Use of Hookah and Age of Asthma Onset Among US Adults

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ABSTRACT

OBJECTIVE: To explore the association of hookah use on the age of asthma onset among adults who were asthma/COPD free and who did not use cigarettes, cigars, electronic cigarettes or smokeless tobacco prior to asthma onset.

METHODS: Secondary data analyses were conducted of the waves 1-6 (2013-2021) of the US nationally representative Population Assessment of Tobacco and Health Study among adults (>18 years). The four hookahs use exposures evaluated were (1) past 30-day (P30D) hookah use at the first wave of participation, (2) total number of waves before asthma onset in which adults reported P30D hookah use, (3) total number of years since first hookah use, and (4) average length of hookah sessions. Lower and upper age limits were estimated using the age reported at the first wave of participation and the number of weeks between follow-up waves until asthma was first reported or censored. Associations of the exposures on the age of asthma onset were estimated using weighted interval-censoring-Cox-regression.

RESULTS: The total sample size for analysis was 5,768, representing 66.6 million adults. There was a lack of statistical power to detect differences in the age of asthma onset by (1) P30D hookah use (Adjusted Hazard Ratio (AHR) 3.77, 95CI%: .90-15.71). There was an association between (2) total number of waves of P30D hookah use (AHR 1.72, 95% CI 1.28-2.30), (3) total number of years since first hookah use (AHR 2.94, 95% CI 1.36-6.36), and (4) average length of hookah sessions (AHR 4.52, 95% CI 1.61-12.67) with the age of asthma onset. Females and Hispanics with over one year since first hookah use had higher risk of earlier age of asthma onset.

CONCLUSION: Prevention and cessation programs for adults who use hookah are needed to educate the public, protect public health, prevent adverse health outcomes, and motivate hookah users to stop.

KEYWORDS: past 30-day hookah use, number of waves of hookah use, number of years since first hookah use, average length of hookah session, COPD, incidence

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ACCESS TO DATA: Adriana Pérez and Sarah Valencia had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Introduction

Hookah, also known as waterpipe tobacco, narghile, sisha, maassel, argileh, hubble bubble or goza, is a combustible tobacco product (TP) used socially.[1-3] The 2021 National Health Interview Survey among adults (aged 18 years or older) reported the prevalence of every day or some days use of hookah was 1.0%.[4] The Population Assessment of Tobacco and Health (PATH) Study is a nationally representative study in the U.S. to measure tobacco use and health outcomes in adults. The PATH study found the prevalence of past 30-day (P30D) hookah use was 2.2% (representing 5.19 million adults) in 2013-2014 and 1.3% (representing 3.29 million adults) in 2022-2023 (See Figure 1). The PATH Study also found, among 560 adults who used hookah at least once a month, the average length of a hookah session use varied between <30 min (17.4%, 95%CI: 13.3-22.4), 30-60 min (51.3%, 95%CI: 46.1-56.4), 1-2 h

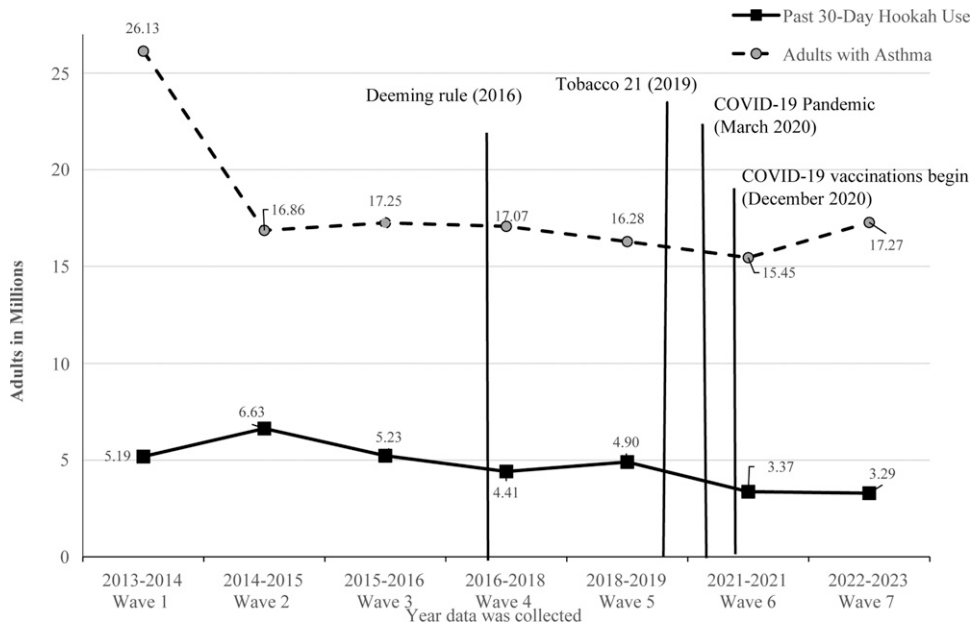

Figure 1. The prevalence of past 30-day hookah use and the prevalence of ever being diagnosed with asthma by a doctor or health professional among adults in the PATH[a] study (2013-2023). [a]The restricted file received disclosure to publish: 06/12/2024 - 08/01/2024. United States Department of Health 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. Inter-university Consortium for Political and Social Research [distributor], 2024-06-14. https://www.icpsr.umich.edu/web/NAHDAP/studies/36231/versions/V39.

