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E-cigarette Use and Regular Cigarette Smoking Among Youth: Population Assessment of Tobacco and Health Study (2013–2016)

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Abstract

Introduction: This study examines the association between current e-cigarette use at baseline and regular cigarette smoking at follow-up among U.S. youth.

Methods: A longitudinal analysis of youth (aged 12–17 years) data from Waves 1–3 of the Population Assessment of Tobacco and Health Study (2013–2016) was conducted between January 2019 and December 2019. Youth who reported past 30–day current e-cigarette use at baseline were identified and followed for regular cigarette smoking (≥20 days) at follow-up.

Results: Compared with non-current e-cigarette users at baseline, current e-cigarette users (cigarette nonsmokers) had 5.0 (95% CI=1.9, 12.8) times higher odds of becoming regular cigarette smokers 1 year later. Additionally, there was a direct linear relationship between the number of days of e-cigarette use at baseline and the number of days of cigarette smoking 1 year later.

Conclusions: Current e-cigarette use among U.S. youth is associated with higher odds of transitioning to regular cigarette smoking, likely reflecting robust transitions rather than experimentation. These results suggest that promoting e-cigarettes as the current practice for tobacco harm reduction will likely have the unintended consequence of initiating youth cigarette smokers.

INTRODUCTION

E-cigarettes have become the most common tobacco/nicotine product among U.S. youth, with an increase from 20.8% in 2018 to 27.5% in 2019 in current e-cigarette use among high

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school students.[1,2] Increasingly, e-cigarette use among youth is reported by those who have never smoked before. According to the 2013–2016 Population Assessment of Tobacco and Health (PATH) Study, 38% of e-cigarette users in Wave 3 were never cigarette smokers compared with 24% in Wave 1 (unpublished data). This is happening at a time when e-cigarettes are promoted as a tobacco harm reduction product that offers hope for adult smokers who could not quit otherwise.[3,4] Several reports have suggested that e-cigarettes can help established smokers quit or reduce their harm by switching to e-cigarettes.[5,6]

The balance between these two aspects of e-cigarette's role in the society, that is, helping adult smokers versus recruiting youth to nicotine, has become a defining feature of the tobacco harm reduction debate and has policy and regulatory implications.[3,7,8] One of the main factors that will likely have significant bearing on this debate is whether e-cigarette use among youth can be considered a risk factor for subsequent cigarette smoking. This so-called "gateway" effect has been the subject of several studies that have generated heated arguments among public health researchers and beyond.[9] Studies and metanalyses suggesting such an effect have been criticized mainly for being based on cross-sectional designs not suitable for causal inference, lack of adjustment of relevant factors (e.g., susceptibility to smoking, substance use), small sample size and short follow-up, or looking at experimentation rather than more regular use patterns. Related to the last point is the argument that, for the most part, "gateway" studies fail to account for the frequency of either e-cigarette use or subsequent cigarette smoking. So, for a population known for experimenting with different tobacco products (youth), the documented associations between e-cigarettes and subsequent cigarette smoking likely represent experimentation and common liability rather than robust transitions.[4,10]

With the recent availability of three waves of the PATH cohort, an opportunity to look at the "gateway" question in a way that addresses the main critiques highlighted above has been provided. Using the youth data from the PATH'S three waves, this study aims to answer the question: Does current use of e-cigarette at baseline among cigarette nonsmokers increase the risk of regular cigarette smoking later? To answer this question, this study examines current e-cigarette use and frequency (among cigarette non-current users) at Wave 1 or Wave 2 and their associations with subsequent regular cigarette smoking at Wave 2 or Wave 3 for a 1-year progression. Similarly, the authors examine the 2-year progression of e-cigarette use at Wave 1 and its association with subsequent smoking at Wave 3.

METHODS

Study Sample

Data were from the PATH Study, an ongoing, nationally representative, longitudinal cohort study of 45,971 adults and youth (aged ≥12 years) in the U.S. initiated by the NIH and Food and Drug Administration.[11] Details of the PATH Study design and methods have been described elsewhere.[11-13] Youth data from Waves 1 (2013–2014), 2 (2014–2015), and 3 (2015–2016) were used for this current study. The present analytic sample was restricted to youth who had complete information on current e-cigarette and were non-current cigarette users at Wave 1/2 from the youth questionnaire. Florida International University IRB approved this current study and deemed it exempt.

Measures

Current (past 30–day) e-cigarette use was based on positive responses at Wave 1 and Wave 2 to the question about e-cigarette use in the past 30 days (exclusive of never e-cigarette users), among cigarette nonsmokers (those who did not report cigarette smoking in the past 30 days). The number of days of e-cigarette use in the past 30 days was used to denote e-cigarette use frequency (as a continuous scale).

Regular cigarette smoking at Wave 2 and Wave 3 was defined as reporting cigarette smoking on ≥20 days in the past 30 days, as compared with no report of any cigarette smoking in the past 30 days. The number of days smoked cigarettes in the past 30 days was used as a continuous scale.

