Electronic Cigarette Use and Progression From Experimentation to Established Smoking

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abstract

BACKGROUND: It has been shown that never-smoking adolescents who try electronic cigarettes (e-cigarettes) are at increased risk of subsequent conventional cigarette smoking. We evaluated associations between e-cigarette use and progression to established smoking among adolescents who had already tried cigarettes.

METHODS: Among participants (age 12–17 years) in the nationally representative Population Assessment of Tobacco and Health survey who had smoked a cigarette (≥1 puff) but not yet smoked 100 cigarettes (N = 1295), we examined 3 outcomes at 1-year follow-up as a function of baseline e-cigarette use: (1) having smoked ≥100 cigarettes (established smoking), (2) smoking during the past 30 days, and (3) both having smoked ≥100 cigarettes and past 30-day smoking (current established smoking). Survey-weighted multivariable logistic regression models were fitted to obtain odds ratios (ORs) and 95% confidence intervals (CIs) adjusted for smoking risk factors.

RESULTS: Versus e-cigarette never use, having ever used e-cigarettes was positively associated with progression to established cigarette smoking (19.3% vs 9.7%), past 30-day smoking (38.8% vs 26.6%), and current established smoking (15.6% vs 7.1%). In adjusted models, e-cigarette ever use positively predicted current established smoking (OR: 1.80; 95% CI: 1.04–3.12) but did not reach statistical significance (α = .05) for established smoking (OR: 1.57; 95% CI: 0.99–2.49) and past 30-day smoking (OR: 1.32; 95% CI: 0.99–1.76).

CONCLUSIONS: Among adolescent cigarette experimenters, using e-cigarettes was positively and independently associated with progression to current established smoking, suggesting that e-cigarettes do not divert from, and may encourage, cigarette smoking in this population.

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Dr Chaffee contributed to the design and conceptualization of the study and the analysis plan, conducted statistical analyses, and prepared the initial manuscript draft; Dr Watkins contributed to the design and conceptualization of the study and the analysis plan and conducted statistical analyses; Dr Glantz contributed to the design and conceptualization of the study and the analysis plan; and all authors revised and reviewed the manuscript, approved the final manuscript as submitted, and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: In previous studies of youth who have never smoked cigarettes, those who tried electronic cigarettes (e-cigarettes) were more likely to initiate conventional cigarette smoking compared with e-cigarette never users. In cross-sectional studies, e-cigarette use is associated with established youth smoking.

WHAT THIS STUDY ADDS: Among youth who already experimented with cigarettes but were not yet established smokers, having used e-cigarettes was prospectively associated with onset of current established cigarette smoking. For these youth, e-cigarettes appear to encourage progression to established smoking.

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Electronic cigarettes (e-cigarettes) are increasingly popular among youth; from 2014 to 2016, more US middle and high school students used e-cigarettes than any other tobacco product, including conventional cigarettes.[1] All currently available longitudinal studies have revealed that among never-smoking adolescents and young adults, e-cigarette use is associated with subsequent cigarette smoking.[2–6] This association was shown in studies taking place in California,[3] Hawaii,[2] and the Mid-Atlantic region,[7] as well as in nationally representative US samples,[6,8] Canada,[4] and the United Kingdom.[5] Seven of these studies were summarized in a recent meta-analysis, revealing more than a threefold increase in the risk of cigarette smoking initiation when comparing youth e-cigarette ever users to never users.[9] Although this association between e-cigarettes and smoking initiation has been consistent across the literature and could be explained by using a proposed "catalyst" model,[10] some have argued that the relationship partly reflects a shared propensity for experimentation with different nicotine-containing products.[11]

Many individuals at low risk of smoking initiation may be included in studies of baseline cigarette never-users. In contrast, youth who have already begun cigarette experimentation represent a population at high risk of progression to greater levels of cigarette use later in adolescence and into adulthood. Although smoking even 1 cigarette is concerning, becoming an established smoker in adolescence is of substantial clinical and public health concern and is strongly associated with continuing to smoke regularly.[12] Therefore, in the present investigation we consider high-risk youth, as evident by having already tried smoking (ever smoked ≥1 puff) but not yet smoked 100 cigarettes, and evaluate whether e-cigarette use in this population predicts progression from experimentation to established cigarette smoking 1 year later.