(26.9%, 95%CI: 23.3-30.8), and > 2 h (4.4%, 95%CI: 3.1-6.2) in 2013-2014.[5] Authors did not evaluate the effect of hookah use on health outcomes.[5]

Many users do not consider hookah use harmful[3,6] and perceive hookah use as less harmful than cigarettes.[7-10] Previous studies have shown that one hookah session contains 40 times the amount of tar[11] and 2 times the amount of nicotine compared to a single cigarette.[11,12] One hour session of hookah use is about 200 times the volume that is drawn from smoking one cigarette.[13] Chemical analyses of hookah charcoal that is used to heat the shisha or hookah tobacco identified 7 carcinogens, 39 central nervous system depressants, and 31 respiratory irritants, all which are associated with potential health risks such as asthma among adults.[3,7,9,14-24] Acute and chronic exposure of experimental animals to hookah has been shown to induce lung inflammation and injury.[20,25] Among young adults, hookah use was associated with changes in cellular composition in the lungs, inducing systemic oxidative stress, inflammatory responses, decrements in lung function, lung, gastro-intestinal, and bladder malignancies, pulmonary impairments, and respiratory symptoms.[26-30]

Other combustible TPs are associated with increased asthma risk.[31] The prevalence of asthma among adults has increased since the 1980s, with more than 25 million U.S. adults afflicted in 2020 (8.4% of adults 18 years or older).[32] Asthma is one of the costliest diseases with an estimated total annual burden of $963.1 billion due to uncontrolled asthma in the U.S.[33] of which $300 billion is attributed to missed school or work days, mortality, and medical costs.[34,35] Adults are not routinely screened for asthma.[36] As a result, asthma in adults is often misdiagnosed as Chronic Obstructive Pulmonary Disease (COPD)[36] or underdiagnosed.[37] The PATH study found the prevalence of ever being diagnosed with asthma by a doctor or health professional was 11.1% (representing 26.13 million adults) in 2013, and the prevalence of being diagnosed with asthma in the past 12 months varied from 7.1% (16.86 million adults) in 2014-2015 to 8.7% (17.27 million adults) in 2022-2023 (See Figure 1). In addition, previous research has identified sex[38] and race/ethnicity[39,40] as factors associated with asthma prevalence. National data shows that in 2021 the prevalence of female and male adults with lifetime asthma was 15.1% (SE = .38) and 12.1% (SE = .33), respectively.[41] The prevalence of lifetime asthma among white non-Hispanic, black non-Hispanic, other non-Hispanic, and Hispanic adults was 14.0% (SE = .31), 15.7% (SE = .79), 12.5% (SE = .97), and 11.4% (SE = .59), respectively.[41] Despite the significant health and financial impacts of asthma, and its association with combustible TPs, research on the relationship between hookah use and asthma has been understudied. Pérez et al examined the association of P30D electronic nicotine delivery systems (ENDS) on the age of asthma onset, and adults who used P30D ENDS had a 252% increased risk of the onset of asthma at earlier ages (Adjusted Hazard Ratio 3.52, 95%CI 1.24-10.02).[42] While there is a scientific premise for the relationship of hookah use with the age of asthma onset, this relationship has never been studied and reported in a nationally representative study with longitudinal follow-up. In addition, no prior studies have examined the impact of the interaction of hookah use and

sex as well as the interaction of hookah use and race/ethnicity on the age of asthma onset longitudinally. Therefore, in this study, we examined the association between hookah use and the age of asthma onset, using four different exposure measures. The interaction between the four exposures hookah use (i) with sex, and (ii) with race/ethnicity were also assessed. Our study strengthens this body of research and results can be used to help to communicate and educate the public about health risks associated with hookah use, motivate users to quit, and modify asthma screening guidelines for earlier detection and treatment, all of which may reduce morbidity or mortality from asthma.

Methods

Study Design and Included Adults

The PATH Study began in 2013-2014 with the wave 1 cohort with annual follow-up until 2015-2016. In 2016-2017, the wave 4 cohort of adults was added due to attrition and was followed up biannually. A special adult collection, wave 5.5 was conducted in 2019-2020. Adults (>20 years old) in 2020 were measured through an adult telephone survey (ATS). The analysis included adults who entered the PATH Study at Wave 1 and Wave 4; these cohorts were tracked longitudinally across waves after entry. Secondary longitudinal analyses of restricted datasets from waves 1-6 (2013-2021) of the PATH Study were conducted among adults that reported not having asthma or Chronic Obstructive Pulmonary Disease (COPD) and who did not use cigarettes, cigars, ENDS, or smokeless tobacco at the first wave of participation. Institutional review board approval was obtained from the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston (HSC-SPH-22-0751). This manuscript follows the STROBE reporting guidelines for cohort studies.[43]

Measures

Exposures: Hookah Use. The exposures used in this study were four participant-reported measures of hookah use, each assessed prior to asthma incidence: (1) P30D hookah use reported at the first wave of participation (*P30D*), (2) total number of waves prior to asthma onset in which adults reported P30D hookah use (*total waves of P30D*), (3) total number of years since first hookah use at first wave of participation (*years since first hookah use*), and (4) average length of hookah sessions reported at the first wave of participation (*hookah session length*). *P30D* and *total waves of P30D* were measured with the question, "In the past 30 days, have you smoked tobacco in a hookah, even one or two puffs?". *Total waves of P30D* were calculated by counting the number of waves that the adults reported P30D hookah use either prior to the wave reporting asthma onset, or, among those remaining asthma-free, through the last wave of participation. The question "How old were you the first time you smoked hookah, even one or two puffs?" was used to calculate *years since first hookah use* by subtracting the age at the first wave of participation from the recalled age of first hookah use. *Hookah session length* was assessed with the question, "On average, how long [is/was] one hookah session for you [and the people you share/d it with]?". With categories of response less than 30 min, more than 30 min up to 1 h, 1 to 2 h, and more than 2 h. This exposure was collapsed to less than or equal to 30 min vs more than 30 min due to small sample size in over one-hour categories of response. In addition, adults who reported never hookah use were collapsed into the less than or equal to 30 min *hookah session length*.

Outcome: Age of Asthma Onset

Asthma and Chronic Obstructive Pulmonary Disease (COPD) Assessment. At the first wave of participation (waves 1 or 4), adults were asked "Has a doctor or other health professional ever told you that you had [asthma]/[COPD]?". Adults that responded "no" at their first wave of participation were then asked in Waves 2-6 about asthma diagnosis in the past 12-months. Adults who reported in the same Wave (2-6) asthma and COPD were excluded.

