

Use of E-cigarettes and Other Tobacco Products and Progression to Daily Cigarette Smoking

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abstract

OBJECTIVES: To identify predictors of becoming a daily cigarette smoker over the course of 4 years.

METHODS: We identified 12- to 24-year-olds at wave 1 of the US Population Assessment of Tobacco and Health Study and determined ever use, age at first use, and daily use through wave 4 for 12 tobacco products.

RESULTS: Sixty-two percent of 12- to 24-year-olds (95% confidence interval [CI]: 60.1% to 63.2%) tried tobacco, and 30.2% (95% CI: 28.7% to 31.6%) tried ≥ 5 tobacco products by wave 4. At wave 4, 12% were daily tobacco users, of whom 70% were daily cigarette smokers (95% CI: 67.4% to 73.0%); daily cigarette smoking was 20.8% in 25- to 28-year-olds (95% CI: 18.9% to 22.9%), whereas daily electronic cigarette (e-cigarette) vaping was 3.3% (95% CI: 2.4% to 4.4%). Compared with single product triers, the risk of progressing to daily cigarette smoking was 15 percentage points higher (adjusted risk difference [aRD] 15%; 95% CI: 12% to 18%) among those who tried ≥ 5 products. In particular, e-cigarette use increased the risk of later daily cigarette smoking by threefold (3% vs 10%; aRD 7%; 95% CI: 6% to 9%). Daily smoking was 6 percentage points lower (aRD -6%; 95% CI: -8% to -4%) for those who experimented after age 18 years.

CONCLUSIONS: Trying e-cigarettes and multiple other tobacco products before age 18 years is strongly associated with later daily cigarette smoking. The recent large increase in e-cigarette use will likely reverse the decline in cigarette smoking among US young adults.



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The funders had no role in the development or analyses of this article.

Dr Pierce conceptualized and designed this study, drafted the initial manuscript, and reviewed and revised the manuscript; Mr Chen and Ms White had input in the study design, undertook the analyses for this study, and reviewed and revised the manuscript; Drs Messer and Benmarhnia had input in the study design, oversaw all analyses undertaken, and reviewed and revised the manuscript for important intellectual content; Drs Leas, Trinidad, and Strong, Mr Stone, and Ms Kealey had input in the study design and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: <https://doi.org/10.1542/peds.2020-025122>

Accepted for publication Nov 5, 2020

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WHAT'S KNOWN ON THIS SUBJECT: Since the introduction of electronic cigarettes, US adolescents and young adults who experiment with tobacco commonly try multiple tobacco products. The impact of this on subsequent prevalence of daily cigarette smoking, the most harmful form of tobacco use, is unclear.

WHAT THIS STUDY ADDS: This 4-year nationally representative study documents that youth who use electronic cigarettes (versus never users) are at a threefold higher risk of later daily cigarette smoking. Other predictors include tobacco use before age 18 years and the number of tobacco products tried.

To cite: Pierce JP, Chen R, Leas EC, et al. Use of E-cigarettes and Other Tobacco Products and Progression to Daily Cigarette Smoking. *Pediatrics*. 2021;147(2):e2020025122

The pattern of experimentation with tobacco products has changed considerably over the past decade, with adolescents and young adults now commonly experimenting with multiple tobacco products.¹⁻³ From 2016 to 2019, lifetime cigarette smoking among US high school seniors declined from 28.3% to 22.3%, whereas lifetime electronic cigarette (e-cigarette) use increased from 38.8% to 45.6%.⁴ However, US daily cigarette smoking prevalence was stable from 2007 to 2013 at 16% to 17%.^{5,6} It remains unclear how the rise in multiple tobacco product experimentation will impact future daily cigarette smoking prevalence. A scenario of concern is that those experimenting with multiple products may be more likely to transition to daily cigarette smoking,^{7,8} leading to an increase in this most harmful form of tobacco use.

Results of cross-sectional studies have suggested that the recent rise in e-cigarette experimentation among young people may not be associated with later regular cigarette smoking.⁹ However, many e-cigarette experimenters are concurrent users of multiple products, including up to one-third of young adult cigarette smokers^{2,10} and half of adolescent and young adult e-cigarette vapers.¹¹ Because it takes a number of years for most people to become fully nicotine dependent,¹² longitudinal studies are needed to identify the association between products tried and later daily cigarette smoking.

We use 4 annual waves of the nationally representative Population Assessment of Tobacco and Health (PATH) Study¹³ to explore progression to daily use among experimenters of 12 tobacco products. Our population of interest is youth and young adults (aged 12–24 years) identified at wave 1 in 2013–2014. For each product, we report age at first use and patterns of daily use by age at wave 4 in 2017. Finally, we consider whether the

number of tobacco products tried and the age at first use of tobacco is associated with progression to daily cigarette smoking at wave 4.