In a previous cross-sectional analysis of the 2011 and 2012 National Youth Tobacco Surveys (NYTSs), among youth who had ever smoked a cigarette, ever use of e-cigarettes was associated with being an established smoker (lifetime smoked ≥100 cigarettes), including after adjusting for socio-demographic variables.[13] However, the cross-sectional design of that analysis precluded causal conclusions because of uncertain temporal sequencing between e-cigarette use and established smoking.

In the current study, we used the nationally representative Population Assessment of Tobacco and Health (PATH) Study[14] Waves 1 (2013–2014) and 2 (2014–2015) to examine these same relationships prospectively. We hypothesized that among PATH youth participants who had already tried cigarette smoking but not yet smoked a total of 100 cigarettes, use of e-cigarettes would be positively associated with becoming an established cigarette smoker within 1 year.

METHODS

Researchers from the PATH Study selected participants using a 4-stage stratified probability design with oversampling for tobacco users, African Americans, and young adults (ages 18–24 years). The PATH youth sample consisted of adolescents (up to 2 per household) whose parents were selected for the PATH adult sample.[14] Researchers from the PATH Youth Study enrolled 13 651 US adolescents ages 12 to 17 years at baseline (2013–2014), with 87.9% retention (unweighted) at Wave 2 (2014–2015).

In-home in-person computer-assisted interviews were conducted in administering the PATH questionnaire. In separate sections, participants were asked about their tobacco use (eg, ever use, number of lifetime uses, and number of days used in the past 30 days) for 8 types of tobacco and nicotine-containing products, including cigarettes and e-cigarettes. Tobacco use questions were repeated during the Wave 2 interview, including for individuals who reached age 18 before follow-up and were therefore administered the Wave 2 adult questionnaire.

In the present analysis, we included youth who had smoked ≥1 cigarette puff but had not yet smoked 100 cigarettes at baseline (smoking experimenters), with known smoking status at follow-up (N = 1295). We examined 3 outcomes at follow-up as a function of baseline e-cigarette use: (1) having smoked ≥100 cigarettes (established smoking), (2) smoking during the past 30 days, and (3) both having smoked ≥100 cigarettes and past 30-day smoking (current established smoking). We categorized e-cigarette use in 2 ways: (1) ever use or never use, and (2) never use, nonpast 30-day use (former use), or past 30-day use.

Logistic regression models (Stata 14; StataCorp, College Station, TX) were used to adjust for hypothesized confounding variables in 3 stages. First, 6 separate unadjusted models were fitted to cover each combination of independent variable (Wave 1 e-cigarette never or ever use and e-cigarette never or former or past 30-day use) and dependent variable (Wave 2 established smoking, current smoking, and current established smoking). In the second stage, we added sex, age (in years), and race and/or ethnicity (Hispanic and/or Latino, non-Hispanic white, non-Hispanic African American, other) as covariables in all models, matching the confounders used in a previous cross-sectional analysis of NYTS data.[13] In the third stage, parent education (≥1 parent with a

TABLE 1 Progression From Cigarette Experimentation to Established Smoking, According to Baseline E-cigarette Use

