




Age of Onset of Susceptibility to Different Tobacco Products Among Non-Susceptible US Young Adults: Findings from the Population Assessment of Tobacco and Health Study Waves 2-4 (2014-2017)

Tobacco Use Insights
Volume 14: 1–16
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DOI: 10.1177/1179173X211065643


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ABSTRACT

INTRODUCTION: Initiation of tobacco products is increasing in young adulthood. This study prospectively estimated the age of onset of susceptibility to cigarettes, e-cigarettes, hookah, smokeless tobacco, and cigarillos among young adults, which is a cognitive precursor to initiation.

METHODS: Secondary data analyses of the Population Assessment of Tobacco and Health (PATH) study, a nationally representative longitudinal cohort study of US adults. Young adults (18-24 years) who were non-susceptible to each tobacco product (cigarettes, e-cigarettes, hookah, smokeless tobacco, and cigarillos) at waves 2 or 3 were followed-up into waves 3-4 to prospectively estimate the age of onset of susceptibility to each tobacco product. Weighted interval-censored survival methods and interval-censored Cox regression models were implemented to estimate the age of onset of susceptibility, and to estimate differences in the hazard function by sex and by race/ethnicity, while controlling for the total number of other tobacco products ever used at their first wave of participation in PATH.

RESULTS: By age 21, 16.5%, 16.0%, 12.6%, 12.4%, and 5.9% of young adults reported onset of susceptibility to hookah, e-cigarettes, cigarillos, cigarettes, and smokeless tobacco, respectively. Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, the highest increase in onset of susceptibility occurred between ages 18 and 19 for cigarettes, e-cigarettes, and hookah, while the highest increase in onset of susceptibility occurs between ages 22 and 23 for cigarillos. Young adult males had increased risk of onset of susceptibility to cigarillos and smokeless tobacco at earlier ages than young adult females. Differences in onset of susceptibility to each tobacco product were also observed by race/ethnicity among young adults.

CONCLUSIONS: With the changing landscape of tobacco products, monitoring the age of onset of susceptibility of tobacco product use among non-susceptible young adults longitudinally is critical to prevent initiation. Communication and education campaigns tailored to address differences in susceptibility among young adults by tobacco product and sociodemographic factors will be useful.

KEYWORDS: cigarettes, e-cigarettes, hookah, cigarillos, smokeless tobacco, survival analysis

RECEIVED: April 8, 2021. **ACCEPTED:** November 9, 2021.

TYPE: Original Research

DECLARATION OF CONFLICTING INTERESTS The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article, except Dr. Harrell is a consultant in litigation involving the vaping industry.

FUNDING The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Research reported in this publication was supported to Dr Pérez by grant number R01CA234205 from the National Cancer Institute (NCI) and the FDA Center for Tobacco Products (CTP). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health (NIH) or the

Food and Drug Administration (FDA). NIH and FDA was not involved in the design and conduct of this study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit this manuscript for publication.

ETHICAL APPROVAL IRB approval for this study was obtained from the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston with number HSC-SPH-17-0368, and ICPSR approved our restricted-use access to PATH data. The original investigators of the PATH study obtained written informed consent for participants.

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Introduction

Tobacco use remains a leading cause of preventable diseases and death in the US.^{1,2} There are many intervention campaigns that are focused specifically on prevention, deterring groups known

to be vulnerable to tobacco use before they actually start, as tobacco prevention is a cost-effective strategy to mitigate the health and economic burden of tobacco use. However, these campaigns are typically targeted toward youth instead of young



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adults,³ despite the fact that an increasing amount of tobacco product initiation occurs during young adulthood.⁴⁻⁹ Thus, identifying the age at which young adults become susceptible to tobacco product use is critical for prevention efforts.

Susceptibility to tobacco use is measured among those who have not yet used a tobacco product, and is defined as a lack of a firm decision not to use a particular tobacco product.¹⁰⁻¹⁴ While most research on this construct has focused on youth (i.e., 12- to 17-year-olds),^{12,15-23} recent research demonstrates it is relevant to young adults, too. Previous research on tobacco product susceptibility has indicated that susceptibility varies by specific tobacco products and age in young adults.²⁴⁻²⁹ The 2012-2013 National Adult Tobacco Survey (NATS) found that 19.7% of young adults (18-24 years old) were susceptible to cigarette use.²⁴ A convenience sample of college students in Upstate New York in 2013 found that among 18, 19, and 20 to 23-year-olds, the prevalence of susceptibility to e-cigarette use was 39.5%, 40.8%, and 36.8%, respectively.²⁵ A different 2014-2015 nationally representative study of adolescents and young adults (ages 13-25) found that among never users of hookah and little cigars/cigarillos (LCCs), 17.7% and 14.8% were susceptible to use, respectively.²⁶ In 2016-2017, a study surveying college freshmen at a large university found that 30.0% of those who reported they were non-susceptible to hookah use at baseline reported onset of susceptibility to hookah use by the end of the academic year.²⁷ Additionally, a 2014-2015 study reported that among a sample of 3166 Texas college students aged 18 to 25 who were non-susceptible to smokeless tobacco use at baseline, 7.1% reported onset of susceptibility to smokeless tobacco at a 6-month follow-up.²⁸ Thus, susceptibility is relevant to young adult populations. However, the age at which the onset of susceptibility occurs in young adulthood among never users of each tobacco product has not yet been reported.

Importantly, previous research has shown that susceptibility to cigarettes and non-cigarette tobacco products is a reliable predictor of initiation, even among young adults.^{24,27,29} Among college students in Texas aged 18 to 25 in 2014-2015, 6.3% reported susceptibility to cigarette use, and susceptibility was positively associated with cigarette initiation after 1.5 years of follow-up (AOR = 3.02; 95% CI = 2.14-4.27).²⁹ A different study of college freshmen at a large university found that susceptibility to hookah use was predictive of hookah initiation and continued hookah use.²⁷ The 2014 Southern California Children's Health Study among 11th and 12th graders evaluated the association between susceptibility to cigarettes, e-cigarettes, hookah, and any cigar product and initiation of each tobacco product 16 months later, which found that the odds of initiating each product were 3.72 for cigarettes (95% CI = 2.40-5.77), 3.64 for e-cigarettes (95% CI = 2.61-5.09), 3.68 for hookah (95% CI = 2.54-5.33), and 3.90 for any cigar product (95% CI = 2.46-6.19) among those who were susceptible to each product at baseline.³⁰ Thus, a better understanding of susceptibility in young adulthood could inform preventive interventions designed to reduce onset of tobacco use.

Research on differences in susceptibility by sex and by race/ethnicity has indicated that these differences, when present, vary by tobacco product among young adults. While previous studies have

reported no sex difference in the odds of susceptibility to hookah,²⁷ e-cigarettes,²⁵ and smokeless tobacco²⁸ among college students, as well as the odds of susceptibility to little cigars/cigarillo use among adult cigarette users,³¹ a nationally representative study indicated that young adult (18-24 years old) males who were "non-established" cigarette users (i.e., less than 100 cigarettes ever used and now smokes "not at all") have higher odds of susceptibility to cigarettes compared with females (AOR = 1.6; 95% CI = 1.2-2.3).²⁴ A cross-sectional study of the 2012-2013 NATS found that there were no differences in the prevalence of cigarette susceptibility among young adults (18-24 years old) by race/ethnicity.²⁴ Similarly, a study of college students (18-23 years old) in 2013 found that there were no differences in the prevalence of e-cigarette susceptibility between Non-Hispanic White compared with Hispanic and Non-Hispanic other college students.²⁵ Among young adults (aged 18-25) who were susceptible to smokeless tobacco, a 2015 study reported that compared with Non-Hispanic White young adults, Hispanic/Latino had increased odds of susceptibility to smokeless tobacco (AOR = 1.54; 95% CI = 1.08-2.20).²⁸ Finally, a probability sample of U.S. adults (ages 18-60+) found a significant association among Non-Hispanic Black (AOR = 2.02; 95% CI = 1.06-3.84) and Non-Hispanic other adults (AOR = 3.39; 95% CI = 1.48-7.76) with susceptibility to little cigar/cigarillo use compared with Non-Hispanic White adults.³¹

Previous research has shown there has been a large increase in the proportion of people initiating cigarette use during young adulthood. In 2002, 20.6% of young adult (18- to 23-year-olds) ever cigarette users initiated in that age range, which increased to 42.6% in 2018.⁴ While it is important for interventionists to target youth, the increasing proportion of tobacco users initiating tobacco use during young adulthood calls for increased research and intervention strategies designed to impact this age group's susceptibility to tobacco use to, in turn, prevent onset. Additionally, the increasing variety of tobacco products available to users, such as e-cigarettes, hookah, and smokeless tobacco, all of which are growing in popularity among young adults,³²⁻³⁴ calls for specific research on susceptibility to each product. Understanding sociodemographic differences in susceptibility to these products can help vulnerable sub-groups who may be at increased risk to initiate tobacco use at earlier ages.