METHODS

The PATH Study is a US nationally representative longitudinal study of tobacco use and health and is funded by the Center for Tobacco Products under the US Food and Drug Administration and the National Institute on Drug Abuse of the National Institutes of Health.¹³ A stratified address-based area probability sample identified US civilian, noninstitutional households for a screener questionnaire, after which young adults, adult tobacco users, and African Americans were oversampled. Surveys were conducted by using audio, computer-assisted self-interviews in English or Spanish. In the PATH wave 1 survey, data were collected from September 2013 to December 2014. Participants were contacted for additional annual survey waves around the anniversary of their wave 1 survey. Wave 4 (2017 survey) was completed by early January 2018.

In this article, we report on waves 1 to 4 data from the PATH restricted use files.¹⁴ The study is conducted by Westat and overseen by the Westat Institutional Review Board. All participants 18 and older provided informed consent, with youth providing assent after a parent or legal guardian provided consent. The response rate to the wave 1 household screener was 54%. The unweighted attrition rate among the wave 1 (2013–2014) sample was 16% at wave 2 (2015), 21% at wave 3 (2016), and 27% at wave 4 (2017). The full sample and replicate weights are provided to adjust for the complex study design, including oversampling and attrition, so that estimates are representative of the US civilian, noninstitutionalized population. We limit our study to

those aged 12–24 years at wave 1 ($n = 15\,826$) who completed all 4 survey waves.

Tobacco Use Measures

The following tobacco products were investigated in each PATH Study survey: cigarettes, e-cigarettes, cigarillos, traditional cigars, filtered cigars, smokeless tobacco, snus, pipes, hookah, dissolvable tobacco, kreteks (youth only) and bidis (youth only). Respondents were asked whether they had ever used the product, even 1 or 2 times (for cigarettes, even 1 or 2 puffs). In follow-up annual surveys, respondents were asked if they had used each product in the past 12 months and asked about the frequency of use in the past 30 days. A response of ever use on any survey classified a respondent as an ever user. Ever users were asked the age at which they first tried each product. Those who reported starting use of a product after wave 1 were assigned the age at the reporting survey. Age at first tobacco use was the youngest age reported. The number of products tried was the sum of ever use reported across products. Daily use in the adult survey was determined by a response of “every day” to the question “Do you now use [the product] every day, some days, or not at all?” Adolescent survey respondents who reported using a product at least 25 days in the past 30 days were considered daily users.

Study Covariates

Age, sex, and race and/or ethnicity were reported by respondents and their family members. We categorized race and/or ethnicity as non-Hispanic white, non-Hispanic Black, Hispanic, Asian, and multiracial, and we categorize age groups at wave 1 as 12 to 14, 15 to 17, 18 to 21, and 22 to 24 years. Household exposure to cigarettes and other tobacco products was assessed from wave 1 self-reports of any exposure to use by others within the past 7 days (categorized as not exposed and

exposed). Home smoking restrictions were reported at wave 1 and categorized as “yes” for those who reported a smoke-free home (without exceptions) and “no” for all others.

Managing Missing Data

Any missing data on respondent surveys for age, sex, or race and/or ethnicity were already imputed in the restricted use file, as described in PATH Study restricted use files user guide.¹⁴ Those who gave a “don’t know” or “refused” response to the question on ever use of a product were considered nonusers of that product. However, nonusers at wave 1 may have reported ever use in a later survey. Ever users of a product who could not recall the age at first use were recorded with a missing age for that product. In the study logistic regression, the variable with the most missing data was age at first tobacco use (8.5%).

Statistical Analyses

We use weights for all waves and replicate weights provided at wave 4 to obtain statistically valid estimates from longitudinal analyses. Variances and 95% confidence intervals (CIs) for estimates were obtained by using balanced repeated replication weights with Fay’s adjustment ($\rho = 0.3$). Estimates with a denominator of <50 or a relative SE $\geq 30\%$ are not presented.

To examine associations with progression to daily use of cigarettes at wave 4, we ascertained the subsample who were not daily users of tobacco at wave 1 and who did use at least 1 tobacco product by wave 3. Adjusted risk differences (aRDs) were computed from multivariable logistic regression by using the following 3 models: (1) age at first experimentation with any tobacco product + sex + race and/or ethnicity + age + smoke-free home + exposure to smokers, (2) the number of tobacco products tried + age at first experimentation with any

