

Association between tobacco product use and asthma among US adults from the Population Assessment of Tobacco and Health (PATH) Study waves 2–4

Mary F Brunette,^{1,2,3,4} Michael J Halenar,⁵ Kathryn C Edwards,⁵ Kristie A Taylor,⁵ Jennifer A Emond,^{2,3} Susanne E Tanski,^{2,3} Steven Woloshin,^{3,4} Laura M Paulin,^{2,3} Andrew Hyland,⁶ Kristen Lauten,⁵ Martin Mahoney,⁶ Carlos Blanco,⁷ Nicolette Borek,⁸ Louis Claudio DaSilva,⁸ Lisa D Gardner,⁸ Heather L Kimmel,⁷ James D Sargent^{2,3}

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For numbered affiliations see end of article.

Correspondence to

Dr Mary F Brunette;
Mary.F.Brunette@hitchcock.org

ABSTRACT

Background Research on cigarettes and adult asthma offers mixed findings, perhaps due to overlap with chronic obstructive pulmonary disease (COPD) and inadequate adjustment for other smoke exposures. Associations between other tobacco products, including e-cigarettes, and asthma are also understudied.

Research question Using Population Assessment of Tobacco and Health Study waves 2–4 (2014/2015–2016/2017) data, we assessed the relation between tobacco product use and asthma in persons unlikely to have COPD.

Study design and methods Prospective study of 10 267 adults aged 18–39 years without COPD diagnoses. Past-month tobacco use at wave 2 was modelled first as combustible versus non-combustible use and second as specific product categories (former, cigarettes, e-cigarettes, cigars, hookah, smokeless tobacco). Outcomes included lifetime asthma prevalence at wave 2, incidence (waves 3 and 4) and Asthma Control Test score (lower=worse). Multivariable regressions adjusted for predictors of asthma, including other smoke exposures: cigarette pack-years, secondhand smoke and marijuana use. Sensitivity analyses examined findings when persons >39 years and those with both COPD and asthma were added, and when smoke exposure adjustments were removed.

Results No product, including cigarettes and e-cigarettes, was associated with prevalence or incidence of asthma. Among people with asthma at wave 2, combustible tobacco (beta=−0.86, 95% CI (−1.32 to −0.39)) and cigarettes (beta=−1.14, 95% CI (−1.66 to −0.62)) were associated with worse asthma control. No tobacco product was associated with asthma control over time. In sensitivity analyses, tobacco use became associated with incident asthma as adults >39 years and those with asthma+COPD were added, and as adjustments for other smoke exposures were omitted.

Interpretation Although cigarette use was associated with worse asthma control, there were no longitudinal associations between combustible tobacco or e-cigarette use and new onset or worsening asthma in these preliminary analyses. Research on tobacco and asthma

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous research on the relationship between tobacco use and adult asthma is mixed. Studies with positive findings often did not account for the effects of confounders such as other smoke exposure and presence of comorbid chronic obstructive pulmonary disease (COPD) in study subjects.

WHAT THIS STUDY ADDS

⇒ This study avoids the problem of confounding seen in previous studies. After removing participants with comorbid COPD and adjusting for pack-years of smoking, secondhand smoke and use of cannabis, the cross-sectional analyses found that cigarette smoking was associated with poorer asthma control, but longitudinal analyses found that cigarettes and e-cigarettes were not associated with new-onset asthma or worsening of asthma over time.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Future research on tobacco and adult asthma should select samples to avoid confounding comorbid conditions and carefully adjust for other smoke exposures.

should exclude COPD and adjust for smoking history and other smoke exposures.

INTRODUCTION

Asthma is the most prevalent chronic respiratory disease worldwide.^{1 2} Unlike chronic obstructive pulmonary disease (COPD), which primarily begins in middle age among people with host risk factors and long-term exposure to tobacco smoke or air pollutants,^{3–5} asthma is a heterogeneous disease of reversible expiratory airflow limitation,



often beginning in childhood.⁶ Asthma is thought to result from the complex interaction between genetic factors and environmental exposures at critical periods throughout life.^{7,8}

The relationship between tobacco product use and adult asthma is complex. Cigarette smoking has long been thought to contribute to asthma onset and severity in adults (see reviews of prospective studies⁹ and cross-sectional studies in clinical populations^{10–13}). Yet, several prospective studies found no association or mixed findings.^{14–18} Moreover, cigarette smokers with asthma frequently use other products, including electronic (e-) cigarettes,^{19,20} about which there are very few prospective studies.²¹

Methodological problems may have contributed to previous mixed findings. Many studies of tobacco use and asthma did not assess cigarette smoking history, use of multiple tobacco products and other smoke exposures, such as secondhand smoke and marijuana use, that could be confounders,^{16,18,22–25} and most prospective studies of asthma and tobacco did not account for COPD.^{16,17,22–26} (Up to one-third of adults with asthma eventually develop comorbid COPD,^{27,28} when patients present with features distinct from asthma.^{29,30}) For example, a recent paper²² noted that combustible tobacco and e-cigarette use were both associated with adult-onset asthma; however, that study addressed neither comorbid COPD, nor history of cigarette smoking and other smoke exposures, all important potential confounders. Careful, prospective research is needed to clarify the relation between tobacco product use and asthma outcomes.

The Population Assessment of Tobacco and Health (PATH) Study is a large, national, longitudinal survey of tobacco product use and self-reported health outcomes.³¹ This report evaluated the relationships between tobacco product use and asthma diagnosis and symptoms among people aged 18–39 years old without comorbid COPD. Sensitivity analyses explored how adding participants over 40 years and those with comorbid COPD, as well as removing adjustments for cigarette smoking history and other smoke exposures, affected the association between tobacco product use and asthma.

METHODS

Study design, setting and participants

The PATH Study recruitment employed a stratified address-based, area-probability sampling design at wave 1 (W1; 2013–2014) that oversampled adult tobacco users, young adults (18–24 years) and African-American adults.

Respiratory symptoms, including asthma symptoms, were first assessed in wave 2 (W2: 2014–2015, N=28 362), which served as the baseline assessment for this study. The weighted response rate at W2 was 83.2%. Follow-up data were collected at waves 3 and 4 (W3: 2015–2016; W4: 2016–2017) including 28 148 and 27 757 adult participants, respectively, with weighted response rates of 78.4% and 73.5% of W2 participants, respectively. Respondents

were assessed in person with a computer-assisted interview approximately yearly.

For this study, we selected all W2 adults aged 18–39 years, excluding adults over 39 years and those who reported COPD (including chronic bronchitis or emphysema) or other non-asthma respiratory diseases at W1–4, to increase certainty that we were studying adult asthma (N=11 675). Participants with missing data on independent or dependent variables (N=1408, 12.1%) were also excluded, for a complete case analytical sample of 10 267.³² (Multiple imputation analyses were also conducted on the full sample, as described in the Statistical analysis section below.)

Complete PATH Study design methods have previously been published in detail;^{33,34} interviewing procedures, questionnaires, sampling, weighting and response rates can be found at <https://doi.org/10.3886/Series606>. All adult respondents provided informed consent.

Patient and public involvement

Patients or the public WERE NOT involved in the design, or conduct, or reporting, or dissemination plans of our research.

Patient-reported asthma diagnosis and symptoms

Asthma diagnosis

Similar to the National Health and Nutritional Examination Survey (NHANES),³⁵ lifetime asthma diagnosis was assessed at baseline by asking: ‘Has a doctor, nurse or other health professionals EVER told you that you had any of the following lung or respiratory conditions? Choose all that apply. Asthma, COPD, etc.’ New diagnosis was assessed by asking: ‘IN THE PAST 12 MONTHS, has a doctor ever told you that you had any of the following lung or respiratory conditions? Choose all that apply. Asthma, COPD, etc.’ The asthma diagnosis questions were validated by demonstrating that self-reported asthma diagnosis in the PATH Study was associated with greater respiratory symptoms and impairments in functional status (see online supplemental appendix 1). Additionally, the prevalence of asthma diagnosis in the PATH Study was similar to the prevalence of asthma diagnosis in NHANES (see online supplemental appendix 1). Asthma at baseline (W2) and new asthma at follow-up (W3 or W4) were assessed by a combination of these two questions.

Asthma control

The Asthma Control Test (ACT), a validated questionnaire designed for patients with asthma, includes five items on self-reported asthma symptoms (online supplemental table 1), each with answer options 1–5. Summary scores range from 5 to 25 (higher=better asthma control, for example, fewer symptoms; ACT score <20 indicates poorly controlled asthma).³⁶ It has high internal consistency (Cronbach’s alpha=0.79), test–retest reliability (r=0.77) and criterion validity (correlation with specialist rating of asthma control r=0.52).³⁷ An ACT score of 19

provided an optimum balance of sensitivity (71.3%) and specificity (70.8%) for detecting poorly controlled asthma in non-smokers³⁷ and a score of 18.6 provided the maximum area under the receiver operator characteristic curve in smokers.³⁸ The asthma symptom questions in the PATH Study were validated by demonstrating that self-reported asthma symptom severity was associated with functional status, and prevalence of asthma symptoms (wheeze) was similar to the prevalence of symptoms in NHANES (see online supplemental appendix 1). People with asthma were also asked whether they used asthma medications in the past 12 months ('treated asthma') and what class of medications they regularly used.

Exposures

Tobacco product use

Participants reported lifetime and past-month use of combustible products (cigarettes, traditional cigars, cigarillos, filtered cigars, pipe tobacco and hookah) and non-combustible products (snus pouches, other smokeless tobacco (loose snus, moist snuff, dip, spit or chewing tobacco) and e-cigarettes). Pictures and descriptions were displayed for each product to ensure accuracy.

Tobacco product use was modelled two ways. First, models included four mutually exclusive past-month categories—never use, former use but none in the past month, current non-combustible use only and current combustible product use (including those with non-combustible use).

Second, six product type categorical variables were developed that described past-month use: tobacco use but none in the past 30 days ('former users'), and past 30-day use of cigarettes, e-cigarettes, cigars, smokeless tobacco, pipe or hookah. These 30-day use groups were not mutually exclusive, so individuals could be counted in several groups if they had used multiple products.

Finally, a variable for intensity of product use was created for each product type (frequency of use in the past month×quantity used per day on the days used). This variable was used in a series of additional analyses to assess for any linear or non-linear dose–response relationships between each product and both asthma prevalence and asthma incidence using bivariate and multivariable analyses. Lowess curves were created to examine whether there was a threshold at which exposure impacted asthma incidence or control (online supplemental file 2). Because no threshold was observed, we did not create any 'threshold of use' variables.

Covariates

As described in table 1, covariates were derived mostly from W2 data, and included variables that could be associated both with tobacco exposure and asthma (or respiratory symptoms in people with asthma). Sociodemographic variables included age, sex, race/ethnicity, education and urbanicity. Other W2 smoke-related exposures that could be associated with respiratory symptoms

included pack-years of cigarette smoking,³⁹ secondhand smoke exposure⁴⁰ and past-month marijuana use.⁴¹ We included obesity categories based on self-reported height and weight (underweight: body mass index (BMI) <18.5; normal: BMI=18.5–24.9, overweight: BMI=25–29.9, class 1 obesity: BMI=30–34.9, class 2 obesity: BMI ≥35).

Statistical analysis

All main analyses were weighted using the W4 longitudinal (all waves) full-sample and replicate weights to adjust for the complex sample design and loss to follow-up. Weighted estimates from W1 to W4 of the PATH Study represent the residents of the USA at W4 who were in the civilian, non-institutionalised population at W1 (only W1 cohort was used). Variances were estimated using the Balanced Repeated Replication (BRR) method⁴² with Fay's adjustment set to 0.3 to increase estimate stability.⁴³ Pack-years of cigarette smoking, tobacco product past 30-day frequency variables and secondhand smoke exposure were Winsorised at the 95th, 95th and 99th percentiles, respectively, to limit the influence of outliers.⁴⁴

Missing data

Participants who had missing asthma diagnosis data, tobacco product use/intensity data, or covariate data were omitted from the analytical sample. Compared with the analytical sample, the non-analytical sample was older (online supplemental table 6), included more men and racial/ethnic minorities, and had lower education level, contained more cigarette smokers (14.9% vs 10.8%, respectively) and more with ever asthma diagnosis (16.1% vs 12.2%, respectively). We repeated all main analyses (model 1 in tables 2–5) using multiple imputation to address missing data for all predictors and covariates using BRR, as was done in the complete case analyses. The multiple imputation analyses found only very small differences for a few variables, primarily in the CIs; thus, we report the complete case analyses here.

Analytical approach

We first examined the associations between tobacco use and covariates using either X^2 or analysis of variance, as appropriate. We then examined cross-sectional associations between tobacco product use at W2 and both the presence of lifetime asthma diagnosis and asthma control (symptom severity) at W2. Finally, we evaluated the longitudinal associations between W2 tobacco product use and both new asthma diagnoses at W3 and W4 and ACT score at W3.

