

# Initiation of any tobacco and five tobacco products across 3 years among youth, young adults and adults in the USA: findings from the PATH Study Waves 1–3 (2013–2016)

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► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/tobaccocontrol-2019-055573>).

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Received 16 December 2019

Revised 7 February 2020

Accepted 10 February 2020



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**To cite:** Stanton CA, Sharma E, Seaman EL, *et al.* *Tob Control* 2020;**29**:s178–s190.

## ABSTRACT

**Objective** This study reports weighted cross-sectional prevalence of never use of tobacco, and longitudinal past 12-month (P12M), past 30-day (P30D) and frequent P30D any tobacco or specific tobacco product initiation across three 1-year waves. Longitudinal three-wave pathways are examined to outline pathways of exclusive and polytobacco initiation, as well as pathways of new initiators of electronic nicotine delivery systems (ENDS) or cigarettes.

**Design** Data were drawn from the first three waves (2013–2016) of the Population Assessment of Tobacco and Health Study, a nationally representative, longitudinal cohort study of US youth and adults. Respondents with data at all three waves (youth, N = 11 046; young adults, N = 6478; adults 25+, N = 17 188) were included in longitudinal analyses.

**Results** Across the three age groups, weighted cross-sectional analyses revealed never any tobacco use decreased each year from 2013 to 2016, reflecting overall increases in tobacco initiation in the population during this time. Compared with cigarettes, cigars, hookah and smokeless tobacco, ENDS had the highest proportion of P12M initiation from Wave 1 to Wave 3 (W3) for each age group. Among youth Wave 2 P30D initiators of exclusive ENDS or cigarettes, the most common W3 outcome was not using any tobacco (ENDS: 59.0% (95% CI 48.4 to 68.8); cigarettes: 40.3% (95% CI 28.7 to 53.1)).

**Conclusions** Initiation rates of ENDS among youth and young adults have increased the number of ever tobacco users in the US prevention strategies across the spectrum of tobacco products which can address youth initiation of tobacco products.

## INTRODUCTION

National estimates of tobacco use in the US have demonstrated a decline in ever cigarette use in the past two decades; lifetime cigarette use among 12th graders was down to 23.8% in 2018, compared with 63.1% in 1991, according to Monitoring the Future data.<sup>1</sup> Lifetime smokeless tobacco use among 12th graders was down to 10.1% in 2018, compared with 32.4% in 1992, demonstrating

a similar pattern.<sup>1</sup> Ever use of electronic nicotine delivery systems (ENDS), which in this report refers largely to e-cigarettes, has increased in recent years among youth (12–17 years).<sup>2–8</sup> The 2019 National Youth Tobacco Survey results indicate that 27.5% of US high school students are current users of e-cigarettes and 5.8% are current cigarette smokers.<sup>8</sup> Among adults, data from the Population Assessment of Tobacco and Health (PATH) Study indicate that 11% of young adults (18–24 years) initiated current tobacco use over a 1-year period from Wave 1 (W1) in 2013/2014 to Wave 2 (W2) in 2014/2015, compared with only 4% initiation of current tobacco use between W1 and W2 among adults 25+ (ages 25 and older).<sup>9</sup>

Initiation of tobacco use can be defined broadly as new ever use,<sup>10–13</sup> or in reference to a specific time period such as past 12-month use (P12M),<sup>11 14</sup> past 30-day use (P30D)<sup>10 13</sup> or frequent use (eg, 20 or more days) in the past 30 days.<sup>15 16</sup> These increasingly narrow definitions for new use can help distinguish when new use may be a function of experimentation (ie, P12M use) or more regular use (ie, frequent use in the past 30 days). Reports of any tobacco initiation have traditionally been driven by cigarette use<sup>4</sup>; however, recent increases in use of non-cigarette tobacco products calls for monitoring initiation of other tobacco products among existing tobacco users (eg, cigarette smokers who initiate ENDS).<sup>17 18</sup>

It has been shown that most people who ever smoked daily try their first cigarette during youth or young adulthood, with very few (<1.5%) initiating cigarette use after age 26.<sup>4</sup> Cross-sectional 2016 data from National Survey on Drug Use and Health (NSDUH) report retrospective P12M initiation rates of cigarettes, smokeless tobacco and cigars for youth at 3.2%, 1.5% and 2.4%, respectively, and for adults ages 18 and older at 1.1%, 0.4% and 1.1%, respectively.<sup>14</sup> Moreover, P30D daily cigarette smoking in the P12M is higher among youth compared with adults, as shown by cross-sectional NSDUH rates that were tracked from 2006 to 2013.<sup>16</sup>

It is important to understand patterns of any tobacco initiation among never tobacco users and

new product initiation among existing tobacco users because a robust literature suggests that early cigarette smoking initiation, independent of sociodemographics, increases the risk of experiencing smoking-related morbidities and all-cause mortality later in life.<sup>19</sup> An analysis of W1 and W2 PATH Study data found that among youth participants, any use of ENDS, hookah, non-cigarette combustible tobacco or smokeless tobacco was associated with cigarette initiation over the next year, and that polytobacco use increased the odds of cigarette initiation.<sup>10</sup> Several studies examining initiation of ENDS use have reported that ENDS initiation among never cigarette smokers may influence the initiation of cigarette smoking among youth.<sup>7 20 21</sup> The many ways in which ever and current tobacco product use can shape future tobacco product initiation and progression are important to track in longitudinal studies that can monitor how these patterns impact addiction liability and potential negative health outcomes.

The current study draws from the nationally representative, longitudinal data of the PATH Study to follow participants' tobacco use over three waves of data collection (2013/14, 2014/15 and 2015/16). The availability of these longitudinal data allows a detailed examination over time of W1 (2013/14) never any tobacco or never specific-tobacco-product users to follow initial uptake and transitions across 2 years at Wave 2 (W2; 2014/15) and W3 (2015/16). Our first aim is to report weighted cross-sectional prevalence of never tobacco use (for any tobacco and individual tobacco products: cigarettes, ENDS, cigars, hookah and smokeless tobacco) among youth, young adults and adults 25+. The second aim is to report weighted P12M, P30D and frequent (20 or more days) P30D initiation rates among never users for each age group across 2 years (W1–W3) and compare initiation rates of the products in each of the 1 year intervals (W1–W2, W2–W3). The third aim is to test age group differences in weighted longitudinal W1–W2–W3 P30D exclusive and polytobacco use initiation pathways among W1 never tobacco users. Given that recent studies have linked ENDS use and subsequent new cigarette smoking among youth,<sup>7 10 20–24</sup> the fourth aim is to descriptively explore the subgroups of W2 ENDS initiation and cigarette initiation to better understand pathways among initiators of these products such as continued use, discontinued use and switching at W3.

## METHODS

### Study design and population

The PATH Study is an ongoing, nationally representative, longitudinal cohort study of youth (ages 12–17) and adults (ages 18 or older) in the US. Self-reported data were collected using audio computer-assisted self-interviews administered in English and Spanish. The PATH Study recruitment employed a stratified address-based, area-probability sampling design at W1 that oversampled adult tobacco users, young adults (ages 18–24) and African American adults. An in-person screener was used at W1 to randomly select youth and adults from households for participation in the study. At W1, the weighted response rate for the household screener was 54.0%. Among screened households, the overall weighted response rate was 78.4% for youth and 74.0% for adults at W1, 87.3% for youth and 83.2% for adults at W2, and 83.3% for youth and 78.4% for adults at W3. Further details regarding the PATH Study design and W1 methods are published elsewhere.<sup>25 26</sup> Details on interview procedures, questionnaires, sampling and weighting and information on accessing the data are available at <https://doi.org/10.3886/Series606>. The study was conducted by Westat and approved by the Westat Institutional Review Board. All participants ages 18 and older provided

informed consent, with youth participants ages 12–17 providing assent while their parent/legal guardian provided consent.

Online supplementary figure 1 shows the full W1 sample respondents who have data at Waves 1, 2 and 3. The current analysis reports cross-sectional estimates from 13 651 youth and 32 320 adults who participated in W1 data collection (12 September 2013 through 14 December 2014); or 12 172 youth and 28 362 adults at W2 (23 October 2014 through 30 October 2015); or 11 814 youth and 28 148 adults at W3 (19 October 2015 to 23 October 2016). The differences in number of completed interviews between W1, W2 and W3 reflect attrition due to non-response, mortality and other factors, as well as youth who enrol in the study at W2 or W3.<sup>25</sup> We report on initiation estimates in all age groups: longitudinal W1–W2 data include participants in W1 who were also in W2 (youth, n=11 996; young adults, n=7324; adults 25+, n=19 116); W2–W3 data include participants in W2 who were also interviewed at W3 (youth, n=11 279; young adults, n=7252; adults 25+, n=18 129). We also report longitudinal estimates for participants with data at all three waves (youth, n=11 046; young adults, n=6478; adults 25+, n=17 188). Youth included those who were youth at all three waves (n=7595) and those who were youth at W1 and aged up to the young adult group at W2 (n=1714) or W3 (n=1737). The young adults included those who were young adults at all three waves (n=4590) or aged up to the adults 25+ group in W2 (n=949) or W3 (n=939).

