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Title

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Abbreviations PATH=Population Assessment of Tobacco and Health **,** W= PATH study survey wave, aRD= adjusted risk difference; CI=Confidence Interval;

Article Summary

This cohort study examines age of first experimentation and daily use of multiple tobacco products, then investigates predictors of progression to daily cigarette smoking.

What's Known on this Subject:

Since the introduction of e-cigarettes, US adolescents and young adults who experiment with tobacco commonly try multiple tobacco products. The impact of this is unclear on subsequent prevalence of daily cigarette smoking, the most harmful form of tobacco use.

What this Study Adds

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

Contributors Statement

Dr. Pierce conceptualized and designed this study, drafted the initial manuscript and reviewed and revised the manuscript.

Mr. Chen and Ms. White had input into the study design, undertook the analyses for this study, and reviewed and revised the manuscript.

Drs. Messer and Benmarhnia had input into the study design and oversaw all analyses undertaken. They also reviewed and revised the manuscript for important intellectual content.

Drs Leas, Trinidad and Strong and Mr Stone and Ms Kealey had input into the study design and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

ABSTRACT

Objective
To identify predictors of becoming a daily cigarette smoker over 4 years.

Methods
We identified 12- to 24-year-olds at Wave 1 (W1) of the US Population Assessment of Tobacco and Health (PATH) Study and determined ever use, age of first use, and daily use through Wave 4 (W4) for 12 tobacco products.

Results
Sixty two percent of 12- to 24-year-olds (95% confidence interval [CI]: 60.1%–63.2%) tried tobacco and 30.2% (95% CI: 28.7%–31.6%) tried 5+ tobacco products by W4. At W4, 12% were daily tobacco users, with 70% of these being daily cigarette smokers (95% CI: 67.4%–73.0%); daily cigarette smoking was 20.8% in 25- to 28-year-olds (95% CI 18.9%–22.9%) while daily e-cigarette vaping was 3.3% (95% CI: 2.4%–4.4%). Compared to single product triers, the risk of progressing to daily cigarette smoking was 15 percentage points higher (adjusted Risk Difference [aRD] 15%; 95% CI: 12%–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%-9%). Daily smoking was 6 percentage points lower (aRD -6%; 95% CI: -8%– -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

INTRODUCTION

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 2016-2019, lifetime cigarette smoking among US high school seniors declined from 28.3% to 22.3%, whereas lifetime e-cigarette use increased from 38.8% to 45.6%.[4] However, US daily cigarette smoking prevalence was stable from 2007-2013 at 16-17%. [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 experimenters 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.

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] As 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) Study[13] 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 (W1) in 2013-2014. For each product, we report age of first use and patterns of daily use by age at Wave 4 (W4) in 2017. Finally, we consider whether the number of tobacco products tried and the age of first use of tobacco are associated with progression to daily cigarette smoking at W4.

METHODS

The PATH Study is a US nationally representative longitudinal study of tobacco use and health funded by the Center for Tobacco Products, Food and Drug Administration (FDA) and the National Institute on Drug Abuse, National Institutes of Health.[13] A stratified address-based, area probability sample identified US civilian, non-institutional households was drawn for screener questionnaire after which young adults, adult tobacco users, and African Americans were oversampled. Surveys were conducted using audio, computer-assisted self-interviews in English or Spanish. The PATH W1 survey collected data from September 2013 to December 2014. Participants were contacted for additional annual survey waves around the anniversary of their W1 survey. W4 (2017 survey) was completed by early January 2018.

This paper reports on W1 through W4 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/legal guardian provided consent. The response to the W1 household screener was 54%. The

unweighted attrition rate among the W1 (2013-2014) sample was 16% at W 2 (2015), 21% at W3 (2016) and 27% at W4 (2017). 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, non-institutionalized population. We limit our study to those aged 12-24 years at W1 (n=15826) 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 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 W1 were assigned the age at the reporting survey. Age of 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 <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 were considered daily users.

Study Covariates

Age, sex, and race/ethnicity were reported by respondents and their family members. We categorized race/ethnicity as Non-Hispanic (NH) White, NH Black, Hispanic, Asian, and Mixed Race and categorize age groups (y) at W1 as 12-14, 15-17, 18-21, 22-24. Household exposure to cigarettes and other tobacco use was assessed from W1 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 W1 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-ethnicity was 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 non-users of that product. However, non-users on W1 may have reported ever use on 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 of first tobacco use (8.5%).

Statistical Analyses

We use all-waves weights and replicate weights provided at W4 to obtain statistically valid estimates from longitudinal analyses. Variances and 95% confidence intervals (CI) for estimates were obtained using balanced

repeated replication weights with Fay's adjustment ($\rho=0.3$). Estimates with a denominator of <50 or a relative standard error (RSE) ≥30% are not presented.

