	1.0521 (0.235)
Parent vaped when respondent was aged 16 years	—	1.0507 (0.223)	—	0.8666 (-0.566)	—	1.8078** (2.675)	—	1.2527 (0.654)
Constant	0.4909** (-6.056)	0.3395* (-2.061)	0.1631** (-11.403)	0.1889** (-2.825)	0.2015** (-10.840)	0.0346** (-4.790)	0.0719** (-11.926)	0.0146** (-3.781)
Demographic and state fixed effects?	No	Yes	No	Yes	No	Yes	No	Yes
<i>n</i>	1,424	1,414	1,424	1,406	1,417	1,399	1,417	1,263
Adjusted <i>R</i> ²	0.078	0.161	0.066	0.187	0.029	0.097	0.016	0.096
Wald test <i>p</i> -values								
$\beta_{\text{CC then EC}} = \beta_{\text{EC then CC}}$	0.000**	0.003**	0.000**	0.001**	0.029*	0.044*	0.176	0.332
$\beta_{\text{Parent Smoked, R 16}} =$	—	0.021*	—	0.001**	—	0.106	—	0.684
$\beta_{\text{Parent Vaped, R 16}}$								

Note: Boldface indicates statistical significance (* $p < 0.05$, ** $p < 0.01$). Logistic regressions examine how patterns of cigarette experimentation prior to age 18 years relate to indicators of habitual smoking and vaping among ever-triers aged 18–21 years. Each numbered column presents a separate regression analysis, with controls for demographic variables and state fixed effects included in the even-numbered analyses only. Demographic controls not listed above are fixed effects for sex, age, Hispanic ethnicity, race (black, Asian, Native Hawaiian/Other Pacific Islander, and American Indian/Alaska Native), and whether any parent had completed 1 year or more of college. The reference group is white, non-Hispanic, females aged 18 years who had not experimented with either CCs or ECs as minors, and whose parents had not used either of these when the respondent was aged 16 years.

^aHaving first tried CCs and ECs on the same date perfectly predicts current established vaping and daily vaping. Similarly, some states' fixed effects perfectly predict the dependent variable's value. Thus, vaping regressions and analyses with state fixed effects drop some respondents. CC, combustible cigarette; EC, e-cigarette.

computer literacy, though this may be less of an issue for individuals aged 18–21 years). Similarly, recall bias could be a problem: if those who try a tobacco product only once are less likely to recall doing so, the sample may be somewhat more susceptible to habitual use than the general ever-trier population.³⁰ Reassuringly, evidence suggests high accuracy in recalled smoking status data even 20 years later, regardless of current smoking status; and this survey's respondents typically report on behaviors occurring within the prior 10 years.³¹ Other data limitations include lack of data on additional indicators of susceptibility to tobacco use, as well as use of noncigarette tobacco products and zero-nicotine e-cigarettes, a common behavior among youths who vape.^{32,33} If those who only experimented with e-cigarettes were more likely to use zero-nicotine e-cigarettes, this might help explain the negative relationship between e-cigarette–only experimentation and later habitual smoking.

Cohort effects limit the results' generalizability to today's youth. Specifically, respondents lacked access to e-cigarettes at very young ages and would not have had access to the more modern (and higher nicotine delivery) products (e.g., JUUL). Thus, as e-cigarette products evolve and younger cohorts age into adolescence, these results and their policy implications should be revisited. Also, as the data do not cover behavior after age 21 years, conclusions here rely on the fact that most habitual smoking begins prior to this age.²⁴ Because of this censoring, results may not reflect longer-run habit formation, with potential for bias stemming from the relatively earlier age of first combustible cigarette use relative to first e-cigarette use in this sample (leaving less time for habit formation in the latter case). Because relatively few respondents reported both having used only e-cigarettes as minors and exclusive smoking at their survey date, future work should assess the stability of these results related to this subgroup, and account for behaviors in later young adulthood.

Finally, these analyses identify associations, not causal effects. Importantly, this does not preclude their use to identify minors at highest risk for future habitual smoking.

CONCLUSIONS

Results indicate that not all youth cigarette experimentation is equal in terms of later habit formation. Specifically, minors who tried combustible cigarettes first (or only) showed substantially greater likelihoods of habitual smoking by ages 18 to 21 years relative to both (1) those who tried e-cigarettes before combustible cigarettes, and (2) those whose did not try either product as minors. By contrast, those who tried only e-cigarettes as minors had a

lower probability of developing habitual smoking by ages 18 to 21 years, with no significant impact on habitual vaping. Thus, the group at highest risk for habitual smoking was minors who tried combustible cigarettes, much more so than minors who used e-cigarettes alone. Because minors' combustible cigarette use remains the strongest predictor of later habitual smoking, prevention efforts should take care not to divert funds away from effective anti-smoking efforts, even as they aim to address newer tobacco products.