Multivariable weighted Poisson regression was used to obtain adjusted risk ratios (aRRs) and 95% CIs for each of the dichotomous outcomes. Multivariable linear regression was used to model asthma symptom control (ACT scores) at W3, adjusted for W2 ACT values to control for baseline asthma symptom severity.⁴⁵ Similar regressions were used in two sensitivity analyses (online supplemental



Table 1 Characteristics of adults 18–39 years at wave 2 of the PATH Study*, by lifetime asthma status (percentages and means are weighted to reflect US population)

	Total (N=10 267)		Doctor ever said you have asthma?			P value§
			No (N=8835)	Yes (N=1432)		
				Asthma medication in P12M?†		
	N‡	% or mean	%	No (N=1144)	Yes (N=288)	
Past 30-day tobacco use						
Combustible versus non-combustible tobacco use						0.41
Never used tobacco	2010	30.5	30.9	28.6	26.0	
Formerly used tobacco	3231	34.0	33.7	35.2	39.3	
Non-combustible use only	392	3.1	3.1	2.7	4.7	
Any combustible use	4634	32.4	32.3	33.4	29.9	
Specific tobacco products used						
Cigarette	3708	25.9	25.9	26.7	21.5	0.27
Cigar	1645	10.8	10.5	13.4	10.5	0.03
Hookah	984	6.2	6.1	6.7	7.5	0.44
E-cigarette	1323	9.1	9.1	9.6	9.0	0.83
Smokeless	576	4.3	4.3	4.6	3.6¶	0.77
Other smoke-related exposures						
Cigarette pack-years (mean)	10 267	2.0	2.1	1.9	1.7	0.41
Past-week hours of SHS exposure (mean)	10 267	5.4	5.4	5.8	5.8	0.32
Past-month marijuana use**	2225	15.2	14.7	19.1	17.2	<0.01
Relevant medical history						
Body mass index						<0.01
Underweight	336	2.8	2.9	2.3	3.3¶	
Normal	4292	40.3	40.9	38.7	27.0	
Overweight	2906	30.3	30.3	29.3	33.3	
Class 1 obese	1521	14.6	14.5	14.9	15.0	
Class 2+ obese	1212	12.0	11.4	14.8	21.5	
Asthma Control Test (mean score)	1420	23.1	N/A	23.7	20.6	<0.01
Sociodemographics						
Age						<0.01
18–24	5292	34.1	33.2	41.6	35.0	
25–39	4975	65.9	66.8	58.4	65.0	
Sex						<0.01
Female	5341	50.4	50.0	50.3	63.2	
Male	4926	49.6	50.0	49.7	36.8	
Race/ethnicity						0.01

Continued

Table 1 Continued

	Total (N=10267)		Doctor ever said you have asthma?			P value§
			No (N=8835)	Yes (N=1432)		
				Asthma medication in P12M?†		
	N‡	% or mean	%	No (N=1144)	Yes (N=288)	
White††	5569	58.3	57.9	61.3	62.1	
Black††	1512	11.9	11.7	13.7	13.5	
Other††	884	9.8	9.9	9.5	5.8	
Hispanic	2302	19.9	20.5	15.5	18.7	
Education						0.71
No high school degree	1158	8.2	8.4	7.3	6.9	
GED	573	4.6	4.7	3.9	4.1¶	
High school grad	2484	21.6	21.7	20.6	19.9	
Some college	3950	36.2	35.8	38.9	39.6	
≥College graduate	2102	29.4	29.4	29.4	29.5	
Live in an urban area‡‡	8499	84.0	83.8	84.0	91.3	0.07

Online supplemental table 8 reports SEs for all the weighted estimates presented in this table and unweighted Ns for all the variables in the model.

*N=10267 wave 2 adult (age 18–39) respondents without COPD or other non-asthma respiratory diseases at waves 2–4, with wave 4 PATH Study longitudinal (all waves) weights, and complete data on all analytical variables of adult tobacco users. A total of 1408 participants were excluded for missing data on one or more variables in the analysis. Young adults aged 18–24 years, and black participants (or African-Americans) were oversampled relative to population proportions. The weighting procedures adjusted for oversampling and non-response.

†Any P12M asthma meds based on an answer of ‘quick-relief inhaler’ or ‘controller or long-acting inhaler including steroid inhaler’ to the question ‘In the past 12 months, which of the following medications did you regularly take for COPD or asthma?’.

‡Unweighted.

§X² test was used for categorical variables and ANOVA was used for continuous variables. Bold p values are statistically significant at p<0.05.

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

**Marijuana use variable does not distinguish between combustible and non-combustible use.

††Non-Hispanic.

‡‡Derived at wave 1 of the PATH Study.

ANOVA, analysis of variance; COPD, chronic obstructive pulmonary disease; GED, General Education Development (high school equivalency certificate); PATH, Population Assessment of Tobacco and Health; P12M, past 12-month; SHS, secondhand smoke.

table 7) in which we first included adults over 40 years and those with both COPD and asthma diagnoses, and then also removed adjustments for cigarette pack-years, marijuana use and secondhand smoke exposure. All analyses were conducted using Stata survey data procedures, V.15.1 (StataCorp, College Station, Texas, USA), and using PATH Study W1–W4 Restricted Use Files.

RESULTS

Participants with asthma

The weighted prevalence of lifetime asthma was 12.2% (SE=0.4). Characteristics and tobacco use of people with asthma are shown in table 1. About one-fifth of people with asthma (288 of the 1432) had taken asthma medication in the past 12 months. Tobacco use characteristics were largely similar between those never having asthma,

those with untreated asthma (not taking medication) and those with treated asthma (taking medication), although those with untreated asthma were more likely to be past 30-day cigar smokers and current marijuana users than the other groups (p=0.03 and p<0.01, respectively). Four tables present the association between tobacco product use and asthma prevalence (table 2), asthma incidence (table 3), cross-sectional asthma control (table 4) and prospective asthma control (table 5), as described below.

Cross-sectional relationships between tobacco exposure and asthma prevalence

Multivariable models showed significant associations between lifetime asthma (table 2, model 2) and current cigar use (lifetime prevalence 14.5% in past 30-day cigar smokers vs 11.9% non-past 30-day cigar smokers,



Table 2 Weighted cross-sectional associations between past 30-day tobacco use and lifetime asthma diagnosis at wave 2 of the PATH Study*

Risk factor at wave 2	N†	US population %	Lifetime asthma diagnosis %	Models predicting asthma			
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used	
				Adjusted RR‡	95% CI	Adjusted RR‡	95% CI
Past 30-day tobacco use							
Combustible versus non-combustible tobacco use							
Never used tobacco	2010	30.5	11.2	Ref	Ref	–	–
Formerly used tobacco	3231	34.0	12.9	1.14	0.94 to 1.38	–	–
Non-combustible use only	392	3.1	12.4	1.09	0.76 to 1.55	–	–
Any combustible use	4634	32.4	12.3	1.02	0.83 to 1.24	–	–
Specific tobacco products used							
Former							
No	7036	66.0	11.8	–	–	Ref	Ref
Yes	3231	34.0	12.9	–	–	1.14	0.96 to 1.36
Cigarette							
No	6559	74.1	12.2	–	–	Ref	Ref
Yes	3708	25.9	12.1	–	–	0.98	0.83 to 1.15
Cigar							
No	8622	89.2	11.9	–	–	Ref	Ref
Yes	1645	10.8	14.5	–	–	1.17	1.00 to 1.36
Hookah							
No	9283	93.8	12.1	–	–	Ref	Ref
Yes	984	6.2	13.5	–	–	0.99	0.81 to 1.20
E-cigarette							
No	8944	90.9	12.1	–	–	Ref	Ref
Yes	1323	9.1	12.7	–	–	0.99	0.83 to 1.19
Smokeless							
No	9691	95.7	12.2	–	–	Ref	Ref
Yes	576	4.3	12.5	–	–	1.08	0.84 to 1.40
Other smoke-related exposures							
Cigarette pack-years (per each 5 pack-years)	10267	–	–	0.97	0.89 to 1.06	0.98	0.90 to 1.07
Past-week SHS exposure (per each 5 hours/week)	10267	–	–	1.01	0.99 to 1.03	1.01	0.99 to 1.03
Past-month marijuana use§							
No	8042	84.8	11.7	Ref	Ref	Ref	Ref
Yes	2225	15.2	15.1	1.29	1.10 to 1.50	1.26	1.07 to 1.48
Relevant medical history							
Body mass index							
Underweight	336	2.8	10.7	0.95	0.65 to 1.39	0.95	0.65 to 1.40
Normal	4292	40.3	11.0	Ref	Ref	Ref	Ref
Overweight	2906	30.3	12.1	1.19	1.01 to 1.40	1.19	1.01 to 1.40
Class 1 obese	1521	14.6	12.5	1.25	1.00 to 1.56	1.25	1.00 to 1.56
Class 2+ obese	1212	12.0	16.4	1.62	1.30 to 2.02	1.62	1.30 to 2.01

Online supplemental table 9 reports SEs for all the weighted estimates presented in this table and adjusted RRs for all the variables in the model.
 *N=10267 wave 2 adult (age 18–39) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory diseases at waves 2–4, with wave 4 PATH Study longitudinal (all waves) weights, and complete data on all analytical variables.
 †Unweighted.
 ‡All RRs adjust for the variables in the table plus age, sex, ethnicity/race, education and lives in an urban area. Bold RRs are statistically significant at p<0.05.
 §Marijuana use variable does not distinguish between combustible and non-combustible use.
 PATH, Population Assessment of Tobacco and Health; RRs, risk ratios; SHS, secondhand smoke.

Table 3 Weighted prospective associations between wave 2 past 30-day tobacco use and new-onset asthma diagnosis at waves 3 or 4 of the PATH Study*

Risk factor at wave 2	N†	US population %	New-onset asthma diagnosis %	Models predicting asthma			
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used	
				Adjusted RR‡	95% CI	Adjusted RR‡	95% CI
Past 30-day tobacco use							
Combustible versus non-combustible tobacco use							
Never used tobacco	1755	30.9	0.8§	Ref	Ref	–	–
Formerly used tobacco	2762	33.7	1.1	1.39	0.63 to 3.07	–	–
Non-combustible use only	345	3.1	1.2§	1.55	0.34 to 7.07	–	–
Any combustible use	3973	32.3	1.2	1.27	0.58 to 2.79	–	–
Specific tobacco products used							
Former							
No	6073	66.3	1.0	–	–	Ref	Ref
Yes	2762	33.7	1.1	–	–	1.36	0.70 to 2.63
Cigarette							
No	5652	74.1	1.0	–	–	Ref	Ref
Yes	3183	25.9	1.1	–	–	0.99	0.53 to 1.86
Cigar							
No	7464	89.5	1.0	–	–	Ref	Ref
Yes	1371	10.5	1.5	–	–	1.44	0.77 to 2.72
Hookah							
No	8000	93.9	1.0	–	–	Ref	Ref
Yes	835	6.1	1.5	–	–	1.35	0.65 to 2.80
E-cigarette							
No	7700	90.9	1.0	–	–	Ref	Ref
Yes	1135	9.1	1.3	–	–	1.12	0.50 to 2.51
Smokeless							
No	8343	95.7	1.0	–	–	Ref	Ref
Yes	492	4.3	0.9§	–	–	0.97	0.29 to 3.28
Other smoke-related exposures							
Cigarette pack-years (per each 5 pack-years)	8835	–	–	1.06	0.83 to 1.37	1.09	0.84 to 1.41
Past-week SHS exposure (per each 5 hours/week)	8835	–	–	0.98	0.91 to 1.06	0.98	0.91 to 1.06
Past-month marijuana use¶							
No	6956	85.3	1.0	Ref	Ref	Ref	Ref
Yes	1879	14.7	1.2	1.12	0.68 to 1.84	1.05	0.66 to 1.69
Relevant medical history							
Body mass index							
Underweight	294	2.9	0.8§	0.82	0.24 to 2.87	0.82	0.24 to 2.83
Normal	3749	40.9	0.8	Ref	Ref	Ref	Ref
Overweight	2510	30.3	0.8	1.11	0.59 to 2.08	1.11	0.59 to 2.09
Class 1 obese	13,03	14.5	1.0	1.30	0.67 to 2.51	1.30	0.67 to 2.52
Class 2+ obese	979	11.4	2.5	3.12	1.67 to 5.86	3.11	1.66 to 5.82

Online supplemental table 10 reports SEs for all the weighted estimates presented in this table and adjusted RRs for all the variables in the model.
 *N=8835 wave 2 adult (age 18–39) respondents never diagnosed with asthma, without chronic obstructive pulmonary disease or other non-asthma respiratory diseases at waves 2–4, with wave 4 PATH Study longitudinal (all waves) weights, and complete data on all analytical variables.
 †Unweighted.
 ‡All RRs adjust for the variables in the table plus age, sex, ethnicity/race, education and lives in an urban area. Bold RRs are statistically significant at p<0.05.
 §Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the coefficient of variation of the estimate or its complement is larger than 30%.
 ¶Marijuana use variable does not distinguish between combustible and non-combustible use.
 PATH, Population Assessment of Tobacco and Health; RRs, risk ratios; SHS, secondhand smoke.