To examine associations with progression to daily use of cigarettes at W4, we ascertained the subsample who were not daily users of tobacco at W1 and who did use at least one tobacco product by W3. Adjusted Risk Differences (aRDs) were computed from multivariable logistic regression, using the following 3 models: a) age of first experimentation with any tobacco product + sex + race/ethnicity + age + smoke-free home + exposure to smokers; b) the number of tobacco products tried + age of first experimentation with any tobacco product + sex + race/ethnicity + age + smoke-free home + exposure to smokers; c) ever used e-cigarette (y/n) + ever used other non-cigarette tobacco products (y/n) + age of first experimentation with any tobacco product + sex + race/ethnicity + age + smoke-free home + exposure to smokers in the past 7 days.

Confidence intervals for the aRD were computed by the quantiles from a parametric bootstrap distribution, 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) and R (version 3.5.3).

RESULTS

Ever and Daily Tobacco Use among 12- to 24-year-olds at W1 (2013-2014)

Over half of W1 respondents (54.5%; 95 % CI: 53.1–55.9) were classified as never tobacco users and this proportion declined dramatically with age [12-14 years old: 90.7% (95 % CI: 89.8–91.6); 22-24 years old: 28.1% (95 % CI: 24.9–31.3)]. (**Table 1**) Ever use of tobacco was more common among males (48.0, 95% CI 46.4,49.6) vs females (42.9%, 95% CI 41.3,44.6); non-Hispanic Whites (47.4, 95% CI 45.8,49.7) than Asians (34.5, 95% CI 29.8,39.4) or non-Hispanic Blacks (41.2, 95% CI 38.9,43.5); those without a smoke-free home (65.1%, 95% CI 63.3,66.8) vs those with one (38.1%, 95% CI 36.6,39.7); and those exposed to other smokers (61.9%, 95% CI 60.4,63.4) vs those not so exposed (27.4%, 95% CI 26.0,28.9).

Daily tobacco use (10.1%, 95 % CI: 9.5–10.7) was strongly associated with age [15-17 years old: 3.3% (95 % CI: 2.6–4.0); 22-24 years old: 19.8% (95 % CI: 18.1–21.5)] as well as with sex [Males: 12.2% (95% CI: 11.3–13.1) vs Females: 7.9% (95% CI: 7.1–8.7)]. Daily use was higher among Non-Hispanic Whites (12.8%) and those of mixed race-ethnicities (12.9%) than for 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 W4

Ever tobacco use increased from 45.5% at W1 (**Table 1**) to 61.7% at W4 (95% CI: 60.1–63.2). (**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 over half tried hookah and cigarillos. Five other tobacco products (traditional cigars, filtered cigars, smokeless products, pipes and snus) were tried by more than 10% of respondents.

Except for e-cigarettes, the median age of first use for every product was 16-17 years. (**Table 2**) We show 95% quantiles for age of first experimentation with each product and note that the youngest 2.5% of all experimenters were under 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 17-21 years, leading to a higher median age of first use. (**Figure 1**) In the first year of tobacco use, 63.9% (95% CI: 62.8%–65.0%) of experimenters used one product, 16.9% (95% CI: 15.8%–17.9%) used 2 products and 12.5% used 3 or more products.

Daily Use of Tobacco Products at W4 (2017)

At W4, 1,935 W1 respondents (12.4%; 95% CI: 11.8%–13.1%) were daily users of a tobacco product, with just under half of these (5.0%; 95% CI: 4.6%–5.4%) starting daily tobacco use after W1. Most daily users (70.3%; 95% CI: 67.4%–73.0%) were cigarette smokers, **(Table 3)** which was over 4 times the proportion who were daily e-cigarette vapers 16.6% (95% CI:

14.3%–19.2%). Very few were daily users of both cigarettes and e-cigarettes (2.1%; 95% CI: 1.5%–2.9%). Daily cigarette smokers had a higher probability of exclusive use (63.5%; 95% CI: 60.6%–66.2%) than daily e-cigarette vapers (42.1%; 95% CI: 36.1%–48.4%). Among daily e-cigarette vapers, the most common non-daily use of a concurrent product was cigarettes (44.9%; 95% CI: 39.0%–51.0%).

Among ever users of tobacco at W1-W4, 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%–13.2%) and 25- to 28-year-olds (20.8%; 95% CI: 18.9%–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 2016-17, 6.3% reported using any tobacco product on 25 of past 30 days (daily use as defined on the PATH Youth survey).