## Measures

### Tobacco use

At each wave, adults and youth were asked about their tobacco use behaviours for cigarettes, ENDS (which includes e-cigarettes), traditional cigars, cigarillos, filtered cigars, pipe tobacco, hookah, snus pouches, other smokeless tobacco (loose snus, moist snuff, dip, spit or chewing tobacco) and dissolvable tobacco. Respondents were asked about 'e-cigarettes' at W1 and 'e-products' (ie, e-cigarettes, e-cigars, e-pipes and e-hookah) at W2 and W3; for the purposes of this paper, all electronic products noted above are referred to as ENDS. In addition, youth were asked about their use of bidis and kreteks. However, use of bidis, kreteks and dissolvable tobacco was not included in the analyses due to small sample sizes.

### Outcome measures

**Never use:** never use of any tobacco and each individual product (cigarettes, ENDS, hookah, cigar, and smokeless tobacco) is defined as not having ever used the product/any tobacco even once or twice.

**Initiation of use:** P12M initiation is defined as never use at W1 and any tobacco/tobacco product use at follow-up for a specific tobacco product independent of other tobacco product use. P30D initiation is defined as never use at W1 and any tobacco/tobacco product use within the past 30 days at follow-up, and frequent P30D initiation is defined as never use at W1 and any tobacco/tobacco product use within the past 30 days on at least 20 or more days at follow-up. Each stricter timeframe for initiation is a subset of the larger timeframe preceeding it. Duration of follow-up is either 1 or 2 years depending on the aim. See table footnotes for more details. P30D exclusive initiation is defined as never tobacco use at W1 and new use of only one tobacco product in the past 30 days at a subsequent wave. P30D polytobacco initiation is defined as never tobacco use at W1 and new use of two or more tobacco products in the past 30 days at a subsequent wave (W2 or W3). Longitudinal outcomes examined

also include P30D initiation of exclusive or polytobacco ENDS or cigarettes at W2 among W1 never users.

### Analytic approach

To address Aim 1, weighted cross-sectional prevalence of never any tobacco use and never use of each individual product was estimated at each wave, stratified by age group. For Aim 2, weighted P12M, P30D and frequent P30D initiation rates for any tobacco and the individual tobacco products for each age group from W1 to W2, W2 to W3 and W1 to W3 were estimated. To address Aim 3, longitudinal W1–W2–W3 P30D exclusive initiation and polytobacco initiation pathways among W1 never users were examined. For Aim 4, transitions in P30D tobacco use by W3 among W1 never tobacco users who initiated ENDS or cigarette use at W2 are reported separately.

Cross-sectional estimates (Aim 1) were calculated using PATH Study cross-sectional weights for W1 and single-wave (pseudocross-sectional) weights for W2 and W3. The weighting procedures adjusted for complex study design characteristics and non-response. Combined with the use of a probability sample, the weighted data allow these estimates to be representative of the non-institutionalised, civilian, resident US population aged 12 or older at the time of each wave. Longitudinal estimates

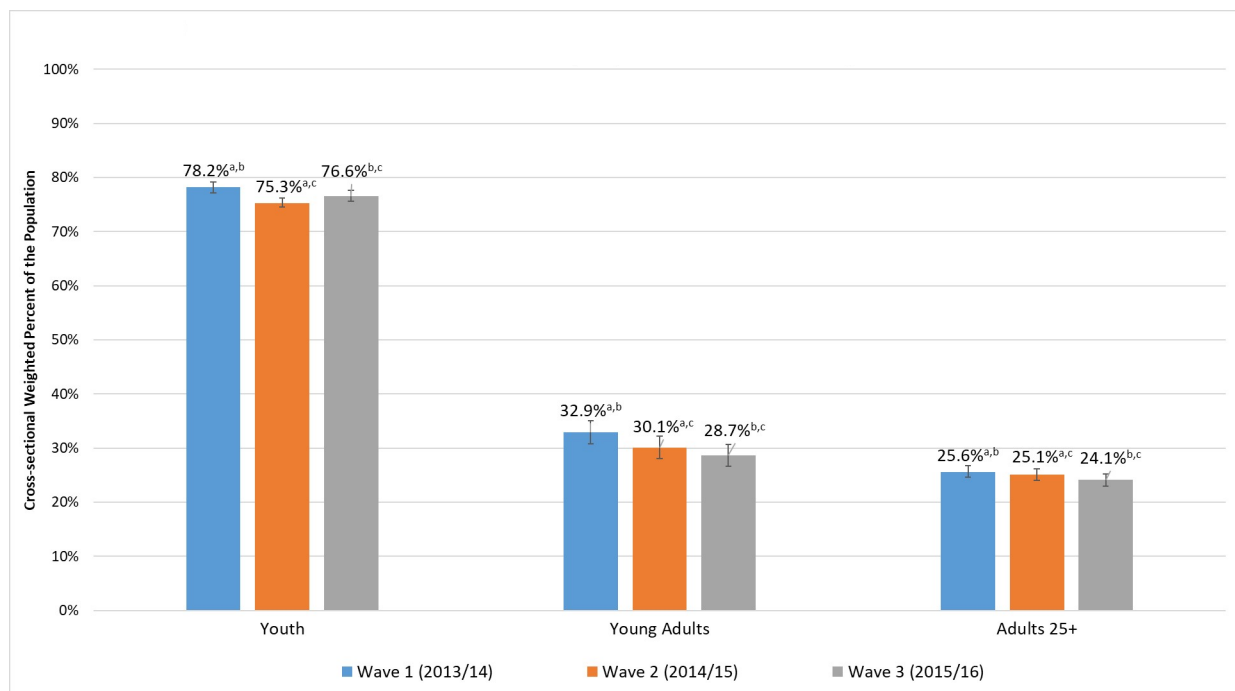
(Aims 2, 3 and 4) were calculated using the PATH Study W3 all-waves weights. These weighted estimates are representative of the resident US population aged 12 and older at the time of W3 (other than those who were incarcerated) who were in the civilian, non-institutionalised population at W1. For Aims 1–3, weighted t-tests were conducted on differences in proportions to assess statistical significance. To correct for multiple comparisons, Bonferroni *post-hoc* tests were conducted.

All analyses were conducted using SAS Survey Procedures, V.9.4 (SAS Institute). Variances were estimated using the balanced repeated replication method<sup>27</sup> with Fay's adjustment set to 0.3 to increase estimate stability.<sup>28</sup> Analyses were run on the W1–W3 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>). Estimates based on fewer than 50 observations in the denominator or with a coefficient of variation greater than 0.30 were flagged.

## RESULTS

### Cross-sectional weighted prevalence

Prevalence estimates of never any tobacco and product-specific never use at W1, W2 and W3 by each age group (youth, young adults and adults 25+) are shown in figure 1. There were relatively modest, but statistically significant, decreases across waves



**Figure 1** Cross-sectional weighted percentages of never tobacco use among youth, young adults and adults 25+ in W1, W2 and W3 of the PATH Study.

W1 = Wave 1; W2 = Wave 2; W3 = Wave 3; PATH = Population Assessment of Tobacco and Health

W1/W2/W3 never tobacco use unweighted Ns: youth (ages 12–17) = 10 246/8721/8487; young adults (ages 18–24) = 1755/1850/2096; adults 25+ (ages 25 and older) = 2761/2323/2193.

X-axis shows three age groups: youth, young adults and adults 25+. Y-axis shows weighted percentages of W1, W2 and W3 never users in these three age groups. Sample analysed includes all W1, W2 and W3 respondents at each wave. The PATH Study cross-sectional (W1) or single-wave weights (W2 and W3) were used to calculate estimates at each wave. All respondents with data at one wave are included in the sample for that wave's estimate and do not need to have complete data at all three waves. Never tobacco use is defined as not having used any tobacco, even once or twice in lifetime.