Based on prior literature related to youth tobacco use, susceptibility, and perceptions,[14] the following variables from Wave 1 were included as covariates: age, sex, race/ethnicity, parent's education, sensation seeking, and the following variables from Wave 1/2: other tobacco product use, ever alcohol use, ever marijuana use, ever prescription drug abuse, lives with a tobacco user, susceptibility to cigarette smoking, and noticed cigarette health warning labels. Age (12–14 years versus 15–17 years) and sex (male versus female) were dichotomized. Race/ethnicity had four categories: white, African American, Hispanic, and other, with white as the comparison group. Missing data on age, sex, race, and Hispanic ethnicity were imputed as described in the PATH Public Use File User Guide.[11] Parent's education was categorized as high school or less, some college, and bachelor's degree or higher. Sensation seeking was assessed from three modified items of the Brief Sensation Seeking Scale: (1) *I like to do frightening things*, (2) *I like new and exciting experiences even if I have to break the rules*, and (3) *I prefer friends who are exciting and unpredictable* [15] Response options for each item (*strongly agree, agree, neither agree nor disagree, disagree, strongly disagree*) were summed to create an overall score (range, 1–15), with higher scores indicating lower sensation seeking, and the mean scores reported. The scale was found to be internally consistent among youth in PATH Study (Cronbach's α=0.76).[16] Additionally, the three questions were categorized into *yes* and *no* by deriving the variable from responses to the Likert scale: Those who responded *neither agree nor disagree, disagree*, or *strongly disagree* were classified as *no* whereas other responses were classified as *yes*. Then, a combined categorical sensation-seeking variable was derived from these three questions, with participants who responded no on all items coded as *no*, whereas other responses were coded as *yes*.

For the variable other tobacco product use, respondents who answered *yes* to the past 30–day use of any of the following tobacco products—traditional cigars, cigarillos, filtered cigars, pipe, hookah, snus, smokeless tobacco, dissolvable tobacco, bidi, and kreteks—were coded as *yes*, and participants who responded *no* on all tobacco products were coded as *no*. Ever use of alcohol, marijuana, and prescription drug abuse (Ritalin, Adderall, painkillers, sedatives, and tranquilizers) were assessed from questions about participants' self-reported ever use of alcohol, marijuana, or prescription drug abuse as appropriate. The variable, lives with a tobacco user, was assessed from the question about …*anyone who lives with you now use tobacco?* and the responses were coded as *yes* and *no*.

Susceptibility to cigarette smoking was assessed using a 3-item enhanced susceptibility scale[14]: *Have you been curious about a cigarette?* (*yes* or *no*), *Do you think you will smoke a cigarette in the next year?*, and *If one of your best friends were to offer you a cigarette, would you use it?* (response options for the latter two were: *definitely yes, probably yes, probably not, definitely not*). Responses of definitely not were regarded as *no* on the latter two measures, and all other responses were classified as *yes*.[16] The authors combined the measures to create a single variable from the *yes* or *no* responses, with those who endorsed *yes* to any of the three variables grouped as *yes*. Noticed cigarette health warning labels was assessed with the following item: *In the past 30 days, how often, if at all, have you noticed the health warnings in packages of cigarettes?* Participants responded using a 5-point response scale: *never, rarely, sometimes, often,* or *very often*. A dichotomized variable was derived with never coded as *no* and all other options as *yes*. The authors derived a variable, risk taking defined as the endorsement of one of the following items, as *yes*: ever alcohol/marijuana/prescription drug abuse, susceptibility to cigarette smoking, and sensation-seeking similar to previous literature[14] owing to the low prevalence rates of regular cigarette smokers who endorsed the individual items in this study.

Statistical Analysis

All estimates used were weighted in Stata, version 15 using the Wave 3 youth longitudinal weights with the balanced repeated replication method of Fay's adjustment of 0.3 to account for the PATH study's complex sampling design. Participants were followed from Wave 1 or Wave 2 who used e-cigarettes, for subsequent cigarette smoking at Wave 2 or Wave 3 for the 1-year progression model. For the 2-year progression model, participants from Wave 1 who used e-cigarettes were followed up at Wave 3 for subsequent cigarette smoking. Analyses were restricted to youth who had complete information on follow-up waves: 7,438 (for 1-year progression model), and 7,185 (for 2-year progression model). Study participants from the 1- and 2-year progression models are not mutually exclusive. This study examined the distribution of sociodemographic and tobacco-related variables by regular cigarette use. Pearson's chi-square test and *t*-test were used to test for equality of proportions and means by regular cigarette use, respectively.