Progression to Daily Cigarette Smoking at W4

We examined 7088 nondaily tobacco users at W1 who had tried at least one tobacco product by W3. In a logistic regression controlling for age, sex, race-ethnicity, smoke-free home at W1, and exposure to other smokers at W1, we found that those who first experimented with tobacco after age 18 years had an adjusted risk difference (aRD) for progression to daily cigarette smoking that was 6 percentage points lower (95% CI: -8%– -4%) compared to those who first experimented when younger than 18 years.

Trying one tobacco product was reported by 20.9% (95% CI: 19.5%–22.3%) with 19.1% (95% CI: 17.9%–20.4%) reporting 2 products, 29.9% (95% CI:

28.7%–31.2%) reporting 3-4 products, and 30.1% (95% CI: 28.7%–31.5%) reporting trying 5 or more tobacco products. We found a strong dose-response relationship between the number of products used and report of daily cigarette smoking at W4. Fewer than 1% of those who only tried one product by W3 progressed to daily cigarette smoking by W4. Experimentation with a second product by W3 increased the risk of daily cigarette use at W4 by an aRD of 2 percentage points (95% CI: 0.3%–4%) (i.e., 2 additional daily cigarette smokers per 100 tobacco users compared to single product users). (**Figure 2A**) Those who had tried 3 or 4 tobacco products had an aRD of becoming daily smokers of 7 percentage points (95% CI: 5%–9%) compared to single product users. Those who had tried 5 or more tobacco products, had an aRD of becoming a daily cigarette smoker of 15 percentage points (95% CI: 12%–18%) (i.e., 15 additional daily cigarette smokers per 100 tobacco users, compared to single product users). Figure 2B shows that ever use of an e-cigarette (vs. never use) increased the risk of later daily cigarette smoking by threefold (3% vs. 10%; aRD = 7%; 95% CI: 6%-9%), adjusted for confounders and ever use of other non-cigarette tobacco products.

DISCUSSION

Our longitudinal analysis of multiple tobacco product use in the nationally-representative PATH Study found that 62% of US youth had tried at least one tobacco product prior to W4 (2017) and 30% had tried 5 or more products. Equal numbers of respondents had tried e-cigarettes vs cigarettes, which

were by far the most frequently tried products At W4 daily cigarette smoking made up 70% of all daily tobacco use. Among those who were not daily users at W1, ever use of e-cigarettes was associated with more than a threefold increase in daily cigarette smoking at W4, from 3% for never e-cigarette users to 10%. Further, each additional tobacco product tried was associated with a marked increase in W4 daily smoking.   While 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 (e.g. 21% of 25- to 28-year-olds at W4) was 6 times higher than the proportion who progressed to daily e-cigarette vaping (3.3% of 25- to 28-year-olds). Indeed, more than 20% of those aged 25-28 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 of 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 more than 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 of 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 artefact of the recent introduction of e-cigarettes with pharmacokinetic nicotine delivery systems much closer to cigarettes.[17] In 2013, over one third of our study population was already over the age of 18 years. Given that e-cigarettes were widely considered as less harmful than cigarettes in 2013-14,[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 of first experimentation with e-cigarettes will decline as those who entered their teen years when e-cigarettes were already popular, become adults.

Among daily cigarette smokers, one third also used another tobacco product, with half of these vaping e-cigarettes on a non-daily basis. Among daily vapers, almost half were also non-daily cigarette smokers. Further follow-up will determine whether these young daily tobacco users continue to be dual product users or whether they stabilize on a single product such as cigarettes. In the W1 PATH 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

use[17] is quite common.[21] Such a secondary role for e-cigarettes may change with the more efficient e-cigarette nicotine delivery systems[17] that became popular in the US after 2017. [22,23]

The PATH Study has numerous strengths. These include the large representative sample of the US population with annual in-household follow-up self-assessments. While there was attrition between surveys, all-survey weights are available to minimize effects on study estimates. This manuscript relies on self-reported frequency of use for the wide-range of tobacco products assessed in the PATH 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.

CONCLUSION

In this representative sample of US youth and young adults, almost two thirds had experimented with at least one tobacco product and almost one third experimented with 5 or more tobacco products of which e-cigarettes and cigarettes were the most popular. Over the 4-year study, 12% reported daily tobacco use with over two thirds of these reporting daily cigarette smoking. Progression to daily cigarette smoking between W1 and W4 was three times higher among ever e-cigarette users compared to non-users. 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 the US young

adults.