TABLE 1 Sociodemographic Characteristics by Tobacco Use Status in 12- to 24-Year-Olds, PATH Study Wave 1, 2013–2014

| Sociodemographic Characteristic | No. | Tobacco Use Status at Wave 1, Weighted % (95% CI) | | |
|---------------------------------|--------|---|---------------------------------|----------------------------------|
| | | Tobacco Never Users ^a | Tobacco Ever Users ^b | Daily Tobacco Users ^c |
| Overall | 15 826 | 54.5 (53.1 to 55.9) | 45.5 (44.1 to 46.9) | 10.1 (9.5 to 10.7) |
| Age, y | | | | |
| 12–14 | 5315 | 90.7 (89.8 to 91.6) | 9.3 (8.4 to 10.4) | 0.2 (0.0 to 0.4) |
| 15–17 | 4771 | 68.3 (66.8 to 69.8) | 31.7 (30.2 to 33.2) | 3.3 (2.6 to 4.0) |
| 18–21 | 3230 | 38.0 (35.7 to 40.3) | 62.0 (59.7 to 64.3) | 14.8 (13.5 to 16.1) |
| 22–24 | 2510 | 28.1 (24.9 to 31.3) | 71.9 (68.7 to 74.8) | 19.8 (18.1 to 21.5) |
| Sex | | | | |
| Male | 7888 | 52.0 (50.4 to 53.6) | 48.0 (46.4 to 49.6) | 12.2 (11.3 to 13.1) |
| Female | 7938 | 57.1 (55.4 to 58.8) | 42.9 (41.3 to 44.6) | 7.9 (7.1 to 8.7) |
| Race and/or ethnicity | | | | |
| Non-Hispanic white | 7637 | 52.3 (50.3 to 54.3) | 47.7 (45.8 to 49.7) | 12.8 (11.9 to 13.7) |
| Non-Hispanic Black | 2389 | 58.8 (56.5 to 61.1) | 41.2 (38.9 to 43.5) | 8.7 (7.3 to 10.1) |
| Hispanic | 4338 | 54.9 (52.9 to 56.9) | 45.1 (43.1 to 47.1) | 5.4 (4.7 to 6.1) |
| Asian | 438 | 65.5 (60.9 to 70.1) | 34.5 (29.8 to 39.4) | 2.6 (0.2 to 5.0) |
| Multiracial | 1024 | 52.7 (49.3 to 56.1) | 47.3 (43.9 to 50.8) | 12.9 (10.6 to 15.2) |
| Smoke-free home | | | | |
| No | 4140 | 34.9 (33.2 to 36.7) | 65.1 (63.3 to 66.8) | 23.0 (21.5 to 24.6) |
| Yes | 11 686 | 61.9 (60.3 to 63.4) | 38.1 (36.6 to 39.7) | 5.2 (4.8 to 5.7) |
| Exposed to smokers ^d | | | | |
| No | 7925 | 72.6 (71.1 to 74.0) | 27.4 (26.0 to 28.9) | 1.4 (1.1 to 1.7) |
| Yes | 7901 | 38.1 (36.6 to 39.6) | 61.9 (60.4 to 63.4) | 18.0 (17.0 to 19.0) |

^a Respondents answering negatively when asked whether they had ever used the product, even 1 or 2 times (for cigarettes, even 1 or 2 puffs).

^b Respondents answering affirmatively when asked whether they had ever used the product, even 1 or 2 times (for cigarettes, even 1 or 2 puffs).

^c Daily use in the PATH adult survey (respondents ≥ 18 y) was determined by a response of “every day” to the question “Do you now use [the product] every day, some days, or not at all?” Daily use in the PATH youth survey (respondents <18 y) was determined if youth survey respondents reported using a product at least 25 d in the past 30 d.

^d Exposed in previous 7 d.

tobacco product + sex + race and/or ethnicity + age + smoke-free home + exposure to smokers, and (3) ever use of e-cigarettes (yes or no) + ever use of other noncigarette tobacco products (yes or no) + age at first experimentation with any tobacco product + sex + race and/or ethnicity + age + smoke-free home + exposure to smokers in the past 7 days.

CIs for the aRDs were computed by using the quantiles from a parametric bootstrap distribution and by resampling 1000 draws from a multivariate normal distribution, with the mean and covariance equal to the maximum likelihood estimates for the sampling distribution of the estimated model parameters. Analyses were conducted in SAS (version 9.4; SAS Institute, Inc, Cary, NC) and R (version 3.5.3; R

Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Ever and Daily Tobacco Use Among 12- to 24-Year-Olds at Wave 1 (2013–2014)

More than half of wave 1 respondents (54.5%; 95% CI: 53.1 to 55.9) were classified as tobacco never users, and this proportion declined dramatically with age (12–14 years old: 90.7% [95% CI: 89.8 to 91.6]; 22–24 years old: 28.1% [95% CI: 24.9 to 31.3]; Table 1). Ever use of tobacco was more common among male respondents (48.0%; 95% CI: 46.4 to 49.6) than female respondents (42.9%; 95% CI: 41.3 to 44.6), among non-Hispanic white respondents (47.4%, 95% CI: 45.8 to 49.7) than Asian (34.5%; 95% CI: 29.8 to 39.4)