Estimating Age of Asthma Onset. The PATH Study dataset does not include adults date of birth or exact age of asthma onset. In this study, the age of asthma onset was estimated prospectively by using age in years at first wave of participation and the number of weeks between waves. The lower age bound estimated the age at the last wave where adults did not report asthma and the upper age bound estimated the age at the wave that adults reported asthma incidence. Adults who did not report asthma onset were censored. Age of asthma onset was estimated using adults' response in waves 2-6, including wave 5.5 and ATS.

Covariates at First Wave of Participation. The PATH Study imputed sex, race and Hispanic ethnicity using the household information. In the PATH Study, race was categorized as: Asian, Black, White, and other race (i.e., multiracial and any other race not otherwise specified); and ethnicity as: Hispanic or non-Hispanic. Response to race and ethnicity questions were combined to create the following categories: Hispanic, non-Hispanic Black, non-Hispanic White, and other (non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified). These variables were included to control for demographic differences in asthma and hookah use among adults.[42,44] Other covariates included education level (less than high school, high school or general education development test, some college or associate's degree, and bachelor's degree or higher), binge drinking (adult males, ≥5 drinks in one sitting; adult females, ≥4 drinks in one sitting), ever marijuana use, total number of waves of emergent cigarette use prior to asthma onset, any person present at home who uses TPs, rules at home about TP use (never allowed vs allowed anywhere, sometimes, or anytime), and weight status categories (underweight, healthy

weight, obese class 1, obese class 2). To assess the effect of the four exposures of hookah use with (i) sex and with (ii) race/ethnicity on the age of asthma onset, four new variables were created to represent the interaction of each hookah exposure with sex, and four additional variables represented the interaction of each hookah exposure with race/ethnicity. Males who reported never hookah use were the reference category. Due to small sample sizes, non-Hispanic white and other race/ethnicity categories were collapsed together when exploring these interactions. Non-Hispanic white and other race/ethnicity who reported never hookah use were the reference category.

Statistical Analysis

The PATH study utilizes a four-staged stratified complex sampling design using sampling weights and 100 balance repeated replicate (BRR) weights at the first wave of participation with Fay's adjustment set to .3 in all statistical analyses. Weighted summary statistics were calculated to describe socio-demographic characteristics, exposure to hookah use, and other covariates at first wave of participation. The median follow-up time was estimated by adding the number of weeks between the first wave of participation and the first wave of asthma onset, or, for censored adults, the last wave of participation (waves 2-6). A week of participation was assumed to estimate the median follow-up time for adults who were lost to follow-up from the first wave of participation to wave 6. Weighted nonparametric survival analyses for interval-censored data was implemented using cubic splines (3 knots) as the baseline hazard function to explore the association of exposures of hookah use on the age of asthma onset. For each exposure of hookah use three models were fitted; a crude model, a full multivariable model (model 1) that included covariates with *P*-value < .2 in the univariate analysis, and a reduced multivariable model (model 2) with only significant covariates (*P*-value < .05). Hazard ratios (HR) and 95% confidence intervals were reported. Socio-demographic characteristics and other TP use were included in final models regardless of significance. To assess the effect of each one of the four interaction variables of hookah use exposures with sex on the age of asthma onset, eight Cox proportional hazards models were fitted as a crude model (each interaction alone) as well as controlling for race/ethnicity, education level, weight status categories, and ever marijuana use at first wave of PATH participation. Similarly, to assess the effect of each one of the four interaction variables of hookah use exposures with race/ethnicity, eight additional Cox proportional hazards models were fitted as a crude model (each interaction alone) as well as controlling for sex, education level, weight status categories, and ever marijuana use at first wave of PATH participation. Only Cox proportional hazard models evaluating these interactions with statistically significant findings were shown. Sensitivity data analyses were conducted with asthma/COPD free adults who did not use cigarettes or cigars. Supplemental eTable 1 shows the reasons, number and percentage of adults excluded or included in the sensitivity analyses. Additional covariates considered were P30D ENDS, P30D smokeless tobacco (SMK) use at the first wave of participation, total number of waves reporting P30D ENDS/P30D SMK use prior to asthma onset, total number of years that adults reported ever ENDS and SMK use before the first wave of participation. The interaction between sex and race/ethnicity with each one of the four hookah use exposures in the sensitivity analyses were not estimated due to the number of variables already included in the model. Statistical analyses were conducted in SAS version 9.4-Tslevel1M6.

Results

The number and percentage of adults excluded or included in the primary analysis and sensitivity analyses are provided in Table 1 and eTable1, respectively. Table 2 shows the demographic characteristics, exposure, and outcome measures of the adults included in this study (i.e., who reported not having asthma/COPD and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco during the first wave of participation, referred to going forward as asthma-free adults). The sample size was 5768 adults (3649 females [weighted percentage, 63.13%] and 2119 males [weighted percentage, 36.87%]) representing approximately 66.6 million asthma-free adults. Asthma-free adults included 1398 Hispanics (weighted percentage, 20.08%), 1155 non-Hispanic Black (weighted percentage, 14.40%), 2626 non-Hispanic Whites (weighted percentage, 53.24%), and 589 other race or ethnicity (weighted percentage, 12.28%). The median (SE) follow-up time among adults in the study was 5.02 (.08) years. Figure 2 shows the distribution of the estimated age of asthma onset among asthma-free adults. By age 25 years, 4.5 per 1000 adults reported incidence of asthma (HR, .45%, 95% CI, .31%-.63%), by age 40 years, 13.5 per 1000 adults reported incidence of asthma (HR, 1.35%, 95% CI, .94%-1.80%), and by age 65 years, 36.6 per 1000 adults reported incidence of asthma (HR, 3.66%, 95% CI 2.77%-4.53%).