Previous studies have not examined the age at which non-susceptible young adults become susceptible to different tobacco products. Highlighting differences in the age of onset of susceptibility by sex and race/ethnicity is equally important to examine, as this has been under-reported in young adults in other studies. Therefore, this study conducted secondary analyses of the Population Assessment of Tobacco and Health (PATH) study waves 2-4 (2014-2017) for the age of onset of susceptibility among US young adults (18-24 years old) for cigarettes, e-cigarettes, cigarillos, hookah, and smokeless tobacco overall, by sex and by race/ethnicity.

Methods

Study Design and Participants

The PATH study is a cohort study of tobacco use behaviors that used a four-stage stratified probability sampling design to obtain

a nationally representative sample of youth and adults.³⁵ Audio computer-assisted self-interviews (ACASI) in English and Spanish were used to collect information on tobacco use from respondents, which minimizes the information bias inherent in data collection from hard copy surveys. Further details on the PATH study design have been previously described.³⁵ Secondary analyses of young adult participants (18–24 years old) who were never users of each tobacco product and non-susceptible to use at wave 2 (when susceptibility questions were first asked among young adults) or wave 3 (among “aged-up” adults, that is, youth who turn 18) (2014–2016) were included for analyses by product. This resulted in five different samples of young adults who were non-susceptible to each tobacco product to examine the age of onset of susceptibility by product prospectively. Age of onset of susceptibility was followed-up in waves 3–4 (2015–2017), but was only asked among 18- to 24-year-olds. Therefore, a 24-year-old participant who had susceptibility measured at wave 3 could not be followed-up in wave 4 because susceptibility questions were not asked among participants aged 25+. Age of onset of susceptibility to cigarillo use was only followed-up in wave 3 because susceptibility questions were not asked for this tobacco product in wave 4. Institutional review board approval for this study was obtained from the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston with number HSC-SPH-17-0368, and the Inter-university Consortium for Political and Social Research (ICPSR) approved our restricted-use access to PATH data. The original investigators of the PATH study obtained written informed consent for participants 18 years and older.³⁵

Susceptibility to tobacco product use. PATH measured susceptibility using questions guided by previous research.^{11,14} The following questions were used to measure susceptibility to each product (cigarettes, e-cigarettes, hookah, smokeless tobacco, and cigarillos) across waves 2–4 (2014–2017): (i) “Have you ever been curious about smoking/using a [product]?” (ii) “Do you think that you will try a [product] soon?” and (iii) “If one of your best friends were to offer you a [product], would you smoke/use it?”. Response options included: (i) “very curious,” “somewhat curious,” “a little curious,” and “not at all curious” and (ii)/(iii) “definitely yes,” “probably yes,” “probably not,” and “definitely not.” Respondents who answered “not at all curious” to question (i) and “definitely not” to questions (ii) and (iii) for each tobacco product were considered non-susceptible to that product, and any other combination of responses were considered susceptible. Only young adult participants who answered that they were non-susceptible at wave 2 (when susceptibility questions were first asked among young adults) or wave 3 (among “aged-up” adults, that is, youth who turn 18) were included in the study to have their age of onset of susceptibility followed-up prospectively (waves 3–4).

Age of Onset of Susceptibility

Interval-censoring is a method used to estimate the timing of an event when an event is known to occur within an interval

instead of on an exact date.³⁶ PATH does not provide participants’ birthdays, and it is unfeasible to ask participants the exact date they became susceptible to tobacco product use, so we used 2 other variables to derive an interval-censored age of onset of susceptibility. At each wave, PATH provided participant age in years and a variable representing the number of weeks between waves of participation. Participant age was converted from years to weeks using these variables to provide a more precise estimate of participant age at the time of the outcomes of interest. A lower and an upper age limit for onset of susceptibility to each tobacco product was calculated, between which susceptibility onset occurred. The lower age limit was determined by using the age at the last wave that the participants reported non-susceptibility for both those who became susceptible at later waves and those who remained non-susceptible to each tobacco product by the end of follow-up. For those who became susceptible in waves 3–4, the upper age limit for susceptibility to each tobacco product was determined by adding participants’ age at the last wave they report non-susceptibility and the number of weeks between subsequent waves (waves 3–4) in which they first report susceptibility to each tobacco product. Participants who were determined to be non-susceptible to each tobacco product through their last wave of participation (waves 3–4) were censored in their upper age limit. This resulted in five interval-censored ages of onset of susceptibility to cigarettes, e-cigarettes, hookah, smokeless tobacco, and cigarillos. For example, if a participant was 19 years old at wave 1, with 56 weeks as the number of weeks between wave 1 and wave 2, then the age at wave 2 was $19 + (45/52) = 18.86$ years; if the number of weeks between wave 2 and wave 3 was 50 weeks, then the age at wave 3 was $19 + (45 + 50)/52 = 19.91$ years. Suppose this participant reported non-susceptibility to e-cigarette use at waves 1 and 2, but susceptibility to e-cigarette use at wave 3, the age interval of susceptibility to e-cigarette use was (18.86, 19.91).

Sex and Race/Ethnicity

PATH provided a variable for sex that categorized participants as males and females, which was imputed by PATH at wave 1 but not at waves 2–4. PATH also provided a variable for participant race that included the following four categories: White race alone, Black race alone, Asian race alone, and other race (including multi-racial), which was imputed by PATH at wave 1 but not at waves 2–4. Additionally, PATH provided a variable to measure ethnicity of participants as either Hispanic or Non-Hispanic (imputed by PATH at wave 1 but not at waves 2–4). We collapsed these two variables into a race/ethnicity variable to effectively compare with the previous Surgeon General’s report,³⁷ resulting in the following categories: Non-Hispanic White, Hispanic, Non-Hispanic Black, and Non-Hispanic other. Participants who reported Hispanic ethnicity and missing race were coded as Hispanic,

participants who reported White race alone and missing ethnicity were coded as Non-Hispanic White, participants who reported Black race alone and missing ethnicity were coded as Non-Hispanic Black, and participants who reported Asian/other race alone and missing ethnicity were coded as Non-Hispanic other.

Other Tobacco Product Use

PATH asked all participants about ever use of each tobacco product (Have you ever used [tobacco product], even once or twice/one or two puffs?). We used seven tobacco products to control for the total number of other tobacco products ever used prior to onset of susceptibility: cigarettes, e-cigarettes, large cigars, cigarillos, filtered cigars, hookah, and smokeless tobacco. We created separate variables for each susceptibility analysis that reflected the total number of other tobacco products ever used. For example, for the age of onset of susceptibility to cigarettes, we created a variable that reflected ever use of e-cigarettes, large cigars, cigarillos, filtered cigars, hookah, and smokeless tobacco. We examined other tobacco product use at participants' first wave of adult participation to ensure that the other tobacco product use preceded the onset of susceptibility. The total number of other tobacco products ever used was categorized as 0 tobacco products, 1 tobacco product, and 2+ tobacco products.

Statistical Analysis and Data Management

All data analyses incorporated sampling weights and 100 balance repeated replicate (BRR) weights to account for the PATH's complex study design with a Fay's correction factor set to .3.³⁸ Summary statistics including means and proportions are provided for age, wave of entry into the study, sex, race/ethnicity, and the total number of other tobacco products ever used prior to onset of susceptibility. There was very little missingness in PATH, and missing values are reported. Interval-censoring methods for survival analysis³⁹⁻⁴¹ were implemented to estimate the probability of the age of onset of susceptibility to each tobacco product using the Turnbull method.⁴² The hazard functions, reported as cumulative incidence, and their 95% confidence intervals (CIs) at different ages are reported. Differences in the age of onset of susceptibility to each tobacco product by sex and by race/ethnicity, while controlling for the total number of other tobacco products ever used, were estimated by fitting interval-censoring Cox proportional hazard regression models with a piecewise constant baseline function. Crude and adjusted hazard ratios (AHR) and their 95% CIs are reported. When differences in the age of onset of susceptibility for each tobacco product were significant by either sex or race/ethnicity, the full hazard function for the age of onset of susceptibility stratified by that variable was reported. All statistical data analyses were conducted using SAS 9.4.⁴³

Results

Sociodemographic Characteristics

There were 9110 wave 1 young adults aged 18-24 years, and after identifying never users who were non-susceptible to each tobacco product at wave 2 or 3, this resulted in 2989 (N = 10 039 610) young adults non-susceptible to cigarette use, 2671 (N = 9 194 696) young adults non-susceptible to e-cigarette use, 3108 (N = 10 455 055) young adults non-susceptible to hookah, 7190 (N = 21 905 175) young adults non-susceptible to smokeless tobacco, and 3356 (N = 14 376 706) young adults non-susceptible to cigarillos at wave 2 or 3 (Table 1). Among young adults non-susceptible to each product, most entered the PATH study at wave 1 (66.1%-83.5%), their weighted mean age was between 19.6 to 20.9 years (SE = .02-.05), most were female (50.1%-59.0%), most were Non-Hispanic White (50.6%-56.0%), and the proportion of participants who reported ever using 0 other tobacco products ranged from 46.3% to 75.1%.