TABLE 2 Ever Tobacco Use at Wave 4 (2017) and Age at First Use by Product Among PATH Study Respondents Aged 12–24 Years at Wave 1 (2013–2014; *n* = 15 826)

| | Ever Tobacco Use ^a at Wave 4 | | Percentage of All Tobacco Users Using Product, Weighed % (95% CI) | Age at First Use, ^b y | |
|---------------------|---|---------------------|---|----------------------------------|---------------|
| | No. | Weighted % (95% CI) | | Median | 95% Quantiles |
| Tobacco product | — | — | — | — | 2.5%–97.5% |
| Any tobacco | 9410 | 61.7 (60.1 to 63.2) | 100.0 (—) | 16 | 7–23 |
| Individual products | | | | | |
| E-cigarettes | 7238 | 45.3 (43.9 to 46.7) | 73.1 (71.9 to 74.3) | 19 | 8–22 |
| Cigarettes | 6766 | 44.9 (43.6 to 46.2) | 72.4 (71.1 to 73.7) | 16 | 12–25 |
| Hookah | 5723 | 38.7 (37.0 to 40.3) | 62.4 (60.4 to 64.3) | 17 | 13–23 |
| Cigarillos | 5230 | 34.4 (33.1 to 35.7) | 55.5 (54.1 to 56.9) | 17 | 11–23 |
| Traditional cigars | 3616 | 24.7 (23.6 to 25.9) | 39.9 (38.4 to 41.3) | 17 | 12–24 |
| Filtered cigars | 2935 | 18.4 (17.4 to 19.4) | 29.6 (28.4 to 30.9) | 17 | 12–24 |
| Smokeless tobacco | 2259 | 14.4 (13.6 to 15.1) | 23.2 (22.1 to 24.2) | 16 | 9–23 |
| Pipes | 2107 | 13.3 (12.5 to 14.0) | 21.4 (20.4 to 22.4) | 16 | 11–23 |
| Snus | 1821 | 11.3 (10.7 to 12.0) | 18.3 (17.3 to 19.2) | 16 | 12–23 |
| Kreteks | 610 | 2.7 (2.5 to 3.0) | 4.4 (4.1 to 4.8) | 16 | 12–17 |
| Dissolvable tobacco | 605 | 2.7 (2.5 to 2.9) | 4.4 (4.0 to 4.7) | 16 | 12–20 |
| Bidis | 604 | 2.7 (2.5 to 2.9) | 4.4 (4.0 to 4.7) | 16 | 13–17 |

—, not applicable.

^a Respondents answered affirmatively when asked whether they had ever used the product, even 1 or 2 times (for cigarettes, even 1 or 2 puffs).

^b The youngest age reported for ever use of a tobacco product. Those who reported starting use of a product after wave 1 were assigned the age at the reporting survey.

or non-Hispanic Black respondents (41.2%; 95% CI: 38.9 to 43.5); among those without a smoke-free home (65.1%; 95% CI: 63.3 to 66.8) than those with one (38.1%; 95% CI: 36.6 to 39.7); and among those exposed to other smokers (61.9%; 95% CI: 60.4 to 63.4) than those not so exposed (27.4%; 95% CI: 26.0 to 28.9).

Daily tobacco use (10.1%; 95% CI: 9.5 to 10.7) was strongly associated with age (15–17 years old: 3.3% [95% CI: 2.6 to 4.0]; 22–24 years old: 19.8% [95% CI: 18.1 to 21.5]) as well as with sex (male respondents: 12.2% [95% CI: 11.3 to 13.1] versus female respondents: 7.9% [95% CI: 7.1 to 8.7]). Daily use was higher among non-Hispanic white respondents (12.8%) and those of multiple races or ethnicities (12.9%) than those identifying as non-Hispanic Black (8.7%), Hispanic (5.4%), or Asian (2.6%). Daily use was also higher in those without a smoke-free home (23.0% vs 5.2%). Exposure to others who smoked in the past week was also strongly associated with daily use (18.0% vs 1.4%).

Ever Tobacco Use at Wave 4

Ever tobacco use increased from 45.5% at wave 1 (Table 1) to 61.7%

at wave 4 (95% CI: 60.1 to 63.2; Table 2). The 4 tobacco products most frequently tried were e-cigarettes (45.3%), cigarettes (44.9%), hookah (38.7%), and cigarillos (34.4%). Among tobacco users, 70% tried cigarettes and e-cigarettes and more than half tried hookah and cigarillos. Five other tobacco products (traditional cigars, filtered cigars, smokeless products, pipes, and snus) were tried by >10% of respondents.