	n	Weighted % With Outcome	Unadjusted		Adjusted[a]		Adjusted[b]	
			OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Outcome: smoked 100 cigarettes								
Wave 1 predictors								
E-cigarette never	646	9.7	Reference	—	Reference	—	Reference	—
E-cigarette ever	582	19.3	2.23 (1.55–3.21)	<.001	2.07 (1.41–3.04)	<.001	1.57 (0.99–2.49)	.05
E-cigarette never	646	9.7	Reference	—	Reference	—	Reference	—
E-cigarette former	406	18.6	2.13 (1.43–3.18)	<.001	2.04 (1.33–3.12)	.001	1.55 (0.94–2.56)	.09
E-cigarette in the past 30 d	171	21.5	2.56 (1.58–4.14)	<.001	2.22 (1.31–3.74)	.003	1.69 (0.93–3.05)	.08
Outcome: smoked during the past 30 d								
Wave 1 predictors								
E-cigarette never	699	26.6	Reference	—	Reference	—	Reference	—
E-cigarette ever	596	38.8	1.75 (1.35–2.27)	<.001	1.65 (1.26–2.15)	<.001	1.32 (0.99–1.76)	.06
E-cigarette never	699	26.6	Reference	—	Reference	—	Reference	—
E-cigarette former	415	36.1	1.56 (1.15–2.12)	.004	1.48 (1.09–2.02)	.01	1.20 (0.86–1.68)	.29
E-cigarette in the past 30 d	176	45.3	2.29 (1.64–3.19)	<.001	2.10 (1.47–2.99)	<.001	1.64 (1.12–2.41)	.01
Outcome: smoked 100 cigarettes and smoked during the past 30 d								
Wave 1 predictors								
E-cigarette never	644	7.1	Reference	—	Reference	—	Reference	—
E-cigarette ever	580	15.6	2.43 (1.55–3.80)	<.001	2.23 (1.39–3.59)	<.001	1.80 (1.04–3.12)	.03
E-cigarette never	644	7.1	Reference	—	Reference	—	Reference	—
E-cigarette former	406	15.5	2.41 (1.46–3.97)	<.001	2.29 (1.35–3.89)	.002	1.85 (1.02–3.36)	.04
E-cigarette in the past 30 d	171	16.3	2.56 (1.52–4.32)	<.001	2.19 (1.24–3.88)	.007	1.76 (0.92–3.37)	.09

ORs and CIs corresponding to model covariates are shown in Supplemental Table 2. —, not applicable.

[a] Model covariates include the following: sex, age, and race and/or ethnicity.

[b] Model covariates additionally include the following: parent education, urban residence, household tobacco use, alcohol ever use, tobacco advertisement receptivity, sensation-seeking score, cigarette warning label exposure, interview time of year, and ever use of any other tobacco product.

bachelor degree or greater), urban residence (based on sampling units), household tobacco use (lives with ≥1 tobacco user), alcohol ever use, tobacco advertisement receptivity[15] (can recall brand of favorite advertisement), sensation-seeking score (scale from 3 to 15), cigarette warning label exposure (Likert-type scale), interview time of year (summer versus all other months), and ever use of any other tobacco product (ie, cigars, pipes, hookah, bidis, kreteks, snus, dissolvable tobacco, and conventional moist snuff or chewing smokeless tobacco) were also included in additional adjusted models. A sensation-seeking score was a composite of 3 Likert-type items (liking frightening things, willingness to break rules, and preference for exciting and unpredictable friends) and has been shown to correlate with youth tobacco use.[16] Interview time of year was included because, for youth, the scholastic calendar may play a role both in opportunity and social pressure to experiment with tobacco products.

All models were weighted for sampling design and nonresponse by using balanced repeated replication to be representative of the Wave 1 target population.[17] Multiple imputation was performed for missing observations (0.7% of data), with variance estimates adjusted accordingly.

An institutional review board at the University of California, San Francisco reviewed and designated the study protocol exempt for this analysis of deidentified survey data. The PATH Study protocol received a National Institutes of Health Certificate of Confidentiality and approval from the Westat Institutional Review Board. Parental consent was requested on behalf of participating youth. Youth who completed the questionnaire were given $25.

RESULTS

Among baseline cigarette experimenters (mean age: 15.5 years; 48.3% girls), having ever used e-cigarettes was positively associated with progression to established cigarette smoking in Wave 2 (Table 1). Compared with e-cigarette never users, e-cigarette ever users were twice as likely to report Wave 2 established smoking (19.3% vs 9.7%; $P < .001$) and current established smoking (15.6% vs 7.1%; $P < .001$) and were more likely to report past 30-day smoking (38.8% vs 26.6%; $P < .001$).

