



Association between tobacco product use and respiratory health and asthma-related interference with activities among U.S. Adolescents

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ABSTRACT

Tobacco use adversely affects long-term respiratory health. We examined the relationship between sole and dual tobacco product use and both respiratory health and respiratory-related quality of life during adolescence in the U.S.

Using adolescent data (baseline age 12–17) from Waves 4.5 (data collected from December 2017–December 2018) and 5 (data collected from December 2018–November 2019) of the Population Assessment of Tobacco and Health Study, we examined the associations between combustible (i.e., cigarette or cigar), vaped, and dual (i.e., both cigar/cigarette and e-cigarette) tobacco/nicotine use at baseline and two respiratory symptoms (all adolescents, $n = 11,748$) and new asthma diagnosis (adolescents with no baseline diagnosis, $n = 9,422$) at follow-up. Among adolescents with asthma (Wave 5, $n = 2,421$), we estimated the association between current tobacco use and the extent to which asthma interfered with daily activities.

At follow-up, 12.3 % of adolescents reported past 12-month wheezing/whistling, 17.4 % reported past 12-month dry cough, and 1.9 % reported newly diagnosed asthma. Baseline current cigarette/cigar smoking was associated with subsequent wheezing/whistling and baseline report of another tobacco product use pattern was associated with subsequent asthma diagnosis. Among adolescents with asthma, 5.7 % reported it interfering with activities some of the time and 3.1 % reported interference most/all of the time in the past 30 days. Past 30-day sole cigarette/cigar smoking and dual use was positively associated with asthma-related interference with activities compared to never tobacco use and sole e-cigarette use.

Combustible and dual tobacco use pose direct risk to respiratory health and indirect risk to quality of life through respiratory health.

1. Introduction

Tobacco and nicotine use predominantly begins and becomes established during adolescence (US Department of Health and Human Services, 2014; US Department of Health and Human Services, 2012). Given that tobacco use is the leading cause of preventable disease and death in the U.S., (US Department of Health and Human Services, 2014) preventing tobacco use among adolescents is critical to ending the U.S. tobacco epidemic (US Department of Health and Human Services, 2012).

U.S. adolescents (aged 12–17) who use tobacco products most commonly use e-cigarettes (7.6 % in 2021 (Gentzke et al., 2020), cigarettes (1.5 %), and cigars (1.4 %). (Gentzke et al., 2020; Cooper et al., 2022; Wang et al., 2018; Gentzke et al., 2019; Gentzke et al., 2022) Multiple tobacco product use, particularly dual use of e-cigarettes and combustible tobacco products such as cigarettes and cigars, (Wang et al., 2018; Mirbolouk et al., 2018; King et al., 2018) is common and increasing among U.S. adolescents (National Cancer Institute, 2021). Between 2017 and 2021, the prevalence of dual/poly use increased from 2.4 % to 4.0 % for middle school students and from 9.2 % to 14.6 % for

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high school students (Cooper et al., 2022; Gentzke et al., 2019).

Tobacco use has serious adverse effects on respiratory health (US Department of Health and Human Services, 2016). While lung cancer, emphysema, and other chronic lung disease follow years of tobacco use and usually present in later adulthood, adverse respiratory symptoms could appear in adolescence, an age of particular vulnerability to respiratory pollutants (Barrington-Trimis et al., 2014). Combustible tobacco use (cigarettes, all types of cigars, pipes and hookah) is associated with respiratory symptoms such as wheezing and nighttime coughing for youth (Tanski et al., 2022). Some research suggests that e-cigarettes might also have negative respiratory consequences for young people, (Chaffee et al., 2021; McConnell et al., 2017) but findings from population studies are inconsistent (Tanski et al., 2022; Chaffee et al., 2021; McConnell et al., 2017; Boyd et al., 2021; Tackett et al., 2020). Both cross-sectional (Tanski et al., 2022; Boyd et al., 2021) and longitudinal (Tackett et al., 2020; Stevens, 2022) studies with nationally representative U.S. samples reported no significant association between e-cigarette use and wheezing and coughing, (Tanski et al., 2022; Boyd et al., 2021; Tackett et al., 2020) two of the most common childhood respiratory symptoms, while state-level studies have reported e-cigarette use associated with symptoms of bronchitis (Chaffee et al., 2021; McConnell et al., 2017) and shortness of breath (Chaffee et al., 2021).