Except for e-cigarettes, the median age at first use for every product was 16 to 17 years (Table 2). We show 95% quantiles for age at first experimentation with each product and note that the youngest 2.5% of all experimenters was <10 years of age for only 2 products (e-cigarettes and smokeless tobacco). Unlike other tobacco products, experimentation with e-cigarettes was reported by ~10% for each age from 17 to 21 years, leading to a higher median age at first use (Fig 1). In the first year of tobacco use, 63.9% (95% CI: 62.8% to 65.0%) of experimenters used 1 product, 16.9% (95% CI: 15.8% to 17.9%) used 2 products, and 12.5% used ≥3 products.

Daily Use of Tobacco Products at Wave 4 (2017)

At wave 4, 1935 wave 1 respondents (12.4%; 95% CI: 11.8% to 13.1%) were daily users of a tobacco product, with just less than half of these (5.0%; 95% CI: 4.6% to 5.4%) starting daily tobacco use after wave 1. Most daily users (70.3%; 95% CI: 67.4% to 73.0%) were cigarette smokers (Table 3), which was >4 times the proportion who were daily e-cigarette vapers (16.6%; 95% CI: 14.3% to 19.2%). Few were daily users of both cigarettes and e-cigarettes (2.1%; 95% CI: 1.5% to 2.9%). Daily cigarette smokers had a higher probability of exclusive use (63.5%; 95% CI: 60.6% to 66.2%) than daily e-cigarette vapers (42.1%; 95% CI: 36.1% to 48.4%). Among daily e-cigarette vapers, the most common nondaily use of a concurrent product was smoking cigarettes (44.9%; 95% CI: 39.0% to 51.0%).

Among ever users of tobacco at waves 1 to 4, daily tobacco use increased with age (Table 4). In particular, daily cigarette use almost doubled between 18- to 21-year-olds (11.7%; 95% CI: 10.4% to 13.2%) and 25- to 28-year-olds (20.8%; 95% CI: 18.9% to

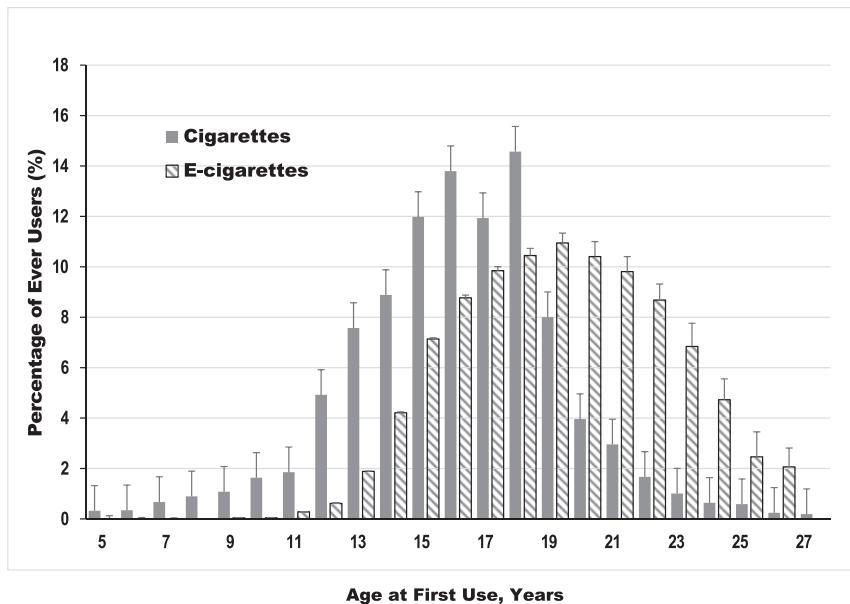


FIGURE 1

Age at first use of cigarettes and e-cigarettes among PATH Study respondents aged 12 to 24 years at wave 1 ($n = 15\ 826$). Age at first use is the youngest age reported for ever use of a tobacco product. Those who reported starting use of a product after wave 1 were assigned the age at the reporting survey.

22.9%). The proportion of daily e-cigarette vapers did not differ by age (range 3.3%–4.7%). For those younger than 18 years in 2016–2017, 6.3% reported using any tobacco product on 25 of the past 30 days (daily use, as defined by the PATH Study youth survey).

Progression to Daily Cigarette Smoking at Wave 4

We examined 7088 nondaily tobacco users at wave 1 who had tried at least 1 tobacco product by wave 3. In a logistic

regression, after controlling for age, sex, race and/or ethnicity, having a smoke-free home at wave 1, and exposure to other smokers at wave 1, we found that those who first experimented with tobacco after age 18 years had an aRD for progression to daily cigarette smoking that was 6 percentage points lower (95% CI: –8% to –4%) compared with those who first experimented when younger than 18 years.