<sup>a</sup>Significant difference at  $p < 0.0167$  (Bonferroni corrected for three comparisons) between W1 and W2.

<sup>b</sup>Significant difference at  $p < 0.0167$  (Bonferroni corrected for three comparisons) between W1 and W3.

<sup>c</sup>Significant difference at  $p < 0.0167$  (Bonferroni corrected for three comparisons) between W2 and W3.

The logit-transformation method was used to calculate the 95% CIs.

Analyses were run on the W1, W2 and W3 public use files (<https://doi.org/10.3886/ICPSR36498.v8>).

**Table 1a** Weighted Percentage of Tobacco and Product-Specific Initiation at W2 or W3 Among W1 Never Users

W1 (2013/14)	W2 (2014/15) or W3 (2015/16)					
	P12M Initiation		P30D Initiation		Frequent P30D Initiation	
Youth	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	24.4	(23.4-25.4)	9.5	(8.8-10.2)	1.3	(1.1-1.6)
Never cigarette use	9.9 <sup>a,d</sup>	(9.3-10.6)	4.7 <sup>a,b,d</sup>	(4.2-5.3)	0.6 <sup>b,c</sup>	(0.5-0.8)
Never ENDS* use	22.7 <sup>a,e,f,g</sup>	(21.6-23.7)	6.4 <sup>a,e,f,g</sup>	(5.8-7.1)	0.9 <sup>e,f,g</sup>	(0.7-1.2)
Never hookah use	8.9 <sup>e,i</sup>	(8.3-9.7)	3.4 <sup>b,e,i</sup>	(3.0-3.8)	0.2 <sup>b,e,i</sup>	(0.1-0.4)
Never cigar use	9.0 <sup>f,j</sup>	(8.3-9.7)	4.0 <sup>f,j</sup>	(3.7-4.4)	0.1 <sup>c,f,j</sup>	(0.1-0.2)
Never smokeless use	4.2 <sup>d,g,i,j</sup>	(3.7-4.7)	1.8 <sup>d,g,i,j</sup>	(1.6-2.1)	0.5 <sup>g,i,j</sup>	(0.4-0.7)
Young adults	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	22.8	(20.0-26.0)	12.2	(10.1-14.6)	1.7	(1.1-2.7)
Never cigarette use	10.3 <sup>a,b,d</sup>	(8.8-12.0)	6.1 <sup>d</sup>	(5.1-7.4)	1.1 <sup>b,c</sup>	(0.7-1.6)
Never ENDS use	28.4 <sup>a,e,f,g</sup>	(26.5-30.4)	7.4 <sup>g</sup>	(6.4-8.4)	1.0 <sup>e,f,g</sup>	(0.7-1.5)
Never hookah use	14.1 <sup>b,e,i</sup>	(12.5-15.8)	6.4 <sup>i</sup>	(5.3-7.7)	0.2 <sup>b,e</sup>	(0.1-0.4)
Never cigar use	12.0 <sup>f,j</sup>	(10.8-13.4)	7.2 <sup>j</sup>	(6.2-8.4)	0.3 <sup>c,f</sup>	(0.2-0.6)
Never smokeless use	2.5 <sup>d,g,i,j</sup>	(2.1-2.9)	1.4 <sup>d,g,i,j</sup>	(1.1-1.7)	0.4 <sup>g</sup>	(0.2-0.6)
Adults 25+	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	4.0	(3.1-5.0)	2.7	(2.0-3.6)	0.4 <sup>†</sup>	(0.2-0.9)
Never cigarette use	2.4 <sup>a,d</sup>	(1.8-3.2)	1.8 <sup>b,d</sup>	(1.3-2.6)	0.4 <sup>†</sup>	(0.2-0.7)
Never ENDS use	6.7 <sup>a,e,f,g</sup>	(6.3-7.2)	2.3 <sup>e,g</sup>	(2.0-2.5)	0.5 <sup>e,g</sup>	(0.4-0.6)
Never hookah use	1.4 <sup>e,h,i</sup>	(1.2-1.7)	0.7 <sup>b,e,h</sup>	(0.6-0.9)	0.0 <sup>e,h</sup>	(0.0-0.1)
Never cigar use	3.3 <sup>f,h,j</sup>	(2.8-3.9)	2.1 <sup>h,j</sup>	(1.8-2.6)	0.3 <sup>h,j</sup>	(0.2-0.5)
Never smokeless use	0.7 <sup>d,g,i,j</sup>	(0.5-0.8)	0.5 <sup>d,g,i,j</sup>	(0.4-0.7)	0.1 <sup>†g,i,j</sup>	(0.0-0.1)

W1 total group unweighted denominators (P12M initiation/P30D initiation/Frequent P30D initiation):

Never tobacco use - youth (ages 12-17): 8,245/8,143/8,078; young adults (ages 18-24): 1,312/1,308/1,295; adults 25+ (ages 25 and older): 2,043/2,046/2,039

Never cigarette use - youth: 9,596/9,590/9,576; young adults: 2,310/2,310/2,294; adults 25+: 2,903/2,906/2,894

Never ENDS use - youth: 9,849/9,793/9,764; young adults: 3,697/3,651/3,639; adults 25+: 11,532/11,403/11,431

Never hookah use - youth: 10,239/10,231/10,199; young adults: 2,921/2,924/2,920; adults 25+: 13,071/13,083/13,065

Never cigar use - youth: 9,916/9,876/9,849; young adults: 2,817/2,818/2,770; adults 25+: 7,494/7,510/7,444

Never smokeless use - youth: 10,252/10,248/10,236; young adults: 5,145/5,152/5,135; adults 25+: 13,116/13,155/13,094

Analysis included youth, young adult, and adult 25+ W1 never tobacco or tobacco product users with data at W1, W2, and W3. Respondent age was calculated based on age at W1. W3 longitudinal (all-waves) weights were used to calculate estimates.

Never tobacco/product initiation is defined as not having used any tobacco or the specific product, even once or twice in lifetime.

1) P12M initiation: Defined as a never user at W1 who used any tobacco or the specific product within the past 12 months at W2 or W3.

2) P30D initiation (a subset of P12M initiation): Defined as a never user at W1 who used any tobacco or the specific product within the past 30 days at W2 or W3.

3) Frequent P30D initiation (a subset of P30D initiation): Defined as a never user at W1 who used any tobacco or the specific product within the past 30 days on at least 20 or more days at W2 or W3.

All significance tests were done between product initiations only (not any tobacco initiation).

<sup>a</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and ENDS

<sup>b</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and hookah

<sup>c</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and cigar

<sup>d</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and smokeless

<sup>e</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and hookah

<sup>f</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and cigar

<sup>g</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and smokeless

<sup>h</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and cigar

<sup>i</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and smokeless

<sup>j</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigar and smokeless

\*Respondents were asked about "e-cigarettes" at W1 and "e-products" (i.e., e-cigarettes, e-cigars, e-pipes, and e-hookah) at W2 and W3

The logit-transformation method was used to calculate the 95% CIs.

<sup>†</sup>Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W1, W2, and W3 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>).

CI, confidence interval; ENDS, electronic nicotine delivery system; P30D, past 30-day; P12M, past 12-month; W1, Wave 1; W2, Wave 2; W3, Wave 3.

**Table 1b** Weighted Percentage of Tobacco and Product-Specific Initiation at W2 Among W1 Never Users

W1 (2013/14)	W2 (2014/15)					
	P12M Initiation		P30D Initiation		Frequent P30D Initiation	
Youth	Weighted %	95% CI	Weighted %	95% CI	Weighted %	95% CI
Never tobacco use	15.0	(14.2-15.8)	5.3	(4.7-5.8)	0.7	(0.5-0.9)
Never cigarette use	4.6 <sup>a,d</sup>	(4.2-5.1)	2.1 <sup>a,d</sup>	(1.8-2.4)	0.4 <sup>c</sup>	(0.3-0.5)