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All authors contributed to the survey development and had access to the data. Dr. Friedman designed and conducted the statistical analysis, prepared the manuscript's first draft, and contributed to subsequent revisions. Drs. Sindelar and Buckell contributed to the data interpretation and manuscript revisions.

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REFERENCES

1. Soneji S, Barrington-Trimis JL, Wills TA, et al. Association between initial use of e-cigarettes and subsequent cigarette smoking among adolescents and young adults: a systematic review and meta-analysis. *JAMA Pediatr.* 2017;171(8):788–797. <https://doi.org/10.1001/jamapediatrics.2017.3209>.
2. National Academies of Sciences, Engineering, and Medicine. Public Health Consequences of E-Cigarettes. Washington, DC: The National Academies Press; 2018. www.nap.edu/catalog/24952/public-health-consequences-of-e-cigarettes. Accessed February 21, 2018.
3. Loukas A, Marti CN, Cooper M, Pasch KE, Perry CL. Exclusive e-cigarette use predicts cigarette initiation among college students. *Addict Behav.* 2018;76:343–347. <https://doi.org/10.1016/j.addbeh.2017.08.023>.
4. Leventhal AM, Strong DR, Kirkpatrick MG, et al. Association of electronic cigarette use with initiation of combustible tobacco product smoking in early adolescence. *JAMA.* 2015;314(7):700–707. <https://doi.org/10.1001/jama.2015.8950>.
5. Primack BA, Soneji S, Stoolmiller M, Fine MJ, Sargent JD. Progression to traditional cigarette smoking after electronic cigarette use among U.S. adolescents and young adults. *JAMA Pediatr.* 2015;169(11):1018–1023. <https://doi.org/10.1001/jamapediatrics.2015.1742>.
6. Wills TA, Knight R, Sargent JD, Gibbons FX, Pagano I, Williams RJ. Longitudinal study of e-cigarette use and onset of cigarette smoking among high school students in Hawaii. *Tob Control.* 2016;26(1):34–39. <https://doi.org/10.1136/tobaccocontrol-2015-052705>.
7. Barrington-Trimis JL, Urman R, Berhane K, et al. E-cigarettes and future cigarette use. *Pediatrics.* 2016;138(1):e20160379. <https://doi.org/10.1542/peds.2016-0379>.
8. Primack B, Shensa A, Sidani JE, et al. Initiation of cigarette smoking after e-cigarette use: a nationally representative study [abstract]. www.sbm.org/UserFiles/file/2016AbstractSupplement.pdf. Accessed July 15, 2016.