Table 4 Weighted cross-sectional associations between past 30-day tobacco use and Asthma Control Test (ACT) score among adults 18–39 years with asthma at wave 2 of the PATH Study, lower coefficients reflect worse asthma control*

Risk factor at wave 2	N†	US population %	Mean ACT score‡	How tobacco use is modelled			
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used	
				Adjusted coefficient§	95% CI	Adjusted coefficient§	95% CI
Past 30-day tobacco use							
Combustible versus non-combustible tobacco use							
Never used tobacco	255	28.3	23.6	Ref	Ref	–	–
Formerly used tobacco	463	35.9	23.4	–0.13	–0.56 to 0.29	–	–
Non-combustible use only	47	3.1	22.9¶	–0.40	–1.50 to 0.69	–	–
Any combustible use	655	32.6	22.4	–0.86	–1.32 to –0.39	–	–
Specific tobacco products used							
Former							
No	957	64.1	22.9	–	–	Ref	Ref
Yes	463	35.9	23.4	–	–	–0.13	–0.53 to 0.27
Cigarette							
No	901	74.4	23.5	–	–	Ref	Ref
Yes	519	25.6	22.1	–	–	–1.14	–1.66 to –0.62
Cigar							
No	1147	87.1	23.2	–	–	Ref	Ref
Yes	273	12.9	22.5	–	–	–0.08	–0.53 to 0.37
Hookah							
No	1272	93.1	23.1	–	–	Ref	Ref
Yes	148	6.9	22.6	–	–	–0.04	–0.66 to 0.59
E-cigarette							
No	1233	90.5	23.2	–	–	Ref	Ref
Yes	187	9.5	22.3	–	–	–0.26	–0.88 to 0.36
Smokeless							
No	1337	95.6	23.1	–	–	Ref	Ref
Yes	83	4.4	22.9	–	–	0.15	–0.59 to 0.89
Other smoke-related exposures							
Cigarette pack-years (per each 5 pack-years)	1420	–	–	–0.09	–0.31 to 0.13	–0.02	–0.23 to 0.19
Past-week SHS exposure (per each 5 hours/week)	1420	–	–	–0.03	–0.09 to 0.02	–0.02	–0.08 to 0.04
Past-month marijuana use**							
No	1076	81.2	23.2	Ref	Ref	Ref	Ref
Yes	344	18.8	22.6	–0.07	–0.48 to 0.33	–0.01	–0.41 to 0.40
Relevant medical history							
Body mass index							
Underweight	41	2.5	23.2¶	0.22	–1.22 to 1.67	0.23	–1.21 to 1.68
Normal	539	36.4	23.3	Ref	Ref	Ref	Ref
Overweight	394	30.2	23.1	0.02	–0.39 to 0.43	0.01	–0.39 to 0.42
Class 1 obese	215	14.8	23.0	–0.19	–0.62 to 0.25	–0.20	–0.63 to 0.24
Class 2+ obese	231	16.1	22.7	–0.35	–0.80 to 0.09	–0.37	–0.81 to 0.07

Continued

Table 4 Continued

Risk factor at wave 2	N†	US population %	Mean ACT score‡	How tobacco use is modelled				
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used		
				Adjusted coefficient§	95% CI	Adjusted coefficient§	95% CI	
P12M asthma controller medications††								
No	1275	90.3	23.4	Ref	Ref	Ref	Ref	
Yes	145	9.7	20.1	-3.26	-4.05 to -2.46	-3.31	-4.09 to -2.52	
Sociodemographics								
Sex								
Female	770	53.0	22.9	Ref	Ref	Ref	Ref	
Male	650	47.0	23.3	0.47	0.16 to 0.78	0.44	0.11 to 0.76	
Education								
No high school degree	165	7.2	22.3	Ref	Ref	Ref	Ref	
GED	73	3.9	22.5	0.31	-0.77 to 1.38	0.34	-0.74 to 1.43	
High school grad	309	20.3	22.7	0.44	-0.21 to 1.09	0.40	-0.23 to 1.04	
Some college	577	39.1	23.1	0.72	0.13 to 1.32	0.70	0.12 to 1.29	
≥College graduate	296	29.4	23.7	1.07	0.34 to 1.79	0.99	0.27 to 1.71	

Online supplemental table 11 reports SEs for all the weighted estimates presented in this table and adjusted RRs for all the variables in the model. *N=1420 wave 2 adult (age 18–39) respondents with valid ACT scores, without chronic obstructive pulmonary disease or other non-asthma respiratory diseases at waves 2–4, with wave 4 PATH Study longitudinal (all waves) weights, and complete data on all analytical variables.

†Unweighted.

‡ACT scores can range from 5 to 25. A higher ACT score represents more controlled asthma.

§All (unstandardised) coefficients adjust for the variables in the table plus age, race/ethnicity and lives in an urban area. Bold coefficients are statistically significant at $p < 0.05$.

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

**Marijuana use variable does not distinguish between combustible and non-combustible use.

††P12M use of asthma controller medication(s).

GED, General Education Development (high school equivalency certificate); PATH, Population Assessment of Tobacco and Health; P12M, past 12-month; RRs, risk ratios; SHS, secondhand smoke.

aRR=1.17, 95% CI (1.00 to 1.36)); marijuana use (15.1% vs 11.7%, aRR=1.26, 95% CI (1.07 to 1.48)); and weight status (16.4% vs 11.0%, aRR=1.62, 95% CI (1.30 to 2.01) for class 2 obesity vs normal weight). However, the relationship between cigars and lifetime asthma was borderline statistically significant ($p=0.057$). Additional analyses with quantity/frequency measures of tobacco product use did not detect a dose–response relationship between intensity of tobacco product use and lifetime asthma (not shown).

Relationship between tobacco exposure and asthma incidence

New-onset asthma at W3 or W4 was diagnosed in 1.3% (SE=0.2) of young adults aged 18–24 years, and 0.9% (SE=0.1) of adults aged 25–39 years (online supplemental table 10). In the multivariable longitudinal analyses (table 3, models 1 and 2), we found no association between any type of tobacco product use and new-onset asthma; we did find significant associations between new asthma and weight status (aRR=3.12, 95% CI (1.67 to 5.86) for class 2 obesity vs normal weight). Similar to the

cross-sectional findings, additional analyses using quantity/frequency measures of tobacco product use were consistent with the lack of association (not shown).

Cross-sectional relationships between tobacco exposure and asthma control among people with asthma

Figure 1 illustrates asthma control (as measured by ACT scores) by four categories of tobacco use in W2. Figure 1A shows that mean ACT score was about 1 point lower in combustible tobacco users compared with people who had never used tobacco (22.4 (SE=0.1) vs 23.6 (SE=0.2), respectively, two-sample t-test $p < 0.01$). To illustrate the clinical significance of this finding, figure 1B shows that this difference translated into a higher percentage of combustible tobacco users with uncontrolled asthma symptoms compared with never tobacco users with uncontrolled asthma symptoms (16.1% (SE=1.6) vs 4.2% (SE=1.3), two-sample X^2 $p < 0.01$). Although non-combustible tobacco users had numerically lower asthma control (mean ACT scores) and higher proportions of people with uncontrolled symptoms than never tobacco users, the size of the non-combustible user group was



Table 5 Weighted prospective associations between wave 2 past 30-day tobacco use and wave 3 Asthma Control Test (ACT) score among adults aged 18–39 years at wave 2 of the PATH Study, controlling for wave 2 ACT score, negative coefficients reflect worsening of asthma symptoms over time*

Risk factor at wave 2	N†	Mean wave 2 ACT score‡	Mean wave 3 ACT score‡	How tobacco use is modelled			
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used	
				Adjusted coefficient§	95% CI	Adjusted coefficient§	95% CI
Past 30-day tobacco use							
Combustible versus non-combustible tobacco use							
Never used tobacco	244	23.5	23.5	Ref	Ref	–	–
Formerly used tobacco	428	23.3	23.4	0.06	–0.36 to 0.48	–	–
Non-combustible use only	44	22.9¶	22.4¶	–0.58	–1.86 to 0.70	–	–
Any combustible use	610	22.4	22.6	–0.04	–0.46 to 0.38	–	–
Specific tobacco products used							
Former							
No	898	22.9	23.0	–	–	Ref	Ref
Yes	428	23.3	23.4	–	–	0.07	–0.33 to 0.47
Cigarette							
No	844	23.4	23.4	–	–	Ref	Ref
Yes	482	22.1	22.4	–	–	0.03	–0.43 to 0.49
Cigar							
No	1075	23.2	23.2	–	–	Ref	Ref
Yes	251	22.5	22.6	–	–	–0.11	–0.55 to 0.33
Hookah							
No	1189	23.1	23.1	–	–	Ref	Ref
Yes	137	22.5	22.9	–	–	0.26	–0.17 to 0.69
E-cigarette							
No	1152	23.2	23.2	–	–	Ref	Ref
Yes	174	22.3	22.3	–	–	–0.42	–0.96 to 0.13
Smokeless							
No	1249	23.1	23.1	–	–	Ref	Ref
Yes	77	23.1	22.9	–	–	–0.06	–0.73 to 0.61
Other smoke-related exposures							
Cigarette pack-years (per each 5 pack-years)	1326	–	–	–0.10	–0.36 to 0.16	–0.09	–0.35 to 0.18
Past-week SHS exposure (per each 5 hours/week)	1326	–	–	0.00	–0.05 to 0.04	0.00	–0.05 to 0.05
Past-month marijuana use**							
No	1007	23.2	23.2	Ref	Ref	Ref	Ref
Yes	319	22.6	22.8	–0.02	–0.36 to 0.33	0.01	–0.34 to 0.37
Relevant medical history							
ACT score at wave 2	1326	–	–	0.53	0.45 to 0.62	0.53	0.44 to 0.62
Body mass index							
Underweight	39	23.3¶	22.9¶	–0.39	–1.37 to 0.59	–0.39	–1.39 to 0.61
Normal	509	23.3	23.5	Ref	Ref	Ref	Ref
Overweight	361	23.1	23.1	–0.17	–0.49 to 0.14	–0.19	–0.51 to 0.13
Class 1 obese	206	23.0	23.0	–0.17	–0.64 to 0.30	–0.17	–0.64 to 0.29
Class 2+ obese	211	22.6	22.6	–0.38	–1.03 to 0.27	–0.39	–1.03 to 0.25
P12M asthma controller medications††							
No	1186	23.4	23.5	Ref	Ref	Ref	Ref
Yes	140	20.2	20.2	–1.47	–2.40 to –0.54	–1.49	–2.42 to –0.57

Continued



Table 5 Continued

Risk factor at wave 2	N†	Mean wave 2 ACT score‡	Mean wave 3 ACT score‡	How tobacco use is modelled			
				Model 1 Combustible versus non-combustible tobacco use		Model 2 Specific tobacco products used	
				Adjusted coefficient§	95% CI	Adjusted coefficient§	95% CI
Sociodemographics							
Sex							
Female	727	22.8	22.8	Ref	Ref	Ref	Ref
Male	599	23.4	23.5	0.37	0.09 to 0.65	0.37	0.07 to 0.67
Education							
No high school degree	153	22.2	22.1	Ref	Ref	Ref	Ref
GED	60	22.4	21.9	-0.23	-1.13 to 0.67	-0.23	-1.14 to 0.67
High school grad	290	22.7	22.7	0.41	-0.25 to 1.08	0.4	-0.27 to 1.07
Some college	542	23.1	23.1	0.56	-0.05 to 1.17	0.57	-0.05 to 1.19
≥College graduate	281	23.6	23.8	0.86	0.10 to 1.62	0.87	0.10 to 1.64

Online supplemental table 12 reports SEs for all the weighted estimates presented in this table and adjusted coefficients for all the variables in the model.

*N=1326 wave 2 adult (age 18–39) respondents with valid wave 2 and wave 3 ACT scores, without chronic obstructive pulmonary disease or other non-asthma respiratory diseases at waves 2–4, with wave 4 PATH Study longitudinal (all waves) weights, and complete data on all analytical variables.

†Unweighted.

‡ACT scores can range from 5 to 25. A higher ACT score represents more controlled asthma.

§All (unstandardised) coefficients adjust for the variables in the table plus age, race/ethnicity and lives in an urban area. Bold coefficients are statistically significant at $p < 0.05$.

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

**Marijuana use variable does not distinguish between combustible and non-combustible use.

††P12M use of asthma controller medication(s).

GED, General Education Development (high school equivalency certificate); PATH, Population Assessment of Tobacco and Health; P12M, past-12 month; SHS, secondhand smoke.

small and these differences were not statistically significant.

In the cross-sectional, adjusted, multivariable analyses of asthma control (ACT scores; table 4), scores were lower (worse control) among current combustible tobacco users (beta=-0.86, 95% CI (-1.32 to -0.39); model 1) and cigarette users (beta=-1.14, 95% CI (-1.66 to -0.62); model 2). We also found significant associations between asthma control and sex (male sex beta=0.47 (0.16 to 0.78)) and education (eg, for some college beta=0.72 (0.13 to 1.32)). ACT scores among those with treated asthma were lower than ACT scores in untreated asthma by about 3 points (beta=-3.26, 95% CI (-4.05 to -2.46); model 1). Additional analyses with quantity/frequency measures of each tobacco product use also found a negative association between intensity of cigarette use and ACT scores (not shown).

Longitudinal relationships between tobacco exposure and asthma control among people with asthma

In the longitudinal multivariable analyses, there was little association with asthma control (mean ACT score) over time (W3 ACT score, while controlling for W2 ACT score). No tobacco use category at W2 was associated with ACT score at W3 (table 5, models 1 and 2). Of all the predictor variables, higher ACT score at W2, male sex and higher education were significantly associated with better W3 asthma control in both models, while using asthma controller medication at W2 predicted significantly worse W3 asthma control in both models. Additional analyses

that modelled quantity/frequency of tobacco product use were consistent with the lack of a longitudinal association between presence or absence of specific product use and ACT scores.

Sensitivity analyses examining the relationships between tobacco exposure and asthma prevalence and incidence

To examine why these findings differed from a previous report using PATH Study data,²² a series of sensitivity analyses were conducted to explore how including older people (≥40 years), those with COPD and asthma, and covariates indicating other smoke exposures and pack-years of smoking impacted the estimates described above. As illustrated in figure 2A, expanding the sample resulted in significant cross-sectional associations between tobacco use and asthma, suggesting that these associations are due to the relationship between tobacco and COPD rather than tobacco use and asthma. As shown in figure 2B, associations with asthma became statistically significant for former smokers, cigar users and e-cigarette users. Longitudinal associations also became larger, and the associations between new-onset asthma and any combustible use and cigarette use become statistically significant (online supplemental table 7).