Previous studies suggest that smoking also significantly increases risk of developing asthma during adolescence (Centers for Disease Control and Prevention., 2020; Gilliland et al., 2006; Mattingly et al., 2023). Respiratory symptoms in adolescence can portend future consequences of poor respiratory health. Understanding whether and to what extent tobacco use during adolescence negatively impacts respiratory symptoms and asthma onset is essential to comprehensive understanding of the consequences of both combustible and vaped nicotine for population health.

In addition to foreshadowing future disease, harm to respiratory health in adolescence may also diminish current quality of life by interfering with adolescents' ability to fully engage in their daily activities. Asthma is a leading cause of chronic illness-related school absenteeism, (Akinbami et al., Sep 2010.191-200.) and asthma-related school absenteeism affects more than half (59 %) of children aged 5–17 with asthma (Akinbami et al., Sep 2010.191-200.). Adolescents with asthma have reported worse perceived physical and mental health-related quality of life compared to those without asthma (Juniper, 1997; Williams et al., 2000; Hullmann et al., 2013). Tobacco use likely exacerbates these impacts of asthma on quality of life (Han et al., 2020). For example, among adolescents with asthma, adolescents who currently smoke reported more days of both poor physical and mental health than those who did not currently smoke (Cui, 2015). Identifying whether the respiratory effects of tobacco use interfere with daily life in adolescence advances our understanding of the more immediate consequences of adolescent tobacco use. In light of report (US Department of Health and Human Services, 2012) that adolescents are not concerned about the long-term consequences of tobacco use, measuring shorter-term impacts might be more relevant for targeted interventions for this group.

Dual use of e-cigarettes and combustible tobacco products poses greater risks to health than using either product alone (Reddy et al., 2021). Adolescents who use multiple tobacco products might be particularly susceptible to respiratory illness and asthma-related consequences (Reid et al., 2018). Compared to exclusive use of either product, dual use of cigarettes and e-cigarettes was associated with more risk of diagnosed bronchitis, pneumonia, and chronic cough among U.S. youth (Mukerjee et al., 2023). Among US individuals aged 12 and older, cigarette and e-cigarette dual use was associated with higher levels of nicotine and other carcinogen exposure than use of either product alone (Divvi and Kengadaran, 2019; United States Department of Health and Human Services, 2019) and almost double the odds of developing respiratory symptoms compared to smoking cigarettes alone (Reddy et al., 2021). Understanding the impact of tobacco use on adolescents must consider dual tobacco product use.

In this study, we investigated the extent to which sole and dual tobacco product use might both directly impact respiratory health and indirectly impact quality of life through respiratory health using data from a nationally representative survey of youth ages 12–17. First, we investigated whether adolescents who used e-cigarettes and/or cigarettes/cigars were more likely to report experiencing two respiratory symptoms and asthma onset in the following year than those who had never used tobacco products. Then, for adolescents with asthma, we investigated whether adolescents who used e-cigarettes and/or cigarettes/cigars reported their asthma interfering more with their daily activities than adolescents who had never used tobacco products.

2. Methods

2.1. Data source and study samples

We analyzed data from Wave 4.5 (December 2017–December 2018) Youth file and Wave 5 Youth and Adult (to obtain aged-up youth) files (December 2018–November 2019) of the nationally representative Population Assessment of Tobacco and Health (PATH) Study (United States Department of Health and Human Services, 2021). Using a multistage and stratified sampling design (Hyland et al., 2017), the survey collected respondents' information on tobacco product use, health conditions, and other individual-level characteristics using computer-assisted interviewing at home. The response rates were 89.1 % at Wave 4.5 Youth, 83.5 % at Wave 5 Youth, and 88.0 % at Wave 5 Adult surveys (United States Department of Health and Human Services, 2021; United States Department of Health and Human Services, 2021). This study is exempted from the UCSF institutional review board because we used publicly available PATH data.

This study included three samples. The first study sample (Models 1 and 2) included 11,748 adolescents who were aged 12–17 at baseline (Wave 4.5) and responded at follow-up (Wave 5). The second study sample (Model 3) included 9,422 adolescents who were aged 12–17 and who never had reported health professional-diagnosed asthma at baseline and responded at follow-up. The third study sample (Model 4) included 2,421 adolescents aged 12–17 at Wave 5 who reported having health-professional diagnosed asthma. Health-professional diagnosed asthma status was determined by the question: "Have you ever been told by a doctor, nurse, or other health professional that you have asthma?".