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)		
		Never tobacco users[a]	Ever tobacco users[b]	Daily tobacco users[c]
Overall	15826	54.5 (53.1 -55.9)	45.5 (44.1 -46.9)	10.1 (9.5 -10.7)
Age, y				
12-14	5315	90.7 (89.8 -91.6)	9.3 (8.4 -10.4)	0.2 (0.0 -0.4)
15-17	4771	68.3 (66.8 -69.8)	31.7 (30.2 -33.2)	3.3 (2.6 -4.0)
18-21	3230	38.0 (35.7 -40.3)	62.0 (59.7 -64.3)	14.8 (13.5 -16.1)
22-24	2510	28.1 (24.9 -31.3)	71.9 (68.7 -74.8)	19.8 (18.1 -21.5)
Sex				
Male	7888	52.0 (50.4 -53.6)	48.0 (46.4 -49.6)	12.2 (11.3 -13.1)
Female	7938	57.1 (55.4 -58.8)	42.9 (41.3 -44.6)	7.9 (7.1 -8.7)
Race/ethnicity				
Non-Hispanic white	7637	52.3 (50.3 -54.3)	47.7 (45.8 -49.7)	12.8 (11.9 -13.7)
Non-Hispanic black	2389	58.8 (56.5 -61.1)	41.2 (38.9 -43.5)	8.7 (7.3 -10.1)
Hispanic	4338	54.9 (52.9 -56.9)	45.1 (43.1 -47.1)	5.4 (4.7 -6.1)
Asian	438	65.5 (60.9 -70.1)	34.5 (29.8 -39.4)	2.6 (0.2 -5.0)
Mixed	1024	52.7 (49.3 -56.1)	47.3 (43.9 -50.8)	12.9 (10.6 -15.2)
Smokefree home				
No	4140	34.9 (33.2 -36.7)	65.1 (63.3 -66.8)	23.0 (21.5 -24.6)
Yes	11686	61.9 (60.3 -63.4)	38.1 (36.6 -39.7)	5.2 (4.8 -5.7)
Exposed to smokers[d]				
No	7925	72.6 (71.1 -74.0)	27.4 (26.0 -28.9)	1.4 (1.1 -1.7)
Yes	7901	38.1 (36.6 -39.6)	61.9 (60.4 -63.4)	18.0 (17.0 -19.0)

Abbreviations: PATH, Population Assessment of Tobacco and Health; CI, Wilson Confidence Limits.

[a] Never Tobacco User. 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] Ever Tobacco User. 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 Tobacco User. 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 <product> every day, some days, or not at all?" Daily use in the PATH Youth Survey (respondents <18 y) was Youth survey respondents who reported using a product at least 25 days in the past 30 days.

[d] Exposed in previous 7 days

Table 2. Ever Tobacco Use[a] at Wave 4 (2017) and Age of First Use[b] by Product Among PATH Study Respondents Aged 12 to 24 Years at Wave 1 (2013-2014, n=15826)

	Ever tobacco use, W4 No., weighted % (95% CI)			% of all tobacco users using product weighed % (95% CI)		Age at first use, y Median, 95% Quantiles		
Tobacco Product							2.5%	97.5%
Any tobacco	9410	61.7	(60.1 - 63.2)	100.0		16	7	23
Individual Products								
E-cigarettes	7238	45.3	(43.9 - 46.7)	73.1	(71.9 -74.3)	19	8	22
Cigarettes	6766	44.9	(43.6 - 46.2)	72.4	(71.1 -73.7)	16	12	25
Hookah	5723	38.7	(37.0 - 40.3)	62.4	(60.4 -64.3)	17	13	23
Cigarillos	5230	34.4	(33.1 - 35.7)	55.5	(54.1 -56.9)	17	11	23
Traditional cigars	3616	24.7	(23.6 - 25.9)	39.9	(38.4 -41.3)	17	12	24
Filtered cigars	2935	18.4	(17.4 - 19.4)	29.6	(28.4 -30.9)	17	12	24
Smokeless tobacco	2259	14.4	(13.6 - 15.1)	23.2	(22.1 -24.2)	16	9	23
Pipes	2107	13.3	(12.5 - 14.0)	21.4	(20.4 -22.4)	16	11	23

	N	%	CI	%	CI			
Snus	1821	11.3	(10.7 -12.0)	18.3	(17.3 -19.2)	16	12	23
Kreteks	610	2.7	(2.5 -3.0)	4.4	(4.1 -4.8)	16	12	17
Dissolvable tobacco	605	2.7	(2.5 -2.9)	4.4	(4.0 -4.7)	16	12	20
Bidis	604	2.7	(2.5 -2.9)	4.4	(4.0 -4.7)	16	13	17

Abbreviations: PATH, Population Assessment of Tobacco and Health; W4, Wave 4; CI, Wilson Confidence Limits.

[a] Ever Tobacco Use. Respondents answering affirmatively when asked whether they had ever used the product, even 1 or 2 times (for cigarettes, even 1 or 2 puffs).