Table 3 shows the crude, the full multivariable (model 1), and the reduced multivariable (model 2) Cox proportional hazard models for each hookah use exposure (labeled in the columns to differentiate each analytic model). The results were similar between the full model (1) and the reduced model (2) for each hookah use exposure. The reduced models (2) are summarized here. No significant association (*P*-value = .069) was found between *P30D* and age of asthma onset (AHR 3.77, 95% CI .90-15.71). After controlling for covariates, a one-unit increase on the *total waves of P30D* increased by 72% the risk of asthma onset at earlier ages (HR 1.72, 95% CI 1.28-2.30). Adults who reported two or more *years since first hookah use* were at a 194% increased risk of asthma onset at earlier ages compared with adults who reported never hookah use

Table 1. Adults excluded or included in the primary analysis who did not have asthma or chronic obstructive pulmonary disease who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco in the PATH study (2013-2021) at the first wave of participation.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH[a] STUDY	SAMPLE NO.[a]	ESTIMATED NATIONAL POPULATION NO[b]	WEIGHTED % (SE[b])
Excluded Adults			
Age was missing	3	45 487	.02 (.01)
Answer to "doctor or other health professional said you had asthma?" was missing	39	472 621	.17 (.04)
Any cigar use status was missing	28	492 182	.18 (.04)
Any person present at home who uses tobacco products was missing	23	271 195	.10 (.02)
Binge drinking was missing	20	248 250	.09 (.03)
Cigarette use status was missing	24	306 990	.11 (.03)
Marijuana use status was missing	15	154 284	.06 (.02)
Past 30-day use of ENDS[c] was missing	15	263 102	.10 (.03)
Past 30-day use of hookah was missing	15	206 006	.08 (.03)
Past 30-day use of smokeless tobacco was missing	13	120 383	.04 (.02)
Reported any cigar use	818	5 393 470	1.99 (.10)
Reported cigarette use	29 376	179 672 781	66.29 (.58)
Reported COPD and asthma in same wave	29	194 195	.07 (.02)
Reported ENDS[c] use	526	1 733 693	.64 (.04)
Reported smokeless tobacco use	323	2 172 076	.80 (.07)
Reported yes to having asthma	1108	9 621 006	3.55 (.13)
Reported yes to having COPD[d]	23	445 480	.16 (.04)
Rules about tobacco products inside home was missing[e]	9	152 239	.06 (.02)
Total number of years that participant reported hookah use or average hookah session length was missing	10	34 094	.01 (.00)
Weight status category was missing	200	2 431 565	.9 (.07)
Included Adults			
Asthma/COPD free, used neither cigarettes nor cigars nor electronic cigarettes nor smokeless tobacco	5768	66 614 725	24.58 (.55)
Total	38 385	271 045 821	

[a]The restricted file received disclosure to publish: 11/22/2023. 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. Inter-university Consortium for Political and Social Research [distributor], 2023-05-19. https://doi.org/10.3886/ICPSR36231.v36.
[b]Any difference in categories of response with the total sum of the estimated population size is due to rounding of decimals.
[c]ENDS: Electronic nicotine delivery systems or vapes, vaporizers, vape pens, hookah pens, electronic cigarettes, and/or e-pipes.
[d]COPD: Chronic obstructive pulmonary disease.
[e]Categories of response for rules at home about tobacco product use were never allowed, vs allowed anywhere/sometimes/anytime.

(HR 2.94, 95% CI 1.36-6.36). Adults who reported *hookah session length* of more than 30 min had a 352% increased risk of asthma onset at earlier ages in comparison to adults who reported hookah session length of less than 30 min (HR: 4.52, 95% CI 1.61-12.67).

There were no statistically significant differences on the age of asthma onset when evaluating the interaction between (1) sex and *P30D*, (2) sex and *total waves of P30D*, and (4) sex and *hookah session length*, as well as the interaction between (1) race/ethnicity and *P30D*, (2) race/ethnicity and *total waves of P30D*, and (4) race/ethnicity and *hookah session length*. Table 4 shows the crude and multivariable Cox proportional hazard models for the interaction of sex and *years since first hookah use*. After controlling for race/ethnicity, education level, weight status categories, and ever marijuana use, females who reported one or more *years since first hookah use* had a 393% increased risk of asthma onset at earlier ages in comparison to males who reported never hookah use (HR: 4.93, 95% CI 2.10-11.58). Table 5 shows the crude and multivariable Cox proportional hazard models for the interaction of race/ethnicity and *years since first hookah use*. After controlling for sex, education level, weight status categories, and ever marijuana use, Hispanics adults who reported one or more *years since first hookah use* had a 418% increased risk of asthma onset at earlier ages in comparison to non-Hispanic white adults who reported never hookah use (HR: 5.18, 95% CI 2.21-12.16). After controlling for sex, education level, weight status categories, and ever marijuana use, non-Hispanic black adults who reported never hookah use had a 63% increased risk of asthma onset at earlier ages in