Age of Onset of Susceptibility to Each Tobacco Product

Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, the estimated distribution of the age of onset of susceptibility to each tobacco product in waves 3 or 4 are shown in Table 2. Figure 1 shows the full hazard functions. By age 21, 16.5% (95%CI: 14.9%-18.2%) of young adults reported onset of susceptibility to hookah and 16.0% (95%CI: 11.5%-20.6%), 12.6% (95%CI: 10.9%-14.4%), 12.4% (95%CI: 8.6%-16.1%), and 5.9% (95%CI: 3.9%-7.9%) reported onset of susceptibility to e-cigarettes, cigarillos, cigarettes, and smokeless tobacco, respectively. It should be noted that by age 24, the latest age for which we had follow-up (and the upper limit of young adulthood), susceptibility was highest for e-cigarettes at 29.4% (24.0%-34.8%) compared with the other tobacco products. In addition, for all products, the highest increase in susceptibility among young adults who were previously non-susceptible occurred between ages 18 and 19 (7.2% for cigarettes, 6.7% for e-cigarettes, and 8.6% for hookah), except for cigarillos, in which the highest increase occurred between ages 22 and 23 (8.4%). Young adults' susceptibility to smokeless tobacco increased marginally across ages, but the highest increases occurred between 18 to 19 (3.0%) and 22 to 23 years (3.0%).

Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, crude and adjusted hazard ratios exploring differences in the age of onset of susceptibility to each tobacco product by sex and race/ethnicity, while controlling for the total number of other tobacco products ever used, are shown in Table 3.

Differences in the Age of Onset of Susceptibility to Cigarettes

Hispanic young adults were the only race/ethnicity group that had increased risk of an earlier age of onset of susceptibility to

Table 1. Demographic characteristics of PATH* USA young adults non-susceptible to each tobacco product at waves 2 or 3 (2014-2016).

TOTAL	CIGARETTES		E-CIGARETTES		HOOKAH		SMOKELESS TOBACCO		CIGARILLOS		
	N; N	%*	N; N	%*	N; N	%*	N; N	%*	N; N	%*	
<i>Wave of entry into adult PATH study</i>											
Wave 1 young adult	1442; 6 640 206	66.1% (.83)	1395; 6 408 648	69.7% (.78)	1520; 7 003 857	66.9% (.80)	4348; 15 684 808	71.6% (.36)	2290; 12 008 870	83.5% (.44)	
Wave 2 young adult	776; 1 734 233	17.3% (.57)	618; 1 368 121	14.9% (.52)	731; 1 618 695	15.5% (.54)	1452; 3 214 060	14.7% (.29)	1066; 2 367 837	16.5% (.44)	
Wave 3 young adult	771; 1 665 171	16.6% (.53)	658; 1 417 927	15.4% (.57)	857; 1 832 503	17.5% (.56)	1390; 3 006 307	13.7% (.26)	N/A		
Age	Weighted mean (SE)	19.6 (.05)	19.6 (.04)	19.7 (.04)	19.8 (.02)	20.9 (.04)					
Sex	Male	1317; 4 549 974	45.4% (1.01)	1148; 4 065 548	44.2% (1.01)	1539; 5 213 376	49.9% (.90)	2991; 9 378 994	42.8% (.38)	1332; 5 891 065	41.0% (.8)
	Female	1669; 5 481 426	54.6% (1.01)	1521; 5 123 014	55.7% (1.01)	1566; 5 233 469	50.1% (.90)	4197; 12 522 135	57.2% (.38)	2018; 8 463 353	59.0% (.8)
	Missing	n = 3; N = 8211		n = 2; N = 6134		n = 3; N = 8210		n = 2; N = 4046		n = 6; N = 22 288	
Race/Ethnicity	Non-Hispanic White	1397; 5 223 857	52.0% (1.49)	1289; 4 992 430	54.3% (1.7)	1578; 5 855 265	56.0% (1.55)	3240; 11 073 692	50.6% (.82)	1617; 7 544 182	52.5% (1.4)
	Hispanic	714; 1 905 249	19.0% (1.00)	632; 1 706 625	18.6% (1.09)	733; 1 969 468	18.8% (.93)	1972; 4 910 338	22.4% (.59)	920; 3 134 540	21.8% (.95)
	Non-Hispanic Black	596; 1 771 230	17.6% (.85)	509; 1 503 797	16.4% (1.01)	522; 1 555 169	14.9% (.93)	1300; 3 543 914	16.2% (.49)	484; 1 827 227	12.7% (.7)
	Non-Hispanic other	282; 1 139 273	11.3% (1.03)	241; 991 844	10.8% (1.17)	275; 1 075 152	10.3% (1.07)	678; 2 377 230	10.9% (.62)	334; 1 868 349	13.0% (1.1)
	Missing	0		0		0		0		n = 1; N = 2408	
Total number of other tobacco products ever used	0 tobacco products	2047; 7 541 603	75.1% (1.19)	1832; 6 657 864	72.2% (1.25)	2006; 7 406 439	70.8% (1.30)	2708; 10 132 556	46.3% (1.08)	1716; 8 400 420	58.4% (1.41)
	1 tobacco product	560; 1 506 984	15.0% (.81)	415; 1 352 983	14.9% (.86)	450; 1 391 132	13.3% (.80)	1170; 3 420 488	15.6% (.53)	596; 2 468 010	17.2% (.94)
	2+ tobacco products	382; 991 022	9.9% (.70)	381; 1 079 905	11.9% (.80)	652; 1 657 484	15.9% (.88)	3312; 8 352 132	38.1% (.94)	1044; 3 508 277	24.4% (1.04)
	Missing	0		n = 43; N = 103 945		0		0		0	

*PATH restricted file received disclosure to publish: April 6, 2021. United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. ICPSR36231-v13. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], November 5, 2019. <https://doi.org/10.3886/ICPSR36231.v23>

*All percentages represent weighted percentages based on PATH's complex sampling design; N/A: not available.

Table 2. Estimated hazard functions* (95% confidence intervals) of the age of onset of susceptibility to each tobacco product for PATH[¥] USA young adults (aged 18-24).

AGE	WEIGHTED PERCENTAGE OF SUSCEPTIBILITY ONSET TO EACH TOBACCO PRODUCT BY AGE				
	CIGARETTES	E-CIGARETTES	HOOKAH	SMOKELESS TOBACCO	CIGARILLOS
18	0	0	0	0	0
19	7.2 (6.2-8.2)	6.7 (2.1-11.3)	8.6 (7.6-9.6)	3.0 (2.6-3.4)	5.7 (5.0-6.5)
20	10.1 (4.9-15.4)	11.1 (6.5-15.6)	12.8 (9.7-15.9)	4.0 (2.4-5.5)	8.8 (7.5-10.1)
21	12.4 (8.6-16.1)	16.0 (11.5-20.6)	16.5 (14.9-18.2)	5.9 (3.9-7.9)	12.6 (10.9-14.4)
22	16.8 (14.0-19.6)	21.1 (16.3-25.9)	20.2 (18.0-22.3)	8.3 (7.2-9.4)	18.0 (15.5-20.4)
23	19.4 (12.1-26.7)	25.9 (17.4-34.3)	26.2 (15.6-36.7)	11.3 (9.7-12.8)	26.4 (22.7- 30.2)
24	23.7 (20.6-26.7)	29.4 (24.0-34.8)	26.6 (23.9-29.4)	11.5 (10.2-12.8)	N/A

*Hazard functions are reported as cumulative percentages (i.e., cumulative incidence).

N/A: not enough sample size to estimate onset of susceptibility at that age.