Continued



Table 1b Continued

W1 (2013/14)	W2 (2014/15)					
	P12M Initiation		P30D Initiation		Frequent P30D Initiation	
Youth	Weighted %	95% CI	Weighted %	95% CI	Weighted %	95% CI
Never ENDS* use	15.8 <sup>a,e,f,g</sup>	(15.0-16.7)	3.4 <sup>a,e,f,g</sup>	(2.9-3.8)	0.5 <sup>e,f</sup>	(0.3-0.7)
Never hookah use	5.3 <sup>e,i</sup>	(4.9-5.8)	2.0 <sup>e,i</sup>	(1.8-2.3)	0.2 <sup>e</sup>	(0.1-0.3)
Never cigar use	4.6 <sup>f,j</sup>	(4.2-5.1)	2.0 <sup>f,j</sup>	(1.8-2.3)	0.1 <sup>c,f,j</sup>	(0.1-0.2)
Never smokeless use	2.2 <sup>d,g,i,j</sup>	(1.9-2.5)	0.9 <sup>d,g,i,j</sup>	(0.7-1.1)	0.3 <sup>j</sup>	(0.2-0.4)
Young adults	Weighted %	95% CI	Weighted %	95% CI	Weighted %	95% CI
Never tobacco use	15.2	(12.9-17.8)	8.1	(6.5-10.0)	1.4	(0.9-2.3)
Never cigarette use	7.0 <sup>a,b,d</sup>	(6.0-8.2)	4.6 <sup>d</sup>	(3.8-5.5)	0.9 <sup>b,c,d</sup>	(0.6-1.3)
Never ENDS use	23.8 <sup>a,e,f,g</sup>	(22.1-25.7)	4.6 <sup>g</sup>	(3.8-5.5)	0.8 <sup>e,f,g</sup>	(0.5-1.1)
Never hookah use	9.8 <sup>b,e,h,i</sup>	(8.6-11.1)	5.0 <sup>i</sup>	(4.2-5.9)	0.2 <sup>†b,e</sup>	(0.1-0.3)
Never cigar use	7.3 <sup>f,h,j</sup>	(6.4-8.4)	4.1 <sup>j</sup>	(3.4-5.0)	0.2 <sup>†c,f</sup>	(0.1-0.4)
Never smokeless use	1.4 <sup>d,g,i,j</sup>	(1.1-1.8)	0.8 <sup>d,g,i,j</sup>	(0.6-1.0)	0.3 <sup>d,g</sup>	(0.2-0.4)
Adults 25+	Weighted %	95% CI	Weighted %	95% CI	Weighted %	95% CI
Never tobacco use	2.2	(1.7-2.9)	1.4	(1.0-1.9)	0.3 <sup>†</sup>	(0.1-0.6)
Never cigarette use	1.2 <sup>a,c,d</sup>	(0.9-1.6)	0.9 <sup>a,d</sup>	(0.6-1.3)	0.2 <sup>†</sup>	(0.1-0.5)
Never ENDS use	5.5 <sup>a,e,f,g</sup>	(5.1-5.9)	1.4 <sup>a,e,g</sup>	(1.2-1.7)	0.4 <sup>e,f,g</sup>	(0.3-0.5)
Never hookah use	0.8 <sup>e,h,i</sup>	(0.7-1.0)	0.4 <sup>e,h</sup>	(0.3-0.5)	0.0 <sup>†e,h</sup>	(0.0-0.1)
Never cigar use	2.0 <sup>c,f,h,j</sup>	(1.7-2.3)	1.3 <sup>h,j</sup>	(1.1-1.6)	0.2 <sup>f,h</sup>	(0.1-0.3)
Never smokeless use	0.3 <sup>d,g,i,j</sup>	(0.2-0.4)	0.3 <sup>d,g,i</sup>	(0.2-0.4)	0.0 <sup>†g</sup>	(0.0-0.1)

W1 total group unweighted denominators (P12M initiation/P30D initiation/Frequent P30D initiation):

Never tobacco use – youth (ages 12-17): 8,913/8,840/8,799; young adults (ages 18-24): 1,466/1,459/1,451; adults 25+ (ages 25 and older): 2,247/2,247/2,243

Never cigarette use - youth: 10,383/10,379/10,372; young adults: 2,584/2,584/2,569; adults 25+: 3,190/3,191/3,182

Never ENDS use - youth: 10,676/10,621/10,605; young adults: 4,195/4,139/4,141; adults 25+: 12,799/12,636/12,720

Never hookah use - youth: 11,101/11,093/11,067; young adults: 3,304/3,304/3,304; adults 25+: 14,543/14,549/14,543

Never cigar use - youth: 10,775/10,748/10,741; young adults: 3,153/3,155/3,120; adults 25+: 8,339/8,351/8,308

Never smokeless use - youth: 11,151/11,148/11,144; young adults: 5,783/5,786/5,777; adults 25+: 14,560/14,583/14,546

Analysis included youth, young adult, and adult 25+ W1 never tobacco or tobacco product users with data at W1 and W2. Respondent age was calculated based on age at W1.

W2 single-wave weights were used to calculate estimates.

Never tobacco/product initiation is defined as not having used any tobacco or the specific product, even once or twice in lifetime.

1) P12M initiation: Defined as a never user at W1 who used any tobacco or the specific product within the past 12 months at W2.

2) P30D initiation (a subset of P12M initiation): Defined as a never user at W1 who used any tobacco or the specific product within the past 30 days at W2.

3) Frequent P30D initiation (a subset of P30D initiation): Defined as a never user at W1 who used any tobacco or the specific product within the past 30 days on at least 20 or more days at W2.

All significance tests were done between product initiations only (not any tobacco initiation).

<sup>a</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and ENDS

<sup>b</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and hookah

<sup>c</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and cigar

<sup>d</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and smokeless

<sup>e</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and hookah

<sup>f</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and cigar

<sup>g</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and smokeless

<sup>h</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and cigar

<sup>i</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and smokeless

<sup>j</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigar and smokeless

\*Respondents were asked about "e-cigarettes" at W1 and "e-products" (i.e., e-cigarettes, e-cigars, e-pipes, and e-hookah) at W2 and Wave 3.

The logit-transformation method was used to calculate the 95% CIs.

<sup>†</sup>Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W1 and W2 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>).

CI, confidence interval; ENDS, electronic nicotine delivery system; P30D, past 30-day; P12M, past 12-month; W1, Wave 1; W2, Wave 2.

Table 1c Weighted Percentage of Tobacco and Product-Specific Initiation at W3 Among W2 Never Users

W2 (2014/15)	W3 (2015/16)					
	P12M Initiation		P30D Initiation		Frequent P30D Initiation	
Youth	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	8.9	(8.3-9.6)	3.6	(3.1-4.0)	0.6	(0.5-0.8)
Never cigarette use	4.2 <sup>a,b,d</sup>	(3.8-4.6)	1.9 <sup>a,b,d</sup>	(1.6-2.3)	0.2 <sup>b,c</sup>	(0.2-0.3)
Never ENDS* use	6.5 <sup>a,e,f,g</sup>	(6.0-7.1)	2.7 <sup>a,e,f,g</sup>	(2.3-3.1)	0.4 <sup>e,f,g</sup>	(0.3-0.6)
Never hookah use	2.6 <sup>b,e,h,i</sup>	(2.4-3.0)	0.9 <sup>b,e,h</sup>	(0.7-1.1)	0.1 <sup>†b,e</sup>	(0.0-0.1)

Continued

Table 1c Continued

W2 (2014/15)	W3 (2015/16)					
	P12M Initiation		P30D Initiation		Frequent P30D Initiation	
Youth	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never cigar use	3.6 <sup>fhj</sup>	(3.2-4.0)	1.5 <sup>fhj</sup>	(1.3-1.8)	0.0 <sup>†c,fj</sup>	(0.0-0.1)
Never smokeless use	1.7 <sup>d,g,ij</sup>	(1.5-2.0)	0.7 <sup>d,g,i</sup>	(0.6-0.9)	0.2 <sup>gj</sup>	(0.1-0.3)
Young adults	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	11.4	(9.5-13.6)	6.3	(5.1-7.8)	0.6	(0.3-1.0)
Never cigarette use	5.3 <sup>d</sup>	(4.6-6.2)	3.0 <sup>d</sup>	(2.4-3.6)	0.4 <sup>†</sup>	(0.2-0.8)
Never ENDS use	6.2 <sup>g</sup>	(5.5-7.1)	3.6 <sup>g</sup>	(2.9-4.4)	0.2 <sup>†</sup>	(0.1-0.5)
Never hookah use	6.3 <sup>i</sup>	(5.3-7.5)	2.4 <sup>i</sup>	(1.9-3.2)	0.1 <sup>†</sup>	(0.0-0.2)
Never cigar use	5.8 <sup>j</sup>	(5.1-6.6)	3.6 <sup>j</sup>	(3.0-4.4)	0.2 <sup>†</sup>	(0.1-0.4)
Never smokeless use	1.4 <sup>d,g,ij</sup>	(1.1-1.8)	0.8 <sup>d,g,ij</sup>	(0.6-1.1)	0.1 <sup>†</sup>	(0.1-0.3)
Adults 25+	Weighted %	95%CI	Weighted %	95%CI	Weighted %	95%CI
Never tobacco use	1.8	(1.2-2.8)	1.3	(0.7-2.2)	0.2 <sup>†</sup>	(0.0-0.6)
Never cigarette use	1.2 <sup>d</sup>	(0.8-1.8)	0.9	(0.5-1.6)	0.2 <sup>†</sup>	(0.1-0.5)
Never ENDS use	1.4 <sup>e,g</sup>	(1.2-1.6)	0.9 <sup>e,g</sup>	(0.8-1.1)	0.2 <sup>e,g</sup>	(0.1-0.2)
Never hookah use	0.6 <sup>e,h</sup>	(0.4-0.8)	0.3 <sup>e,h</sup>	(0.2-0.5)	0.0 <sup>†e</sup>	(0.0-0.0)
Never cigar use	1.4 <sup>h,j</sup>	(1.1-1.7)	0.9 <sup>h,j</sup>	(0.7-1.1)	0.2 <sup>†</sup>	(0.1-0.3)
Never smokeless use	0.4 <sup>d,g,i</sup>	(0.3-0.5)	0.3 <sup>g,i</sup>	(0.2-0.4)	0.0 <sup>†g</sup>	(0.0-0.1)