Multivariable logistic regression models were applied to evaluate the associations between current e-cigarette use at baseline and regular cigarette smoking at follow-up. Two sets of analyses were conducted. The first analysis included the current e-cigarette use from Wave 1/2, with covariates obtained from Wave 1/2 and assessed with their associations with regular cigarette smoking at Wave 2/3 for the 1-year progression. The second analysis included only Wave 1 current e-cigarette use and covariates and evaluated for their associations with Wave 3 regular cigarette use in the 2-year progression. Unadjusted results (Model 1) and adjusted for demographic and tobacco-related factors (Model 2) were reported in the tables. The linear relationship between the number of days of e-cigarette use in the past 30 days (e-cigarette use frequency) with the number of days of cigarette use in past 30 days at follow-up was tested adjusting for age, sex, race/ethnicity, parent's education, other tobacco use, risk-taking behavior, living with a tobacco user, and noticing a cigarette health warning label. For the 2-year progression, given the extremely small sample sizes of participants with number of days of cigarette use in the past 30 days, the estimates

provided in the linear regression model were unreliable. A zero-inflated negative binomial model was also used to assess this relationship. In another model, susceptibility to cigarette smoking was introduced as a single variable separately from the combined risk-taking variable.

Additionally, a sensitivity analysis was conducted with current e-cigarette users who were never smokers at Wave 1/2 and followed for their regular cigarette use at Wave 2/3. ORs and 95% CIs were calculated for all logistic regression analyses, and β coefficients with their 95% CIs were also calculated for the linear regression models. Two-sided *p*-values of <0.05 were considered statistically significant. All data analysis was conducted between January 2019 and December 2019.

RESULTS

Among youth (*n*=7,438), 5.3% (95% CI=3.1%, 8.9%) of current e-cigarette users at Wave 1/2 reported regular cigarette smoking at the 1-year progression compared with 0.3% (95% CI=0.2%, 0.5%) among non-current e-cigarette users (*P*<0.0001) (Table 1). In the 2-year progression (*n*=7,185), 8.2% (95% CI=3.3%, 19.1%) of current e-cigarette users identified at Wave 1 reported regular cigarette smoking 2 years later compared with 0.8% (95% CI=0.6%, 1.1%) among non-current e-cigarette users (*p*<0.0001) (Table 1).

In the multivariate logistic regression analyses examining the transition from current e-cigarette use to regular cigarette smoking, after adjusting for the covariates, current e-cigarette users were at 5.0 (95% CI=1.9, 12.8) times higher odds of regular cigarette smoking in the 1-year progression model compared with non-current e-cigarette users. In the 2-year progression model, current e-cigarette users had 3.4 (95% CI=1.0, 11.5) times the odds of regular cigarette use compared to non-current e-cigarette users, although not statistically significant (Table 2). Additionally, for every unit increase in the number of days of e-cigarette use at baseline, there was an increase in the number of days of cigarette smoking by 0.4 (β=0.4, 95% CI=0.1, 0.7) in the 1-year progression model (Table 3). Furthermore, results from the zero-inflated negative binomial models showed a similar estimate for this relationship; however, it was slightly lower but still significant (β=0.1, 95% CI=0.0, 0.1) (Appendix Table 1). Results from the models with susceptibility to cigarette smoking introduced separately showed a similar pattern (data not shown).

In the sensitivity analysis, similarly, current e-cigarette users who were never smokers were at 6.1 (95% CI=1.1, 33.2) and 3.0 (95% CI=0.3, 30.8) times higher odds of regular cigarette smoking both in the 1-and 2-year progression models compared with non-current e-cigarette users who were never smokers (Table 4).

DISCUSSION

This study shows the potential of e-cigarette use among youth to lead to regular cigarette smoking later using population-based longitudinal data. Controlling for important socio-behavioral factors known to influence youth's propensity to smoke,[14] this study found that current e-cigarette users (cigarette non-current users) at baseline were 5.0 times more likely to become regular cigarette smokers at 1-year follow-up. However, this association was not

statistically significant in the 2-year progression. Coming from a population-based sample with detailed tobacco use and a 2-year follow-up, such transitions offer strong support to e-cigarette's potential to lead to regular cigarette smoking among youth. Additionally, although small (β=0.4, 95% CI=0.1, 0.7), a dose–response linear relationship was observed between frequency of current e-cigarette use at baseline and frequency of cigarette smoking at the 1-year progression, lending more support to a causal relationship rather than indicating youth experimentation with different tobacco products.

Previous results from the same data set but looking at more lenient predictor (prior e-cigarettes) and outcomes (initiation, current smoking) have shown the same trend.[14,17] Similarly, in a meta-analysis, Soneji and colleagues[18] showed that e-cigarette use is an independent risk factor for future cigarette initiation and current cigarette smoking among adolescents. This study takes this analysis further in response to one of the main critiques of cohort studies, based on measures of ever use or past 30–day use, which may be reflective of one-time experimentation rather than robust transitions,[10] by examining the associations of current e-cigarette and frequency of e-cigarette use with regular cigarette smoking among youth. By focusing on use patterns that are unlikely to reflect experimentation but rather represent robust transitions, this study shows that e-cigarette use precedes and strongly predicts regular cigarette smoking, even after adjusting for factors known to predispose to cigarette smoking. The 2-year progression model did not reveal any statistically significant association between baseline e-cigarette use (non-current cigarette users) and future cigarette use at Wave 3, probably because of the relatively small number of individuals who used e-cigarettes at baseline, which likely limited the statistical power.