¥ PATH restricted file received disclosure to publish: July 24, 2020; July 15, 2020; September 28, 2020. United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. ICPSR36231-v13. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], November 5, 2019. <https://doi.org/10.3886/ICPSR36231.v23>

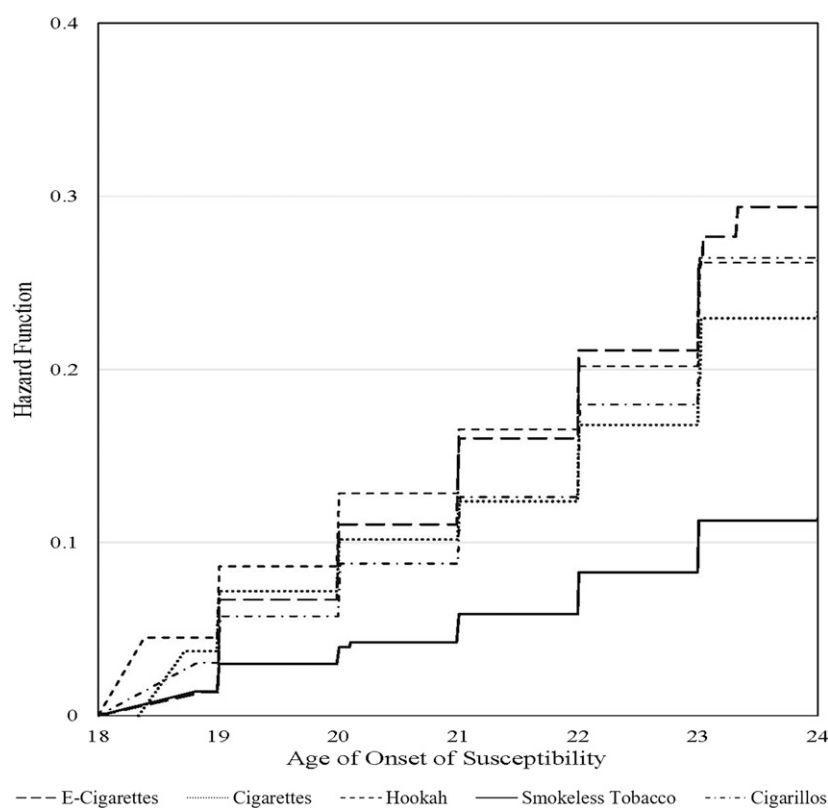


Figure 1. The age of onset of susceptibility to each tobacco product.

cigarettes compared with Non-Hispanic White young adults after controlling for sex and for the total number of other tobacco products ever used. The use of 1 other tobacco product and 2+ tobacco products increased the risk of an earlier age of onset of susceptibility to cigarettes.

Differences in the Age of Onset of Susceptibility to E-cigarettes

Non-Hispanic other young adults were the only race/ethnicity group that had increased risk of onset of susceptibility to e-cigarettes at

Table 3. Crude and adjusted hazard ratios (95% confidence intervals) for age of onset of susceptibility to each tobacco product among PATH[‡] USA young adults (aged 18-24).

PRODUCT	CRUDE HAZARD RATIOS FOR AGE OF SUSCEPTIBILITY ONSET				
	CIGARETTES	E-CIGARETTES	HOOKAH	SMOKELESS TOBACCO	CIGARILLOS
SEX					
Female	1.00	1.00	1.00	1.00	1.00
Male	1.09 (.89-1.34)	1.03 (.84-1.26)	.98 (.80-1.19)	1.87 (1.52-2.29)	1.21 (.98-1.5)
<i>Race/Ethnicity</i>					
Non-Hispanic White	1.00	1.00	1.00	1.00	1.00
Hispanic	1.48 (1.10-2.0)	1.36 (1.00-1.84)	1.22 (.95-1.56)	1.65 (1.30-2.08)	1.23 (.93-1.63)
Non-Hispanic Black	1.28 (.98-1.69)	1.04 (.76-1.43)	1.42 (1.15-1.75)	.93 (.68-1.25)	1.38 (1.01-1.88)
Non-Hispanic other*	1.31 (.89-1.93)	1.58 (1.11-2.26)	1.21 (.79-1.83)	.88 (.59-1.32)	.72 (.47-1.12)
<i>Total number of other tobacco products ever used</i>					
0 Tobacco products	1.00	1.00	1.00	1.00	1.00
1 Tobacco product	1.39 (1.07-1.82)	1.12 (.87-1.46)	1.52 (1.15-2.00)	1.42 (1.02-1.98)	2.03 (1.51-2.74)
2+ Tobacco products	1.43 (1.05-1.97)	1.03 (.79-1.35)	1.78 (1.42-2.25)	1.81 (1.45-2.26)	2.61 (2.08-3.29)
Adjusted hazard ratios for age of susceptibility onset					
Product	Cigarettes	E-cigarettes	Hookah	Smokeless tobacco	Cigarillos
<i>Sex</i>					
Female	1.00	1.00	1.00	1.00	1.00
Male	1.09 (.88-1.35)	1.00 (.82-1.23)	.95 (.78-1.17)	1.84 (1.50-2.26)	1.24 (1.01-1.53)
<i>Race/Ethnicity</i>					
Non-Hispanic White	1.00	1.00	1.00	1.00	1.00
Hispanic	1.51 (1.11-2.04)	1.35 (.99-1.83)	1.25 (.99-1.59)	1.52 (1.20-1.92)	1.14 (.86-1.50)
Non-Hispanic Black	1.28 (.97-1.70)	1.05 (.76-1.45)	1.43 (1.16-1.77)	.91 (.68-1.22)	1.57 (1.16-2.15)
Non-Hispanic other*	1.36 (.92-2.01)	1.59 (1.10-2.29)	1.34 (.89-2.02)	.88 (.59-1.31)	.75 (.49-1.14)
<i>Total number of other tobacco products ever used</i>					
0 Tobacco products	1.00	1.00	1.00	1.00	1.00
1 Tobacco product	1.39 (1.07-1.80)	.98 (.74-1.29)	1.54 (1.18-2.00)	1.46 (1.05-2.05)	2.08 (1.53-2.82)
2+ Tobacco products	1.48 (1.07-2.05)	.99 (.76-1.31)	1.84 (1.46-2.31)	1.79 (1.45-2.22)	2.70 (2.15-3.39)

‡ PATH restricted file received disclosure to publish: July 15 and 24, 2020, and April 6, 2021. United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. ICPSR36231-v13. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], November 5, 2019. <https://doi.org/10.3886/ICPSR36231.v23>
 *Non-Hispanic other includes Asian, multiracial, etc.

earlier ages compared with Non-Hispanic White young adults after controlling for sex and for the total number of other tobacco products ever used. No significant differences in the age of onset of susceptibility to e-cigarettes by sex or the total number of other tobacco products ever used were observed in the adjusted model.

Differences in the Age of Onset of Susceptibility to Hookah

Non-Hispanic Black young adults were the only race/ethnicity group that had increased risk of onset of susceptibility to hookah at earlier ages compared with Non-Hispanic White young adults. Young adults who ever used 1 tobacco product and 2+ tobacco products other than hookah were at increased risk of an earlier age of onset of susceptibility to hookah compared with young adults who had used 0 other tobacco products.

Differences in the Age of Onset of Susceptibility to Smokeless Tobacco

Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, males had increased risk of onset of susceptibility for smokeless tobacco use at earlier ages compared with females, after adjusting for race/ethnicity and the total number of other tobacco products used. Additionally, Hispanic young adults had increased risk of onset of susceptibility to smokeless tobacco at earlier ages compared with Non-Hispanic White young adults. Young adults who ever used 1 other tobacco product and 2+ tobacco products had increased risk of onset of susceptibility to smokeless tobacco at earlier ages compared with young adults who had used 0 other tobacco products.

Differences in the Age of Onset of Susceptibility to Cigarillos

Young adult males also had increased risk of onset of susceptibility to cigarillos at earlier ages compared with young adult females, after adjusting for race/ethnicity and the total number of other tobacco products ever used. In addition, Non-Hispanic Black young adults had increased risk of onset of susceptibility to cigarillo use at earlier ages compared with Non-Hispanic White young adults. Young adults who ever used 1 other tobacco product and 2+ other tobacco products other than cigarillos had increased risk of onset of susceptibility to cigarillos at earlier ages compared with young adults who had used 0 other tobacco products.

Age of Onset of Susceptibility by Sex

Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, Table 4 provides the hazard function by age for smokeless tobacco and cigarillos, as these tobacco products showed differences in the age of onset of susceptibility by sex, and Figure 2 shows the distribution of these hazard functions continuously. By age 21, 8.1% (95%CI: 6.8%-9.5%) of young adult males and 4.3% (95%CI: 3.2%-5.3%) of young adult females reported onset of susceptibility to smokeless tobacco. In addition, while the largest increases in onset of susceptibility to smokeless tobacco among young adult males occurred between ages 18 and 19 (3.9%), as well as between ages 20 and 21 (3.9%), the largest increases in onset of susceptibility for young adult females occurred between ages 22 and 23 (4.2%). By age 21, 13.8% (95%CI:11.3%-19.3%) of males and 11.7% (95%CI:9.6%-13.8%) of young adult females reported onset of susceptibility to cigarillo use. Additionally, for both

young adult males and females, the largest increase in onset of susceptibility to cigarillos occurs between 22 and 23 years (9.2% and 8.0%, respectively).