Table 2. Demographic and measure characteristics of adults that reported not having asthma or chronic obstructive pulmonary disease and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco in the PATH study (2013-2021) at the first wave of participation.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH[a] STUDY		SAMPLE NO. (N[b] = 5768)	ESTIMATED NATIONAL POPULATION NO. (N[b] = 66 614 725)	WEIGHTED % (SE[b])
Wave of entry into the PATH[a] Study				
Wave 1 (2013-2014)		4646	57 696 224	86.61 (.48)
Wave 4 (2016-2018)		1122	8 918 501	13.39 (.06)
Age [Weighted Mean (SE)]		44.35 (.32)		
Sex	Female	3649	42 052 850	63.13 (.75)
	Male	2119	24 561 875	36.87 (.75)
Race and ethnicity	Hispanic	1398	13 373 474	20.08 (.58)
	Non-Hispanic black	1155	9 592 869	14.40 (.46)
	Non-Hispanic white	2626	35 465 282	53.24 (.94)
	Other[c]	589	8 183 100	12.28 (.47)
Education level[d]	Less than high school	882	10 130 212	15.21 (.53)
	High school/GED[e]	1557	17 220 472	25.85 (.63)
	Some college/ associate's degree	1946	19 238 550	28.88 (.68)
	Bachelor's degree or higher	1383	20 025 491	30.06 (.71)
Weight status categories[f]	Underweight	252	2 445 613	3.67 (.31)
	Healthy weight	2335	23 910 282	35.89 (.73)
	Overweight	1684	21 481 031	32.25 (.74)
	Obesity (class 1)	880	11 028 551	16.56 (.64)
	Obesity (class 2)	617	7 749 247	11.63 (.54)
Past 30-day hookah use	No	5660	66 280 337	99.50 (.06)
	Yes	108	334 387	.50 (.06)
Total number of waves prior to asthma onset in which adults reported past 30-day hookah use [Weighted Mean (SE)]		.03 (.003)		
Total number of years since first hookah use	0	5100	64 145 698	96.30 (.18)
	1	160	514 460	.77 (.09)
	2+	508	1 954 567	2.93 (.15)
Average length of hookah session	Less than or equal to 30 min	5630	66 172 057	99.34 (.07)
	More than 30 min	138	442 667	.66 (.07)
Total number of waves reporting emergent cigarette use prior to asthma onset [Weighted Mean (SE)]		.04 (.003)		
Binge drinking	No	5577	65 277 107	98.00 (.23)
	Yes	191	1 337 617	2.00 (.23)
Ever marijuana use	No	5169	61 714 818	92.64 (.44)
	Yes	599	4 899 906	7.36 (.44)
Any person present at home who uses tobacco products	No	4681	56 687 628	85.10 (.72)
	Yes	1087	9 927 097	14.90 (.72)
Rules at home about tobacco product use (anywhere/sometimes/anytime)	Never allowed	4800	56 270 488	84.47 (.74)
	Allowed	968	10 344 236	15.53 (.74)
Interaction sex and years since first hookah use				
Male reported never hookah use		1901	23 774 148	35.69 (.75)
Male reported 1+ years since first hookah use		218	787 726	1.18 (.09)
Female reported never hookah use		3199	40 371 549	60.60 (.75)
Female reported 1+ years since first hookah use		450	1 681 301	2.52 (.15)

(Continued)

Table 2. Continued.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH[a] STUDY	SAMPLE NO. (N[B] = 5768)	ESTIMATED NATIONAL POPULATION NO. (N[B] = 66 614 725)	WEIGHTED % (SE[B])
Interaction race ethnicity and years since first hookah use			
Hispanic reported never hookah use	1210	12 822 850	19.25 (.59)
Hispanic reported 1+ years since first hookah use	188	550 623	.83 (.07)
Non-Hispanic reported never hookah use	1045	9 210 708	13.83 (.45)
Non-Hispanic black reported 1+ years since first hookah use	110	382 161	.57 (.07)
Non-Hispanic white/other[g] reported never hookah use	2845	42 112 139	63.22 (.86)
Non-Hispanic white/other[g] reported 1+ years since first hookah use	370	1 536 242	2.31 (.14)

[a]The restricted file received disclosure to publish: 12/06/2023-12/13/2023. 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. Inter-university Consortium for Political and Social Research [distributor], 2023-05-19. https://doi.org/10.3886/ICPSR36231.v36.
[b]Any difference in categories of response with the total sum of the estimated population size is due to rounding of decimals, SE = standard error.
[c]Other included Non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified.
[d]Highest level of education attained by adults.
[e]GED: General Educational Development Test.
[f]Weight status was computed: Adult body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adults with a BMI score less than 18.5 were classified as underweight, 18.5 to 25 as healthy weight, 25 to 30 as overweight, 30 to 35 as obesity class 1, and greater than 35 as obesity class 2.
[g]Non-Hispanic White and Other (Non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified) were collapsed due to small sample size.

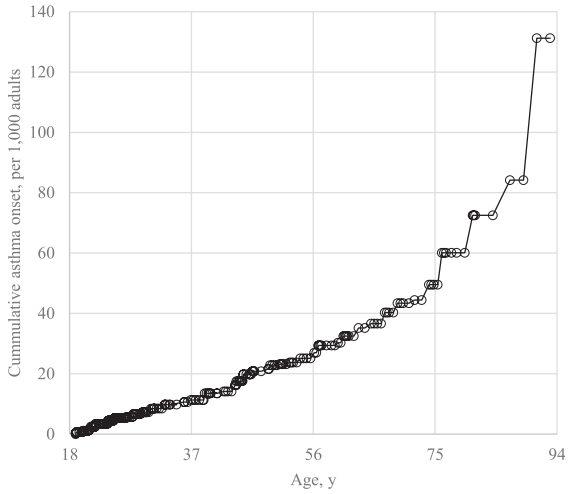

Figure 2. Cumulative hazard function for age of asthma onset among adults who did not have asthma or chronic obstructive pulmonary disease and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco at the first wave of participation in the PATH[a] study, 2013-2021. [a] The restricted file received disclosure to publish: 12/06/2023. 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. Inter-university Consortium for Political and Social Research [distributor], 2023-05-19. https://doi.org/10.3886/ICPSR36231.v36.

comparison to non-Hispanic white adults who reported never hookah use (HR: 1.63, 95% CI 1.09-2.43).

The sensitivity analyses are reported in Supplemental eTables 2–4, and eFigure. After controlling for covariates, asthma-free adults who did not use cigarettes or cigars at the first wave of participation, all four exposures: (1) *PD30*, (2) *total waves of P30D*, (3) *years since first hookah use*, and (4) *hookah session length* were each one individually associated with the age of asthma onset (see eTable 3 and eTable4).`