Additionally, a dose–response pattern of this relationship was observed, which, given the prospective nature of the data, lend further support to a causal relationship. A plausible explanation for this study findings is that, because e-cigarette use is similar to the pattern of cigarette smoking (hand-to-mouth movements, puffing, inhalation, and exhalation),[18,19] youth who majorly use e-cigarettes may acquire and learn cigarette smoking-related behavior through e-cigarette use, thus allowing for an easy transition to cigarette smoking.[18] Furthermore, youth who become addicted to nicotine through e-cigarettes may transition to cigarettes as they may try to satisfy their cravings for nicotine.[18]

Limitations

Despite the study's strengths, there are some limitations to be considered in the interpretation of the results. First, tobacco/nicotine use were self-reported, so they may be subject to self-reported bias; however, prior studies have shown a good correlation between self-reported tobacco use and biomarkers of tobacco exposure among youth.[20] Secondly, not all included youth in the main analyses were naive to cigarette use; however, the authors conducted a sensitivity analysis that looked at never cigarette users, and e-cigarette users were at higher odds of subsequent cigarette smoking in both the 1- and 2-year progression models. It is also likely that the statistical power was limited in this study even though it found significant associations for the 1-year progression models. Lastly, given the current tobacco use landscape among youth that is dominated by poly-tobacco use, this study could not have exclusive e-cigarettes or cigarette predictors and outcomes. However, the predictor

variable (current e-cigarette use) did not include any current cigarette smoking (current nonsmokers), and the authors adjusted for other tobacco products use in the regression analyses.

CONCLUSIONS

In a large, nationally representative sample of U.S. youth, this study shows temporal transitions between e-cigarette use and cigarette smoking that unlikely reflect experimentation. These findings suggest that promoting e-cigarettes as the current practice for tobacco harm reduction will likely have the unintended consequence of initiating youth cigarette smokers. Given the considerable increase in e-cigarette use among U.S. youth in recent years, these results call for careful consideration of e-cigarettes' harm reduction potential in the society and for a strong policy and regulatory efforts to protect the American youth.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

1. Cullen KA, Ambrose BK, Gentzke AS, Apelberg BJ, Jamal A, King BA. Notes from the field: use of electronic cigarettes and any tobacco product among middle and high school students—United States, 2011–2018. MMWR Morb Mortal Wkly Rep. 2018;67(45): 1276–1277. 10.15585/mmwr.mm6745a5. [PubMed: 30439875]
2. Cullen KA, Gentzke AS, Sawdey MD, et al. E-cigarette use among youth in the United States, 2019. JAMA. 2019;322(21):2095–2103. 10.1001/jama.2019.18387.
3. Abrams DB, Glasser AM, Pearson JL, Villanti AC, Collins LK, Niaura RS. Harm minimization and tobacco control: reframing societal views of nicotine use to rapidly save lives. Annu Rev Public Health. 2018;39:193–213. 10.1146/annurev-publhealth-040617-013849. [PubMed: 29323611]
4. Warner KE. How to think—not feel—about tobacco harm reduction. Nicotine Tob Res. 2019;21(10):1299–1309. 10.1093/ntr/nty084. [PubMed: 29718475]
5. Notley C, Ward E, Dawkins L, Holland R. The unique contribution of e-cigarettes for tobacco harm reduction in supporting smoking relapse prevention. Harm Reduct J. 2018;15(1):31 10.1186/s12954-018-0237-7. [PubMed: 29921278]
6. Hajek P, Phillips-Waller A, Przulj D, et al. A randomized trial of e-cigarettes versus nicotine-replacement therapy. N Engl J Med. 2019;380(7):629–637. 10.1056/nejmoa1808779. [PubMed: 30699054]
7. McNeill A, Brose LS, Calder R, Hitchman SC, Hajek P, McRobbie H. E-cigarettes: an evidence update. A report commissioned by Public Health England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733022/Ecigarettes_an_evidence_update_A_report_commissioned_by_Public_Health_England_FINAL.pdf . Published 2015 Accessed January 17, 2020.