[b] Age of First Use. The youngest age reported for ever use of a tobacco products. Those who reported starting use of a product after Wave 1 were assigned the age at the reporting survey.

Figure 1: Age of First Use[a] of Cigarettes and E-cigarettes Among PATH Study Respondents Aged 12 to 24 Years at Wave 1 (n=15826)
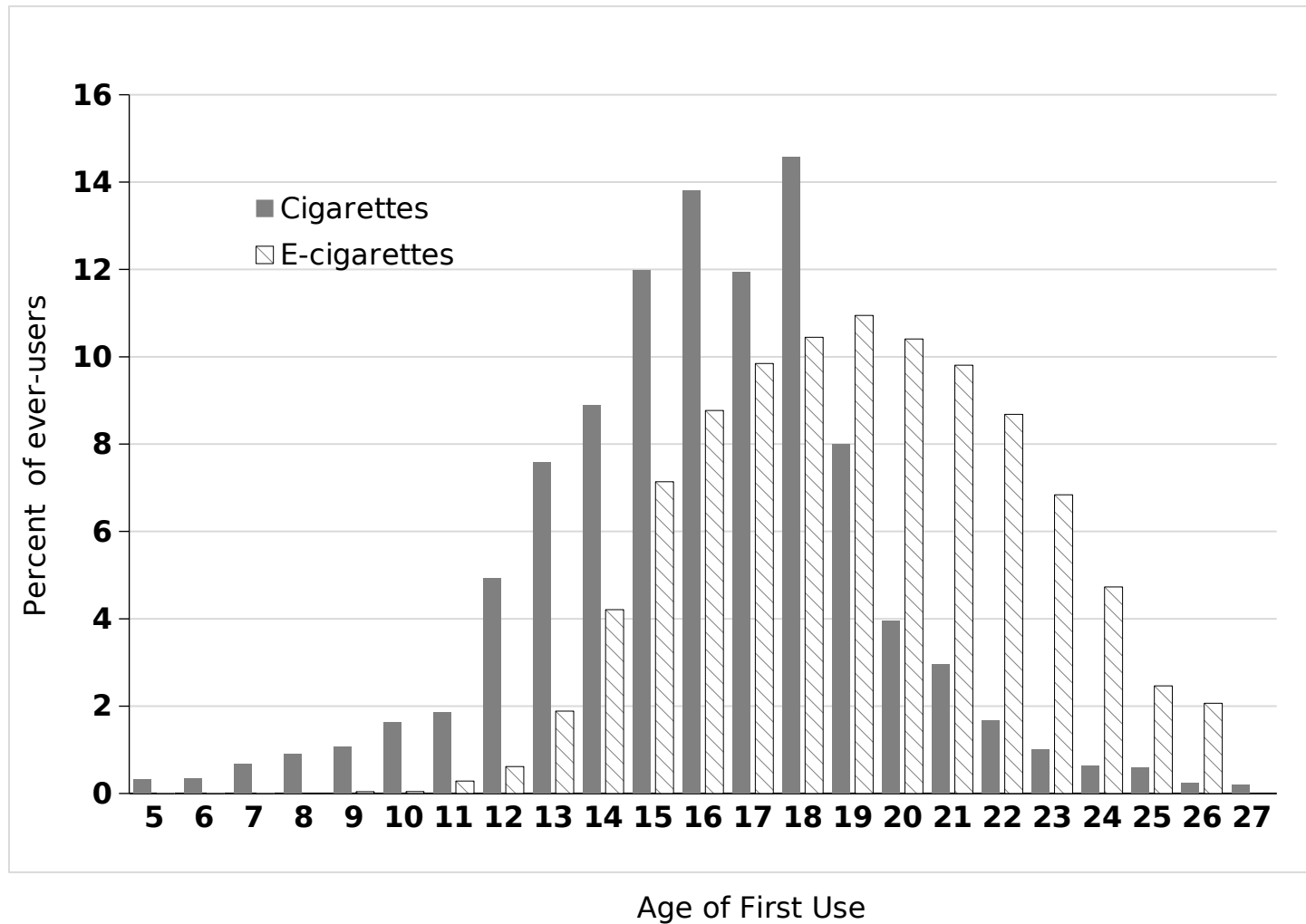
[a] Age of First Use. The youngest age reported for ever use of a tobacco products. Those who reported starting use of a product after Wave 1 were assigned the age at the reporting survey.