DISCUSSION

In this large, nationally representative, prospective study, combustible tobacco and cigarettes were associated with poorer asthma control compared with control among

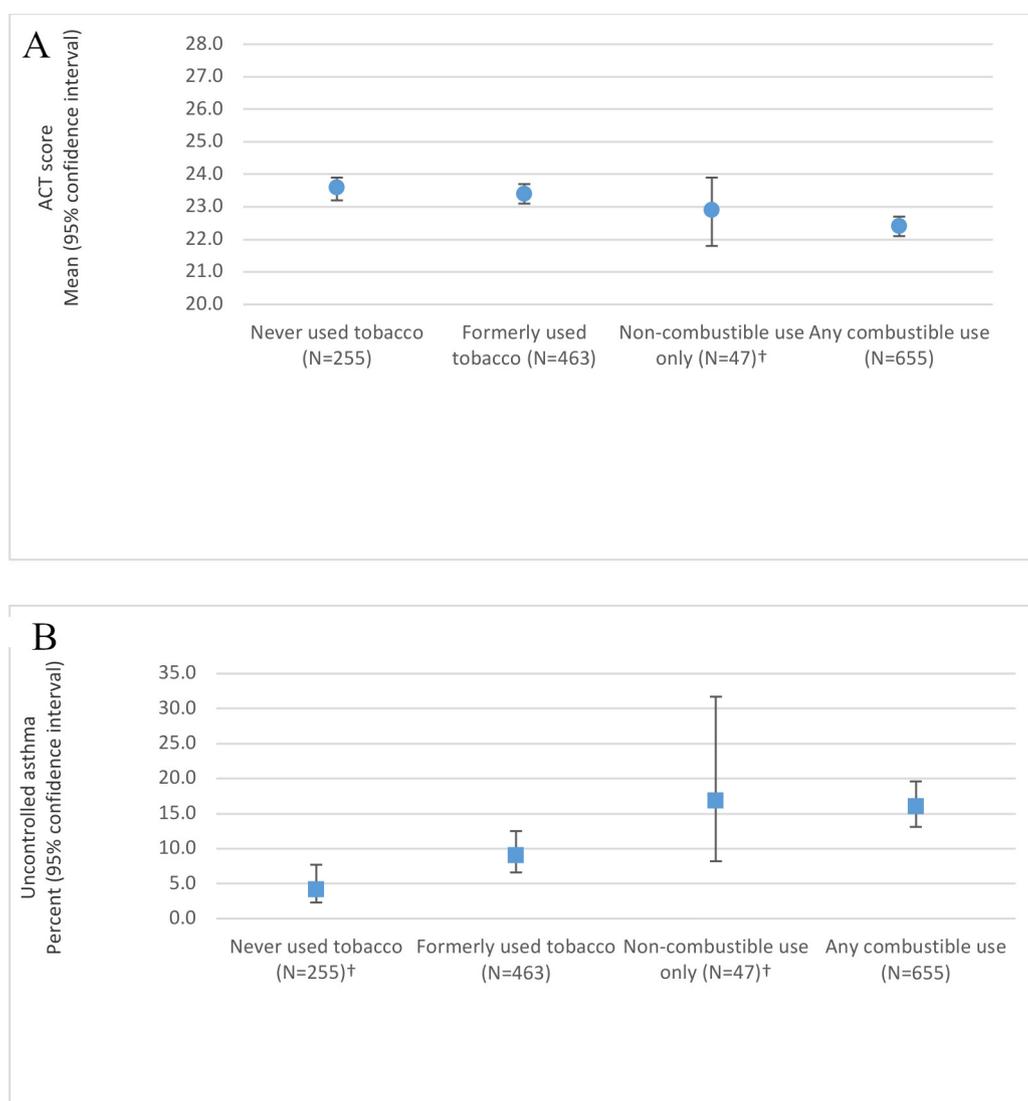


Figure 1 Asthma control by Wave 2 tobacco use^a among adults age 18-39 of the PATH Study,^bPanel A, Weighted mean Asthma Control Test (ACT) score, and Panel B, Percent with uncontrolled asthma^c.

^aNever used tobacco = Never used tobacco, not even one puff; Formerly used tobacco = ever used tobacco, but not in the past 30 days; Non-combustible use only = exclusive non-combustible (e-cigarette, smokeless tobacco, or snus) use in the past 30 days; Any combustible use = combustible (cigarette, pipe, hookah, or cigar) use in the past 30 days regardless of non-combustible use.

^bN = 1,420 Wave 2 adult (age 18-39 years) respondents with valid Wave 2 ACT scores, without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, and with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights and complete data on all analytic variables.

^cUncontrolled asthma is defined as an ACT score of 19 or less. The ACT has a possible range of 5 to 25, where a higher score represents better controlled asthma.

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

non-users in the cross-sectional analysis. These findings strengthen the body of research showing adverse effects of cigarette exposure, even in a young population. No type of tobacco use was associated with a new diagnosis of asthma among adults nor with worsening asthma control over time in analyses that carefully excluded persons with COPD and adjusted for smoking history and other smoke exposures.

In contrast, unadjusted sensitivity analyses including older adults and those with COPD and asthma resulted in significant associations between tobacco use and asthma, suggesting that these associations between tobacco product use and asthma in the sensitivity analyses are spurious, or due to the relationship between tobacco and COPD rather than between tobacco and asthma. A recent meta-analysis of eight epidemiological

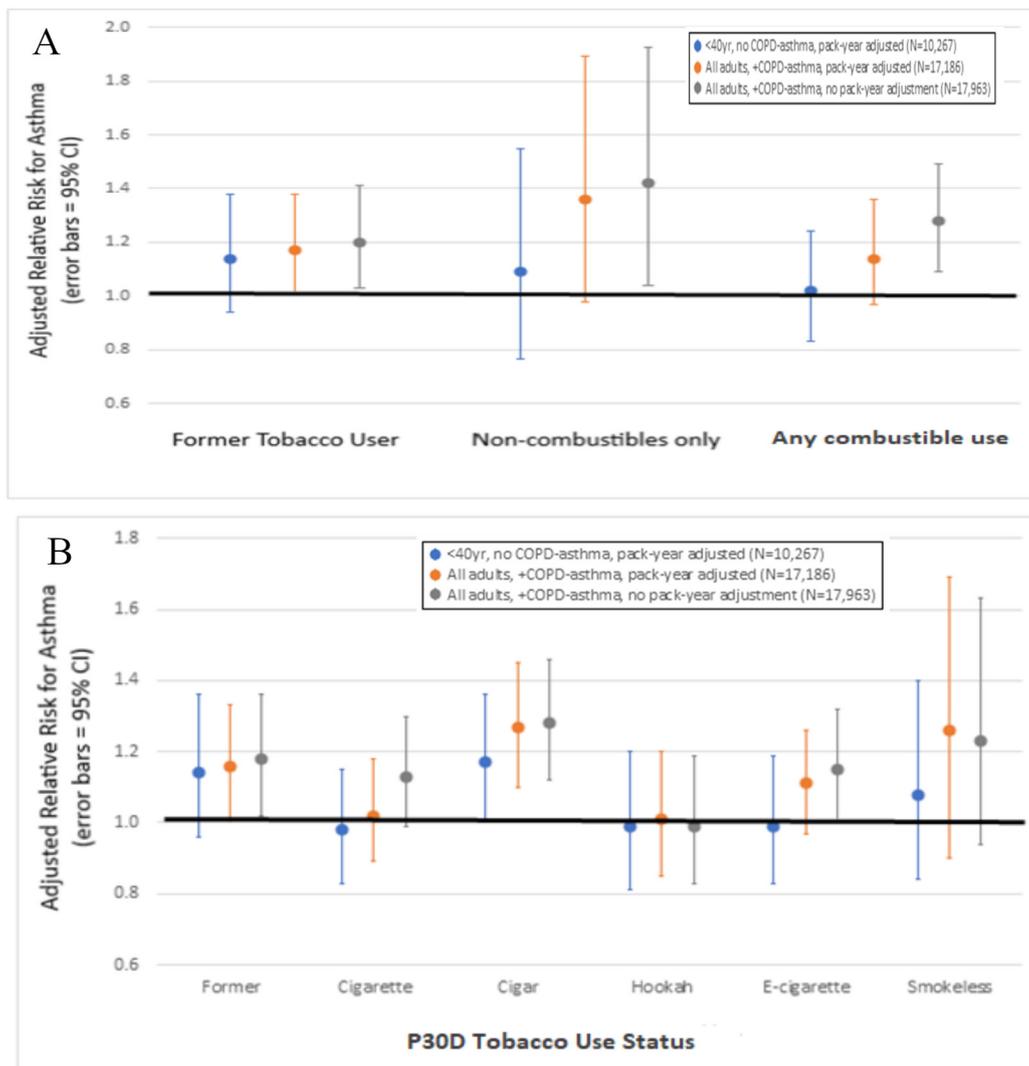


Figure 2 Weighted and adjusted^a sensitivity analyses^b for cross-sectional associations between past 30-day combustible v. non-combustible tobacco use^c (Panel A) and past 30-day tobacco product use^d (Panel B) and lifetime asthma diagnosis among adults 18+ at Wave 2 of the PATH Study.

^aAll relative risks are adjusted for body mass index, age, sex, race/ethnicity, education, and lives in urban area. Relative risks in the “<40, No COPD” and “All, COPD+asthma” groups are also adjusted for cigarette pack-years, past-week secondhand smoke, and past-month marijuana use.

^b<40 years, No COPD = Wave 2 adult (age 18-39 years) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables; All adults, COPD+asthma = Wave 2 adult (age 18+ years) respondents without chronic obstructive pulmonary disease at Waves 2-4, unless also having asthma at Waves 2-4, or other non-asthma respiratory disease at Waves 2-4, with Wave 4 PATH Study longitudinal (all-waves) weights, and complete data on all analytic variables; All adults, COPD+asthma, without adjustment = Wave 2 adult (age 18+ years) respondents without chronic obstructive pulmonary disease at Waves 2-4, unless also having asthma at Waves 2-4, or other non-asthma respiratory disease at Waves 2-4, with Wave 4 PATH Study longitudinal (all-waves) weights, and complete data on all analytic variables. For this group, cigarette pack-years, past-week secondhand smoke, and past-month marijuana use are not involved in defining the analytic sample and are not included in the models.

^cNever used tobacco (reference group) = Never used tobacco, not even one puff; Formerly used tobacco = ever used tobacco, but not in the past 30 days; Non-combustible use only = exclusive non-combustible (e-cigarette, smokeless tobacco, or snus) use in the past 30 days; Any combustible use = combustible tobacco (cigarette, pipe, hookah, or cigar) use in the past 30 days regardless of non-combustible use.

^dEach past 30-day tobacco product use category is dichotomous as any use versus no use in the past 30 days. COPD, chronic obstructive pulmonary disease.

studies concluded that smoking was related to incident asthma (RR 1.61, 95% CI (1.07 to 2.42)),⁹ but most failed to exclude people with COPD,^{16 17 22-26} and many

did not adjust for other smoke exposures,^{16 18 22-25} which may explain the different conclusion in the present study.



Other cross-sectional research has also shown that smoking was associated with poor asthma control,^{10 11 13} and unadjusted prospective studies have also indicated that smoking predicted poor asthma control and asthma exacerbation over time,^{46 47} but these studies also did not remove people with COPD or adjust for cumulative past smoking and other smoke exposures. In contrast, at least one study that carefully controlled for these factors did not show an association between smoking and new asthma⁴⁸; rather, similar to our study, use of controller medications at baseline was associated with persistence of asthma.⁴⁸

Similar to other recent research, cigarette smoking was not associated with a higher or lower risk of lifetime asthma in W2 of the PATH Study (2014–2015),^{10 14 49} indicating that asthma is not deterring smoking in the USA. Because smoking is associated with worse asthma control in this and other studies,^{50 51} and causes or exacerbates multiple other diseases, people with asthma should still be encouraged to quit. Tailored interventions may be useful.⁵²

Little is known about e-cigarette use and the development of asthma in adults. Our study conclusion—that there is no association between e-cigarette use and new-onset asthma—contrasts with cross-sectional epidemiological studies⁵³ and the only other prospective epidemiological study of e-cigarette use and asthma.²² The prospective study used the same data as our study but included older adults as well as those with asthma and COPD and did not adjust for history of smoking and other smoke exposures. By omitting people with COPD and those over age 40 years from this study, as well as by adjusting for other smoke exposures, we carefully isolated the effect of tobacco product use on the development of asthma in adulthood. It should be noted that about 80% of e-cigarette users in this cohort also smoked cigarettes. The small numbers of e-cigarette-only users in this study limited the ability to test for modest associations.

The heterogeneity of asthma may also contribute to mixed findings in epidemiological research, with some types of asthma potentially being more sensitive to smoking. For example, in a longitudinal study that measured lung function, smoking did not worsen the decline of lung function among those with childhood-onset asthma but was associated with greater decline in lung function among patients with adult-onset asthma.¹⁴ The PATH Study did not obtain information that would allow us to determine asthma subtypes.

Several additional study limitations warrant discussion. At the time of these analyses, PATH Study data for tobacco, asthma and asthma symptoms were available W2 through W4, or for only three waves. Analyses over longer time periods will be able to elucidate the longer-term impact of tobacco product use on asthma. Additionally, the e-cigarettes used during the years of these analyses were different from the fourth-generation e-cigarettes now on the market. E-cigarette devices are changing rapidly and are still relatively recent; thus, additional

research should examine e-cigarettes over time. Finally, the PATH Study does not measure all subject characteristics and exposures associated with asthma risk, such as allergy or atopy,⁵⁴ environmental ozone specifically,^{26 55} environmental air pollution in general⁵⁶ and prenatal smoke exposure.⁵⁷ Such measures could enable more specific predictive models. Despite these limitations, these carefully adjusted analyses of a US population sample provide important, current information about the impact of tobacco products on asthma.

CONCLUSION

Combustible tobacco and cigarette use were associated with worse asthma control cross-sectionally, but combustible tobacco product and e-cigarette use were not associated with asthma prevalence, incident asthma or change in symptom severity in adults with asthma when individuals with COPD were excluded and analyses were adjusted for other smoke exposures. Clinicians caring for patients with asthma should address smoking, and research on the impacts of tobacco on health should carefully measure and adjust for these potential confounders.

Author affiliations

¹Research Division, Department of Psychiatry, Dartmouth Health, Lebanon, New Hampshire, USA

²Dartmouth College Geisel School of Medicine, Hanover, New Hampshire, USA

³The C Everette Koop Institute, Dartmouth College, Lebanon, New Hampshire, USA

⁴The Dartmouth Institute for Health Policy and Clinical Practice, Dartmouth College, Lebanon, New Hampshire, USA

⁵Behavioral Health and Health Policy Practice, Westat, Rockville, Maryland, USA

⁶Department of Health and Behavior, Roswell Park Comprehensive Cancer Center, Buffalo, New York, USA

⁷Division of Epidemiology, Services and Prevention Research (DESPR), National Institute on Drug Abuse, Bethesda, Maryland, USA

⁸Office of Science, Center for Tobacco Products, Silver Spring, Maryland, USA

Twitter Susanne E Tanski @stkidsdoc

Contributors JDS, MFB and SET were involved in the initial conception of the research questions. All authors were involved in the planning of the data analyses and interpretation of the data analyses. MJH analysed the data. MFB wrote the manuscript. All authors were involved in reviewing, editing and final approval of the manuscript. MFB is responsible for the overall content.