8. Warner KE, Mendez D. E-cigarettes: comparing the possible risks of increasing smoking initiation with the potential benefits of increasing smoking cessation. Nicotine Tob Res. 2019;21(1):41–47. 10.1093/ntr/nty062. [PubMed: 29617887]

9. Chapman S, Bareham D, Maziak W. The gateway effect of e-cigarettes: reflections on main criticisms. Nicotine Tob Res. 2019;21(5):695–698. 10.1093/ntr/nty067. [PubMed: 29660054]

10. Etter JF. Gateway effects and electronic cigarettes. Addiction. 2018;113(10):1776–1783. 10.1111/add.13924. [PubMed: 28786147]

11. HHS, NIH, National Institute on Drug Abuse, Food and Drug Administration, Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Public-Use Files. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2018-5-01 10.3886/ICPSR36498.v7.

12. Hyland A, Ambrose BK, Conway KP, et al. Design and methods of the Population Assessment of Tobacco and Health (PATH) Study. Tob Control. 2017;26(4):371–378. 10.1136/tobaccocontrol-2016-052934. [PubMed: 27507901]

13. Osibogun O, Taleb ZB, Bahelah R, Salloum RG, Maziak W. Correlates of poly-tobacco use among youth and young adults: findings from the Population Assessment of Tobacco and Health study, 2013–2014. Drug Alcohol Depend. 2018;187:160–164. 10.1016/j.drugalcdep.2018.02.024. [PubMed: 29674249]

14. Berry KM, Fetterman JL, Benjamin EJ, et al. Association of electronic cigarette use with subsequent initiation of tobacco cigarettes in U.S. youths. JAMA Netw Open. 2019;2(2):e187794 10.1001/jamanetworkopen.2018.7794. [PubMed: 30707232]

15. Stephenson MT, Hoyle RH, Palmgreen P, Slater MD. Brief measures of sensation seeking for screening and large-scale surveys. Drug Alcohol Depend. 2003;72(3):279–286. 10.1016/j.drugalcdep.2003.08.003. [PubMed: 14643945]

16. Sawdey MD, Day HR, Coleman B, et al. Associations of risk factors of e-cigarette and cigarette use and susceptibility to use among baseline PATH study youth participants (2013–2014). Addict Behav. 2019;91:51–60. 10.1016/j.addbeh.2018.11.027. [PubMed: 30473246]

17. Watkins SL, 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. 10.1001/jamapediatrics.2017.4173. [PubMed: 29297010]

18. 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. 10.1001/jamapediatrics.2017.1488. [PubMed: 28654986]

19. 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. 10.1001/jamapediatrics.2015.1742. [PubMed: 26348249]

20. Brener ND, Billy JO, Grady WR. Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: evidence from the scientific literature. J Adolesc Health. 2003;33(6):436–457. 10.1016/s1054-139x(03)00052-1. [PubMed: 14642706]

Table 1.

Characteristics of Study Participants by Regular Cigarette Use Among Youth (aged 12–17 years): PATH, 2013–2016