W2 total group unweighted denominators (P12M initiation/P30D initiation/Frequent P30D initiation):

Never tobacco use – youth (ages 12-17): 8,087/8,064/8,039; young adults (ages 18-24): 1,680/1,683/1,669; adults 25+ (ages 25 and older): 2,111/2,116/2,111

Never cigarette use – youth: 9,954/9,950/9,945; young adults: 2,985/2,986/2,979; adults 25+: 3,083/3,085/3,081

Never ENDS use – youth: 9,651/9,643/9,629; young adults: 3,715/3,716/3,701; adults 25+: 10,870/10,879/10,836

Never hookah use – youth: 10,520/10,520/10,507; young adults: 3,395/3,397/3,394; adults 25+: 13,221/13,228/13,216

Never cigar use – youth: 10,267/10,251/10,241; young adults: 3,377/3,380/3,349; adults 25+: 7,570/7,579/7,548

Never smokeless use – youth: 10,497/10,496/10,490; young adults: 5,825/5,829/5,819; adults 25+: 13,749/13,771/13,741

Analysis included youth, young adult, and adult 25+ W2 never tobacco or tobacco product users with data at W2 and W3. Respondent age was calculated based on age at W2. W3 longitudinal (all-waves) weights were used to calculate estimates.

Never tobacco/product initiation is defined as not having used any tobacco or the specific product, even once or twice in lifetime.

1) P12M initiation: Defined as a never user at W2 who used any tobacco or the specific product within the past 12 months at W3.

2) P30D initiation (a subset of P12M initiation): Defined as a never user at W2 who used any tobacco or the specific product within the past 30 days at W3.

3) Frequent P30D initiation (a subset of P30D initiation): Defined as a never user at W2 who used any tobacco or the specific product within the past 30 days on at least 20 or more days at W3.

All significance tests were done between product initiations only (not any tobacco initiation).

<sup>a</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and ENDS

<sup>b</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and hookah

<sup>c</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and cigar

<sup>d</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigarette and smokeless

<sup>e</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and hookah

<sup>f</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and cigar

<sup>g</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between ENDS and smokeless

<sup>h</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and cigar

<sup>i</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between hookah and smokeless

<sup>j</sup>denotes significant difference at  $p < 0.005$  (Bonferroni corrected for ten comparisons) between cigar and smokeless

\*Respondents were asked about “e-cigarettes” at Wave 1 and “e-products” (i.e., e-cigarettes, e-cigars, e-pipes, and e-hookah) at W2 and W3.

The logit-transformation method was used to calculate the 95% CIs.

†Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W2 and W3 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>).

CI, confidence interval; ENDS, electronic nicotine delivery system; P30D, past 30-day; P12M, past 12-month; W1, Wave 1; W2, Wave 2; W3, Wave 3.

in the percentage of never tobacco users within each age group, except an increase in never tobacco among youth between W2 and W3. Estimates of never tobacco use by product among youth, young adults and adults 25+ are presented in online supplementary figure 3.

### Longitudinal weighted pathways

P12M, P30D and frequent P30D initiation among W1 never users across two waves

Table 1a presents, undefined by age group, any tobacco initiation and product-specific initiation across 2 years CA (at W2 or W3) among W1 never tobacco users. Among W1 never tobacco users,

24.4% (95% CI 23.4 to 25.4) of youth, 22.8% (95% CI 20.0 to 26.0) of young adults, and 4.0% (95% CI 3.1 to 5.0) of adults 25+ started using any tobacco product at W2 or W3.

ENDS had the highest proportion of P12M initiation from W1 to W3 for youth (22.7% (95% CI 21.6 to 23.7)), young adults (28.4% (95% CI 26.5 to 30.4)), and adults 25+ (6.7% (95% CI 6.3 to 7.2)) compared to P12M initiation rates of all other products. Across all age groups, P12M initiation was the lowest for smokeless tobacco compared to the other four tobacco products.

Compared to P12M initiation, the percentage of P30D initiation across all specific tobacco products had less variability in each age group ranging from 1.8% to 6.4% among youth, 1.4%

to 7.4% among young adults and 0.5% to 2.3% among adults 25+. Similar to P12M initiation rates, ENDS had the highest proportion of P30D initiation from W1 to W3 compared to P30D initiation rates of all other products among youth (6.4% (95% CI 5.8 to 7.1)) and young adults (7.4% (95% CI 6.4 to 8.4)). Frequent P30D initiation for youth, young adults and adults 25+ was rare with rates equal to or less than 1.1% for each of the specific tobacco products.

#### W1–W2 and W2–W3 initiation, P30D initiation and frequent P30D initiation among W1 never users

Examining tobacco product-specific initiation over each of the 1-year intervals (table 1b and 1c) for each of the five tobacco products, ENDS had the highest proportion of W2 P12M initiation at W1–W2 for each age group (youth: 15.8% (95% CI 15.0 to 16.7); young adults: 23.8% (95% CI 22.1 to 25.7); adults 25+: 5.5% (95% CI 5.1 to 5.9)). In youth, P30D specific product initiation was 2%–3%, except for smokeless tobacco (<1%) and frequent P30D initiation was less than 1% for all the products. In young adults (table 1b), P12M W2 ENDS initiation was the highest (23.8% (95% CI 22.1 to 25.7)) compared to other products such as hookah (9.8% (95% CI 8.6 to 11.1)), cigars (7.3% (95% CI 6.4 to 8.4)), cigarettes (7.0% (95% CI 6.0 to 8.2)) and smokeless tobacco (1.4% (95% CI 1.1 to 1.8)). Similarly, in adults 25+, P12M W2 ENDS initiation was the highest (5.5% (95% CI 5.1 to 5.9)) compared to hookah (0.8% (95% CI 0.7 to 1.0)), cigars (2.0% (95% CI 1.7 to 2.3)), cigarettes (1.2% (95% CI 0.9 to 1.6)) and smokeless tobacco (0.3% (95% CI 0.2 to 0.4)). In young adults, W2 P30D initiation of specific tobacco products was approximately 4%–5% except for smokeless tobacco (0.8%), and frequent P30D initiation of specific products was <1%. In adults 25+, less than 2% of adults 25+ initiated a specific tobacco product in the past 30 days, and less than 1% initiated frequent P30D use of a tobacco product.

Examining 1 year initiation rates between W2 and W3 (table 1c), the differences between the products were less pronounced. In youth, ENDS had 6.5% (95% CI 6.0% to 7.1%) W3 P12M initiation compared with cigarette (4.2% (95% CI 3.8 to 4.6)), cigar (3.6% (95% CI 3.2 to 4.0)), hookah (2.6% (95% CI 2.4 to 3.0)) and smokeless tobacco (1.7% (95% CI 1.5 to 2.0)). In young adults, P12M W3 initiation of each product was approximately 5%–6%, although smokeless tobacco was much lower than other products at 1.4% (95% CI 1.1 to 1.8). In young adults, P30D initiation of each product was approximately 2%–4%, except for smokeless tobacco (0.8%) and W3 frequent P30D initiation was less than 1%. In adults 25+, P12M W2–W3 initiation of cigarettes, ENDS and cigars was approximately 1%–2%, with hookah and smokeless tobacco initiated by less than 1%. W3, P30D initiation and frequent P30D initiation were both less than 1%.