In models adjusted for sex, age, and race and/or ethnicity (Table 1), Wave 1 e-cigarette ever use (versus never use) was associated with approximately twice the odds of progression to Wave 2 established cigarette smoking (odds ratio [OR]: 2.23; 95% confidence interval [CI]: 1.55–3.21; $P < .001$), past 30-day smoking (OR: 1.75; 95% CI: 1.35–2.27; $P < .001$), and current

established smoking (OR: 2.43; 95% CI: 1.55–3.80; $P < .001$). Associations were attenuated in fully adjusted models (Table 1), but e-cigarette ever use remained a positive and statistically significant predictor of current established smoking (OR: 1.80; 95% CI: 1.04–3.12; $P = .035$). Associations did not reach the threshold for statistical significance for established smoking (OR: 1.57; 95% CI: 0.99–2.49; $P = .055$) and past 30-day smoking (OR: 1.32; 95% CI: 0.99–1.76; $P = .059$).

When baseline e-cigarette former use (tried but not used in past 30 days) and past 30-day use were considered separately, there was a stepwise increase in the probability of progression to future established smoking from never to former to past 30-day e-cigarette use (Table 1). For example, the probability of Wave 2 past 30-day cigarette smoking rose from baseline e-cigarette never use (26.6%) to former use (36.1%) to past 30-day use (45.3%). Both e-cigarette former use and past 30-day use remained statistically significantly associated with all 3 Wave 2 cigarette outcomes in models adjusted for sex, age, and race and/or ethnicity (Table 1). In fully adjusted models, baseline e-cigarette former use remained a statistically significant predictor of progression to current established smoking (OR: 1.85; 95% CI: 1.02–3.36; $P = .042$), and baseline e-cigarette past 30-day use statistically significantly predicted progression to past 30-day smoking (OR: 1.64; 95% CI: 1.12–2.41; $P = .010$). Adjustment variables that were consistently associated with greater progression to established smoking included household tobacco use and tobacco advertisement receptivity (Supplemental Table 2).

DISCUSSION

In this study, among youth who had experimented with cigarettes but had not progressed to established smoking, additional use of e-cigarettes was positively associated with future onset of current established smoking. Across 3 different definitions of established smoking and 2 different specifications of e-cigarette use, baseline e-cigarette users were at 1.5 to 2 times greater odds of progression to established smoking than e-cigarette never users, after adjustment for confounding variables. Fully adjusted associations with e-cigarette ever use were statistically significant for 1 definition of established smoking (current established smoking; $P = .035$) but fell just short of the a priori threshold for statistical significance for established smoking ($P = .055$) and past 30-day smoking ($P = .059$). The ORs in the present longitudinal analysis were in the same direction but smaller in magnitude than in the previous cross-sectional analysis of NYTS data[13] in which new trials of e-cigarettes among previously established smokers could have been captured.

Regardless of how Wave 1 e-cigarette and Wave 2 smoking variables were specified, positive associations persisted after statistical adjustment for sex, age, and race and/or ethnicity. Adding the full set of confounding variables to models, such as household tobacco use, warning label exposure, and baseline use of other tobacco products, reduced the strength of some of the observed associations to below the threshold for statistical significance. However, all associations remained positive in direction and similar in magnitude across different definitions of e-cigarette exposure and the smoking outcome.

Suggested in these results is that e-cigarette use is more likely to encourage youth smoking than to divert youth from smoking when considering individuals who have already experimented with cigarette use. Unlike adults, particularly cigarette smokers, who commonly report a desire to quit smoking as a main motivator for e-cigarette use,[18] youth are more likely to cite curiosity as a reason to try e-cigarettes.[19] E-cigarette use was not associated with cigarette quit attempts or with quit contemplation among US middle and high school students in any NYTS wave from 2011 to 2015.[20]

In existing studies of youth who had never smoked a cigarette at baseline, those who tried e-cigarettes were more likely to initiate cigarette smoking in the future.[2–6,9] In addition to smoking initiation among youth never-smokers, we demonstrate in the current study that e-cigarette use was also associated with progression to current established smoking among youth smoking experimenters.