Discussion

This study prospectively estimated the age of asthma onset among asthma-free adults who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco at their first wave of participation. The included sample of 5768 asthma-free adults (~66.6 million) was smaller than our previous publication with a sample of 7766 asthma-free adults (~ 80 million adults) who never used cigarettes at their first wave of participation,[42] reflecting the large number of adults who used TPs other than cigarettes. Among asthma-free adults, we reported that the cumulative incidence for the age of asthma onset by age 25 years as 4.5 per 1000 adults (95% CI, 3.08%-6.31%) and by age 30 as 7.2 per 1000 adults (95% CI, 6.16%-10.64%). These findings are similar to another study among asthma-free adults who never used cigarettes at the first wave of participation; the cumulative incidence for the age of asthma onset by age 25 years was 4.6 per 1000 adults (95% CI, 3.53-6.24) and by age 30 years was 7.5 per 1000 adults (95% CI, 6.53-10.33),[42] respectively. Our results are also consistent with previous studies reporting that the incidence of asthma onset in adults did not decrease with increasing age and the increase in asthma in the US and globally.[42,45-48] In 2021 (most recent data available), the Centers for Disease Control reported cross-sectional lifetime or current prevalence of asthma by age groups. However, prevalence statistics are not comparable to our results because our study started with asthma free adults who were followed up annually or biannually for asthma incidence. A possible explanation for the increase of age of asthma onset after 56 years of age (shown in Figure 2) could be that adults may have been diagnosed with asthma-COPD overlap syndrome (person has clinical features of both asthma and COPD)[49] when reporting

Table 3. Association of hookah use with the age of asthma onset among the 5768 adults who did not have asthma or chronic obstructive pulmonary disease and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco in the PATH study (2013-2021) at the first wave of participation.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH STUDY		CRUDE ASSOCIATION	P30D		TOTAL WAVES OF P30D		YEARS SINCE FIRST HOOKAH USE		HOOKAH SESSION LENGTH	
			MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2
		HR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)	AHR (95% CI)
Past 30-day hookah use	No	1	1	1	NA	NA	NA	NA	NA	NA
	Yes	4.22 (1.04-17.09)	2.98 (.64-13.85)	3.77 (.90-15.71)	NA	NA	NA	NA	NA	NA
Total number of waves prior to asthma onset in which adults reported past 30-day hookah use (SE[b])		1.69 (1.33-2.15)	NA	NA	1.64 (1.20-2.25)	1.72 (1.28-2.30)	NA	NA	NA	NA
Total number of years since first hookah use	0	1	NA	NA	NA	NA	1	1	NA	NA
	1	4.16 (.80-21.70)	NA	NA	NA	NA	3.09 (.59-16.24)	3.76 (.80-17.74)	NA	NA
	2+	3.79 (1.86-7.73)	NA	NA	NA	NA	2.62 (1.16-5.90)	2.94 (1.36-6.36)	NA	NA
Average length of hookah session	Less than or equal to 30 min	1	NA	NA	NA	NA	NA	NA	1	1
	More than 30 min	5.38 (1.99-14.56)	NA	NA	NA	NA	NA	NA	3.87 (1.31-11.46)	4.52 (1.61-12.67)
Sex	Male	1	1	1	1	1	1	1	1	1
	Female	1.27 (.80-2.01)	1.34 (.85-2.09)	1.37 (.87-2.16)	1.34 (.86-2.09)	1.37 (.87-2.16)	1.32 (.85-2.07)	1.35 (.86-2.13)	1.33 (.85-2.09)	1.36 (.86-2.16)
Race and ethnicity	Hispanic	.79 (.45-1.39)	1.11 (.59-2.11)	1.07 (.55-2.08)	1.1 (.58-2.09)	1.06 (.54-2.07)	1.09 (.58-2.05)	1.04 (.54-2.02)	1.10 (.58-2.09)	1.06 (.54-2.07)
	Non-Hispanic black	1.50 (1.00-2.27)	1.56 (1.03-2.37)	1.55 (1.04-2.32)	1.54 (1.02-2.33)	1.52 (1.02-2.28)	1.55 (1.02-2.36)	1.54 (1.03-2.31)	1.56 (1.03-2.37)	1.55 (1.03-2.31)
	Non-Hispanic white	1	1	1	1	1	1	1	1	1
	Other[c]	.59 (.27-1.31)	.63 (.27-1.47)	.64 (.28-1.48)	.63 (.27-1.46)	.64 (.28-1.47)	.63 (.27-1.46)	.64 (.28-1.47)	.63 (.27-1.47)	.64 (.28-1.48)
Education level[d]	Bachelor's degree or higher	1	1	1	1	1	1	1	1	1
	Less than high school	.59 (.32-1.09)	.49 (.24-.99)	.54 (.26-1.10)	.49 (.24-.99)	.54 (.26-1.10)	.51 (.25-1.02)	.55 (.27-1.13)	.49 (.25-.99)	.54 (.26-1.10)
	High school/GED[e]	.87 (.53-1.44)	.78 (.47-1.29)	.84 (.51-1.38)	.78 (.47-1.29)	.84 (.51-1.38)	.79 (.47-1.32)	.86 (.52-1.41)	.78 (.47-1.29)	.84 (.51-1.39)
	Some college/associates degree	1.21 (.73-2.01)	1.02 (.62-1.68)	1.06 (.64-1.75)	1.02 (.62-1.68)	1.06 (.64-1.75)	1.03 (.63-1.71)	1.07 (.64-1.78)	1.02 (.62-1.68)	1.06 (.64-1.75)
Weight status categories[f]	Healthy weight	1	1	1	1	1	1	1	1	1
	Underweight	.25 (.04-1.51)	.24 (.04-1.55)	.26 (.04-1.67)	.24 (.04-1.53)	.26 (.04-1.65)	.25 (.04-1.57)	.27 (.04-1.69)	.24 (.04-1.55)	.26 (.04-1.67)
	Overweight	1.01 (.62-1.63)	1.00 (.62-1.64)	1.02 (.63-1.66)	1.01 (.62-1.65)	1.03 (.63-1.67)	1.03 (.63-1.69)	1.04 (.64-1.70)	1.01 (.62-1.64)	1.02 (.63-1.66)
	Obesity (class 1)	.89 (.52-1.51)	.83 (.49-1.38)	.87 (.52-1.47)	.83 (.49-1.39)	.87 (.52-1.48)	.85 (.50-1.45)	.9 (.53-1.53)	.83 (.49-1.39)	.88 (.52-1.48)
	Obesity (class 2)	1.90 (1.02-3.52)	1.68 (.86-3.28)	1.84 (.97-3.47)	1.69 (.87-3.29)	1.85 (.98-3.48)	1.74 (.88-3.45)	1.9 (.99-3.63)	1.69 (.86-3.30)	1.85 (.98-3.50)
Total number of waves reporting emergent cigarette use prior to asthma onset [Weighted Mean (SE)]		1.21 (.45-3.21)	NA	NA	NA	NA	NA	NA	NA	NA
Binge drinking	No	1	1	NA	1	NA	1	NA	1	NA
	Yes	3.62 (1.16-11.28)	2.94 (.80-10.77)	NA	2.95 (.82-10.70)	NA	2.82 (.77-10.29)	NA	2.94 (.81-10.70)	NA
Ever marijuana use	No	1	1	1	1	1	1	1	1	1
	Yes	2.58 (1.40-4.76)	2.23 (1.17-4.24)	2.42 (1.28-4.58)	2.21 (1.16-4.21)	2.40 (1.26-4.55)	2.07 (1.09-3.96)	2.23 (1.17-4.24)	2.20 (1.16-4.19)	2.39 (1.26-4.53)
Any person present at home who uses tobacco products	No	1	1	NA	1	NA	1	NA	1	NA
	Yes	1.89 (1.14-3.12)	1.57 (.92-2.69)	NA	1.57 (.92-2.69)	NA	1.54 (.90-2.64)	NA	1.57 (.91-2.68)	NA
Rules at home about tobacco product use (anywhere/sometimes/anytime)	Never allowed	1	1	NA	1	NA	1	NA	1	NA
	Allowed	1.55 (.92-2.62)	1.26 (.74-2.16)	NA	1.25 (.73-2.15)	NA	1.25 (.73-2.14)	NA	1.26 (.74-2.16)	NA