Age of Onset of Susceptibility by Race/Ethnicity

Among young adults who were non-susceptible to each tobacco product at waves 2 or 3, the hazard function of the age of onset of susceptibility by race/ethnicity for each of the five tobacco products are shown in Table 5. Figure 3 shows the distribution of these hazard functions continuously. By age 21, 11.0% (95% CI: 6.5%-9.7%) of Non-Hispanic White young adults, 16.7% (95%CI: 11.0%-16.6%) of Hispanic young adults, 12.9% (95% CI: 9.0%-16.8%) of Non-Hispanic Black young adults, and 11.2% (6.1%-16.4%) of Non-Hispanic other young adults reported onset of susceptibility to cigarette use. By age 21, 15.9% (13.1%-18.8%) of Non-Hispanic White, 24.5% (18.8%-30.2%) of Hispanic, 16.2% (8.6%-23.7%) of Non-Hispanic Black, and 21.7% (11.2%-32.3%) of Non-Hispanic other young adults reported onset of susceptibility to e-cigarette use.

For hookah, by age 21, 14.8% (95%CI: 12.8%-16.9%) of Non-Hispanic White young adults, 17.5% (95%CI: 11.0%-24.1%) of Hispanic young adults, 14.9% (95%CI: 11.4%-18.4%) of Non-Hispanic Black young adults, and 18.4% (95% CI: 11.1%-25.6%) of Non-Hispanic other young adults reported onset of susceptibility to hookah. For smokeless tobacco, by age 21, 5.0% (95%CI: 3.5%-6.5%) of Non-Hispanic White young adults, 9.6% (95%CI: 3.1%-16.0%) of Hispanic young adults, 4.3% (95%CI; 2.5%-6.2%) of Non-Hispanic Black young adults, and 5.1% (95%CI: 2.8%-7.4%) of Non-Hispanic other young adults reported onset of susceptibility to smokeless tobacco. For cigarillos, by age 21, 12.4% (95%CI: 9.9%-14.9%)

Table 4. Estimated hazard functions* (95% confidence interval) for the age of onset of susceptibility by sex among PATH[¥] USA young adults (aged 18-24).

AGE	AGE OF ONSET OF SUSCEPTIBILITY			
	SMOKELESS TOBACCO		CIGARILLOS	
	MALE	FEMALE	MALE	FEMALE
18	0.0	0.0	0.0	0.0
19	3.9 (3.2-4.5)	2.4 (1.9-2.9)	6.6 (5.1-8.0)	5.2 (4.3-6.1)
20	4.2 (2.4-6.0)	3.2 (1.6-4.8)	9.4 (7.4-11.3)	8.2 (6.7-9.7)
21	8.1 (6.8-9.5)	4.3 (3.2-5.3)	13.8 (11.3-19.3)	11.7 (9.6-13.8)
22	11.7 (10.1-13.2)	4.3 (3.4-5.1)	20.9 (17.0-24.7)	15.8 (12.7-18.9)
23	14.0 (9.2-18.8)	8.5 (6.4-10.6)	30.1 (24.2-36.1)	23.8 (19.2-28.4)
24	15.2 (13.2-17.2)	8.7 (7.2-10.2)	N/A	N/A

*Hazard functions are reported as cumulative percentages (i.e., cumulative incidence).

N/A: not enough sample size to estimate onset of susceptibility at that age.

¥PATH restricted file received disclosure to publish: July 24, 2020, and July 15, 2020. United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. ICPSR36231-v13. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], November 5, 2019. <https://doi.org/10.3886/ICPSR36231.v23>

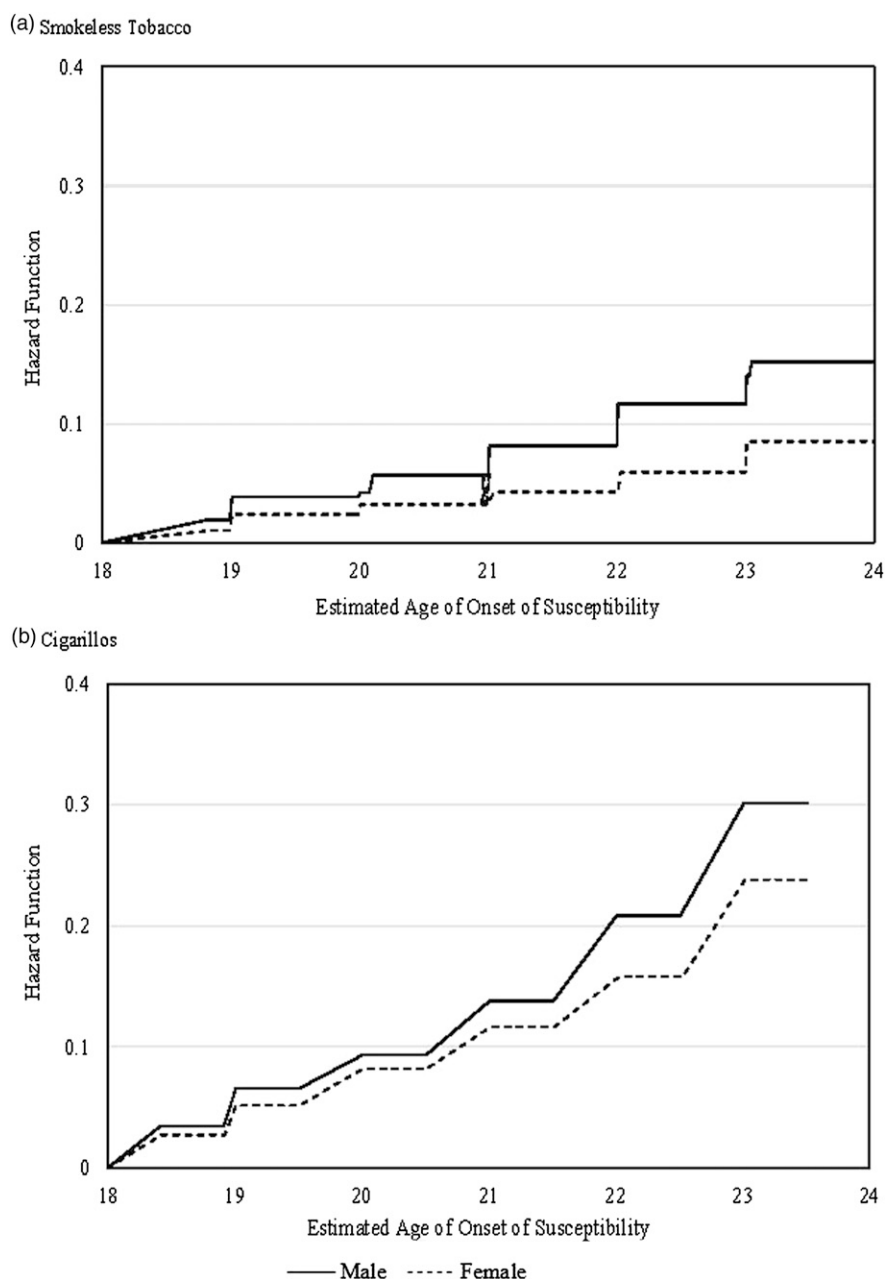


Figure 2. The age of onset of susceptibility stratified by sex.

of Non-Hispanic White young adults, 14.4% (95%CI: 10.9%–17.8%) of Hispanic young adults, 14.9% (95%CI: 10.6%–19.3%) of Non-Hispanic Black young adults, and 8.2% (95%CI: 3.7%–12.7%) of Non-Hispanic other young adults reported onset of susceptibility to cigarillos. By age 24, the latest age for which we had follow-up, Hispanic young adults reported the highest proportion in onset of susceptibility to cigarettes (27.8%; 95%CI: 21.1%–34.6%), Non-Hispanic other young adults reported the highest proportion in onset of susceptibility to e-cigarettes (39.8%; 95%CI: 26.3%–53.4%), Non-Hispanic Black young adults reported the highest proportion in onset of susceptibility to hookah (34.4%; 95%CI: 28.2%–40.7%), and Hispanic young adults reported the highest proportion in onset

of susceptibility to smokeless tobacco (15.9%; 95%CI: 12.9%–18.9%). Hispanic (29.8%; 95%CI: 23.3%–36.2%) and Non-Hispanic Black young adults (30.1; 95%CI: 20.4%–39.7%) reported the highest proportion in onset of susceptibility to cigarillos by age 23, which was the latest year of follow-up for cigarillos.

Discussion

Taken together, the findings indicate that a substantial proportion of onset of susceptibility occurred in young adulthood, among those who previously reported that they were not susceptible to that particular tobacco product. To the best of our knowledge, this is the first study to provide prospective

Table 5. Estimated hazard functions^a (95% confidence intervals) for the age of onset of susceptibility to each tobacco product by race/ethnicity among PATH[¥] USA young adults (aged 18-24).