#### W1–W2–W3 initiation pathways of exclusive and polytobacco P30D tobacco use among W1 never tobacco users

Online supplementary figure 2 provides an overview of the possible transitions in product use across W2 and W3 among W1 never tobacco users. The detailed pathways of the transitions are shown in online supplementary table 1. Table 2 provides aggregated transitions of exclusive or polytobacco any tobacco P30D initiation rates by age group. Across all ages, more W1 adults 25+ never users remained never users across all three waves compared with youth and young adults (youth, 89.3% (95% CI 88.4 to 90.1); young adults, 86.6% (95% CI 83.9 to 88.9); adults 25+, 97.3% (95% CI 96.3 to 98.0)).

#### W3 exclusive and polytobacco use among the subsample of W2 P30D initiators of ends or cigarettes

Table 3a and 3b show results from a subsample of W2 initiators of ENDS or cigarettes, by age group. Among W2 youth P30D exclusive ENDS initiators (table 3a), transitioning to no tobacco use at W3 was the most common pathway (59.0% (95% CI 48.4 to 68.8)). Among youth who initiated P30D exclusive cigarette smoking at W2 (table 3b), no tobacco use at W3 was also the most common pathway (40.3% (95% CI 28.7 to 53.1)). About 20% of W1 youth never tobacco users fell into the pathway of W2 exclusive ENDS initiators who remained exclusive ENDS users at W3 (table 3a, row 2). Similarly, about 19% of W1 youth never tobacco users fell into the pathway of W2 exclusive cigarette initiators who remained exclusive cigarette users at W3 (table 3b, row 2). About 19% of youth who initiated with exclusive cigarette use at W2 transitioned to ENDS and cigarette use at W3 (table 3b, row 4). Youth who initiated with exclusive ENDS use at W2 and transitioned to ENDS and cigarette use at W3 (table 3a, row 4) were less common, and this estimate was flagged due to high relative standard error.

#### DISCUSSION

Data from the US nationally representative PATH Study revealed never any tobacco use decreased over the three waves from 2013 to 2016 for youth, young adults and adults 25+. Decreases in never tobacco use reflect increases in initiation that were driven by initiation of ENDS, which was gaining in popularity and availability in the USA during this time period. Initiating use of traditional tobacco products like cigarettes, smokeless tobacco and cigars has remained relatively stable (eg, youth P12M initiation of cigarettes in 2014/2015=4.2%, and in 2015/2016=4.6%). The PATH Study instrument was updated and questions were changed from asking about e-cigarettes to asking about all ENDS products between W1 and W2 as well. P12M initiation rates from 2015 to 2016 for traditional tobacco products like cigarettes, smokeless tobacco and cigars are comparable to those reported by NSDUH in 2016 (within ~1% for each age group).<sup>14</sup>

A unique strength of this analysis is that three different definitions of initiation (P12M, P30D and frequent P30D) for overall tobacco use and product specific tobacco use are reported over a 2-year period, as well as the 1-year intervals within that time span, for three different age groups. Within each age group and looking across tobacco products, the highest proportion of P12M initiation was among W1 never ENDS users who initiated ENDS use at W2. The higher rates of P12M ENDS initiation compared with other definitions may signal that a fair amount of ENDS initiation is experimental and does not persist to be identified as P30D or frequent P30D use. Across all age groups, initiation from W1 to W2 of smokeless tobacco was lower than initiation of the other products for both P12M and P30D. Initiation of ENDS from W2 to W3 was not higher than initiation of cigarettes, cigars or hookah. It is noted that these data were collected before the documented increase in use of ENDS among US youth in 2018.<sup>20</sup> Specifically, data collection occurred before the rapid growth of JUUL in the USA between 2016 and 2018; JUUL delivers a high dose of nicotine and therefore has a greater potential for addictiveness than many of the first generation products available in 2013–2016.<sup>29–32</sup>

Examining longitudinal three-wave pathways, most never tobacco users at W1 remained never users across all three waves. A pattern of persistent never tobacco use across the waves

**Table 2** Summary of transitions in P30D exclusive tobacco or polytobacco use at W2 (2014/15) and W3 (2015/16) among W1 (2013/14) never tobacco users

Pathways	Youth				Young Adults				Adults 25+			
	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI
Never use across all three waves	6,245	13,830,877	89.3 <sup>a</sup>	(88.4-90.1)	995	7,630,859	86.6 <sup>b</sup>	(83.9-88.9)	1,955	48,675,654	97.3 <sup>a,b</sup>	(96.3-98.0)
Initiated exclusive use at W2 - remain exclusive at W3	89	217,736	1.4 <sup>a</sup>	(1.1-1.8)	23	150,302	1.7 <sup>b</sup>	(1.0-2.9)	10	203,507	0.41 <sup>a,b</sup>	(0.2-0.8)
Initiated exclusive use at W2 - PTU at W3	59	149,431	1.0 <sup>a</sup>	(0.7-1.3)	5	45,121	0.51 <sup>†</sup>	(0.2-1.3)	1	22,402	0.01 <sup>a</sup>	(0.0-0.3)
Initiated exclusive use at W2 - no use at W3	147	345,521	2.2 <sup>a</sup>	(1.9-2.6)	44	317,079	3.6 <sup>b</sup>	(2.5-5.1)	15	380,334	0.80 <sup>a,b</sup>	(0.5-1.2)
Initiated PTU at W2 - remain PTU at W3	41	89,232	0.6 <sup>a</sup>	(0.4-0.8)	15	93,433	1.1 <sup>b</sup>	(0.6-1.8)	1	30,611	0.11 <sup>a,b</sup>	(0.0-0.5)
Initiated PTU at W2 - exclusive use at W3	33	73,838	0.5 <sup>a</sup>	(0.3-0.7)	11	98,442	1.11 <sup>b</sup>	(0.5-2.3)	1	20,514	0.01 <sup>a,b</sup>	(0.0-0.2)
Initiated PTU at W2 - no use at W3	24	50,294	0.3	(0.2-0.5)	8	46,297	0.51 <sup>†</sup>	(0.2-1.2)	2	58,593	0.11 <sup>†</sup>	(0.0-0.5)
Initiated exclusive use at W3	227	515,855	3.3 <sup>a</sup>	(2.9-3.9)	49	354,156	4.0 <sup>b</sup>	(2.9-5.5)	20	562,667	1.11 <sup>a,b</sup>	(0.6-2.1)
Initiated PTU at W3	100	223,195	1.4 <sup>a</sup>	(1.2-1.7)	11	73,838	0.81 <sup>†</sup>	(0.4-1.6)	3	82,516	0.21 <sup>a</sup>	(0.0-0.6)

Analysis included youth (ages 12-17), young adult (ages 18-24), and adult 25+ (ages 25 and older) W1 never tobacco users with data at all three waves. Respondent age was calculated based on age at W1. W3 longitudinal (all-waves) weights were used to calculate estimates.

Pathways among W1 never tobacco users:

- 1) Never use across all three waves: Defined as never use of any tobacco products at W2 and W3.
- 2) Initiated exclusive use at W2 - remain exclusive at W3: Defined as exclusive tobacco product use within the past 30 days at W2 and W3.
- 3) Initiated exclusive use at W2 - PTU at W3: Defined as exclusive tobacco product use within the past 30 days at W2 and PTU use within the past 30 days at W3.
- 4) Initiated exclusive use at W2 - no use at W3: Defined as exclusive tobacco product use within the past 30 days at W2 and no use of any tobacco products within the past 30 days at W3.
- 5) Initiated PTU at W2 - remain PTU at W3: Defined as PTU within the past 30 days at W2 and W3.
- 6) Initiated PTU at W2 - exclusive use at W3: Defined as PTU within the past 30 days at W2 and exclusive tobacco product use within the past 30 days at W3.
- 7) Initiated PTU at W2 - no use at W3: Defined as PTU within the past 30 days at W2 and no use of any tobacco products within the past 30 days at W3.
- 8) Initiated exclusive use at W3: Defined as no use of any tobacco products within the past 30 days at W2 and exclusive tobacco product use within the past 30 days at W3.
- 9) Initiated PTU at W3: Defined as no use of any tobacco products within the past 30 days at W2 and PTU within the past 30 days at W3.

<sup>a</sup>denotes significant difference at <0.0167 (Bonferroni corrected for three comparisons) between youth and adults 25+

<sup>b</sup>denotes significant difference at <0.0167 (Bonferroni corrected for three comparisons) between young adults and adults 25+

The logit-transformation method was used to calculate confidence intervals.