Table 3. Tobacco Product Use in Daily Users[a] at Wave 4 (2017) Among PATH Study Respondents Aged 12 to 24 Years at Wave 1 (2013-2014), n=1935

Product(s) Used Daily at W4	Daily Tobacco Product Use at Wave 4 — No., Weighted % (95% CI)						Non-Daily Tobacco Product Use at Wave 4 — No., Weighted % (95% CI)								
	Total daily users of product			Exclusive daily use of product			e-cigarettes			cigarettes			Other Product[d]		
Cigarettes	1383	70.3	(67.4-73.0)	846	63.5	(60.6-66.2)	278	17.4	(15.4-19.4)	NR[e]			429	29.4	(26.7,32.2)
E-cigarettes	299	16.6	(14.3-19.2)	116	42.1	(36.1-48.4)	NR[e]		.	144	44.9	(39.0-51.0)	120	37.1	(30.7,44.0)
Cigarettes & e-cigarettes	41	2.1	(1.5-2.9)	19	50.8	(34.7-66.8)	NR[e]		.	NR[e]			22	49.2	(33.2,65.3)
Smokeless Tobacco[b]	133	7.4	(6.0-9.1)	70	54.4	(46.0-62.7)	8	5.4	(2.6-10.6)	32	22.7	(16.-31.0)	42	31.3	(24.1,39.6)
Other tobacco[c]	79	3.6	(2.9-4.6)	22	27.3	(17.3-40.2)	24	24.8	(16.6-35.3)	43	54.4	(40.8-67.5)	40	45.1	(34.2,56.4)

Abbreviations: CI, Wilson confidence limits; NR, not reported; PATH, Population Assessment of Tobacco and Health.

[a] Daily Tobacco User. 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 <product> every day, some days, or not at all?" Daily use in the PATH Youth Survey (respondents <18 y) was Youth survey respondents who reported using a product at least 25 days in the past 30 days.

[b] Smokeless tobacco includes dissolvable tobacco and snus.

[c] Other tobacco includes hookah, cigarillos, traditional cigars, filtered cigars, pipes, kreteks, and bidis.

[d] Other product includes smokeless tobacco, dissolvable tobacco, snus, hookah, cigarillos, traditional cigars, filtered cigars, pipes, kreteks, and bidis

[e] not reported because of limited sample size

Table 4. Daily Use[a] of Tobacco Products by Age at Wave 4 among Ever Users of Tobacco Waves 1-4[b] (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 (2.4-4.3)	2.8 (2.0-3.9)	0.5 (0.2-0.9)	6.3 (5.1-7.7)
18-21	11.7 (10.4-13.2)	4.7 (3.9-5.6)	2.6 (2.0-3.3)	18.6 (17.0-20.3)
22-24	15.6 (14.0-17.4)	3.7 (2.8-4.8)	2.3 (1.8-3.1)	21.2 (19.2-23.4)
25-28	20.8 (18.9-22.9)	3.3 (2.4-4.4)	2.4 (1.8-3.1)	26.0 (23.9-28.2)

Abbreviations: CI, Wilson confidence limits.

[a] Daily Tobacco User. 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 <product> every day, some days, or not at all?" Daily use in the PATH Youth Survey (respondents <18 y) was survey respondents who reported using a product at least 25 days in the past 30 days. 1590 participants were still not 18 years when surveyed at Wave 4 and hence they completed the Wave 4 Youth Survey rather than Adult survey.
[b]This table is a cross-sectional analysis of W4 respondents and so includes ever users at any survey including W4.

Figure 2: Multivariable logistic regression adjusted[a] and weighted risk differences in rates of progression to daily cigarette smoking at Wave 4 by A) the number of tobacco products reported as ever tried on Waves 1-3 and B) ever used e-cigarette or ever used other non-cigarette tobacco products (except e-cigarette) at Wave 3[b]. Bars represent 95% confidence intervals[c]. Sample drawn the Population Assessment of Tobacco and Health (PATH) Study who were 12-24 years old at Wave 1 and who had reported trying at least one tobacco product between Waves 1 and 3 surveys but who were not daily tobacco users at Wave 1 (n=7088). RD: Risk difference. CI: Confidence Interval.