2.2. Measures

Dependent variables: We analyzed four dependent variables at Wave 5: (1) wheezing or whistling in the chest in the past 12 months, (2) dry cough at night in the past 12 months, (3) new health-professional diagnosed asthma, and (4) asthma-related interference with activities in the past 30 days. Adolescents with asthma were asked: "In the past 30 days, how much of the time did your asthma keep you from getting as much done at work, school or home?". We created three levels of asthma-related interference: (1) "none" or "a little" of the time (reference group), (2) "some" of the time, and (3) "most" or "all" of the time.

Independent variables. We controlled for the following independent variables measured at Wave 4.5 (baseline) for Models 1–3 and measured at Wave 5 for Model 4.

Tobacco use status. We classified "ever use" of a tobacco product if the respondent had ever tried the product, even once or twice; "current use" if they used the product in the past 30 days; "former use" if they had ever used the product but not in the past 30 days; and "never use" if they had never tried the product. Based on respondents' self-reported use of cigarettes, cigars, e-cigarettes, and seven other tobacco products (pipes, hookah, snus, smokeless tobacco, dissolvable tobacco, bidis, and kreteks), we categorized tobacco use into five mutually exclusive groups: (1) "never tobacco use" for those who had never used any tobacco product (reference group); (2) "current sole cigarette/cigar smoking" for those who currently smoked cigarettes and/or cigars but did not

currently use e-cigarettes, regardless of whether they currently used other tobacco products; (3) “current sole e-cigarette use” for those who currently used e-cigarettes but not cigarettes/cigars, regardless of whether they currently used other tobacco products; (4) “dual use of cigarettes/cigars and e-cigarettes” for those who currently used both cigarettes/cigars and e-cigarettes regardless of whether they currently used other tobacco products; and (5) “other tobacco use” for those who were former users of cigarettes/cigars, e-cigarettes, or any of the seven other tobacco products, and/or current users of only other tobacco products.

Current cannabis use status was measured as whether a respondent reported using marijuana, hash, THC, grass, pot or weed in the past 30 days.

Socio-demographic characteristics included sex, age group, race and ethnicity, annual household income, and parents’ education.

Home tobacco rules. Smoke-free environments such as those resulting from smoke-free legislation have been shown to improve respiratory health among all populations, (Rando-Matos et al., 2017) so we controlled for whether the respondent lived in a home with a comprehensive rule against tobacco inside. We used three questions asking whether the use of following tobacco products are allowed inside the home: combustible tobacco products; e-cigarettes; and other non-combustible tobacco products. We coded a comprehensive home tobacco rule if respondents reported tobacco use was not allowed anywhere/anytime inside the home for all three product categories.

Living with tobacco use was controlled because children living with someone who uses tobacco can be exposed to secondhand tobacco smoke or vaping aerosols, which has been linked to childhood risk of respiratory illness (U.S. Department of Health, 2006; Alnajem et al., 2020). We coded a respondent as living with tobacco use if they reported anyone living with them now using any tobacco products.

Respiratory symptoms. We controlled for baseline wheezing or whistling for Model 1 and baseline dry cough for Model 2.

2.3. Statistical analysis

We estimated four models. First, we conducted longitudinal analyses to examine the associations between past 30-day tobacco use at baseline and past 12-month subsequent wheezing and whistling (Model 1) and past 12-month dry cough (Model 2) at follow-up for all adolescents ($n = 11,748$). We then conducted a longitudinal analysis to estimate the association between past 30-day tobacco use at baseline and subsequent diagnosed asthma at follow-up among adolescents who never had asthma at baseline (Model 3; $n = 9,422$). For each of these models, we compared the prevalence of each outcome across baseline tobacco use status subgroups using chi-squared tests. Then, we used multivariable logistic regression to estimate the probability of each outcome as a function of tobacco use status and all other independent variables at baseline.

In the fourth model (Model 4), because both dependent variable (asthma-related interference with activities) and key independent variable (tobacco use) were measured in the past 30 days, to assess whether smoking, vaping, and dual use might reduce adolescent quality of life, we conducted a cross-sectional analysis of Wave 5 data to examine the association between past 30-day tobacco use and past 30-day asthma-related interference with activities among adolescents who ever had asthma ($n = 2,421$). This approach focuses on the association between concurrent patterns of product and symptoms. We first determined whether the prevalence of asthma-related interference with activities differed significantly across tobacco use status subgroups using a chi-squared test. We then used multinomial logistic regression to estimate asthma-related interference with activities as a function of tobacco use status and all other independent variables. We also conducted pairwise comparisons to compare asthma-related interference with activities between each pair of tobacco use groups.