AGE	NON-HISPANIC WHITE	HISPANIC	NON-HISPANIC BLACK	NON-HISPANIC OTHER [†]
AGE OF SUSCEPTIBILITY ONSET TO CIGARETTES				
18	.0%	.0%	.0%	.0%
19	6.0 (4.7, 7.2)	9.7 (5.5, 13.9)	8.1 (5.7, 10.5)	2.9 (.7, 5.1)
20	7.4 (4.3, 10.4)	13.8 (5.2, 22.4)	11.8 (8.9, 14.6)	10.0 (5.1, 15.0)
21	11.0 (5.3, 16.6)	16.7 (11.1, 22.3)	12.9 (9.0, 16.8)	11.2 (6.1, 16.4)
22	14.4 (7.4, 21.3)	16.7 (12.2, 21.3) ^e	18.6 (14.4, 22.8)	16.3 (4.4, 28.2)
23	14.4 (12.0, 16.8)	21.2 (15.7, 26.6)	18.6 (14.4, 22.8)	27.8 (18.1, 37.4)
24	21.7 (16.8, 26.5)	27.8 (21.1, 34.6)	24.3 (18.8, 29.7)	29.2 (19.2, 39.2)
Age of susceptibility onset to e-cigarettes				
18	.0%	.0%	.0%	.0%
19	7.6% (5.1-10.2)	4.2% (1.9-6.4)	5.2% (.0-10.3)	13.8% (.6-27.0)
20	11.9% (9.5-14.3)	10.8% (6.7-14.9)	12.1% (4.8-19.4)	15.1% (7.3-23.0)
21	15.9% (13.1-18.8)	24.5% (18.8-30.2)	16.2% (8.6-23.7)	21.7% (11.2-32.3)
22	20.4% (14.8-25.9)	29.0% (21.2-36.8)	19.5% (14.7-24.2)	32.4% (16.3-48.5)
23	25.5% (15.2-35.9)	29.0% (22.6-35.4)	19.5% (14.8-24.2)	38.2% (24.6-51.8)
24	28.8% (23.7-34.0)	37.8% (29.1-46.6)	32.8% (23.6-42.1)	39.8% (26.3-53.4)
Age of susceptibility onset to hookah				
18	.0%	.0%	.0%	.0%
19	7.8 (6.4-9.2)	9.6 (7.5-11.7)	6.1 (1.0-11.3)	10.9 (1.2-20.7)
20	9.8 (5.4-14.2)	15.0 (4.5-25.5)	14.9 (11.2-18.5)	13.6 (7.3-19.8)
21	14.8 (12.8-16.9)	17.5 (11.0-24.1)	14.9 (11.4-18.4)	18.4 (11.1-25.6)
22	14.8 (12.8-16.9)	23.5 (17.9-29.1)	27.5 (22.3-32.6)	21.8 (12.1-31.5)
23	23.8 (15.0-32.5)	27.7 (21.9-33.5) [‡]	27.5 (22.5- 32.4) ^h	29.2 (17.9-40.5)
24	23.8 (20.3-27.2)	27.7 (21.4-33.9)	34.4 (28.2-40.7)	29.2 (18.7-39.7)
Age of susceptibility onset to smokeless tobacco				
18	.0%	.0%	.0%	.0%
19	2.8 (2.2-3.3)	4.2 (3.2-5.2)	2.2 (1.3-3.1)	1.1 (.2-2.1)
20	3.5 (1.8-5.2)	6.1 (2.7-9.5)	3.2 (2.1-4.4)	4.0 (1.5-6.4) ^ψ
21	5.0 (3.5-6.5)	9.6 (3.1-16.0)	4.3 (2.5-6.2)	5.1 (2.8-7.4)
22	6.6 (3.3-10.0)	13.0 (10.5-15.5)	6.2 (2.9-9.4)	7.3 (3.0-11.6)
23	10.5 (7.7-13.2)	15.4 (9.8-21.0)	7.2 (5.3-9.2)	9.0 (5.6-12.5)
24	10.6 (8.7-12.5)	15.9 (12.9-18.9)	10.2 (7.4-12.8)	N/A
Age of susceptibility onset to cigarillos				
18	.0%	.0%	.0%	.0%
19	5.3 (4.1-6.4)	7.0 (5.1-8.9)	9.3 (6.3-12.2)	2.2 (.5-4.0)
20	8.0 (6.3-9.8)	11.1 (8.5-13.6)	11.8 (8.0-15.5)	5.4 (1.5-9.4)
21	12.4 (9.9-14.9)	14.4 (10.9-17.8)	14.9 (10.6-19.3)	8.2 (3.7-12.7)
22	16.8 (13.6-20.1)	21.6 (16.7-26.5)	21.5 (15.8-27.2)	13.5 (6.9-20.1)
23	26.0 (20.7-31.2)	29.8 (23.3-36.2)	29.4 (19.9-38.8)	21.0 (12.4-29.6) ^Ξ
24	N/A	N/A	N/A	N/A

^aHazard functions are reported as cumulative percentages (i.e., cumulative incidence).

[¥] PATH restricted file received disclosure to publish: July 15 and 24, 2020, and April 6, 2021. United States Department of Health and Human Services. National Institutes of Health. National Institute on Drug Abuse, and United States Department of Health and Human Services. Food and Drug Administration. Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] Restricted-Use Files. ICPSR36231-v13. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], November 5, 2019. <https://doi.org/10.3886/ICPSR36231.v23>

[†] Non-Hispanic other includes Asian, multiracial, etc

^e interval represents 22 years and 16 weeks

[‡] interval represents 23 years and 18 weeks

^h interval represents 23 years and 22 weeks

^ψ interval represents 20 years and 13 weeks

^Ξ interval represents 23 years and 22 weeks

N/A: not enough sample size to estimate onset of susceptibility at that age.

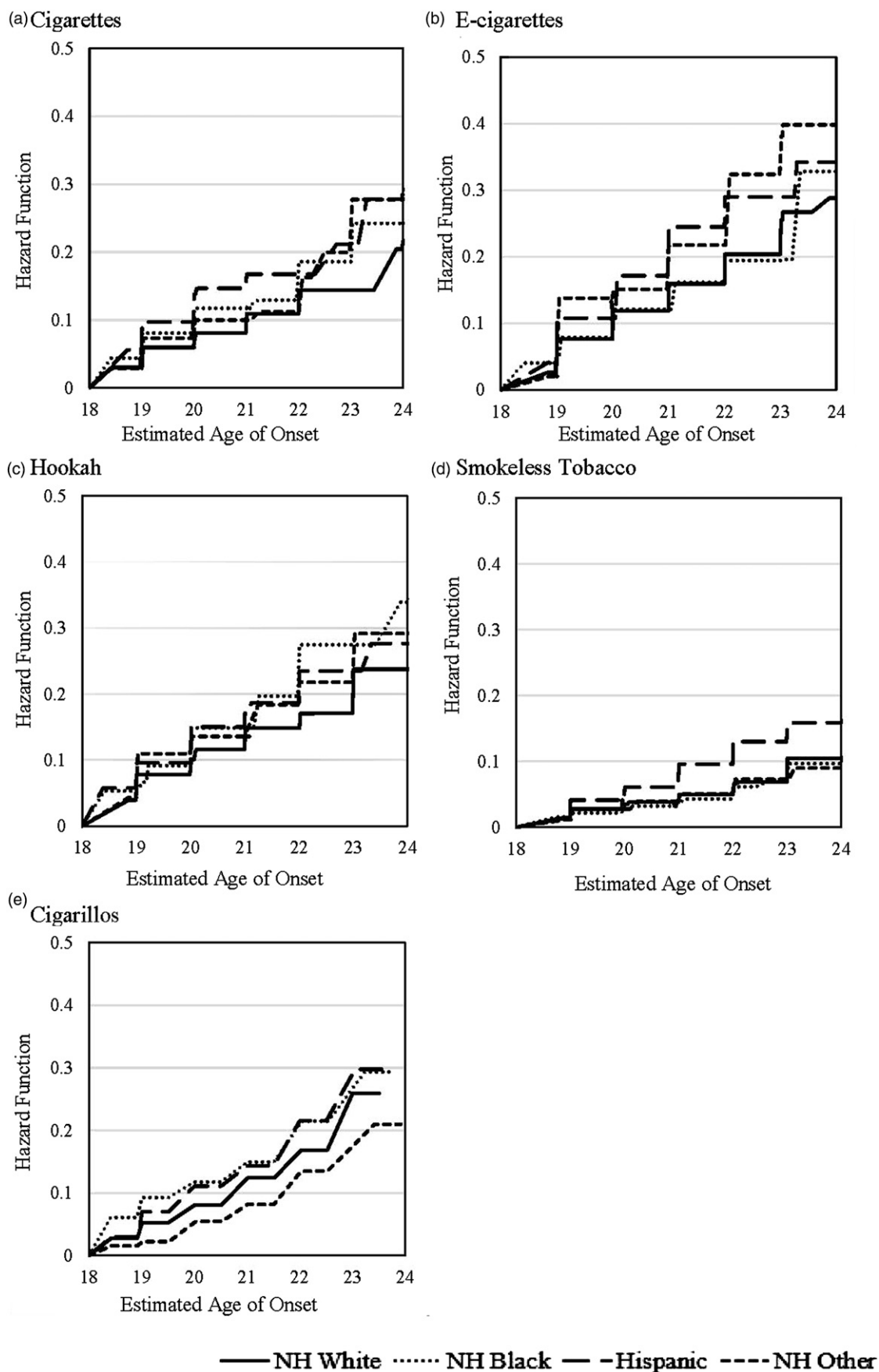


Figure 3. The age of onset of susceptibility stratified by race/ethnicity.

estimates for the age of onset of susceptibility (2014–2017) to cigarettes, e-cigarettes, hookah, smokeless tobacco, and cigarillos among non-susceptible young adults (ages 18–24 years) one or two years later. We found some differences in the age of onset of susceptibility by sex, race/ethnicity, and total number of other tobacco products ever used—and these differed by tobacco products.