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Patient consent for publication Not required.

Ethics approval This study involves human participants. The study was conducted by Westat and approved by the Westat Institutional Review Board (IRB) (Westat IRB # 0000695; PATH project number #8954). Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available in a public, open access repository. PATH data are available for public use at <https://www.icpsr.umich.edu/web/NAHDAP/studies/36498>.

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e-Appendix

Section 1: Validation of asthma measures in the PATH Study

1a. Validation of self-reported asthma diagnosis

For prevalence of asthma, the PATH Study utilized the following questions for lifetime and past 12-month asthma diagnosis: “Has a doctor, nurse or other health professional EVER told you that you had any of the following lung or respiratory conditions? Choose all that apply. COPD, Chronic Bronchitis, Emphysema, Asthma, Some other lung or respiratory condition, None of the above” and “IN THE PAST 12 MONTHS, has a doctor ever told you that you had any of the following lung or respiratory conditions? Choose all that apply. COPD, Chronic Bronchitis, Emphysema, Asthma, Some other lung or respiratory condition, None of the above.” We validated asthma diagnoses with symptoms, functional status and NHANES data.

To assess respiratory symptoms in all patients, the PATH Study utilized the core wheezing module from the widely used International Study of Asthma and Allergies in Children (ISAAC).¹ Responses to the seven ISAAC questions were summed to create a respiratory symptoms index ranging from 0 to 9, where 0 represented no respiratory symptoms, and 9 the highest level of symptoms (i.e., a “yes” to all dichotomous outcomes and the highest level for questions with multiple responses). We previously established that people with a summary score ≥ 3 had symptoms associated with functional impairment, or “functionally important respiratory symptoms.”²

The Asthma Control Test (ACT) was used to assess asthma symptom control or severity among people with an asthma diagnosis. The ACT is a previously validated, five item measure that creates a summary score ranging from 5-25, with a higher score indicating better asthma control (fewer symptoms).³ The ACT items are shown in e-Appendix Table 1.

e-Table 1: Asthma Control Test Questions

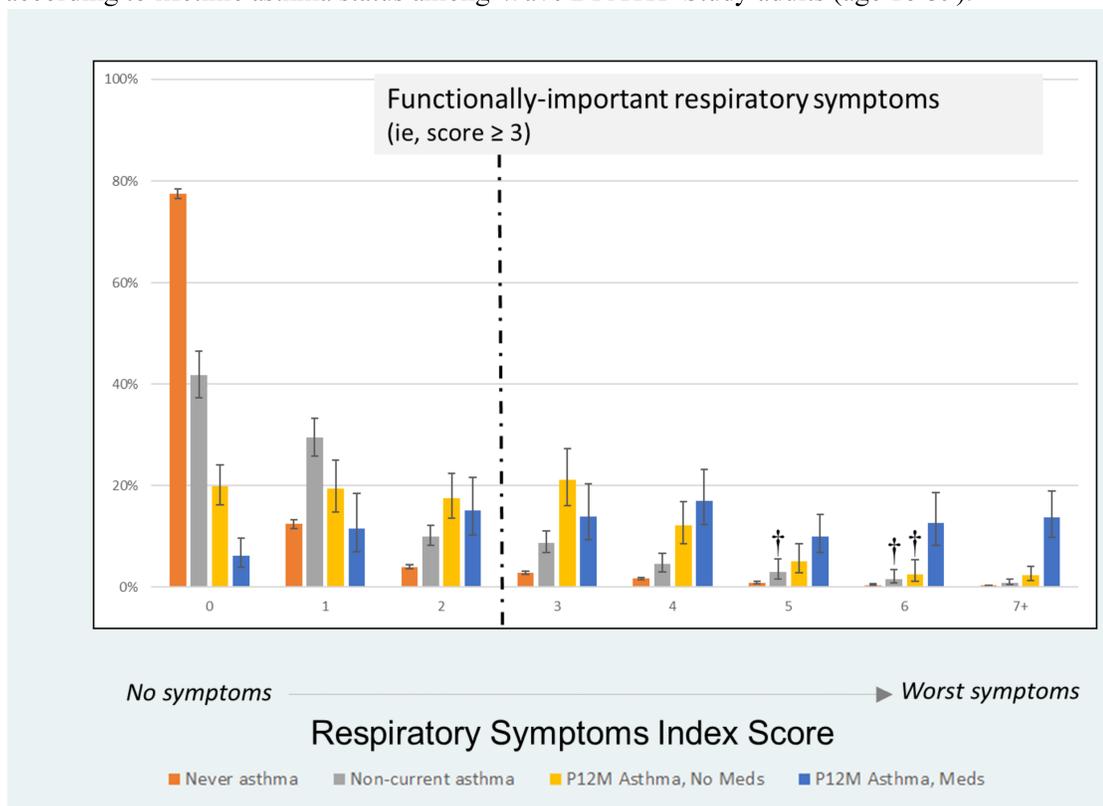
Impact on daily activities (AX0227)	In the past 30 days, how much of the time did your asthma keep you from getting as much done at work, school or at home? 1 All of the time 2 Most of the time 3 Some of the time 4 A little of the time 5 None of the time
Frequency: shortness of breath (AX0228)	In the past 30 days, how often have you had shortness of breath? 1 More than once a day 2 Once a day 3 3-6 times a week 4 Once or twice a week 5 None at all
Sleep disturbance due to asthma symptoms – 30 days (AX0229)	In the past 30 days, how often did your asthma symptoms (such as wheezing, coughing, shortness of breath, chest tightness or pain) wake you up at night or earlier than usual in the morning? 1 4 or more nights a week 2 2 or 3 nights 3 Once a week 4 Once or twice 5 None at all
Frequency: inhaler, nebulizer, controlling medications (AX0230)	In the past 30 days, how often have you used a rescue inhaler, nebulizer treatment, or other controlling medication (such as albuterol)? 1 3 or more times per day 2 1 or 2 times per day 3 2 or 3 times per week 4 Once a week or less 5 Not at all
Asthma control rating (AX0231)	How would you rate your asthma control during the past 30 days? 1 Not controlled at all 2 Poorly controlled 3 Somewhat controlled 4 Well controlled 5 Completely controlled

Concurrent validity of asthma diagnosis

We evaluated concurrent validity of self-reported lifetime and past 12-month asthma diagnosis by examining the relationships between self-reported asthma diagnosis, respiratory symptoms, and asthma treatment among Wave 2 adults age 18-39. Functionally important respiratory symptoms (respiratory symptom index

>=3) were dramatically more common in adults with past 12-month and ever diagnosis of asthma compared to those without asthma: 52.9% (SE=2.4) for those with past 12-month asthma vs. 7.2% (SE=0.3) for those without past 12-month asthma; and 33.1% (SE=1.4) for those with lifetime asthma vs. 6.2% (SE=0.2) for those who never had asthma. The relationship between number of respiratory symptoms and asthma diagnosis is shown in e-Figure 1. These figures also

e-Figure 1. Weighted proportion with respiratory symptoms (index score 0 to 9) according to lifetime asthma status among Wave 2 PATH^a Study adults (age 18-39).



^a Population Assessment of Tobacco and Health. N = 14,800 Wave 2 adults age 18-39 without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Wave 2. PATH Study Wave 2 cross-sectional weights were used.

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

demonstrate the positive relationship between having high levels of respiratory symptoms and asthma diagnosis with past 12-month asthma medication treatment, a marker of more severe asthma.

We also evaluated concurrent validity of self-reported past 12-month asthma diagnosis by examining the relationships between self-reported asthma diagnosis and past 12-month functional outcomes. As previous research has demonstrated that asthma was associated with emergency department utilization,⁴ self-assessment of poor health⁴, as well as anxiety and depression,⁵⁻⁷ we utilized four measures of past 12-month functional impairment, physical health, and mental health to validate asthma diagnosis (measures described in Methods section, ratings for function and health are shown in e-Table 2 below).

e-Table 2. Weighted distributions of health and functional status for Wave 2 PATH^a Study adults (age 18-39)

Question	PATH ID	Responses	% (SE)
In the past 12 months, have you visited an emergency room or urgent care center for a health problem of your own?	AX0302	0 visits	78.4 (0.5)
		1 or 2 visits	17.8 (0.4)
In past 12 months, how often did you make emergency department (ED), urgent care visits due to health conditions? (Health)	AX0155	3+ visits	3.8 (0.2)
In general, how would you rate your physical health? (Health)	AX0090	Excellent	19.0 (0.5)
		V. good	37.5 (0.6)
		Good	33.1 (0.6)
		Fair/Poor	10.4 (0.3)
P12M Internalizing GAIN score (level of depression/ anxiety) (Function)	Derived variables	Low	61.2 (0.6)
		Moderate	23.3 (0.5)
		High	15.5 (0.4)
Your health limits you in: - Walking 1 mile (Function)	AX0097_04	No	94.8 (0.2)
		Yes	5.2 (0.2)

^a Population Assessment of Tobacco and Health Study Wave 2 adults age 18-39 without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Wave 2; N = 15,170 for ED or urgent care visits; N = 15,200 for physical health; N = 15,060 for internalizing GAIN; N = 15,134 for walking 1 mile. PATH Study Wave 2 cross-sectional weights were used.

Using (multinomial) logistic regression models adjusted for age, gender, race/ethnicity and obesity, we found that asthma diagnosis predicted greater levels of emergency department visits and lower ratings of physical and mental health in Wave 2 (shown in e-Table 3).

e-Table 3. Weighted association between lifetime asthma diagnosis and functional outcomes among Wave 2 PATH^a Study adults (age 18-39)

<i>Adjusted^b relative risk ratios (95% CI)</i>						<i>Adjusted^b odds ratio (95% CI)</i>	
P12M emergency department visits		Physical health		P12M internalizing mental health symptoms		Health limits you in walking 1 mile	
0 Visits	Ref	Excellent	Ref	Low	Ref	No	Ref
1-2 Visits	1.46 (1.25, 1.69)	Very good	1.16 (0.97, 1.39)	Moderate	1.28 (1.09, 1.50)	Yes	1.58 (1.20, 2.10)
3+ Visits	2.29 (1.74, 3.02)	Good	1.32 (1.07, 1.63)	High	1.55 (1.30, 1.84)		
		Fair/Poor	1.45 (1.15, 1.84)				

^a Population Assessment of Tobacco and Health Study Wave 2 adults age 18-39 without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Wave 2; N = 14,658 for emergency department visits; N = 14,676 for physical health; N = 14,572 for internalizing GAIN; N = 14,634 for walking 1 mile. PATH Study Wave 2 cross-sectional weights were used.

^b All models control for age, gender, race/ethnicity, and body mass index

Predictive validity of asthma diagnosis

We examined the relationship between self-reported past 12-month asthma diagnosis in one wave and self-reported past 12-month asthma diagnosis in the following wave using W2 adults 18-39 without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with data from Wave 1 to Wave 4. Correlations between diagnoses at one wave and the next waves were high (Wave 2 and Wave 3: $r=0.64$, Wave 3 and Wave 4: $r=0.65$); the correlation between waves over two years were somewhat attenuated (Wave 2 and Wave 4: $r=0.59$.) Of those with past 12-month asthma at Wave 2, 64.1% (SE=2.8) had past 12-month asthma at W3 and 65.0% (SE=2.5) had past 12-month asthma at Wave 4.

1b. Validation of asthma symptom severity

We also sought to validate a measure of asthma symptom severity among those with asthma diagnosis within the PATH Study data. Using a previously validated measure widely used in clinical practice and research, the Asthma Control Test (ACT; questions shown in e-Table 1 above)^{3,8,9}, we examined prevalence of uncontrolled asthma (summary score \leq 19) and the relationship between severity of symptoms (ACT scores) and functional status. Overall, 11.5% (SE=0.8) of adults 18-39 with asthma had uncontrolled asthma based on ACT score \leq 19 in Wave 2: 11.9% (SE=1.1) and 11.2% (SE=1.1) in young adults 18-24 and adults 25-39, respectively. The results for adults were lower than in clinical populations of adults over 18 years (e.g., 31.6%)¹⁰.

We conducted a sensitivity analysis among those with any lifetime asthma diagnosis to assess whether Asthma Control Test (ACT) scores predicted self-reported poor physical health/function. Previous research has indicated that ACT scores less than 19 were indicative of poorly controlled asthma that warranted step-up in asthma therapy³. As such, we deemed this to be clinically relevant symptomatology and assessed the relationship between each of the health/functional status questions above and the summary ACT score less than 19. Weighted, adjusted logistic regressions were conducted.

e-Table 4. Weighted association between asthma symptom severity^a and functional outcomes among Wave 2 PATH^b Study adults (age 18-39)

<i>Adjusted^c relative risk ratios (95% CI)</i>						<i>Adjusted^c odds ratio (95% CI)</i>	
P12M emergency department visits		Physical health		P12M internalizing mental health symptoms		Health limits you in walking 1 mile	
0 Visits	Ref	Excellent	Ref	Low	Ref	No	Ref
1-2 Visits	1.85 (1.26, 2.73)	Very good	2.25 (0.86, 5.87)	Moderate	1.38 (0.92, 2.09)	Yes	3.31 (1.95, 5.62)
3+ Visits	3.46 (2.14, 5.60)	Good	4.71 (1.86, 11.93)	High	4.35 (2.82, 6.69)		
		Fair/Poor	16.59 (6.74, 40.80)				

^a Asthma control test score < 19 represents uncontrolled asthma

^b Population Assessment of Tobacco and Health Study Wave 2 adults age 18-39 without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Wave 2; N = 2,017 for emergency department visits; N = 2,020 for

physical health; N = 2,011 for internalizing GAIN; N = 2,015 for walking 1 mile. PATH Study Wave 2 cross-sectional weights were used.