Trying 1 tobacco product was reported by 20.9% (95% CI: 19.5% to

22.3%), 19.1% (95% CI: 17.9% to 20.4%) reported trying 2 products, 29.9% (95% CI: 28.7% to 31.2%) reported trying 3 to 4 products, and 30.1% (95% CI: 28.7% to 31.5%) reported trying ≥ 5 tobacco products. We found a strong dose-response relationship between the number of products used and report of daily cigarette smoking at wave 4. Less than 1% of those who only tried 1 product by wave 3 progressed to daily cigarette smoking by wave 4. Experimentation with a second product by wave 3 increased the risk of daily cigarette use at wave 4 by an aRD of 2 percentage points (95% CI: 0.3% to 4%) (ie, 2 additional daily cigarette smokers per 100 tobacco users, compared with single product users; Fig 2A). Those who had tried 3 or 4 tobacco products had an aRD of becoming daily smokers of 7 percentage points (95% CI: 5% to 9%) compared with single product users. Those who had tried ≥ 5 tobacco products, had an aRD of becoming a daily cigarette smoker of 15 percentage points (95% CI: 12% to 18%) (ie, 15 additional daily cigarette smokers per 100 tobacco users, compared with single product users). Figure 2B reveals that ever use of an e-cigarette (versus never use) increased the risk of later daily cigarette smoking by threefold (3% vs 10%; aRD 7%; 95% CI: 6% to 9%), adjusted for confounders and ever

TABLE 3 Tobacco Product Use in Daily Users at Wave 4 (2017) Among PATH Study Respondents Aged 12–24 Years at Wave 1 (2013–2014), $n = 1935$

| Product(s) Used Daily at Wave 4 | Daily Tobacco Product Use at Wave 4 | | | | Nondaily Tobacco Product Use at Wave 4 | | | | | |
|---------------------------------|-------------------------------------|---------------------|--------------------------------|---------------------|--|---------------------|-----------------|---------------------|----------------------------|---------------------|
| | Total Daily Users of Product | | Exclusive Daily Use of Product | | E-cigarettes | | Cigarettes | | Other Product ^a | |
| | No. | Weighted % (95% CI) | No. | Weighted % (95% CI) | No. | Weighted % (95% CI) | No. | Weighted % (95% CI) | No. | Weighted % (95% CI) |
| Cigarettes | 1383 | 70.3 (67.4 to 73.0) | 846 | 63.5 (60.6 to 66.2) | 278 | 17.4 (15.4 to 19.4) | NA ^b | NA | 429 | 29.4 (26.7 to 32.2) |
| E-cigarettes | 299 | 16.6 (14.3 to 19.2) | 116 | 42.1 (36.1 to 48.4) | NA ^b | NA | 144 | 44.9 (39.0 to 51.0) | 120 | 37.1 (30.7 to 44.0) |
| Cigarettes and e-cigarettes | 41 | 2.1 (1.5 to 2.9) | 19 | 50.8 (34.7 to 66.8) | NA ^b | NA | NA ^b | NA | 22 | 49.2 (33.2 to 65.3) |
| Smokeless tobacco ^c | 133 | 7.4 (6.0 to 9.1) | 70 | 54.4 (46.0 to 62.7) | 8 | 5.4 (2.6 to 10.6) | 32 | 22.7 (16.0 to 31.0) | 42 | 31.3 (24.1 to 39.6) |
| Other tobacco ^d | 79 | 3.6 (2.9 to 4.6) | 22 | 27.3 (17.3 to 40.2) | 24 | 24.8 (16.6 to 35.3) | 43 | 54.4 (40.8 to 67.5) | 40 | 45.1 (34.2 to 56.4) |

Daily use in the PATH adult survey (respondents ≥ 18 y) was determined by a response of “every day” to the question “Do you now use [the product] every day, some days, or not at all?” Daily use in the PATH youth survey (respondents < 18 y) was determined if youth survey respondents reported using a product at least 25 d in the past 30 d. NA, not applicable.

^a Other product includes smokeless tobacco, dissolvable tobacco, snus, hookah, cigarillos, traditional cigars, filtered cigars, pipes, kreteks, and bidis.

^b NA because of a limited sample size.

^c Smokeless tobacco includes dissolvable tobacco and snus.

^d Other tobacco includes hookah, cigarillos, traditional cigars, filtered cigars, pipes, kreteks, and bidis.