In our study, we found that the highest increase in onset of susceptibility occurs between 18 and 19 years for cigarettes, e-cigarettes, and hookah; for cigarillos, this occurs later in young adulthood, between ages 22 and 23. Our finding that the largest increase in e-cigarette onset of susceptibility occurs between 18 and 19 years is similar to previous research in 2013, which found that college students who were 20 to 23 years old had decreased odds of susceptibility to e-cigarette use compared with 18-year-old college students (AOR = .46; 95%CI: .29%–.75%).²⁵ Additionally, the 2012–2013 NATS study found that younger young adults (18–21 years) had 1.9 times the odds of susceptibility to cigarette use (95%CI: 1.3%–2.7%) compared with 22 to 24-year-olds.²⁴ Both studies analyzed age in groups, while our study analyzed age continuously, so our study goes beyond the previous work by identifying 18- and 19-year-olds as particularly vulnerable to onset of susceptibility to e-cigarettes and cigarettes. As these ages represent the initial transition into young adulthood, prevention efforts should target this vulnerable age group in appropriate ways, as the prevention interventions designed for young adults and strategies used may be different than prevention interventions designed for youth.^{44–46} Susceptibility is a strong predictor of future tobacco use,^{24,26,29,30} and determining the age of onset of susceptibility to each tobacco product in young adults is an important opportunity for educational campaigns to prevent susceptibility or initiation, as young adults are the legal targets of the tobacco industry. It is important to note that youth non-users of tobacco products exhibit increased susceptibility to each tobacco product over time, with recent findings from the PATH study indicating that youth (12–17 years old) never users of e-cigarettes, cigarettes, hookah, or any cigars between 2013–2016, by age 17, 43.8%,⁴⁷ 40.1%,⁴⁸ 44.6%,⁴⁹ and 19.9%⁵⁰ reported susceptibility to e-cigarette, cigarette, hookah or any cigar products, respectively, between 2014–2017.

E-cigarette use is common among college students, with 29.9% and 14.9% of college students in New York State (18–23 years old) reporting ever and past 30-day e-cigarette use in 2013.²⁵ Similarly, a different study of undergraduate college students aged 18 to 25 years at a Midwestern university in 2015 found that the prevalence of ever e-cigarette use was 40.0%.⁵¹ Hookah use is also common among college students, with a 2009 study of college students at the University of Florida (18–25+ years old) showing that ever hookah use is more prevalent than ever cigarette use (46.4% vs 42.1%).⁵² Thus, college campuses may be an appropriate vehicle for prevention programs for e-cigarette and hookah use. In contrast, a 2007–2008 study of 4-year college and non-college students from 5 Midwestern US

states found that cigarette use was more common among non-college students, with 74% and 39% of non-college students reporting ever and past 30 day cigarette use, while 59% and 24% of 4-year college students reporting ever and past 30-day cigarette use, respectively.⁵³ This indicates that vocational schools or worksites may be appropriate avenues for cigarette prevention as cigarette use is highest among young adults who did not attend college. In addition, the later age of onset of susceptibility to cigarillos (22–23 years old) may indicate that cigarillos are relevant to students transitioning out of college, so worksites as an avenue for cigarillo prevention may be of particular importance.

One of the most salient findings from this study is that the use of other tobacco products increases the risk of an earlier age of onset of susceptibility. It has been established that previous use of a particular tobacco product impacts the susceptibility to other tobacco products^{12,14,24,26,27,29,30}; however, most of these studies have focused on youth, and our study provides the first evidence that previous use of other tobacco products specifically impacts the age of onset of susceptibility, decreasing the age at which young adults become susceptible. Cross-sectional data from the 2012–2013 NATS among young adults (18–24 years old), who were not established cigarette users (i.e., less than 100 cigarettes ever used and now smokes “not at all”), found that intermittent hookah users (i.e., those who now use smoke hookah “rarely”) had higher odds of susceptibility to cigarette use (OR = 2.3, 95%CI: 1.6–3.4) compared with non-hookah users (i.e., “not at all” users).²⁴ However, this study included only two of the three questions used to measure susceptibility in the current study.²⁴ A different United States study, the 2012–2013 Dartmouth Media, Advertising, and Health Study of 16 to 26-year-olds found that previous e-cigarette use was associated with susceptibility to combustible cigarette use one year later (AOR = 8.5; 95%CI: 1.3–57.2) among those who were previously non-susceptible to cigarettes.⁵⁴ Additionally, a 2013 study of undergraduate students from 4 colleges in New York State found that both “ever regular” (i.e., both past 30-day and former cigarette users) cigarette use (AOR = 9.41; 95%CI: 3.74–23.66) and any non-cigarette tobacco use (i.e., cigars, pipes, chewing tobacco, snuff, snus, hookah, clove cigarettes, bidis, and other) in the past 30 days (AOR = 1.83; 95%CI: 1.24–2.70) increased the odds of e-cigarette susceptibility.²⁵ Surprisingly, we report null findings on the impact of previous tobacco product use on the age of onset of susceptibility to e-cigarettes. More research is needed to determine if e-cigarettes are the product that young adults become susceptible to first, similar to previous research on how e-cigarettes are increasingly the first tobacco product ever used. The fact that ever use of other tobacco products increases the risk of an earlier age of onset of susceptibility to cigarettes, hookah, smokeless tobacco, and cigarillos indicates that tobacco control efforts should comprehensively address all tobacco products in prevention, rather than focusing on a particular product, such as cigarettes or e-cigarettes. This will be important in moving forward with tobacco control efforts that focus on young adults, as the use of

tobacco products other than cigarettes is increasing in young adults.^{4-9,55}

Our results stand in contrast to previous research regarding the particular products that exhibited sex differences in the age of susceptibility onset. Specifically, a previous nationally representative sample of young adults (18-24 years old) found that males had increased prevalence of susceptibility to cigarette use compared with females (25.6% and 14.1%, respectively),²⁴ while we found no differences in the age of susceptibility onset between males and females. In addition, we found that males were at increased risk of an earlier age of onset of susceptibility to smokeless tobacco, while previous research among college students (18-25 years old) in Texas who had never used smokeless tobacco did not observe a difference in the incidence of susceptibility onset to smokeless tobacco after 6 months of follow-up.²⁸ Furthermore, a 2014 national study of adult (18-60+ years old) "current" (i.e., has used 100+ cigarettes and now uses "every day or some days") cigarette users reported that there was no difference in the prevalence of susceptibility to little cigars/cigarillos by sex,³¹ while our study found that males had increased risk of an earlier age of onset of susceptibility to cigarillo use compared with females. However, our findings on e-cigarette susceptibility are similar to those of another study in 2013 among New York college students (18-23 years old) that reported no differences by sex in the prevalence of susceptibility to e-cigarettes,²⁵ as we found no differences in the age of onset of susceptibility to e-cigarettes by sex. Similarly, a 2016 study among Ohio freshmen college students (mean age = 18.6) who were non-susceptible to hookah use at the beginning of the fall semester found there was no difference in the incidence of susceptibility to hookah by sex at the end of the spring semester,²⁷ which supports our results that there was no difference in the age of onset of susceptibility to hookah by sex. It should be noted that the findings in this article represent the age of onset of susceptibility, while previous studies explored prevalence and incidence of susceptibility. Previous research has reported the age of onset of susceptibility to different tobacco products among youth (ages 12-17 years old) who reported that they were non-susceptible to each product at their first wave of PATH participation using 4 waves of PATH data. These studies found no differences by sex in the age of onset of susceptibility to e-cigarettes⁴⁷ and cigarettes,⁴⁸ which is similar to the findings presented here. Additionally, they also found that male youth have increased risk of an earlier age of onset of susceptibility to cigarillos,⁵⁰ which is in alignment with the current findings in young adults. However, they found that female youth have an increased risk of an earlier age of onset of susceptibility to hookah compared with males,⁴⁹ which is different from our findings in young adults.