^c All models control for age, gender, race/ethnicity, and body mass index

As shown in e-Table 4, uncontrolled asthma (based on ACT summary scores) was significantly related to functional status in adults after adjusting for confounders including demographics and obesity. For example, in Wave 2, those with uncontrolled asthma were more than three times as likely to have trouble walking a mile, and more than sixteen times as likely to have fair/poor physical health compared to those with controlled asthma, providing a strong validation of the ACT in PATH Study data.

1c. Validation of diagnosis and asthma symptom severity with NHANES survey data

We also evaluated concurrent validity of both self-reported asthma diagnosis and symptoms within the PATH Study by comparing them to self-reported asthma diagnosis and symptoms within the National Health and Nutrition Examination Survey (NHANES) 2011-12 demographics, medical conditions, and respiratory health datasets. For the comparison between PATH Study and NHANES data, we compared adults ages 18-39.

As shown in e-Table 5, weighted prevalence of asthma diagnosis was 13.8% (SE=0.4) in the PATH Study compared to 17.5% in NHANES. Past 12-month asthma symptoms (wheeze) were similar in the PATH Study and NHANES both in the full population (13.6% [SE=0.3] vs. 11.2% [SE=1.2], respectively), and in people with asthma (41.2% [SE=1.2] vs. 35.8% [SE=4.1], respectively).

e-Table 5. Weighted asthma diagnosis and symptoms among adults 18-39 years from the Wave 2 PATH^a Study 2 and NHANES^a 2011-12 survey

Question	PATH ID	Un-weighted Ns	Weighted Prevalence ^b (SE)	Question	NHANES ID	Un-weighted Ns
Have you ever been told by a doctor, nurse or other health professional that you have asthma? (Y/N)	Derived variable based on AX0119_04	2,462 13,506	13.8% (0.4) 86.2% (0.4)	Has a doctor or other health professional ever told {you/SP} that {you have/ s/he/SP has} asthma? (Y/N)	MCQ010	389 1,871
Have you had wheezing or whistling in the chest in the past 12 months? (Y/N) (full population)	AX0047 (past 12-month) AX0046 (ever) ^c	2,624 13,390	13.6% (0.3) 86.4% (0.3)	In the past 12 months {have you/has SP} had wheezing or whistling in {your/his/her} chest? (Y/N) (full population)	RDQ070	257 2,003
Have you had wheezing or whistling in the chest in the past 12 months? (Y/N) (Asthmatics)	AX0047 (past 12-month) AX0046 (ever) ^c	1,027 1,426	41.2% (1.2) 58.8% (1.2)	In the past 12 months {have you/has SP} had wheezing or whistling in {your/his/her} chest? (Y/N) (Asthmatics)	RDQ070	138 251

^a PATH = Population Assessment of Tobacco and Health; NHANES = National Health and Nutrition Examination Survey

^b Prevalence weighted to reflect estimate for the United States adult population. PATH Study data weighted using cross-sectional weights.

^c AX0046 was also used because respondents who have never had wheezing did not receive the past 12-month question (AX0047). AX0046 provided additional “no” responses since those respondents had not wheezed in the months.

ID= Identification, N=number, SE=Standard Error, Y/N= Yes/No, SP= sample person

In summary, self-reported asthma diagnosis in the PATH Study was associated with greater respiratory symptoms and impairments in functional status. The prevalence of asthma diagnosis in the PATH Study was similar to the prevalence of asthma diagnosis in NHANES. Self-reported asthma symptom severity was likewise associated with functional status, and prevalence of asthma symptoms (wheeze) was similar to the prevalence of symptoms in NHANES.

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Section 2: Analytic sample compared to non-analytic samplee-Table 6. Comparison between analytic and non-analytic samples at Wave 2 of the PATH Study.^a

Variable	Analytic Sample		Non-Analytic Sample		p-value ^b	
	Weighted Percent	95% CI	Weighted Percent	95% CI		
Age						
	18-24	34.1	[33.3, 34.9]	30.2	[27.3, 33.4]	0.03
	25-39	65.9	[65.1, 66.7]	69.8	[66.6, 72.7]	
Sex						
	Female	50.4	[49.6, 51.1]	45.9	[42.3, 49.6]	0.02
	Male	49.6	[48.9, 50.4]	54.1	[50.4, 57.7]	
Ethnicity/Race						
	White ^c	58.3	[57.1, 59.6]	44.4	[40.6, 48.3]	<0.01
	Black ^c	11.9	[11.2, 12.8]	12.9	[10.9, 15.3]	
	Other ^c	9.8	[8.8, 10.8]	13.7	[10.7, 17.5]	
	Hispanic	19.9	[19.0, 20.9]	29.0	[26.1, 32.0]	
Education						
	No high school degree	8.2	[7.6, 8.9]	19.4	[16.2, 23.0]	<0.01
	GED ^d	4.6	[4.1, 5.1]	7.6	[5.9, 9.8]	
	High school grad	21.6	[20.6, 22.5]	26.9	[23.9, 30.1]	
	Some college	36.2	[35.0, 37.5]	28.9	[25.5, 32.7]	
	≥ College grad	29.4	[28.1, 30.8]	17.2	[14.5, 20.2]	
Exclusive cigarette smoker ^e						
	Yes	10.8	[10.1, 11.6]	14.9	[12.8, 17.2]	<0.01
Ever asthma diagnosis						
	Yes	12.2	[11.4, 13.0]	16.1	[13.5, 19.2]	0.01

^a Wave 2 adult (age 18-39) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights. N = 10,267 for the analytic sample and 1,408 for participants who were excluded for missing data on one or more variables in the analysis. Participants in the non-analytic sample are missing some of the variables in this table, so there is not N = 11,675 for each comparison.

^b Chi-square test was used.

^c Non-Hispanic

^d GED = General Education Development (High School Equivalency Certificate)

^e Current (past 30-day) established (more than 100 lifetime cigarettes) exclusive cigarette smoker
The logit method was used to calculate the 95% confidence intervals.

Section 3. Sensitivity analyses

Table 7.

Weighted and adjusted sensitivity analyses between Wave 2 tobacco use and new-onset asthma at Waves 3 or 4 of the PATH Study^a

Sample	Adults <40, No COPD ^b N=8,835		All adults, COPD+Asth ^c N=14,745		All adults, COPD+Asth ^c N=15,435	
	Yes		Yes		No	
Controlled for cigarette pack-years, MJ ^e , SHS ^f	RR ^g	95% CI	RR ^g	95% CI	RR ^g	95% CI
Comb vs. Non-combustible	Ref	Ref	Ref	Ref	Ref	Ref
Never used tobacco	1.39	[0.63,3.07]	1.28	[0.63,2.61]	1.29	[0.64,2.61]
Formerly used tobacco	1.55	[0.34,7.07]	1.03	[0.34,3.13]	1.01	[0.33,3.08]
Non-combustible use only	1.27	[0.58,2.79]	1.93	As [0.98,3.79]	1.99	[1.03,3.88]

Sample	Adults <40, No COPD ^b N=8,835		All adults, COPD+Asth ^c N=14,745		All adults, COPD+Asth ^c N=15,435	
	Yes		Yes		No	
Controlled for cigarette pack-years, MJ ^e , SHS ^f	RR ^g	95% CI	RR ^g	95% CI	RR ^g	95% CI
Specific Product Used						
Former	1.36	[0.70,2.63]	1.24	[0.70,2.20]	1.26	[0.71,2.20]
Cigarette	0.99	[0.53,1.86]	1.69	[1.09,2.61]	1.80	[1.16,2.71]
cigar	1.44	[0.77,2.72]	1.52	[0.98,2.36]	1.32	[0.85,2.00]
Hookah	1.35	[0.65,2.80]	1.84	[0.89,3.79]	1.66	[0.83,3.33]
Non-cigarette	1.12	[0.50,2.51]	1.14	[0.74,1.77]	1.16	[0.75,1.80]
Smokeless	0.97	[0.29,3.28]	0.75	[0.36,1.58]	0.71	[0.34,1.44]

Population Assessment of Tobacco and Health (PATH) Study. Wave 4 longitudinal (all-waves) weights were used.

No COPD = Wave 2 adult (age 18-39 years) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with complete data on all analytic variables. This sample and the following estimates are the main analyses from Table 3.

All adults, COPD+asthma = Wave 2 adult (age 18+ years) respondents without chronic obstructive pulmonary disease at Waves 2-4, unless also having asthma at Waves 2-4, or other non-asthma respiratory disease at Waves 2-4, with complete data on all analytic variables.

All adults, COPD+asthma, without adjustment = Wave 2 adult (age 18+ years) respondents without chronic obstructive pulmonary disease at Waves 2-4, unless also having asthma at Waves 2-4, or other non-asthma respiratory disease at Waves 2-4, with complete data on all analytic variables. For this group, cigarette pack-years, past-week secondhand smoke, and past-month marijuana use are not included in defining the analytic sample and are not included in the models.

As = Past-month marijuana use. Marijuana use variable does not distinguish between combustible and noncombustible use.

S = Past week secondhand smoke exposure

RR = risk ratios (RR) adjust for body mass index, age, sex, ethnicity/race, education, and lives in an urban area in addition to cigarette pack-years, past-month marijuana use, and past week secondhand smoke exposure if noted. Bold RRs are statistically significant.

Section 4. Full versions of main tables including standard errors

The tables prior to this point have been formatted with the intent to optimize communication of the key points of the analysis. The following tables replicate tables in the published manuscript, except they are formatted to include standard errors for all weighted estimates for readers interested in comparing results across rows or tables.

e-Table 8 - Characteristics for adults 18-39 at Wave 2 of the PATH Study,^a by lifetime asthma status (percentages and means are weighted to reflect US population).

	Total (N = 10,267)			Never asthma (N = 8,835)			Ever asthma (N = 1,432)						p-value ^d	
	N ^b	% or mean	SE	N ^c	% or mean	SE	No P12M asthma meds ^b (N = 1,144)			Any P12M asthma meds ^b (N = 288)				
							N ^b	% or mean	SE	N ^c	% or mean	SE		
Past 30-day tobacco use														
Combustible v. non-combustible tobacco use														0.41
Never used tobacco	2,010	30.5%	1.0	1,755	30.9%	1.0	197	28.6%	2.4	58	26.0%	3.8		
Formerly used tobacco	3,231	34.0%	0.8	2,762	33.7%	0.8	373	35.2%	2.1	96	39.3%	3.9		
Non-combustible use only	392	3.1%	0.2	345	3.1%	0.2	34	2.7%	0.6	13	4.7%	1.3		
Any combustible use	4,634	32.4%	0.7	3,973	32.3%	0.8	540	33.4%	1.8	121	29.9%	3.1		
Specific tobacco products used														
Cigarette														0.27
No	6,559	74.1%	0.6	5,652	74.1%	0.7	705	73.3%	1.6	202	78.5%	2.4		
Yes	3,708	25.9%	0.6	3,183	25.9%	0.7	439	26.7%	1.6	86	21.5%	2.4		
Cigar														0.03
No	8,622	89.2%	0.4	7,464	89.5%	0.4	916	86.6%	1.1	242	89.5%	2.0		
Yes	1,645	10.8%	0.4	1,371	10.5%	0.4	228	13.4%	1.1	46	10.5%	2.0		
Hookah														0.44
No	9,283	93.8%	0.3	8,000	93.9%	0.3	1,028	93.3%	0.6	255	92.5%	1.5		
Yes	984	6.2%	0.3	835	6.1%	0.3	116	6.7%	0.6	33	7.5%	1.5		
E-cigarette														0.83
No	8,944	90.9%	0.4	7,700	90.9%	0.4	991	90.4%	0.9	253	91.0%	1.7		
Yes	1,323	9.1%	0.4	1,135	9.1%	0.4	153	9.6%	0.9	35	9.0%	1.7		
Smokeless														0.77
No	9,691	95.7%	0.2	8,343	95.7%	0.3	1,070	95.4%	0.6	278	96.4%	1.4		
Yes	576	4.3%	0.2	492	4.3%	0.3	74	4.6%	0.6	10	3.6% [†]	1.4		
Other smoke-related exposures														
Cigarette pack-years (mean)	10,267	2.0	0.1	8,835	2.1	0.1	1,144	1.9	0.2	288	1.7	0.3	0.41	
Past-week hours of SHS ^e exposure (mean)	10,267	5.4	0.2	8,835	5.4	0.2	1,144	5.8	0.5	288	5.8	1.0	0.32	
Past-month marijuana use ^f														<0.01
No	8,042	84.8%	0.6	6,956	85.3%	0.6	860	80.9%	1.3	226	82.8%	2.7		
Yes	2,225	15.2%	0.6	1,879	14.7%	0.6	284	19.1%	1.3	62	17.2%	2.7		
Relevant medical history														
Body mass index														<0.01
Underweight	336	2.8%	0.2	294	2.9%	0.2	33	2.3%	0.5	9	3.3% [†]	1.5		
Normal	4,292	40.3%	0.7	3,749	40.9%	0.7	452	38.7%	1.9	91	27.0%	3.5		
Overweight	2,906	30.3%	0.6	2,510	30.3%	0.7	310	29.3%	1.9	86	33.3%	4.0		
Class 1 obese	1,521	14.6%	0.5	1,303	14.5%	0.5	176	14.9%	1.8	42	15.0%	2.6		
Class 2+ obese	1,212	12.0%	0.5	979	11.4%	0.5	173	14.8%	1.4	60	21.5%	3.4		
Asthma Control Test (mean score)	1,420	23.1	0.1	N/A	N/A	N/A	1,132	23.7	0.1	288	20.6	0.2	<0.01	
Sociodemographics														
Age														<0.01
18-24	5,292	34.1%	0.4	4,504	33.2%	0.5	644	41.6%	1.8	144	35.0%	3.4		
25-39	4,975	65.9%	0.4	4,331	66.8%	0.5	500	58.4%	1.8	144	65.0%	3.4		
Sex														<0.01
Female	5,341	50.4%	0.4	4,565	50.0%	0.4	586	50.3%	2.1	190	63.2%	3.8		
Male	4,926	49.6%	0.4	4,270	50.0%	0.4	558	49.7%	2.1	98	36.8%	3.8		
Race/ethnicity														0.01
White ^g	5,569	58.3%	0.6	4,783	57.9%	0.7	631	61.3%	1.6	155	62.1%	3.4		
Black ^g	1,512	11.9%	0.4	1,272	11.7%	0.4	192	13.7%	1.2	48	13.5%	2.1		
Other ^g	884	9.8%	0.5	752	9.9%	0.5	107	9.5%	1.3	25	5.8%	1.6		
Hispanic	2,302	19.9%	0.5	2,028	20.5%	0.5	214	15.5%	1.3	60	18.7%	3.2		
Education														0.71
No high school degree	1,158	8.2%	0.3	993	8.4%	0.4	134	7.3%	0.8	31	6.9%	1.6		
GED ^h	573	4.6%	0.3	500	4.7%	0.3	63	3.9%	0.5	10	4.1% [†]	1.5		
High School Grad	2,484	21.6%	0.5	2,170	21.7%	0.5	250	20.6%	1.7	64	19.9%	2.9		
Some college	3,950	36.2%	0.6	3,370	35.8%	0.6	460	38.9%	2.0	120	39.6%	3.7		
≥ College graduate	2,102	29.4%	0.7	1,802	29.4%	0.7	237	29.4%	2.2	63	29.5%	3.8		
Live in urban area ⁱ														0.07
No	1,768	16.0%	1.4	1,562	16.2%	1.4	179	16.0%	1.9	27	8.7%	2.6		
Yes	8,499	84.0%	1.4	7,273	83.8%	1.4	965	84.0%	1.9	261	91.3%	2.6		