<sup>†</sup>Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W1, W2, and W3 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>).

CI, confidence interval; P30D, past 30-day; PTU, polytobacco use; W1, Wave 1; W2, Wave 2; W3, Wave 3.



**Table 3a** Summary of transitions in P30D tobacco use at W3 (2015/16) among W1 (2013/14) never tobacco users who initiate electronic nicotine delivery system (ENDS)\* use at W2 (2014/15)

Pathways	Youth			Young Adults			Adults 25+		
	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Weighted %
W2 Initiate Exclusive ENDS - W3 No Tobacco	64	146,973	59	(48.4-68.8)	11	92,281	91.3†	(53.3-99.0)	-
W2 Initiate Exclusive ENDS - W3	20	48,948	19.7	(12.5-29.6)	1	8,769	8.7†	(1.0-46.7)	100.0†
W2 Initiate Exclusive ENDS - W3 Exclusive CIGS	1	2,370	1.0†	(0.1-7.2)	-	-	-	-	-
W2 Initiate Exclusive ENDS - W3 CIGS+ENDS PTU	8	23,229	9.3†	(4.4-18.7)	-	-	-	-	-
W2 Initiate Exclusive ENDS - W3 ENDS PTU w/o CIGS	5	12,240	4.9†	(1.9-12.3)	-	-	-	-	-
W2 Initiate Exclusive ENDS - W3 CIGS PTU w/o ENDS	2	4,273	1.7†	(0.4-7.5)	-	-	-	-	-
W2 Initiate Exclusive ENDS - W3 Non-ENDS/Non-CIGS	5	10,961	4.4†	(1.8-10.4)	-	-	-	-	-
W2 Initiate CIGS+ENDS PTU - W3 No Tobacco	11	23,050	28.5†	(16.7-44.3)	3	16,196	20.6†	(4.0-61.4)	-
W2 Initiate CIGS+ENDS PTU - W3 CIGS+ENDS PTU	12	26,231	32.5†	(20.3-47.6)	2	15,953	20.3†	(3.7-62.5)	-
W2 Initiate CIGS+ENDS PTU - W3 Exclusive ENDS	1	3,360	4.2†	(0.6-24.3)	2	18,771	23.9†	(4.8-66.2)	-
W2 Initiate CIGS+ENDS PTU - W3 Exclusive CIGS	7	15,447	19.1†	(9.5-34.7)	1	11,275	14.3†	(1.9-59.3)	-
W2 Initiate CIGS+ENDS PTU - W3 ENDS PTU w/o CIGS	2	3,997	5.0†	(1.2-18.3)	-	-	-	-	-
W2 Initiate CIGS+ENDS PTU - W3 CIGS PTU w/o ENDS	1	3,018	3.7†	(0.4-27.8)	3	16,509	21.0†	(5.6-54.1)	-
W2 Initiate CIGS+ENDS PTU - W3 Non-ENDS/Non-CIGS	2	5,640	7.0†	(1.7-24.2)	-	-	-	-	-
W2 Initiate ENDS PTU w/o CIGS - W3 No Tobacco	3	7,172	13.3†	(3.6-38.6)	2	12,675	41.2†	(6.8-87.1)	-
W2 Initiate ENDS PTU w/o CIGS - W3 ENDS PTU w/o CIGS	2	2,360	4.4†	(1.1-15.5)	1	5,777	18.8†	(1.6-76.3)	-
W2 Initiate ENDS PTU w/o CIGS - W3 Exclusive ENDS	8	18,497	34.2†	(17.5-55.9)	-	-	-	-	-
W2 Initiate ENDS PTU w/o CIGS - W3 Exclusive CIGS	1	2,221	4.1†	(0.5-25.3)	1	12,331	40.1†	(5.7-88.0)	-
W2 Initiate ENDS PTU w/o CIGS - W3 CIGS+ENDS PTU	6	14,920	27.6†	(11.0-53.8)	-	-	-	-	-
W2 Initiate ENDS PTU w/o CIGS - W3 CIGS PTU w/o ENDS	1	1,362	2.5†	(0.3-17.5)	-	-	-	-	-

Continued

Table 3a Continued

Pathways	Youth			Young Adults			Adults 25+		
	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Unweighted Sample Size	Weighted Sample Size	Unweighted Sample Size	Weighted Sample Size	CI
W2 Initiate ENDS PTU w/o CIGS - W3 Non-ENDS/Non-CIGS	3	7,592	14.0†	(3.8-40.2)	-	-	-	-	-

Analysis included youth (ages 12-17), young adult (ages 18-24), and adult 25+ (ages 25 and older) W1 never tobacco users who initiated ENDS use at W2 with data at all three waves. Respondent age was calculated based on age at W1 . W3 longitudinal (all-waves) weights were used to calculate estimates.

W3 tobacco use groups among W1 never tobacco users who initiate ENDS use at W2:

1) No tobacco: Defined as no use of any tobacco products within the past 30 days.

2) Exclusive CIGS: Defined as use of only cigarettes in the past 30 days.

3) Exclusive ENDS: Defined as use of only ENDS in the past 30 days.

4) CIGS+ENDS PTU: Defined as use of only both cigarettes and ENDS in the past 30 days.

5) CIGS PTU w/o ENDS: Defined as use of cigarettes and any other tobacco product(s) except for ENDS in the past 30 days.

6) ENDS PTU w/o CIGS: Defined as use of ENDS and any other tobacco product(s) except for cigarettes in the past 30 days.

7) Non-CIGS, Non-ENDS: Defined as use of one or more tobacco products, excluding cigarettes and ENDS in the past 30 days.

\* Respondents were asked about "e-cigarettes" at W1 and "e-products" (i.e., e-cigarettes, e-cigars, e-pipes, and e-hookah) at W2 and W3.

The logit transformation method was used to calculate confidence intervals.

† Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W1, W2, and W3 Public Use Files (<https://doi.org/10.3886/ICPSR36498.v8>).

-, not applicable because of zero cases; +, and; CI, confidence interval; CIGS, cigarettes; ENDS, electronic nicotine delivery system; P30D, past 30-day, PTU, polytobacco use; W1, Wave 1; W2, Wave 2; W3, Wave 3; w/o, without.

Table 3b Summary of Transitions in P30D Tobacco Use at W3 (2015/16) among W1 (2013/14) Never Tobacco Users Who Initiate Cigarette Use at W2 (2014/15)

Pathways	Youth			Young Adults			Adults 25+		
	Unweighted Sample Size	Weighted Sample Size	Weighted %	CI	Unweighted Sample Size	Weighted Sample Size	Unweighted Sample Size	Weighted Sample Size	CI
W2 Initiate Exclusive CIGS - W3 No Tobacco	28	53,343	40.3	(28.7-53.1)	8	42,448	39.8†	146,299	(18.3-66.1)
W2 Initiate Exclusive CIGS - W3 Exclusive CIGS	11	24,428	18.5	(10.3-30.8)	5	29,320	27.5†	4	(9.5-57.9)
W2 Initiate Exclusive CIGS - W3 Exclusive ENDS*	3	7,208	5.4†	(1.9-14.8)	1	7,740	7.3†	-	(0.9-41.4)
W2 Initiate Exclusive CIGS - W3 CIGS+ENDS PTU	10	25,089	19	(10.9-31.0)	2	15,303	14.3†	-	(3.3-45.4)
W2 Initiate Exclusive CIGS - W3 PTU w/o ENDS	7	18,508	14.0†	(6.7-27.0)	1	8,666	8.1†	-	(1.0-42.5)
W2 Initiate Exclusive CIGS - W3 PTU w/o CIGS	-	-	-	-	-	-	-	-	-
W2 Initiate Exclusive CIGS - W3 Non-ENDS/Non-CIGS	2	3,677	2.8†	(0.6-11.4)	1	3,180	3.0†	-	(0.4-21.2)
W2 Initiate CIGS PTU w/o ENDS - W3 No Tobacco	4	7,864	15.4†	(4.6-40.9)	2	9,811	11.4†	2	(2.1-43.1)
W2 Initiate CIGS PTU w/o ENDS - W3 CIGS PTU w/o ENDS	3	7,014	13.7†	(4.9-33.0)	3	14,819	17.2†	1	(4.0-51.0)
								58,593	(11.7-90.8)
								30,611	(3.2-81.8)