[a]The restricted file received disclosure to publish: 12/07/2023-01/18/2023. 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. Inter-university Consortium for Political and Social Research [distributor], 2023-05-19. https://doi.org/10.3886/ICPSR36231.v36.
[b]SE = standard error.
[c]Other included Non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified.
[d]Highest level of education attained by adults.
[e]GED: General Educational Development Test.
[f]Weight status was computed as follows: Adult body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adults with a BMI score less than 18.5 were classified as underweight, 18.5 to 25 as healthy weight, 25 to 30 as overweight, 30 to 35 as obesity class 1, and greater than 35 as obesity class 2.

asthma incidence. In our study we excluded adults who self-reported asthma and COPD (diagnosed by a doctor or other health professional) in the same Wave (2-6), ensuring asthma incidence only.

Although our results did not find an association of *P30D* hookah use with the age of asthma onset after adjusting for covariates among asthma-free adults who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco at the first wave of participation, the other exposures (2) *total waves of P30D*, (3) *years since first hookah use*, and (4) *hookah session length* were each one individually associated with the age of asthma onset.

When exploring the interaction of each one of the four hookah use exposures with either sex or race/ethnicity, only statistically significant differences were found with (i) sex and *years since first hookah use*, and (ii) race/ethnicity and *years since first hookah use* on the age of asthma onset. Providing evidence on how longevity of hookah use may play a role in the age of

Table 4. Association of the interaction of sex with the total number of years since first hookah use with the age of asthma onset among the 5768 adults who did not have asthma or chronic obstructive pulmonary disease and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco in the PATH study (2013-2021) at the first wave of participation.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH[a] STUDY	CRUDE ASSOCIATION	ADJUSTED MODEL
	HAZARD RATIO (95% CONFIDENCE INTERVAL)	ADJUSTED HAZARD RATIO (95% CONFIDENCE INTERVAL)
Interaction of sex and years since first hookah use		
Male reported never hookah use	1	1
Male reported 1+ years since first hookah use	1.58 (.33-7.53)	1.24 (.25-6.02)
Female reported never hookah use	1.22 (.76-1.94)	1.30 (.82-2.07)
Female reported 1+ years since first hookah use	5.72 (2.46-13.30)	4.93 (2.10-11.58)
Race and ethnicity		
Hispanic	.79 (.45-1.39)	1.04 (.54-2.02)
Non-Hispanic black	1.50 (1.00-2.27)	1.54 (1.03-2.31)
Non-Hispanic white	1	1
Other[b]	.59 (.27-1.31)	.64 (.28-1.47)
Education level[c]		
Bachelor's degree or higher	1	1
Less than high school	.59 (.32-1.09)	.56 (.27-1.14)
High school/GED[d]	.87 (.53-1.44)	.86 (.52-1.42)
Some college/associates degree	1.21 (.73-2.01)	1.08 (.65-1.79)
Weight status categories[e]		
Healthy weight	1	1
Underweight	.25 (.04-1.51)	.27 (.04-1.68)
Overweight	1.01 (.62-1.63)	1.04 (.64-1.69)
Obesity (class 1)	.89 (.52-1.51)	.90 (.53-1.52)
Obesity (class 2)	1.90 (1.02-3.52)	1.89 (.99-3.62)
Ever marijuana use		
No	1	1
Yes	2.58 (1.40-4.76)	2.24 (1.18-4.23)

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[b]Other included Non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified.
[c]Highest level of education attained by adults.
[d]GED: General Educational Development Test.
[e]Weight status was computed as follows: Adult body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adults with a BMI score less than 18.5 were classified as underweight, 18.5 to 25 as healthy weight, 25 to 30 as overweight, 30 to 35 as obesity class 1, and greater than 35 as obesity class 2.

asthma onset. Previous research reported statistical differences in sex and asthma prevalence with current asthma being reported more often by females.[38] The interaction of sex and *years since first hookah use* on the age of asthma onset has not been reported in the literature before but our results were consistent in showing that females who reported more than 1 *years since first hookah use* are at higher risk of earlier ages of asthma onset. Similarly, when exploring the interaction of race/ethnicity and *years since first hookah use*, the findings were consistent with previous studies that indicated that the burden of asthma falls disproportionately on Hispanics and non-Hispanic blacks.[40]

The sensitivity analyses, including asthma-free adults who did not use cigarettes or cigars at the first wave of participation resulted in consistent associations of (2) the *total waves of P30D*, (3) *years since first hookah use*, and (4) *hookah session length* with the age of asthma onset. The association of *P30D* hookah use with the age of asthma onset was reported with larger variability of the estimates (wider confidence intervals). The (1) *P30D* results are consistent with a prospective study (using 2014-2018 data) among adults aged 18-39 years without a COPD diagnosis that did not observe an association between P30D hookah use and the incidence of asthma one or two years later[50] (but our sensitivity analyses are in contrast). Duration of hookah use, either over time or in a single session, is most relevant to the age of asthma onset (in both primary and sensitivity analyses).