A)
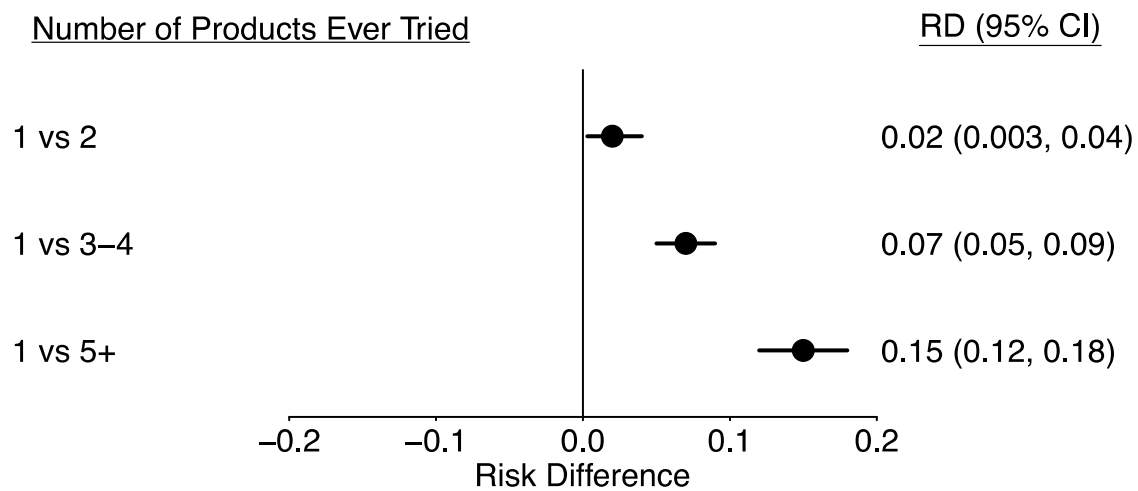
B)
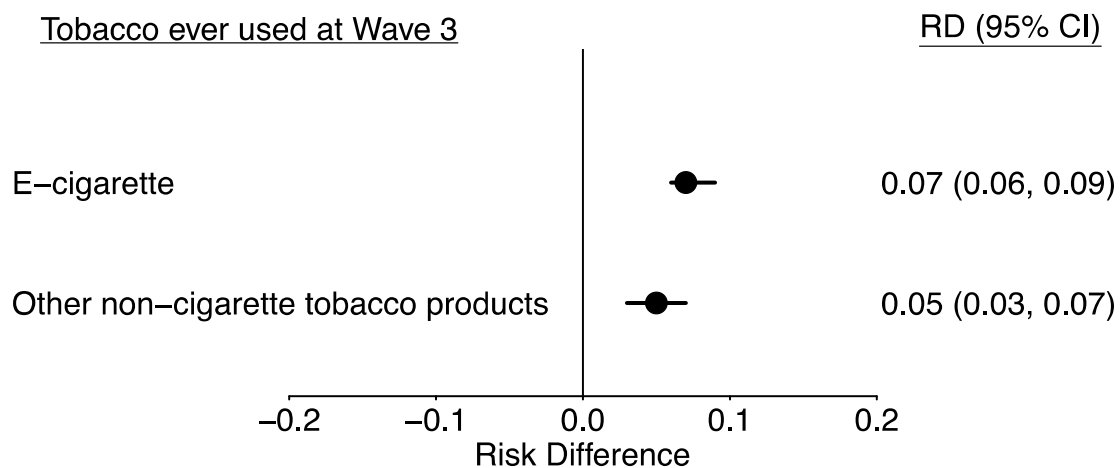
[a] From Logistic regression adjusted for age, sex, race-ethnicity, smokefree home at Wave 1, Exposure to other smokers at Wave 1, and age first used any tobacco product

[b] The two binary predictors: 1) ever used e-cigarette; 2) ever used other non-cigarette tobacco products (except e-cigarette) are assessed simultaneously in panel B. Please refer to model c) in the method.

[c] 95% confidence intervals were computed by the quantiles from parametric bootstrap distributions, 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

REFERENCES

1. Richardson A, Williams V, Rath J, Villanti AC, Vallone D. The next generation of users: prevalence and longitudinal patterns of tobacco use among US young adults. *Am J Public Health.* 2014;104(8):1429-1436.
2. Lee YO, Hebert CJ, Nonnemaker JM, Kim AE. Multiple tobacco product use among adults in the United States: cigarettes, cigars, electronic cigarettes, hookah, smokeless tobacco, and snus. *Prev Med.* 2014;62:14-19.
3. Stanton CA, Sharma E, Seaman EL, et al. 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). *Tob Control.* 2020;29(Suppl 3):s178-s190.
4. National Institute on Drug Abuse. Monitoring the Future Study: Trends in Prevalence of Various Drugs. https://www.drugabuse.gov/drug-topics/trends-statistics/monitoring-future/monitoring-future-study-trends-in-prevalence-various-drugs. Accessed July 27, 2020.
5. US Department of Health and Human Services. *The Health Consequences of Smoking-50 Years of Progress: A Report of the Surgeon General.* Atlanta, GA: Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2014.
6. Taylor KA, Sharma E, Edwards KC, et al. Longitudinal pathways of exclusive and polytobacco cigarette use among youth, young adults and adults in the USA: findings from the PATH Study Waves 1-3 (2013-2016). *Tob Control.* 2020;29(Suppl 3):s139-s146.
7. Odani S, Armour BS, King BA, Agaku IT. E-Cigarette Use and Subsequent Cigarette Initiation and Sustained Use Among Youth, U.S., 2015-2017. *J Adolesc Health.* 2020;66(1):34-38.
8. Pierce JP, Sargent JD, Portnoy DB, et al. Association Between Receptivity to Tobacco Advertising and Progression to Tobacco Use in Youth and Young Adults in the PATH Study. *JAMA Pediatr.* 2018;172(5):444-451.
9. Hallingberg B, Maynard OM, Bauld L, et al. Have e-cigarettes renormalised or displaced youth smoking? Results of a segmented regression analysis of repeated cross sectional survey data in England, Scotland and Wales. *Tob Control.* 2020;29(2):207-216.
10. Kasza KA, Ambrose BK, Conway KP, et al. Tobacco-Product Use by Adults and Youths in the United States in 2013 and 2014. *N Engl J Med.* 2017;376(4):342-353.
11. King JL, Reboussin D, Cornacchione Ross J, Wiseman KD, Wagoner KG, Sutfin EL. Polytobacco Use Among a Nationally Representative Sample