Continued

Table 3b Continued

Pathways	Youth			Young Adults			Adults 25+		
	Unweighted Sample Size	Weighted Sample Size	Weighted % CI	Unweighted Sample Size	Weighted Sample Size	Weighted % CI	Unweighted Sample Size	Weighted Sample Size	Weighted % CI
W2 Initiate CIGS PTU w/o ENDS - W3 Exclusive CIGS	4	7,755	15.2† (4.6-40.2)	1	5,217	6.1† (0.6-40.8)	-	-	-
W2 Initiate CIGS PTU w/o ENDS - W3 Exclusive ENDS	2	4,153	8.1† (2.0-28.2)	1	5,062	5.9† (0.6-39.1)	-	-	-
W2 Initiate CIGS PTU w/o ENDS - W3 CIGS+ENDS PTU	6	13,815	27.1† (12.2-49.9)	1	3,038	3.5† (0.3-30.5)	-	-	-
W2 Initiate CIGS PTU w/o ENDS - W3 ENDS PTU w/o CIGS	4	9,474	18.6† (5.5-47.1)	1	8,734	10.1† (1.2-51.5)	-	-	-
W2 Initiate CIGS PTU w/o ENDS - W3 Non-ENDS/Non-CIGS	1	948	1.9† (0.2-13.0)	4	39,443	45.8† (14.9-80.3)	1	20,514	18.7† (1.9-73.2)

Analysis included youth (ages 12-17), young adult (ages 18-24), and adult 25+ (ages 25 and older) W1 never tobacco users who initiated cigarette use at W2 with data at all three waves. Respondent age was calculated based on age at W1. W3 longitudinal (all-waves) weights were used to calculate estimates.

W3 tobacco use groups among W1 never tobacco users who initiate cigarette use at W2:

1) No tobacco: Defined as no use of any tobacco products within the past 30 days.

2) Exclusive CIGS: Defined as use of only cigarettes in the past 30 days.

3) Exclusive ENDS: Defined as use of only ENDS in the past 30 days.

4) CIGS+ENDS PTU: Defined as use of only both cigarettes and ENDS in the past 30 days.

5) CIGS PTU w/o ENDS: Defined as use of cigarettes and any other tobacco product(s) except for ENDS in the past 30 days.

6) ENDS PTU w/o CIGS: Defined as use of ENDS and any other tobacco product(s) except for cigarettes in the past 30 days.

7) Non-CIGS, Non-ENDS: Defined as use of one or more tobacco products, excluding cigarettes and ENDS in the past 30 days.

Pathways of W2 Initiators of CIGS+ENDS PTU are reported in table 3a.

\* Respondents were asked about "e-cigarettes" at W1 and "e-products" (i.e., e-cigarettes, e-cigars, e-pipes, and e-hookah) at W2 and W3.

The logit-transformation method was used to calculate confidence intervals.

† Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.

Analyses were run on the W1, W2, and W3 Public Use Files (<https://doi.org/10.3886/CPSR36498.v8>).

+, and; -, not applicable because of zero cases; CI, confidence interval; CIGS, cigarettes; ENDS, electronic nicotine delivery system; PTU, polytobacco use; W1, Wave; W2, Wave 2; W3, Wave 3; w/o, without.

## What this paper adds

- ▶ Across all age groups, never any tobacco use decreased from 2013 to 2016, reflecting overall increases in tobacco initiation in the population.
- ▶ The higher rates of past 12-month (P12M) initiation of electronic nicotine delivery systems (ENDS) may signal that a fair amount of ENDS initiation is experimental and does not persist to be identified as past 30-day (P30D) or frequent P30D use.
- ▶ Comparing exclusive and polytobacco use pathways across ages, more youth and young adults than adults 25+ initiated exclusive use of a tobacco product at W2 and then had no tobacco use at W3. More W1 adult 25+ never users remained never users across all three waves compared with youth and young adults.
- ▶ Among youth W2 P30D initiators of exclusive ENDS or cigarettes, the most common W3 outcome was not using any tobacco.

was highest among adults 25+, for whom tobacco abstinence may be an established behaviour. Findings of persistent never use across the three age groups mirror other recent studies of tobacco use transitions.<sup>33 34</sup> P30D exclusive product initiation at W2 or W3 was more common than P30D polytobacco initiation across all age groups. A higher proportion of W2 exclusive initiators stopped using tobacco at W3 compared with W2 initiators who were polytobacco users. Initiating use of multiple tobacco products within the same time period may be a risk factor for continued use over time. Given the growing phenomenon of concurrent multiple tobacco product use,<sup>35–40</sup> prevention strategies could include discussion of how combining use of tobacco products may increase risk of addiction. Kasza *et al*<sup>41</sup> examined predictors of ever or P30D tobacco initiation over a 1-year period and found that after controlling for demographics, ever use of another type of tobacco product was a significant predictor of tobacco product initiation.

Given growing evidence that ENDS initiation is associated with subsequent cigarette initiation,<sup>7 10 20–24</sup> analyses that describe specific ENDS and cigarette pathways across the three waves for each age group were explored. Among youth, 59.0% of W2 exclusive ENDS initiators were not using any tobacco at W3, whereas 40.3% of W2 exclusive cigarette initiators were not using any tobacco at W3. It is noted that approximately 20% of youth who initiated exclusively with ENDS at W2 were also exclusive ENDS users at W3 during this time period of 2013–2016 compared with 18.5% of youth who initiated exclusively with cigarettes and remained exclusive cigarette users at W3. As accessibility and trial of ENDS products among youth in the USA increased from 2017 to 2019,<sup>8 17 30</sup> it remains to be studied what proportion of ENDS initiators remain exclusive ENDS users.

While 19% of youth exclusive cigarette initiators become dual ENDS and cigarette polytobacco users a year later, that same pathway among youth who initiate with ENDS is flagged due to low sample sizes. These observations add to the growing evidence base that traditional tobacco products, such as cigarette use<sup>42</sup> and smokeless tobacco use,<sup>43</sup> may be more likely to be persistent over time compared with other tobacco products such as ENDS, cigars and hookah.<sup>44–46</sup>

## Limitations

Limitations of this report include recall bias from a self-report study questionnaire. Additionally, the PATH Study asked about 'e-cigarettes' at W1 and 'e-products' (ie, e-cigarettes, e-cigars, e-pipes and e-hookah) at W2 and W3. This approach may have resulted in misclassification of ENDS-specific use between W1 and the subsequent waves. It is noted that this report presents prevalence rates unadjusted for demographic or behavioural variables, which may be important variables to consider in future analyses. It is also noted that there may be variability in initiation rates compared with other published PATH Study papers due to differences in definitions or those included in the analytic sample. Weighted longitudinal analyses over the follow-up period excluded participants who were missing data at one of the waves. The extent of missing data and the small number of observations for specific low-prevalence pathways limit interpretation.

## Summary and implications

This report provides a unique examination of rates of never use across 3 years, three different definitions of initiation rates of tobacco overall and product-specific use, and three-wave longitudinal pathways that capture product initiation at W2 and their transitions at W3. Despite growing rates of P12M ENDS initiation in the USA, youth ENDS P30D initiation and frequent P30D initiation are less common. Among W2 P30D initiators of exclusive ENDS or cigarettes, the most common W3 outcome is not using any tobacco. While ENDS initiation rates need to be monitored and addressed in prevention efforts, these data suggest that we must also remain vigilant and maintain a strong public health focus on prevention of cigarette smoking initiation as well as initiation of other tobacco products.

**Contributors** CAS and ES led the conceptual design. CAS drafted initial manuscript and all authors critically revised it. ELS and MJH conducted statistical analysis and all authors contributed to interpretation of results. All authors approved the work for journal publication and agree to be accountable for all aspects of the work.

**Funding** This manuscript is supported with Federal funds from the National Institute on Drug Abuse, National Institutes of Health, and the Center for Tobacco Products, Food and Drug Administration, Department of Health and Human Services, under a contract to Westat (Contract No. HHSN271201100027C).

**Disclaimer** The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Department of Health and Human Services or any of its affiliated institutions or agencies.

**Competing interests** WMC reports long-term stock holdings in General Electric Company, 3M Company, and Pfizer Incorporated, unrelated to this manuscript. No financial disclosures were reported by the other authors of this paper.

**Patient consent for publication** Not required.

**Ethics approval** The study was conducted by Westat and approved by the Westat Institutional Review Board. All participants ages 18 and older provided informed consent, with youth participants ages 12 to 17 providing assent while their parent/ legal guardian provided consent.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data from the PATH Study Wave 1 to Wave 3 are available for download as Public Use Files in a public, open access repository (<https://www.icpsr.umich.edu/icpsrweb/NAHDAP/studies/36498>). Conditions of use are available at the website above.

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