TABLE 4 Daily Use of Tobacco Products by Age at Wave 4 Among Ever Users of Tobacco in Waves 1–4 (*n* = 9384)

| Age Group at Wave 4, y | Daily Tobacco Use at Wave 4, Weighted % (95% CI) | | | |
|------------------------|--|------------------|---|----------------------------------|
| | Cigarettes | E-cigarettes | Product Other Than Cigarettes or E-cigarettes | Daily Use of Any Tobacco Product |
| 15–17 | 3.2 (2.4 to 4.3) | 2.8 (2.0 to 3.9) | 0.5 (0.2 to 0.9) | 6.3 (5.1 to 7.7) |
| 18–21 | 11.7 (10.4 to 13.2) | 4.7 (3.9 to 5.6) | 2.6 (2.0 to 3.3) | 18.6 (17.0 to 20.3) |
| 22–24 | 15.6 (14.0 to 17.4) | 3.7 (2.8 to 4.8) | 2.3 (1.8 to 3.1) | 21.2 (19.2 to 23.4) |
| 25–28 | 20.8 (18.9 to 22.9) | 3.3 (2.4 to 4.4) | 2.4 (1.8 to 3.1) | 26.0 (23.9 to 28.2) |

Daily use in the PATH adult survey (respondents ≥ 18 y) was determined by a response of “every day” to the question “Do you now use [the product] every day, some days, or not at all?” Daily use in the PATH youth survey (respondents < 18 y) was determined if survey respondents reported using a product at least 25 d in the past 30 d. A total of 1590 participants were still not 18 y old when surveyed at wave 4; hence, they completed the wave 4 youth survey rather than the adult survey. This table is a cross-sectional analysis of wave 4 respondents and so includes ever users at any survey, including the wave 4 survey.

use of other noncigarette tobacco products.

DISCUSSION

In our longitudinal analysis of multiple tobacco product use in the nationally representative PATH Study, we found that 62% of US youth had tried at least 1 tobacco product before wave 4 (2017) and that 30% had tried ≥ 5 products. Equal numbers of respondents had tried e-cigarettes and cigarettes, which were by far the most frequently tried products. At wave 4, daily cigarette smoking made up 70% of all daily tobacco use. Among those who were not daily users at wave 1, ever use of e-cigarettes was associated with more than a threefold increase in daily cigarette smoking at wave 4, from 3% for never e-cigarette users to 10% for e-cigarette users. In addition, each additional tobacco product tried was associated with a marked increase in wave 4 daily smoking. Although equal numbers of these young respondents had tried e-cigarettes and cigarettes, the proportion in the oldest age group who progressed to daily cigarette smoking over the 4 year study period (eg, 21% of 25- to 28-year-olds at wave 4) was 6 times higher than the proportion who progressed to daily e-cigarette vaping (3.3% of 25- to 28-year-olds). Indeed, $>20\%$ of those aged 25 to 28 years were daily cigarette smokers, consistent with reports that daily cigarette smoking among US adults may have started to increase in recent years.¹⁵

The reported age at first experimentation ranged from 7 to 23 years, although for most products, half of those who experimented first did so between age 14 and 18 years. Only e-cigarettes and smokeless products had $>2\%$ of ever users trying the product before 10 years of age. This early experimentation has been well documented for e-cigarettes in middle school.¹⁶ We found that one-third of experimenters tried their first product after age 18 years and that these older experimenters were much less likely to progress to daily cigarette smoking over the study period. However, recent school surveys have reported a rapid increase in ever use of e-cigarettes among both middle and high school students, suggesting that age at first experimentation with e-cigarettes is becoming younger.¹⁶ Given our findings, this increase will likely lead to a large increase in daily cigarette smoking in young adults over the next decade.

Our finding of a high proportion of first e-cigarette experimentation among those older than 18 years may be an artifact of the recent introduction of e-cigarettes with pharmacokinetic nicotine delivery systems similar to cigarettes.¹⁷ In 2013, more than one-third of our study population was already older than 18 years. Given that e-cigarettes were widely considered as less harmful than cigarettes in 2013–2014,¹⁸ it is possible that people who had not experimented

with other tobacco were attracted by this new and increasingly popular product.¹⁹ It is likely that age at first experimentation with e-cigarettes will decline as those who entered their teen-aged years when e-cigarettes were already popular become adults.