9. Unger JB, Soto DW, Leventhal A. E-cigarette use and subsequent cigarette and marijuana use among Hispanic young adults. *Drug Alcohol Depend.* 2016;163(suppl C):261–264. <https://doi.org/10.1016/j.drugalcdep.2016.04.027>.
10. Hornik RC, Gibson L, Lerman C. POS5-30: prediction of cigarette use from six-month prior electronic and combustible cigarette use for a U.S. national sample of 13–25 year olds [abstract]. http://c.ymcdn.com/sites/www.srnt.org/resource/resmgr/Conferences/2016_Annual_Meeting/Program/SRNT_2016_Rapids_WEB2.pdf. Accessed November 18, 2017.
11. Spindle TR, Hiler MM, Cooke ME, Eissenberg T, Kendler KS, Dick DM. Electronic cigarette use and uptake of cigarette smoking: a longitudinal examination of U.S. college students. *Addict Behav.* 2017;67:66–72. <https://doi.org/10.1016/j.addbeh.2016.12.009>.
12. Miech R, Patrick ME, O'Malley PM, Johnston LD. E-cigarette use as a predictor of cigarette smoking: results from a 1-year follow-up of a national sample of 12th grade students. *Tob Control.* 2017;26(e2):e106–e111. <https://doi.org/10.1136/tobaccocontrol-2016-053291>.
13. Bold KW, Kong G, Camenga DR, et al. Trajectories of e-cigarette and conventional cigarette use among youth. *Pediatrics.* 2017;141(1):e20171832. <https://doi.org/10.1542/peds.2017-1832>.
14. Glasser A, Abudayyeh H, Cantrell J, Niaura R. Patterns of e-cigarette use among youth and young adults: review of the impact of e-cigarettes on cigarette smoking. *Nicotine Tob Res.* In press. Online May 17, 2018. <https://doi.org/10.1093/ntr/nty103>.
15. Péntzes M, Foley KL, Nádășan V, Paulik E, Ábrám Z, Urbán R. Bidirectional associations of e-cigarette, conventional cigarette and waterpipe experimentation among adolescents: a cross-lagged model. *Addict Behav.* 2018;80:59–64. <https://doi.org/10.1016/j.addbeh.2018.01.010>.
16. Hair EC, Romberg AR, Niaura R, et al. Longitudinal tobacco use transitions among adolescents and young adults: 2014–2016. *Nicotine Tob Res.* 2019;21(4):458–468. <https://doi.org/10.1093/ntr/ntx285>.
17. East K, Hitchman SC, Bakolis I, et al. The association between smoking and electronic cigarette use in a cohort of young people. *J Adolesc Health.* 2018;62(5):539–547. <https://doi.org/10.1016/j.jadohealth.2017.11.301>.
18. Aleyan S, Cole A, Qian W, Leatherdale ST. Risky business: a longitudinal study examining cigarette smoking initiation among susceptible and non-susceptible e-cigarette users in Canada. *BMJ Open.* 2018;8(5):e021080. <https://doi.org/10.1136/bmjopen-2017-021080>.
19. Morgenstern M, Nies A, Goecke M, Hanewinkel R. E-cigarettes and the use of conventional cigarettes: a cohort study in 10th grade students in Germany. *Dtsch Arztebl Int.* 2018;115(14):243–248.
20. Watkins S, Glantz SA, Chaffee BW. Association of noncigarette tobacco product use with future cigarette smoking among youth in the Population Assessment of Tobacco and Health (PATH) Study, 2013–2015. *JAMA Pediatr.* 2018;172(2):181–187. <https://doi.org/10.1001/jamapediatrics.2017.4173>.
21. Jha P, Ramasundarahettige C, Landsman V, et al. 21st-century hazards of smoking and benefits of cessation in the United States. *N Engl J Med.* 2013;368(4):341–350. <https://doi.org/10.1056/NEJMsa1211128>.
22. Pirie K, Peto R, Reeves GK, Green J, Beral V. The 21st century hazards of smoking and benefits of stopping: a prospective study of one million women in the UK. *Lancet.* 2013;381(9861):133–141. [https://doi.org/10.1016/S0140-6736\(12\)61720-6](https://doi.org/10.1016/S0140-6736(12)61720-6).
23. National Center for Health Statistics. National Health Interview Survey, 2015. Public-use data file and documentation. www.cdc.gov/nchs/nhis/quest_data_related_1997_forward.htm. Accessed February 21, 2018.
24. Lillard DR, Molloy E, Sfekas A. Smoking initiation and the iron law of demand. *J Health Econ.* 2013;32(1):114–127. <https://doi.org/10.1016/j.jhealeco.2012.08.006>.
25. Marynak KL, Gammon DG, King BA, et al. National and state trends in sales of cigarettes and e-cigarettes, U.S., 2011–2013. *Am J Prev Med.* 2015;53(1):96–101. <https://doi.org/10.1016/j.amepre.2017.01.016>.
26. Choi WS, Pierce JP, Gilpin EA, Farkas AJ, Berry CC. Which adolescent experimenters progress to established smoking in the United States. *Am J Prev Med.* 1997;13(5):385–391. [https://doi.org/10.1016/S0749-3797\(18\)30159-4](https://doi.org/10.1016/S0749-3797(18)30159-4).
27. Glasser AM, Collins L, Pearson JL, et al. Overview of electronic nicotine delivery systems: a systematic review. *Am J Prev Med.* 2017;52(2):e33–e66. <https://doi.org/10.1016/j.amepre.2016.10.036>.
28. Goniewicz ML, Gawron M, Smith DM, Peng M, Jacob P III, Benowitz NL. Exposure to nicotine and selected toxicants in cigarette smokers who switched to electronic cigarettes: a longitudinal within-subjects observational study. *Nicotine Tob Res.* 2017;19(2):160–167. <https://doi.org/10.1093/ntr/ntw160>.
29. Shahab L, Goniewicz ML, Blount BC, et al. Nicotine, carcinogen, and toxin exposure in long-term e-cigarette and nicotine replacement therapy users: a cross-sectional study. *Ann Intern Med.* 2017;166(6):390–400. <https://doi.org/10.7326/M16-1107>.
30. Sargent JD, Gabrielli J, Budney A, Soneji S, Wills TA. Adolescent smoking experimentation as a predictor of daily cigarette smoking. *Drug Alcohol Depend.* 2017;175:55–59. <https://doi.org/10.1016/j.drugalcdep.2017.01.038>.
31. Krall EA, Valadian I, Dwyer JT, Gardner J. Accuracy of recalled smoking data. *Am J Public Health.* 1989;79(2):200–202. <https://doi.org/10.2105/AJPH.79.2.200>.
32. Miech R, Patrick ME, O'Malley PM, Johnston LD. What are kids vaping? Results from a national survey of U.S. adolescents. *Tob Control.* 2017;26(4):386–391. <https://doi.org/10.1136/tobaccocontrol-2016-053014>.
33. Goldenson NI, Leventhal AM, Stone MD, McConnell RS, Barrington-Trimis JL. Associations of electronic cigarette nicotine concentration with subsequent cigarette smoking and vaping levels in adolescents. *JAMA Pediatr.* 2017;171(12):1192–1199. <https://doi.org/10.1001/jamapediatrics.2017.3209>.