^a N = 10,267 Wave 2 adult (age 18-39) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables. Adult tobacco users, young adults ages 18 to 24, and Blacks (or African Americans) were oversampled relative to population proportions. The weighting procedures adjusted for oversampling and nonresponse.

^b Any past 12-month (P12M) asthma meds based on an answer of "quick-relief inhaler" or "controller or long-acting inhaler including steroid inhaler" to the question "In the past 12 months, which of the following medications did you regularly take for COPD or asthma?"

^c Unweighted

^d Chi-square test was used for categorical variables and ANOVA was used for continuous variables. Bold p-values are statistically significant at p<0.05.

^e SHS = secondhand smoke

^f Marijuana use variable does not distinguish between combustible and noncombustible use.

^g Non-Hispanic

^h GED = General Education Development (High School Equivalency Certificate)

ⁱ Derived at Wave 1 of the PATH Study

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

e-Table 9 - Weighted cross-sectional associations between past 30-day tobacco use and lifetime asthma diagnosis at Wave 2 of the PATH Study.^a

Risk factor at Wave 2	N ^b	US population %	SE	Lifetime asthma diagnosis %	SE	Models predicting asthma			
						Model 1 Combustible v non-combustible tobacco use		Model 2 Specific tobacco products used	
						Adjusted RR ^c	95% CI	Adjusted RR ^c	95% CI
Past 30-day tobacco use									
Combustible v. non-combustible tobacco use									
Never used tobacco	2,010	30.5	1.0	11.2	0.8	Ref	Ref	-	-
Formerly used tobacco	3,231	34.0	0.8	12.9	0.8	1.14	[0.94,1.38]	-	-
Non-combustible use only	392	3.1	0.2	12.4	2.0	1.09	[0.76,1.55]	-	-
Any combustible use	4,634	32.4	0.7	12.3	0.5	1.02	[0.83,1.24]	-	-
Specific tobacco products used									
Former									
No	7,036	66.0	0.8	11.8	0.5	-	-	Ref	Ref
Yes	3,231	34.0	0.8	12.9	0.8	-	-	1.14	[0.96,1.36]
Cigarette									
No	6,559	74.1	0.6	12.2	0.5	-	-	Ref	Ref
Yes	3,708	25.9	0.6	12.1	0.6	-	-	0.98	[0.83,1.15]
Cigar									
No	8,622	89.2	0.4	11.9	0.4	-	-	Ref	Ref
Yes	1,645	10.8	0.4	14.5	0.9	-	-	1.17	[1.00,1.36]
Hookah									
No	9,283	93.8	0.3	12.1	0.4	-	-	Ref	Ref
Yes	984	6.2	0.3	13.5	1.1	-	-	0.99	[0.81,1.20]
E-cigarette									
No	8,944	90.9	0.4	12.1	0.4	-	-	Ref	Ref
Yes	1,323	9.1	0.4	12.7	1.1	-	-	0.99	[0.83,1.19]
Smokeless									
No	9,691	95.7	0.2	12.2	0.4	-	-	Ref	Ref
Yes	576	4.3	0.2	12.5	1.5	-	-	1.08	[0.84,1.40]
Other smoke-related exposures									
Cigarette pack-years (per each 5 pack-years)	10,267	-	-	-	-	0.97	[0.89,1.06]	0.98	[0.90,1.07]
Past-week SHS ^d exposure (per each 5 hours/week)	10,267	-	-	-	-	1.01	[0.99,1.03]	1.01	[0.99,1.03]
Past-month marijuana use ^e									
No	8,042	84.8	0.6	11.7	0.4	Ref	Ref	Ref	Ref
Yes	2,225	15.2	0.6	15.1	1.0	1.29	[1.10,1.50]	1.26	[1.07,1.48]
Relevant medical history									
Body mass index									
Underweight	336	2.8	0.2	10.7	1.9	0.95	[0.65,1.39]	0.95	[0.65,1.40]
Normal	4,292	40.3	0.7	11.0	0.6	Ref	Ref	Ref	Ref
Overweight	2,906	30.3	0.6	12.1	0.8	1.19	[1.01,1.40]	1.19	[1.01,1.40]
Class 1 obese	1,521	14.6	0.5	12.5	1.3	1.25	[1.00,1.56]	1.25	[1.00,1.56]
Class 2+ obese	1,212	12.0	0.5	16.4	1.5	1.62	[1.30,2.02]	1.62	[1.30,2.01]
Sociodemographics									
Age									
18-24	5,292	34.1	0.4	14.4	0.6	Ref	Ref	Ref	Ref
25-39	4,975	65.9	0.4	11.1	0.5	0.73	[0.63,0.85]	0.73	[0.63,0.85]
Sex									
Female	5,341	50.4	0.4	12.8	0.6	Ref	Ref	Ref	Ref
Male	4,926	49.6	0.4	11.6	0.5	0.89	[0.76,1.03]	0.88	[0.75,1.02]
Race/ethnicity									
White ^f	5,569	58.3	0.6	12.8	0.5	Ref	Ref	Ref	Ref
Black ^f	1,512	11.9	0.4	14.0	1.1	1.02	[0.85,1.23]	1.01	[0.84,1.22]
Other ^f	884	9.8	0.5	10.9	1.2	0.86	[0.67,1.09]	0.86	[0.68,1.09]
Hispanic	2,302	19.9	0.5	9.9	0.8	0.75	[0.61,0.92]	0.75	[0.61,0.92]
Education									
No high school degree	1,158	8.2	0.3	10.7	1.1	Ref	Ref	Ref	Ref
GED ^g	573	4.6	0.3	10.5	1.5	0.97	[0.67,1.41]	0.97	[0.67,1.40]
High school grad	2,484	21.6	0.5	11.6	0.9	1.02	[0.80,1.30]	1.02	[0.80,1.30]
Some college	3,950	36.2	0.6	13.1	0.7	1.13	[0.89,1.42]	1.13	[0.89,1.43]
≥ College graduate	2,102	29.4	0.7	12.2	0.9	1.16	[0.90,1.51]	1.16	[0.89,1.51]
Live in an urban area ^h									
No	1,768	16.0	1.4	11.1	1.1	Ref	Ref	Ref	Ref
Yes	8,499	84.0	1.4	12.4	0.4	1.15	[0.92,1.43]	1.15	[0.92,1.43]

^a N = 10,267 Wave 2 adult (age 18-39) respondents without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables.

^b Unweighted

^c All risk ratios (RR) adjust for the variables in the table. Bold RRs are statistically significant at p<0.05.

^d SHS = secondhand smoke

^e Marijuana use variable does not distinguish between combustible and noncombustible use.

^f Non-Hispanic

^g GED = General Education Development (High School Equivalency Certificate)

^h Derived at Wave 1 of the PATH Study

e-Table 10 - Weighted prospective associations between Wave 2 past 30-day tobacco use and new-onset asthma diagnosis at Waves 3 or 4 of the PATH Study.^a

Risk factor at Wave 2	N ^b	US population %	SE	New onset asthma diagnosis %	SE	Models predicting asthma			
						Model 1 Combustible v non-combustible tobacco use		Model 2 Specific tobacco products used	
						Adjusted RR ^c	95% CI	Adjusted RR ^c	95% CI
Past 30-day tobacco use									
Combustible v non-combustible tobacco use									
Never used tobacco	1,755	30.9	1.0	0.8†	0.3	Ref	Ref	-	-
Formerly used tobacco	2,762	33.7	0.8	1.1	0.2	1.39	[0.63,3.07]	-	-
Non-combustible use only	345	3.1	0.2	1.2†	0.7	1.55	[0.34,7.07]	-	-
Any combustible use	3,973	32.3	0.8	1.2	0.2	1.27	[0.58,2.79]	-	-
Specific tobacco products used									
Former									
No	6,073	66.3	0.8	1.0	0.2	-	-	Ref	Ref
Yes	2,762	33.7	0.8	1.1	0.2	-	-	1.36	[0.70,2.63]
Cigarette									
No	5,652	74.1	0.7	1.0	0.2	-	-	Ref	Ref
Yes	3,183	25.9	0.7	1.1	0.2	-	-	0.99	[0.53,1.86]
Cigar									
No	7,464	89.5	0.4	1.0	0.1	-	-	Ref	Ref
Yes	1,371	10.5	0.4	1.5	0.4	-	-	1.44	[0.77,2.72]
Hookah									
No	8,000	93.9	0.3	1.0	0.1	-	-	Ref	Ref
Yes	835	6.1	0.3	1.5	0.4	-	-	1.35	[0.65,2.80]
E-cigarette									
No	7,700	90.9	0.4	1.0	0.1	-	-	Ref	Ref
Yes	1,135	9.1	0.4	1.3	0.4	-	-	1.12	[0.50,2.51]
Smokeless									
No	8,343	95.7	0.3	1.0	0.1	-	-	Ref	Ref
Yes	492	4.3	0.3	0.9†	0.4	-	-	0.97	[0.29,3.28]
Other smoke-related exposures									
Cigarette pack-years (per each 5 pack-years)	8,835	-	-	-	-	1.06	[0.83,1.37]	1.09	[0.84,1.41]
Past-week SHS ^d exposure (per each 5 hours/week)	8,835	-	-	-	-	0.98	[0.91,1.06]	0.98	[0.91,1.06]
Past-month marijuana use ^e									
No	6,956	85.3	0.6	1.0	0.1	Ref	Ref	Ref	Ref
Yes	1,879	14.7	0.6	1.2	0.2	1.12	[0.68,1.84]	1.05	[0.66,1.69]
Relevant medical history									
Body mass index									
Underweight	294	2.9	0.2	0.8†	0.4	0.82	[0.24,2.87]	0.82	[0.24,2.83]
Normal	3,749	40.9	0.7	0.8	0.2	Ref	Ref	Ref	Ref
Overweight	2,510	30.3	0.7	0.8	0.2	1.11	[0.59,2.08]	1.11	[0.59,2.09]
Class 1 obese	1,303	14.5	0.5	1.0	0.3	1.30	[0.67,2.51]	1.30	[0.67,2.52]
Class 2+ obese	979	11.4	0.5	2.5	0.7	3.12	[1.67,5.86]	3.11	[1.66,5.82]
Sociodemographics									
Age									
18-24	4,502	33.2	0.5	1.3	0.2	Ref	Ref	Ref	Ref
25-39	4,331	66.8	0.5	0.9	0.1	0.59	[0.36,0.96]	0.61	[0.37,1.00]
Sex									
Female	4,565	50.0	0.4	1.2	0.2	Ref	Ref	Ref	Ref
Male	4,270	50.0	0.4	0.9	0.2	0.72	[0.43,1.18]	0.71	[0.42,1.20]
Race/ethnicity									
White ^f	4,783	57.9	0.7	1.1	0.2	Ref	Ref	Ref	Ref
Black ^f	1,272	11.7	0.4	1.3	0.3	0.99	[0.50,1.94]	0.93	[0.48,1.83]
Other ^f	752	9.9	0.5	0.4†	0.2	0.38	[0.08,1.74]	0.38	[0.08,1.70]
Hispanic	2,028	20.5	0.5	1.1	0.3	0.79	[0.40,1.57]	0.77	[0.39,1.54]
Education									
No high school degree	993	8.4	0.4	2.1	0.6	Ref	Ref	Ref	Ref
GED ^g	500	4.7	0.3	0.8†	0.3	0.38	[0.16,0.93]	0.38	[0.16,0.93]
High school grad	2,170	21.7	0.5	1.3	0.3	0.57	[0.25,1.28]	0.57	[0.25,1.29]
Some college	3,370	35.8	0.6	1.0	0.2	0.42	[0.21,0.84]	0.42	[0.21,0.84]
≥ College graduate	1,802	29.4	0.7	0.7†	0.2	0.39	[0.16,0.98]	0.39	[0.16,0.96]
Live in an urban area^h									
No	1,562	16.2	1.4	0.8†	0.3	Ref	Ref	Ref	Ref
Yes	7,273	83.8	1.4	1.1	0.1	1.56	[0.74,3.30]	1.53	[0.71,3.28]

^a N = 8,835 Wave 2 adult (age 18-39) respondents never diagnosed with asthma, without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables.