	Regular cigarette Use[a]					
	1-year progression[b] (n=7,438)			2-year progression[c] (n=7,185)		
Characteristics	**n**	**% (95% CI)**		**n**	**n, % (95% CI)**	
Current e-cigarette use		No (n=7,400)	Yes (n=38)		No (n=7,126)	Yes (n=59)
No	**7,217**	**99.7 (99.5, 99.8)**	**0.3 (0.2, 0.5)**	**7,129**	**99.2 (98.9, 99.4)**	**0.8 (0.6, 1.1)**
Yes	**221**	**94.7 (91.1, 96.9)**	**5.3 (3.1, 8.9)**	**56**	**91.8 (80.9, 96.7)**	**8.2 (3.3, 19.1)**
Age, years						
12–14	**5,656**	**99.6 (99.4, 99.8)**	**0.4 (0.2, 0.6)**	**5,487**	**99.4 (99.1, 99.6)**	**0.6 (0.4, 0.9)**
15–17	**1,782**	**99.1 (98.5, 99.5)**	**0.9 (0.5, 1.5)**	**1,698**	**98.3 (97.4, 98.9)**	**1.7 (1.1, 2.6)**
Sex						
Female	3,584	99.5 (99.1, 99.7)	0.5 (0.3, 0.9)	3,447	99.2 (98.8, 99.4)	0.8 (0.6, 1.2)
Male	3,854	99.5 (99.2, 99.7)	0.5 (0.3, 0.8)	3,738	99.1 (98.7, 99.4)	0.9 (0.6, 1.3)
Race/ethnicity						
White	3,512	99.3 (99.0, 99.6)	0.7 (0.4, 1.0)	**3,384**	**98.9 (98.4, 99.2)**	**1.1 (0.8, 1.6)**
African American	1,028	99.7 (99.0, 99.9)	0.4 (0.1, 1.0)	**1,006**	**99.5 (98.8, 99.8)**	**0.5 (0.2, 1.2)**
Hispanic	2,196	99.8 (99.4, 99.9)	0.2 (0.0, 0.6)	**2,124**	**99.6 (99.2, 99.8)**	**0.4 (0.2, 0.8)**
Other	702	99.5 (98.6, 99.8)	0.5 (0.2, 1.4)	**671**	**98.9 (97.9, 99.5)**	**1.1 (0.5, 2.2)**
Parent's educational level						
High school or less	**2,853**	**99.3 (98.8, 99.6)**	**0.7 (0.5, 1.1)**	**2,736**	**98.7(98.1, 99.1)**	**1.3 (0.9, 1.9)**
Some college	**2,316**	**99.4 (98.9, 99.7)**	**0.6 (0.3, 1.1)**	**2,235**	**99.0 (98.5, 99.4)**	**1.0 (0.6, 1.6)**
Bachelor's degree or higher	**2,229**	**99.8 (99.6, 99.9)**	**0.2 (0.0, 0.4)**	**2,175**	**99.7 (99.2, 99.9)**	**0.3 (0.1, 0.8)**
Other tobacco products[d]						
No	**7,203**	**99.7 (99.6, 99.8)**	**0.3 (0.2, 0.5)**	**7,115**	**99.2 (99.0, 99.4)**	**0.8 (0.6, 1.0)**
Yes	**235**	**93.6 (89.6, 96.1)**	**6.4 (3.9, 10.4)**	**69**	**89.3 (78.0, 95.2)**	**10.7 (4.8, 22.0)**
Ever alcohol use						
No	**5,357**	**99.8 (99.6, 99.9)**	**0.2 (0.1, 0.4)**	**5,225**	**99.5 (99.2, 99.7)**	**0.5 (0.3, 0.8)**
Yes	**2,041**	**98.8 (98.3, 99.2)**	**1.2 (0.8, 1.7)**	**1,921**	**98.2 (97.4, 98.8)**	**1.8 (1.3, 2.6)**
Ever marijuana use						
No	**6,967**	**99.7 (99.5, 99.8)**	**0.3 (0.2, 0.5)**	6,785	99.4 (99.2, 99.6)	0.6 (0.5, 0.9)
Yes	**221**	**98.7 (96.2, 99.5)**	**1.3 (0.5, 3.8)**	182	98.6(95.5, 99.6)	1.4 (0.4, 4.6)
Ever prescription drug abuse						
No	**6,884**	**99.6 (99.4, 99.7)**	**0.4 (0.3, 0.6)**	7,126	99.1 (98.9, 99.4)	0.9 (0.7, 1.1)
Yes	**523**	**98.4 (96.9, 99.2)**	**1.6 (0.8, 3.1)**	29	96.4 (74.1, 99.6)	3.6 (0.4, 25.9)
Lives with tobacco user						
No	**5,582**	**99.7 (99.5, 99.8)**	**0.3 (0.2, 0.5)**	**4,779**	**99.6 (99.3, 99.8)**	**0.4 (0.2, 0.7)**
Yes	**1,852**	**98.9 (98.3, 99.3)**	**1.1 (0.7, 1.7)**	**2,331**	**98.1 (97.3, 98.7)**	**1.9 (1.3, 2.7)**
Sensation seeking, mean (SD)[e]	**7,428**	**10.4 (2.8)**	**7.5 (2.9)**	**7,175**	**10.4 (2.8)**	**8.4 (3.1)**

	Regular cigarette Use[a]					
	1-year progression[b] (n=7,438)			2-year progression[c] (n=7,185)		
Characteristics	**n**	**% (95% CI)**		**n**	**n, % (95% CI)**	
Susceptibility to cigarette smoking						
No	**3,924**	**99.9 (99.8, 100.0)**	**0.1 (0.0, 0.2)**	**4,740**	**99.8 (99.6, 99.9)**	**0.2 (0.1, 0.4)**
Yes	**3,065**	**99.6 (99.3, 99.8)**	**0.4 (0.2, 0.7)**	**2,088**	**98.9 (98.4, 99.3)**	**1.1 (0.7, 1.6)**
Noticed cigarette health warning labels						
No	**2,866**	**99.7 (99.4, 99.9)**	**0.3 (0.1, 0.6)**	3,762	99.3 (98.8, 99.6)	0.7 (0.4, 1.2)
Yes	**4,550**	**99.4 (99.1, 99.6)**	**0.6 (0.5, 0.9)**	3,212	99.0(98.5, 99.3)	1.0 (0.7, 1.5)
Any risk taking[f]						
No	**2,422**	**99.9 (99.6, 100.0)**	**0.1 (0.0, 0.4)**	**2,910**	**99.6 (99.3, 99.8)**	**0.4 (0.2, 0.8)**
Yes	**5,016**	**99.3 (99.0, 99.5)**	**0.7 (0.5, 1.0)**	**4,275**	**98.8 (98.4, 99.1)**	**1.2 (0.9, 1.6)**

Notes: The samples of the 1-year and 2-year progressions are not mutually exclusive; n indicates the unweighted sample size, and numbers may not sum to the total because of missing data. Weighted percentages are row percentages. Boldface indicates statistical significance ($p<0.05$).