Among daily cigarette smokers, one-third also used another tobacco product, with half of them vaping e-cigarettes on a nondaily basis. Among daily vapers, almost half were also nondaily cigarette smokers. Further follow-up will determine if these young daily tobacco users will continue to be dual product users or if they will stabilize on a single product, such as cigarettes. In the wave 1 PATH Study survey in 2013–2014, 80% of those who had used an e-cigarette indicated that a reason for use was that they could vape at times when, or in places where, smoking cigarettes was forbidden,²⁰ and such use¹⁷ is common.²¹ Such a secondary role for e-cigarettes may change with the more efficient e-cigarette nicotine delivery systems¹⁷ that became popular in the United States after 2017.^{22,23}

The PATH Study has numerous strengths. These include the large representative sample of the US population and annual in-household follow-up self-assessments. Although there was attrition between surveys, all survey weights are available to minimize effects on study estimates. In this article, we rely on self-

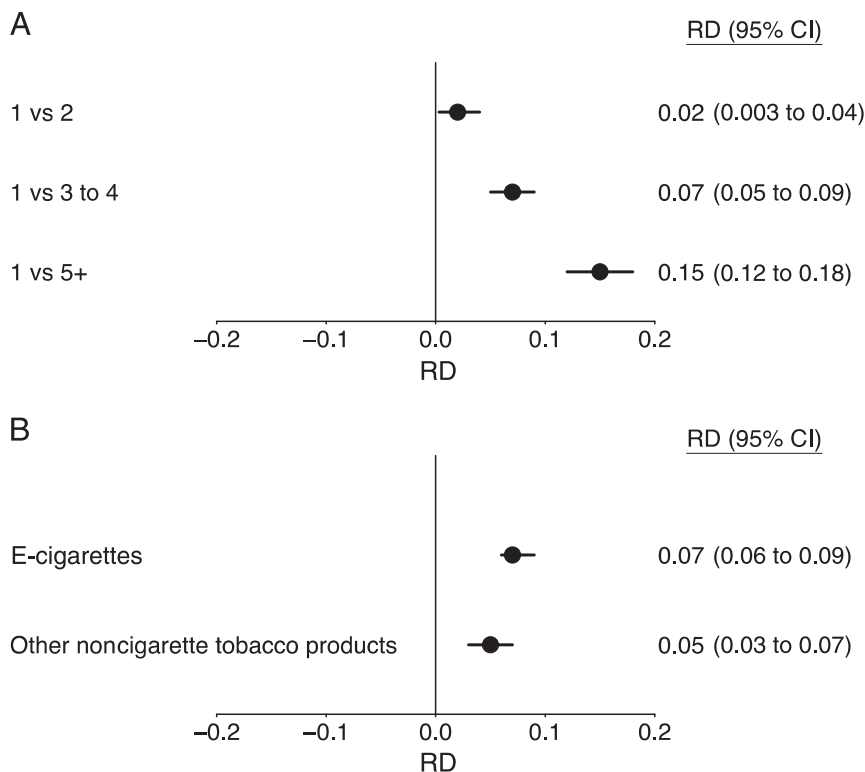


FIGURE 2

A and B, Multivariable logistic regression aRDs and weighted risk differences (RDs) in rates of progression to daily cigarette smoking at wave 4 by the number of tobacco products reported as ever tried at waves 1 to 3 (A) and by ever use of e-cigarettes or other noncigarette tobacco products (except e-cigarettes) at wave 3 (B). The 2 binary predictors, (1) ever used e-cigarettes and (2) ever used other noncigarette tobacco products (except e-cigarettes), are assessed simultaneously in panel B. Please refer to model 3 in the method. The sample was drawn from participants of the PATH Study who were 12 to 24 years old at wave 1 and had reported trying at least 1 tobacco product between the waves 1 and 3 surveys but were not daily tobacco users at wave 1 ($n = 7088$). The logistic regression was adjusted for age, sex, race and/or ethnicity, having smoke-free home at wave 1, exposure to other smokers at wave 1, and age at first use of any tobacco product. Bars represent 95% CIs, which were computed by using the quantiles from parametric bootstrap distributions and by resampling 1000 draws from a multivariate normal distribution, with the mean and covariance equal to the maximum likelihood estimates for the sampling distribution of the estimated model parameters.

reported frequency of use for the wide range of tobacco products assessed in the PATH Study surveys;

however, biological samples were also collected from respondents,¹³ and these have been used to validate self-

report in subsamples.^{24,25} A limitation of any observational study is unmeasured confounding that is uncorrelated with the covariates.

CONCLUSIONS

In this representative sample of US youth and young adults, almost two-thirds had experimented with at least 1 tobacco product and almost one-third experimented with ≥ 5 tobacco products, of which e-cigarettes and cigarettes were the most popular. Over the 4-year study, 12% reported daily tobacco use, with more than two-thirds of these reporting daily cigarette smoking. Progression to daily cigarette smoking between waves 1 and 4 was 3 times higher among e-cigarette ever users compared with nonusers. Each additional product tried markedly increased the odds of becoming a daily cigarette smoker, as did experimenting with tobacco before age 18 years. These results suggest that recent rapid growth in adolescent e-cigarette use will lead to increased daily cigarette smoking in US young adults.

ABBREVIATIONS

aRD: adjusted risk difference
 CI: confidence interval
 e-cigarette: electronic cigarette
 PATH: Population Assessment of Tobacco and Health

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