Strengths, Limitations and Future Research

The use of data from the PATH Study[51] was a primary strength, as the PATH Study is a nationally representative sample of US adults and can be used to test hypotheses with

Table 5. Association of the interaction of race/ethnicity and total number of years since first hookah use with the age of asthma onset among the 5768 adults who did not have asthma or chronic obstructive pulmonary disease and who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco in the PATH study (2013-2021) at the first wave of participation.

VARIABLE REPORTED AT THE FIRST WAVE OF PARTICIPATION IN THE PATH[a] STUDY	CRUDE ASSOCIATION	ADJUSTED MODEL
	HAZARD RATIO (95% CONFIDENCE INTERVAL)	ADJUSTED HAZARD RATIO (95% CONFIDENCE INTERVAL)
Interaction of race and ethnicity and years since first hookah use		
Non-Hispanic white/other[b] reported never hookah use	1	1
Non-Hispanic white/other[b] reported 1+ years since first hookah use	3.45 (1.17-10.10)	2.79 (.91-8.53)
Hispanic reported never hookah use	.79 (.43-1.43)	1.04 (.52-2.10)
Hispanic reported 1+ years since first hookah use	5.79 (2.57-13.04)	5.18 (2.21-12.16)
Non-Hispanic black reported never hookah use	1.61 (1.06-2.44)	1.63 (1.09-2.43)
Non-Hispanic black reported 1+ years since first hookah use	3.97 (.72-22.03)	3.28 (.61-17.69)
Sex		
Male	1	1
Female	1.27 (.80-2.01)	1.35 (.86-2.13)
Education level[c]		
Bachelor's degree or higher	1	1
Less than high school	.59 (.32-1.09)	.57 (.28-1.16)
High school/GED[d]	.87 (.53-1.44)	.88 (.54-1.43)
Some college/associates degree	1.21 (.73-2.01)	1.10 (.67-1.81)
Weight status categories[e]		
Healthy weight	1	1
Underweight	.25 (.04-1.51)	.27 (.04-1.67)
Overweight	1.01 (.62-1.63)	1.05 (.64-1.72)
Obesity (class 1)	.89 (.52-1.51)	.92 (.54-1.56)
Obesity (class 2)	1.90 (1.02-3.52)	1.94 (1.01-3.71)
Ever marijuana use		
No	1	1
Yes	2.58 (1.40-4.76)	2.28 (1.21-4.30)

[a]The restricted file received disclosure to publish: 12/07/2023-11/01/2024. 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. Inter-university Consortium for Political and Social Research [distributor], 2023-05-19. https://doi.org/10.3886/ICPSR36231.v36.
[b]Non-Hispanic White and Other (Non-Hispanic Asian, multiracial, and any other race or ethnicity not otherwise specified) were collapsed due to small sample size.
[c]Highest level of education attained by adults.
[d]GED: General Educational Development Test.
[e]Weight status was computed as follows: Adult body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adults with a BMI score less than 18.5 were classified as underweight, 18.5 to 25 as healthy weight, 25 to 30 as overweight, 30 to 35 as obesity class 1, and greater than 35 as obesity class 2.

longitudinal data on tobacco-related health outcomes. The use of four measures of hookah exposure and prospectively estimating the age of asthma onset between 2013 and 2021 were additional strengths. Limitations included the need to estimate the age of asthma onset with interval-censoring survival methods because the PATH Study[51] did not ask adults the exact date of their asthma diagnosis by a doctor or other health professional. Environmental factors,[52] nutritional intake,[53,54] maternal smoking status,[55] genes,[56,57] allergies,[58] dust mites,[59] and family history of asthma[60] were other risk factors that may influence the age of asthma onset. Still, these factors were not measured in the PATH study, so results should be cautiously interpreted. Lastly, the PATH Study did not measure the total number of hookah sessions per year. Future researchers may need to assess the effect of the total number of hookah sessions use per year as previous publications identified that more 40-50 sessions of hookah use per year had higher odds for coronary artery disease.[61]

Conclusions

This longitudinal study found that asthma-free adults who did not use cigarettes, cigars, electronic cigarettes, or smokeless tobacco at the first wave of participation in the PATH study and who reported: (2) a one-unit increase in the *total waves of P30D* hookah use prior to asthma onset, (3) two or more *years since first hookah use* vs those that never reported hookah use, or (4) *hookah session length* of more than 30 min vs those that reported hookah session length of less than 30 min had an increased risk of asthma onset at earlier ages. The results of our study can be used by the Food and Drug

Administration Federal agency to communicate the impact of hookah use on the age of asthma onset in tobacco control awareness campaigns to help prevention and cessation programs. Our results provide evidence supporting the recommendations by the American Heart Association on the health consequences of hookah use.[3] As part of routine clinical examinations, we recommend that health providers (i) ask individuals about hookah use, hookah use frequency, hookah session length, (ii) provide individuals with credible resources of information about harmfulness, addictiveness, and health consequences of hookah use, (iii) advise adults who use hookah to stop their use, and (iv) assist them in setting up cessation counseling sessions, a quit date, social support, and coping tools.[3] Health providers should highlight and communicate that more than 1 years since first hookah use among females, and Hispanic adults was associated with earlier ages of asthma onset as well as asthma disparities especially among non-Hispanic blacks.

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