In our study, we found significant differences by race/ethnicity in the age of onset of susceptibility for all tobacco products, which is in contrast to several previous studies that reported null findings. For example, we found that Non-Hispanic other young adults were at increased risk of an

earlier age of onset of susceptibility to e-cigarettes, while the 2013 study of college students (18-23 years old) found there was no difference by race/ethnicity in the prevalence of e-cigarette susceptibility.²⁵ This finding could be explained by the specific study sample of college students, while our study is nationally representative of all young adults (18-24 years old), or the fact that Saddleson et al²⁵ only included Non-Hispanic White, Non-Hispanic other, and Hispanic as race/ethnicity categories. A previous 2016 study among Ohio freshmen college students (mean age = 18.6) on the transition of non-susceptible to susceptibility to hookah use did not find any differences in onset of susceptibility by race/ethnicity,²⁷ while our study found that Non-Hispanic Black young adults are at increased risk of an earlier age of onset of susceptibility to hookah compared with Non-Hispanic White young adults. Our study also provides evidence for Non-Hispanic Black young adults having increased risk of an earlier age of onset of susceptibility to cigarillos, which is similar to a 2014 cross-sectional national study that shows that Non-Hispanic Black adults (18-60+ years old) have increased susceptibility to little cigar/cigarillo use compared with Non-Hispanic White adults (AOR = 2.02; 95% CI: 1.06-3.84).³¹ Future research should explore how increased risk of an earlier age of onset of susceptibility to cigarillos in Non-Hispanic Black young adults, which still occurs at a later age compared with the age of susceptibility onset of the other tobacco products, is associated with "delayed tobacco use onset" (i.e., initiating after adolescence) among Non-Hispanic Black young adults.² Future research should examine the risk factors that contribute to Non-Hispanic Black adults' increased risk of tobacco-related health outcomes despite having delayed onset of susceptibility and delayed tobacco product initiation/use compared with Non-Hispanic White adults.² We also found that Hispanic young adults have increased risk of an earlier age of onset of susceptibility to smokeless tobacco, which is in agreement with a 2014-2015 study among college students in Texas (mean age = 20.0) who were non-susceptible to smokeless tobacco use at baseline, which found that Hispanic college students exhibit increased incidence of susceptibility to smokeless tobacco compared with Non-Hispanic White young adults (AOR = 1.54; 95%CI: 1.08-2.20) after 6 months of follow-up.²⁸ While a previous nationally representative study (2012-2013 NATS) found that there were no differences in the prevalence of cigarette susceptibility among young adults (18-24 years old),²⁴ our study found that Hispanic young adults are at increased risk of an earlier age of onset of susceptibility to cigarettes compared with Non-Hispanic White young adults. The studies that examined the age of onset of susceptibility to different tobacco products in youth (ages 12-17) report different patterns of risk by race/ethnicity. Specifically, there were no differences by race/ethnicity in the age of onset of susceptibility to e-cigarettes,⁴⁷ which is in contrast to the findings among young adults. Additionally, while Non-Hispanic Black youth exhibited decreased risk of an earlier age of onset of susceptibility to cigarettes compared with Non-Hispanic White

youth,⁴⁸ there were no differences in the age of susceptibility onset between Non-Hispanic Black and Non-Hispanic White young adults. Hispanic youth were also found to show increased risk of an earlier age of onset of susceptibility to hookah compared with Non-Hispanic White youth,⁵⁶ while the findings among young adults reported no difference between these two groups. Finally, there were no differences in the age of onset of susceptibility to cigarillos/filtered cigars among youth,⁵⁰ while the current study reports increased risk among Non-Hispanic Black young adults. More research is needed to determine the reasons that the pattern of risk for the age of onset of susceptibility to different tobacco products is different by race/ethnicity between youth and young adults.

The findings among non-susceptible young adults that Non-Hispanic other young adults had increased risk of an earlier age of onset of susceptibility to e-cigarettes, Non-Hispanic Black young adults are at increased risk of an earlier age of onset of susceptibility to hookah and cigarillos, and Hispanic young adults are at increased risk of an earlier age of onset of susceptibility to cigarettes and smokeless tobacco is concerning and demands attention. Recent research has identified that culturally relevant intervention and prevention strategies may be particularly effective for minority populations. The Food and Drug Administration's (FDA) new The Fresh Empire initiative is the agency's first mass media campaign that is specifically targeted toward underserved multicultural groups, including Non-Hispanic Black and Hispanic youth.⁵⁷ Given our findings among non-susceptible young adults indicate that Non-Hispanic Black and Hispanic young adults have increased risk of an earlier age of onset of susceptibility, programs that use similar strategies but are more tailored to non-susceptible young adults are needed.

It is also concerning that susceptibility to all tobacco products studied increases among non-susceptible young adults during young adulthood and that previous use of other tobacco products increases the risk of susceptibility to a tobacco product that has never been used. Comprehensive, population-based strategies that target all tobacco products are needed to alleviate the overall burden of non-susceptible young adult tobacco initiation. For example, FDA's new required health warnings that include text and color graphics directly on packaging only apply to cigarettes.⁵⁸ It is possible that implementing similar health warnings on the packaging of other tobacco products could be effective to reduce susceptibility, as previous research found that placement of warning labels on hookah devices significantly increased hookah harm perceptions.⁵⁹ In addition, as of September 2020, 17 US states and territories have expanded their smoke-free indoor air policies to include e-cigarettes,⁶⁰ but this means that most states have not; yet, inclusive smoke-free policies are a known effective strategy against e-cigarette use and initiation.^{61,62} In addition, while cigarettes and e-cigarettes have been prioritized in successful mass media prevention and intervention campaigns, hookah and cigarillos are both widely used but have remained outside the focus of

these campaigns. To prevent tobacco intervention from becoming a moving target, education, prevention interventions, and population-based strategies should be comprehensive of all tobacco products so that tobacco use reduction does not drive the popularity of a particular tobacco product. Finally, Tobacco 21 is a US federal law that changed the minimum age of tobacco sale from 18 years old to 21 years old in December 2019.⁶³ Our study can be used as a baseline for any future evaluation to determine if this law has shifted the distribution of the age of onset of susceptibility by preventing lawful access to each of these tobacco products and after controlling for other prevention interventions (i.e., The Real Cost Campaign⁶⁴).

Conclusion

In conclusion, many young adults, who had never used each tobacco product and who were non-susceptible to each tobacco product at waves 2 or 3, report onset of susceptibility to each tobacco product, which is a cognitive precursor to behavioral initiation. Our study presents a unique opportunity to inform tobacco control efforts to reduce initiation of tobacco product use by targeting prevention and education campaigns tailored to the ages at which young adults become susceptible to the tobacco product, but have not yet initiated tobacco use. Our findings provide strong evidence that 18- to 19-year-olds are particularly vulnerable to susceptibility to e-cigarettes, cigarettes, and hookah. These ages represent the initial transition into young adulthood, and prevention efforts should focus on this vulnerable age group and youth⁴⁷⁻⁵⁰ in appropriate ways.

Strengths and Limitations

One of the strengths of our study is the use of nationally representative data to prospectively estimate the age of onset of susceptibility to five different tobacco products. The use of interval-censoring with non-parametric methods to estimate the age of onset of susceptibility is another strength, as our results do not depend on parametric model assumptions. In addition, one of the strengths of survival analysis is that this method is not hindered by loss-to-follow-up,^{36,42} as participants contribute to the analysis for the time that they participate in the study. One of the limitations of our study is that susceptibility questions in PATH are not asked among young adults until wave 2, which limits the study follow-up period. In addition, PATH did not ask susceptibility questions among young adults for cigarillos at wave 4, which limits the follow-up period for this product to 1 year. Birth dates of PATH participants are not included in the restricted-use data to protect confidentiality, which prevented us from obtaining participants' exact age at each wave, and is a limitation. We overcame this limitation by using the number of weeks between survey waves and interval-censoring to estimate the age of onset of susceptibility. The questions to measure susceptibility of tobacco products were only measured among adults 18 to 24 years old in PATH; therefore, a comparison with adults 25+ is not possible.

Further research with future PATH waves is needed to estimate the joint hazard function of the age of initiation of each tobacco product and the age of onset of susceptibility to each tobacco product, as both outcomes are correlated. Future research should also identify the risk and protective factors for the age of onset of susceptibility of each tobacco product, such as tobacco product marketing, peer and family influences, among others, which was outside the scope of this article.

Acknowledgements

We would like to thank Hui Min Shirlyn Sia for her help in conducting a literature review for this manuscript.

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