In a study of California 10th grade students that included never smokers and current smokers at baseline, greater frequency of e-cigarette use at baseline was associated with subsequently greater levels of smoking frequency (days smoked in past month) and heaviness (cigarettes smoked per day) 6 months later.[21] Similarly, in a school-based study of adolescent never and current smokers in Canada, baseline past 30-day e-cigarette use was associated with initiation of daily smoking 1 year later.[4] In the results of a school-based study of baseline cigarette ever smokers in Hawaii, a statistically significant change at follow-up in smoking frequency (measured as numerical categories) between baseline e-cigarette ever and never users was not yielded.[2] However, in a school-based study of adolescents in the United Kingdom, ever use (versus never use) of e-cigarettes was associated with "escalation" to smoking sometimes or usually among baseline nonsmokers who had used cigarettes in the past.[5] Authors of that study reported an adjusted OR that was similar to the current study

(OR: 1.89; 95% CI: 0.82–4.33) but not statistically significant (P = .13) in a smaller sample (n = 318).[5]

The smoking outcomes evaluated in the current study represent intensity levels of clear clinical and public health concern. Although smoking as infrequently as 1 day in the past month in adolescence is predictive of adult smoking,[22] youth who reach higher levels of smoking are even more likely to continue to smoke.[12] Additionally, although more recent (past 30-day) e-cigarette use was a stronger predictor of future established smoking than former e-cigarette use in unadjusted models, this pattern did not necessarily persist in fully adjusted models. We suggest that any level of e-cigarette use among adolescent cigarette experimenters may be a meaningful risk indicator of smoking progression.

Several study advantages strengthened the conclusions that can be drawn from this research. The large, prospective, and nationally representative nature of the PATH Study enhanced generalizability and certainty regarding the temporal sequence between exposure and outcome. The PATH questionnaire was rigorously pilot tested and administered under a consistent protocol.[14] Furthermore, the magnitude of associations found in this study was largely consistent across different specifications of e-cigarette and cigarette use. Among other study aspects to consider, in-home administration of the PATH questionnaire could have led to differences in estimated tobacco use compared with school-based surveys. However, results of this analysis were qualitatively similar to previous work in which NYTS data was used.[13] As with all observational studies, residual confounding from unmeasured variables cannot be ruled out, although associations remained positive and at the threshold for statistical significance after adjustment for an extensive set of variables known to predict youth cigarette smoking.[23]

In July 2017, the US Food and Drug Administration announced a plan for tobacco and nicotine regulation that delayed federal e-cigarette regulation from 2018 until 2022.[24] However, local governments have taken regulatory action of e-cigarettes. For example, a 2017 San Francisco, California, ordinance prohibits the sale of flavored tobacco products, including e-cigarettes, with the intention of reducing the appeal of tobacco products to youth.[25] It is indicated in our results that among youth cigarette experimenters, those who have also used e-cigarettes are more likely to progress to current established smoking than those who tried cigarettes alone. As long as e-cigarettes remain attractive to youth, concern persists that these products contribute to greater combustible cigarette smoking among adolescents.

CONCLUSIONS

Among youth cigarette experimenters, using e-cigarettes was positively and independently associated with future onset of current established smoking, suggesting that e-cigarettes do not divert from, and may encourage, cigarette smoking in this population. In weighing the overall public health impact of e-cigarette availability, regulation, and use, the potential to increase combustible cigarette smoking by youth deserves special consideration.

ABBREVIATIONS

CI: confidence interval
e-cigarette: electronic cigarette
NYTS: National Youth Tobacco Survey
OR: odds ratio
PATH: Population Assessment of Tobacco and Health

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