of Adolescent and Young Adult E-Cigarette Users. *J Adolesc Health.* 2018;63(4):407-412.

12. Pierce JP, White VM, Emery SL. What public health strategies are needed to reduce smoking initiation? *Tob Control.* 2012;21(2):258-264.

13. Hyland A, Ambrose BK, Conway KP, et al. Design and methods of the Population Assessment of Tobacco and Health (PATH) Study. *Tob Control.* 2017;26(4):371-378.

14. National Addiction & HIV Data Archive Program. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files (ICPSR 36231). https://www.icpsr.umich.edu/icpsrweb/NAHDAP/studies/36231. Accessed July 27, 2020.

15. Cantrell J, Bennett M, Mowery P, et al. Patterns in first and daily cigarette initiation among youth and young adults from 2002 to 2015. *PLoS One.* 2018;13(8):e0200827.

16. Gentzke AS, Creamer M, Cullen KA, et al. Vital Signs: Tobacco Product Use Among Middle and High School Students - United States, 2011-2018. *MMWR Morb Mortal Wkly Rep.* 2019;68(6):157-164.

17. Hajek P, Pittaccio K, Pesola F, Myers Smith K, Phillips-Waller A, Przulj D. Nicotine delivery and users' reactions to Juul compared with cigarettes and other e-cigarette products. *Addiction.* 2020;115(6):1141-1148.

18. Coleman BN, Johnson SE, Tessman GK, et al. "It's not smoke. It's not tar. It's not 4000 chemicals. Case closed": Exploring attitudes, beliefs, and perceived social norms of e-cigarette use among adult users. *Drug Alcohol Depend.* 2016;159:80-85.

19. Strong DR, Leas E, Elton-Marshall T, et al. Harm perceptions and tobacco use initiation among youth in Wave 1 and 2 of the Population Assessment of Tobacco and Health (PATH) Study. *Prev Med.* 2019;123:185-191.

20. Coleman BN, Rostron B, Johnson SE, et al. Electronic cigarette use among US adults in the Population Assessment of Tobacco and Health (PATH) Study, 2013-2014. *Tob Control.* 2017;26(e2):e117-e126.

21. Dunbar ZR, Giovino G, Wei B, O'Connor RJ, Goniewicz ML, Travers MJ. Use of Electronic Cigarettes in Smoke-Free Spaces by Smokers: Results from the 2014-2015 Population Assessment on Tobacco and Health Study. *Int J Environ Res Public Health.* 2020;17(3).

22. Willett JG, Bennett M, Hair EC, et al. Recognition, use and perceptions of JUUL among youth and young adults. *Tob Control.* 2019;28(1):115-116.

23. Vallone DM, Bennett M, Xiao H, Pitzer L, Hair EC. Prevalence and correlates of JUUL use among a national sample of youth and young adults. *Tob Control.* 2019;28(6):603-609.

24. Rostron BL, Corey CG, Chang JT, van Bemmel DM, Miller ME, Chang CM. Associations of Cigarettes Smoked Per Day with Biomarkers of Exposure Among U.S. Adult Cigarette Smokers in the Population Assessment of Tobacco and Health (PATH) Study Wave 1 (2013–2014).

Cancer Epidemiology Biomarkers & Prevention. 2019;28(9):1443-1453.

25. Goniewicz ML, Smith DM, Edwards KC, et al. Comparison of Nicotine and Toxicant Exposure in Users of Electronic Cigarettes and Combustible Cigarettes. *JAMA Netw Open.* 2018;1(8):e185937.