[a] Regular cigarette use (i.e., the use of cigarettes on ≥20 days and compared with non-current cigarette use (i.e., those who had not used cigarettes in the past 30 days).

[b] Variables are obtained from Wave 1 and/or Wave 2 and assessed the association with current cigarette use at Wave 2 and/or Wave 3 in the 1-year progression.

[c] Wave 1 current e-cigarette use and covariates and Wave 3 current cigarette use in the 2-year progression.

[d] Other tobacco products refers to the current use of the following tobacco products in the past 30 days: traditional cigar, cigarillos, filtered cigar, pipe, hookah, smokeless tobacco, snus, dissolvable tobacco, bidi, or kretek.

[e] Higher sensation seeking scores reflect lower sensation seeking.

[f] Any risk taking defined as at least an endorsement of any of the following: alcohol, marijuana, prescription drug abuse, sensationseeking, or susceptibility to cigarette smoking.

PATH, Population Assessment of Tobacco and Health.

Table 2.

Multivariable Association Between Baseline Current E-cigarette Use and Regular Cigarette Use Among Youth (aged 12–17 Years): PATH, 2013–2016

	Regular cigarette use at follow-up[a]			
	1-year progression[b]		2-year progression[c]	
Characteristics	**OR (95% CI) n=7,438**	**AOR (95% CI) n=7,372**	**OR (95% CI) n=7,185**	**AOR (95% CI) n=6,869**
Current e-cigarette use at baseline				
No	ref	ref	ref	ref
Yes	**16.4 (7.8, 34.5)**	**5.0 (1.9, 12.8)**	**11.1 (3.5, 35.2)**	3.4 (1.0, 11.5)
Age, years				
12–14	ref	ref	ref	ref
15–17	**2.4 (1.11, 5.3)**	1.8 (0.8,44)	**2.8 (1.5, 5.3)**	**2.1 (1.0, 4.1)**
Sex				
Female	ref	ref	ref	ref
Male	1.0 (0.4, 2.3)	0.9 (0.3, 2.2)	1.1 (0.6, 1.9)	1.1 (0.6, 1.9)
Race/ethnicity				
White	ref	ref	ref	ref
African American	0.5 (0.1, 24)	0.5 (04, 1.9)	0.5 (0.2, 1.3)	**0.3 (0.1, 0.8)**
Elispanic	0.3 (0.1, 14)	0.3 (04, 1.0)	**0.3 (0.1, 0.8)**	**0.3 (0.1, 0.7)**
Other	0.8 (0.3, 2.6)	0.9 (0.2, 34)	0.9 (04, 2.4)	0.8 (0.3, 1.9)
Parent’s education level				
High school or less	ref	ref	ref	ref
Some college	0.9 (0.4, 24)	07 (0.3, 2.0)	0.7 (04, 1.3)	0.6 (0.3, 1.2)
Bachelor’s degree or higher	0.2 (04, 0.9)	0.2 (0.0, 0.9)	**0.2 (0.1, 0.8)**	**0.3 (0.1, 0.8)**
Other tobacco products				
No	ref	ref	ref	ref
Yes	**22.8 (11.6, 44.9)**	**8.4 (3.5, 20.4)**	**15.6 (5.9, 41.1)**	**5.3 (1.6, 17.4)**
Lives with tobacco user				
No	ref	ref	ref	ref
Yes	**3.8 (1.9, 7.5)**	17 (0.7, 3.8)	**4.8 (2.4, 9.3)**	**3.1 (1.4, 6.5)**
Noticed cigarette health warning labels				
No	ref	ref	ref	ref
Yes	**2.3 (1.0-5.3)**	1.2 (0.5, 2.8)	1.4 (07, 2.8)	0.8 (0.4, 1.7)
Any risk taking				
No	ref	ref	ref	ref
Yes	**8.2 (1.3, 53.1)**	4.1 (0.6, 27.4)	**3.4 (1.5, 8.0)**	**2.9 (1.3, 6.8)**

Notes: Model adjusted for age, sex, race/ethnicity, education, other tobacco product use, any risk taking, living with a tobacco user, and noticed cigarette health warning label. Boldface indicates statistical significance ($p<0.05$).

[a]Regular cigarette use (i.e., the use of cigarettes on ≥20 days in the past 30 days) was compared with non-current cigarette use (i.e., those who had not used cigarettes in the past 30 days).

[b] Current e-cigarette use from Wave 1 and/or Wave 2 and its association with regular cigarette use at Wave 2 and/or Wave 3 in the 1-year progression.

[c] Wave 1 current e-cigarette use and its association with Wave 3 regular cigarette use in the 2-year progression.

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Table 3.