^b Unweighted

^c All risk ratios (RR) adjust for the variables in the table. Bold RRs are statistically significant at p<0.05.

^d SHS = secondhand smoke

^e Marijuana use variable does not distinguish between combustible and noncombustible use.

^f Non-Hispanic

^g GED = General Education Development (High School Equivalency Certificate)

^h Derived at Wave 1 of the PATH Study

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

e-Table 11 - Weighted cross-sectional associations between past 30-day tobacco use and Asthma Control Test (ACT) score among adults 18-39 with asthma at Wave 2 of the PATH Study, lower coefficients reflect worse asthma control.^a

Risk factor at Wave 2	N ^b	US population %	SE	Mean ACT score ^c	SE	How tobacco use is modeled			
						Model 1 Combustible v. non-combustible tobacco use		Model 2 Specific tobacco products used	
						Adjusted coef ^d	95% CI	Adjusted coef ^d	95% CI
Past 30-day tobacco use									
Combustible v. non-combustible tobacco use									
Never used tobacco	255	28.3	2.0	23.6	0.2	Ref	Ref	-	-
Formerly used tobacco	463	35.9	1.8	23.4	0.2	-0.13	[-0.56,0.29]	-	-
Non-combustible use only	47	3.1	0.5	22.9†	0.5	-0.40	[-1.50,0.69]	-	-
Any combustible use	655	32.6	1.5	22.4	0.1	-0.86	[-1.32,-0.39]	-	-
Specific tobacco products used									
Former									
No	957	64.1	1.8	22.9	0.1	-	-	Ref	Ref
Yes	463	35.9	1.8	23.4	0.2	-	-	-0.13	[-0.53,0.27]
Cigarette									
No	901	74.4	1.4	23.5	0.1	-	-	Ref	Ref
Yes	519	25.6	1.4	22.1	0.2	-	-	-1.14	[-1.66,-0.62]
Cigar									
No	1,147	87.1	0.9	23.2	0.1	-	-	Ref	Ref
Yes	273	12.9	0.9	22.5	0.2	-	-	-0.08	[-0.53,0.37]
Hookah									
No	1,272	93.1	0.6	23.1	0.1	-	-	Ref	Ref
Yes	148	6.9	0.6	22.6	0.3	-	-	-0.04	[-0.66,0.59]
E-cigarette									
No	1,233	90.5	0.9	23.2	0.1	-	-	Ref	Ref
Yes	187	9.5	0.9	22.3	0.3	-	-	-0.26	[-0.88,0.36]
Smokeless									
No	1,337	95.6	0.5	23.1	0.1	-	-	Ref	Ref
Yes	83	4.4	0.5	22.9	0.4	-	-	0.15	[-0.59,0.89]
Other smoke-related exposures									
Cigarette pack-years (per each 5 pack-years)	1,420	-	-	-	-	-0.09	[-0.31,0.13]	-0.02	[-0.23,0.19]
Past-week SHS ^e exposure (per each 5 hours/week)	1,420	-	-	-	-	-0.03	[-0.09,0.02]	-0.02	[-0.08,0.04]
Past-month marijuana use ^f									
No	1,076	81.2	1.3	23.2	0.1	Ref	Ref	Ref	Ref
Yes	344	18.8	1.3	22.6	0.2	-0.07	[-0.48,0.33]	-0.01	[-0.41,0.40]
Relevant medical history									
Body mass index									
Underweight	41	2.5	0.5	23.2†	0.6	0.22	[-1.22,1.67]	0.23	[-1.21,1.68]
Normal	539	36.4	1.5	23.3	0.1	Ref	Ref	Ref	Ref
Overweight	394	30.2	1.7	23.1	0.2	0.02	[-0.39,0.43]	0.01	[-0.39,0.42]
Class 1 obese	215	14.8	1.6	23.0	0.2	-0.19	[-0.62,0.25]	-0.20	[-0.63,0.24]
Class 2+ obese	231	16.1	1.5	22.7	0.2	-0.35	[-0.80,0.09]	-0.37	[-0.81,0.07]
P12M asthma controller medications ^g									
No	1,275	90.3	1.0	23.4	0.1	Ref	Ref	Ref	Ref
Yes	145	9.7	1.0	20.1	0.4	-3.26	[-4.05,-2.46]	-3.31	[-4.09,-2.52]
Sociodemographics									
Age									
18-24	781	40.3	1.6	23.1	0.1	Ref	Ref	Ref	Ref
25-39	639	59.7	1.6	23.1	0.1	-0.01	[-0.33,0.31]	0.00	[-0.32,0.31]
Sex									
Female	770	53.0	1.9	22.9	0.1	Ref	Ref	Ref	Ref
Male	650	47.0	1.9	23.3	0.1	0.47	[0.16,0.78]	0.44	[0.11,0.76]
Race/ethnicity									
White ^h	780	61.5	1.5	23.2	0.1	Ref	Ref	Ref	Ref
Black ^h	238	13.7	1.1	22.7	0.2	-0.40	[-0.87,0.07]	-0.42	[-0.89,0.05]
Other ^h	132	8.8	1.1	23.2	0.3	-0.28	[-0.99,0.43]	-0.26	[-0.98,0.45]
Hispanic	270	16.0	1.3	23.0	0.2	-0.15	[-0.63,0.34]	-0.15	[-0.62,0.33]
Education									
No high school degree	165	7.2	0.7	22.3	0.3	Ref	Ref	Ref	Ref
GED ⁱ	73	3.9	0.6	22.5	0.5	0.31	[-0.77,1.38]	0.34	[-0.74,1.43]
High school grad	309	20.3	1.5	22.7	0.2	0.44	[-0.21,1.09]	0.40	[-0.23,1.04]
Some college	577	39.1	1.8	23.1	0.1	0.72	[0.13,1.32]	0.70	[0.12,1.29]
≥ College graduate	296	29.4	1.8	23.7	0.2	1.07	[0.34,1.79]	0.99	[0.27,1.71]
Live in an urban area ^j									
No	205	14.6	1.6	23.3	0.2	Ref	Ref	Ref	Ref
Yes	1,215	85.4	1.6	23.1	0.1	-0.06	[-0.58,0.46]	-0.04	[-0.56,0.48]

^a N = 1,420 Wave 2 adult (age 18-39) respondents with valid ACT scores, without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables.

^b Unweighted

^c ACT scores can range from 5 to 25. A higher ACT score represents more controlled asthma.

^d All (unstandardized) coefficients adjust for the variables in the table. Bold coefficients are statistically significant at p<0.05.

^e SHS = secondhand smoke

^f Marijuana use variable does not distinguish between combustible and noncombustible use.

^g Past 12-month use of asthma controller medication(s)

^h Non-Hispanic

ⁱ GED = General Education Development (High School Equivalency Certificate)

^j Derived at Wave 1 of the PATH Study

e-Table 12 - Weighted prospective associations between Wave 2 past 30-day tobacco use and Wave 3 Asthma Control Test (ACT) score among adults age 18-39 at Wave 2 of the PATH Study, controlling for Wave ACT scores, negative coefficients reflect worsening of asthma symptoms over time.^a

Risk factor at Wave 2	N ^b	Mean Wave 2 ACT score ^c	SE	Mean Wave 3 ACT score ^c	SE	How tobacco use is modeled			
						Model 1 Combustible v. non-combustible tobacco use		Model 2 Specific tobacco products used	
						Adjusted coef ^d	95% CI	Adjusted coef ^d	95% CI
Past 30-day tobacco use									
Combustible v. non-combustible tobacco use									
Never used tobacco	244	23.5	0.2	23.5	0.2	Ref	Ref	-	-
Formerly used tobacco	428	23.3	0.2	23.4	0.2	0.06	[-0.36,0.48]	-	-
Non-combustible use only	44	22.9†	0.6	22.4†	0.8	-0.58	[-1.86,0.70]	-	-
Any combustible use	610	22.4	0.1	22.6	0.1	-0.04	[-0.46,0.38]	-	-
Specific tobacco products used									
Former									
No	898	22.9	0.1	23.0	0.1	-	-	Ref	Ref
Yes	428	23.3	0.2	23.4	0.2	-	-	0.07	[-0.33,0.47]
Cigarette									
No	844	23.4	0.1	23.4	0.1	-	-	Ref	Ref
Yes	482	22.1	0.2	22.4	0.2	-	-	0.03	[-0.43,0.49]
Cigar									
No	1,075	23.2	0.1	23.2	0.1	-	-	Ref	Ref
Yes	251	22.5	0.2	22.6	0.2	-	-	-0.11	[-0.55,0.33]
Hookah									
No	1,189	23.1	0.1	23.1	0.1	-	-	Ref	Ref
Yes	137	22.5	0.3	22.9	0.2	-	-	0.26	[-0.17,0.69]
E-cigarette									
No	1,152	23.2	0.1	23.2	0.1	-	-	Ref	Ref
Yes	174	22.3	0.3	22.3	0.3	-	-	-0.42	[-0.96,0.13]
Smokeless									
No	1,249	23.1	0.1	23.1	0.1	-	-	Ref	Ref
Yes	77	23.1	0.5	22.9	0.5	-	-	-0.06	[-0.73,0.61]
Other smoke-related exposures									
Cigarette pack-years (per each 5 pack-years)	1,326	-	-	-	-	-0.10	[-0.36,0.16]	-0.09	[-0.35,0.18]
Past-week SHS ^e exposure (per each 5 hours/week)	1,326	-	-	-	-	0.00	[-0.05,0.04]	0.00	[-0.05,0.05]
Past-month marijuana use ^f									
No	1,007	23.2	0.1	23.2	0.1	Ref	Ref	Ref	Ref
Yes	319	22.6	0.2	22.8	0.2	-0.02	[-0.36,0.33]	0.01	[-0.34,0.37]
Relevant medical history									
ACT score at Wave 2	1,326	-	-	-	-	0.53	[0.45,0.62]	0.53	[0.44,0.62]
Body mass index									
Underweight	39	23.3†	0.6	22.9†	0.7	-0.39	[-1.37,0.59]	-0.39	[-1.39,0.61]
Normal	509	23.3	0.1	23.5	0.1	Ref	Ref	Ref	Ref
Overweight	361	23.1	0.2	23.1	0.2	-0.17	[-0.49,0.14]	-0.19	[-0.51,0.13]
Class 1 obese	206	23.0	0.2	23.0	0.2	-0.17	[-0.64,0.30]	-0.17	[-0.64,0.29]
Class 2+ obese	211	22.6	0.2	22.6	0.3	-0.38	[-1.03,0.27]	-0.39	[-1.03,0.25]
P12M asthma controller medications ^g									
No	1,186	23.4	0.1	23.5	0.1	Ref	Ref	Ref	Ref
Yes	140	20.2	0.4	20.2	0.5	-1.47	[-2.40,-0.54]	-1.49	[-2.42,-0.57]
Sociodemographics									
Age									
18-24	730	23.1	0.1	23.2	0.1	Ref	Ref	Ref	Ref
25-39	596	23.1	0.1	23.1	0.1	-0.10	[-0.41,0.22]	-0.10	[-0.42,0.21]
Sex									
Female	727	22.8	0.1	22.8	0.1	Ref	Ref	Ref	Ref
Male	599	23.4	0.1	23.5	0.1	0.37	[0.09,0.65]	0.37	[0.07,0.67]
Ethnicity/Race									
White ^h	731	23.2	0.1	23.2	0.1	Ref	Ref	Ref	Ref
Black ^h	218	22.6	0.2	22.7	0.2	-0.21	[-0.63,0.21]	-0.22	[-0.64,0.20]
Other ^h	125	23.2	0.3	23.3	0.2	0.00	[-0.35,0.35]	-0.01	[-0.36,0.35]
Hispanic	252	22.9	0.2	23.0	0.2	-0.01	[-0.40,0.38]	-0.02	[-0.40,0.37]
Education									
No high school degree	153	22.2	0.3	22.1	0.3	Ref	Ref	Ref	Ref
GED ⁱ	60	22.4	0.5	21.9	0.5	-0.23	[-1.13,0.67]	-0.23	[-1.14,0.67]
High school grad	290	22.7	0.2	22.7	0.3	0.41	[-0.25,1.08]	0.4	[-0.27,1.07]
Some college	542	23.1	0.1	23.1	0.1	0.56	[-0.05,1.17]	0.57	[-0.05,1.19]
≥ College graduate	281	23.6	0.2	23.8	0.2	0.86	[0.10,1.62]	0.87	[0.10,1.64]
Live in an urban area ^j									
No	187	23.3	0.2	22.9	0.3	Ref	Ref	Ref	Ref
Yes	1,139	23.0	0.1	23.2	0.1	0.39	[-0.13,0.91]	0.38	[-0.14,0.91]

^a N = 1,326 Wave 2 adult (age 18-39) respondents with valid Wave 2 and Wave 3 ACT scores, without chronic obstructive pulmonary disease or other non-asthma respiratory disease at Waves 2-4, with Wave 4 Population Assessment of Tobacco and Health (PATH) Study longitudinal (all-waves) weights, and complete data on all analytic variables.

^b Unweighted

^c ACT scores can range from 5 to 25. A higher ACT score represents more controlled asthma.

^d All (unstandardized) coefficients adjust for the variables in the table. Bold coefficients are statistically significant at p<0.05.

^e SHS = secondhand smoke

^f Marijuana use variable does not distinguish between combustible and noncombustible use.

^g Past 12-month use of asthma controller medication(s)

^h Non-Hispanic

ⁱ GED = General Education Development (High School Equivalency Certificate)

^j Derived at Wave 1 of the PATH Study

† Estimate should be interpreted with caution because it has low statistical precision. It is based on a denominator sample size of less than 50, or the