Linear Association Between Frequency of Current E-cigarette Use and Frequency of Cigarette Use Among Youth (Aged 12–17 Years): PATH, 2013–2016

	Number of days used cigarettes in past 30 days at follow-up	
	1-year progression (n=60)	
Characteristics	**β (95% CI)**	**Adjusted β (95% CI)**
Number of days used e-cigarettes in past 30 days at baseline	**0.5 (0.1, 0.9)**	**0.4 (0.1, 0.7)**
Age, years		
12–14	ref	ref
15–17	2.7 (−2.6, 8.0)	3.1 (−1.4, 7.7)
Sex		
Female	ref	ref
Male	−0.9 (−0.6, 4.9)	−1.7 (−7.2, 3.8)
Race/ethnicity		
White	ref	ref
African American	4.7 (−8.8, 18.2)	6.6 (−4.2, 17.4)
Hispanic	−2.4 (−8.8, 4.1)	−3.1 (−9.4, 3.1)
Other	−1.6 (−9.7, 6.4)	0.8 (−6.1, 7.7)
Parent’s education level		
High school or less	ref	ref
Some college	−3.8 (−11.0, 3.3)	−4.8 (−11.2, 1.6)
Bachelor’s degree or higher	**−8.4 (−14.9, −2.0)**	**−8.2 (−14.8, −1.7)**
Other tobacco products		
No	ref	ref
Yes	1.8 (−3.2, 6.8)	1.3 (−4.2, 6.8)
Lives with tobacco user		
No	ref	ref
Yes	**6.3 (0.9, 11.7)**	3.2 (−1.6, 8.0)
Noticed cigarette health warning labels		
No	ref	ref
Yes	−1.2 (−7.2, 4.9)	−3.2 (−9.3, 2.8)
Any risk taking		
No	ref	ref
Yes	**5.8 (3.3, 8.2)**	6.6 (−0.3, 13.5)

Notes: Boldface indicates statistical significance ($p<0.05$).

PATH, Population Assessment of Tobacco and Health.

Table 4.

Sensitivity Analysis of the Association Between Baseline Current E-cigarette Use (Never Cigarette Users) and Regular Cigarette Use Among Youth (Aged 12–17 Years): PATH 2013–2016

	Regular cigarette use at follow-up			
	1-year progression		2-year progression	
Characteristics	**OR (95% CI) n=6,983**	**AOR (95% CI) n=6,923**	**OR (95% CI) n=6,828**	**AOR (95% CI) n=6,523**
Current e-cigarette use[a]				
No	ref	ref	ref	ref
Yes	**15.5 (3.5, 68.6)**	**6.1 (1.1, 33.2)**	4.8 (0.3, 73.5)	3.0 (0.3, 30.8)
Age, years				
12–14	ref	ref	ref	ref
15–17	2.7 (0.8, 10.0)	2.5 (0.7, 8.9)	2.1 (1.0, 4.9)	1.8 (07, 4.5)
Sex				
Female	ref	ref	ref	ref
Male	1.1 (0.3, 3.7)	1.0 (0.3, 3.3)	1.0 (0.3, 1.3)	0.7 (0.3, 1.4)
Race/ethnicity[b]				
White	ref	ref	ref	ref
African American	—	—	0.4 (0.1, 1.6)	0.3 (0.1, 1.3)
Elispanic	—	—	0.4 (0.1, 1.4)	0.3 (0.1, 1.3)
Other	0.3 (0.1, 1.3)	0.3 (04, 1.5)	0.6 (04, 24)	0.7 (0.2, 2.6)
Parent’s education level				
High school or less	ref	ref	ref	ref
Some college	0.7 (04, 3.8)	0.7 (04, 3.9)	0.4 (0.2, 1.2)	0.4 (0.1, 1.1)
Bachelor’s degree or higher	0.5 (04, 2.9)	0.5 (04, 3.6)	0.4 (0.1, 1.7)	0.4 (0.1, 1.6)
Other tobacco products				
No	ref	ref	ref	ref
Yes	**14.0 (2.6, 74.3)**	3.9 (0.5, 29.0)	5.2 (0.3, 81.2)	2.4 (0.2, 24.2)
Lives with tobacco user				
No	ref	ref	ref	ref
Yes	**5.0 (1.4, 18.1)**	3.1 (0.7, 14.3)	**3.7 (1.4, 9.4)**	**2.8 (1.0, 7.6)**
Noticed cigarette health warning labels				
No	ref	ref	ref	ref
Yes	4.2 (0.6, 30.3)	2.4 (0.3, 21.1)	1.0 (0.4, 2.6)	0.7 (0.3, 1.8)
Any risk taking				
No	ref	ref	ref	ref
Yes	3.2 (0.4, 22.6)	1.6 (0.2, 12.6)	2.7 (1.0, 7.7)	2.4 (0.8, 6.7)

Notes: Boldface indicates statistical significance ($p<0.05$).

[a]Current e-cigarette users who were never cigarette smokers.

[b]The race/ethnicity variable is dichotomized as white versus non-white for the 1-year progression due to the small sample sizes in the other categories.

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