To account for the complex survey design, we used PATH Study

longitudinal replicate weights for Models 1–3 and Wave 5 single-wave replicate weights for Model 4 with Fay’s balanced repeated replication to calculate 95 % confidence intervals (CI). Weighting in this way makes the sample representative of the civilian, non-institutionalized US youth population at the time of Wave 4 data collection for Models 1–3 (December 2016–January 2018) and representative of the youth population at the time of Wave 5 data collection for Model 4 (December 2018–November 2019). We conducted all analyses using SAS V9.4 (SAS Institute Inc., Cary, NC) and considered a two-tailed p-value < 0.05 to be statistically significant.

3. Results

3.1. Sample distribution

In the first study sample (Models 1 and 2, Table 1), 75.5 % of adolescents had never used tobacco, 1.6 % currently smoking cigarette/cigar alone, 5.1 % currently use e-cigarette alone, and 1.4 % reported current dual use; 4.4 % currently used cannabis. Approximately half of respondents were aged 12–14, approximately half male, and approximately half NH White. More than half lived in a household with an annual income of $\geq \$50,000$ and had parents with less than a bachelor’s degree. Almost three quarters of the sample had comprehensive rules against tobacco use inside their home, and over two-thirds did not live with tobacco use. Characteristics of the Model 3 study sample were similar. Characteristics of the Model 4 study sample were also similar except in tobacco use status, cannabis use, and age group. In the Model 4 study sample, 7.9 % reported current sole e-cigarette use, 2.0 % reported dual use, 6.7 % reported current cannabis use, and 43.8 % were aged 12–14.

3.2. Tobacco use status and subsequent respiratory symptoms and asthma

Among the Model 1–2 study sample, 12.3 % reported past 12-month wheezing or whistling and 17.4 % reported past 12-month dry coughing at follow-up (Table 1). Among adolescents without diagnosed asthma at baseline, 1.9 % reported new asthma diagnosis at follow-up.

Table 2 shows that compared to baseline never tobacco use, adolescents reporting current sole cigarette/cigar smoking (AOR = 1.88, $P < 0.01$) had higher odds of past 12-month wheezing or whistling at follow-up (Model 1); and respondents classified in the other tobacco use patterns group had higher odds of newly diagnosed asthma at follow-up (AOR = 1.91, $P < 0.01$) (Model 3). There were no significant associations between tobacco use and dry cough. Sole e-cigarette use was not statistically different from never tobacco use in whistling/wheezing, dry cough, or new asthma diagnosis at follow-up.

Baseline respiratory symptoms and cannabis use were associated with reporting wheezing or whistling at follow-up (Model 1, Table 2). Being aged 12–14, being female, and living with a someone who used tobacco were each associated with higher odds of reporting wheezing or whistling and having a dry cough at follow-up (Models 1 and 2). Compared to NH White adolescents, NH African American adolescents, NH adolescents of another race, and adolescents whose parent had a bachelor’s degree or above (vs. less than a high school degree) had higher odds of having a dry cough at follow-up (Model 2).

3.3. Current tobacco use status and current asthma-related interference with activities

At Wave 5, among adolescents who ever had asthma, 91.2 % reported interference with activities none/little of the time, 5.7 % reported interference with activities some of the time, and 3.1 % reported interference with activities most/all of the time (Table 1). Compared to never tobacco use, current sole cigarette/cigar smoking (AOR = 8.49, $P < 0.01$), current dual use (AOR = 13.07, $P < 0.01$), and other tobacco use patterns (AOR = 2.70, $P < 0.01$) were significantly associated with

Table 1

Sample distribution of U.S. youth respondents, PATH Waves 4.5 (December 2017-December 2018) Youth file and Wave 5 (December 2018-November 2019) Youth and Adult files.

Outcome variable	Models 1–2		Model 3		Model 4	
	Two respiratory symptoms that occurred in the past 12 months		Diagnosed asthma in the past 12 month		Asthma-related interference with activities in the past 30 days	
Study cohort	Among youth who completed both wave 4.5 and wave 5 surveys		Among youth who completed both wave 4.5 and wave 5 surveys and who never had asthma at wave 4.5		Among all youth who ever had a diagnosis of asthma at Wave 5	
	N	Weighted column %	N	Weighted column %	N	Weighted column %
Total	11,748	100.0	9,422	100.0	2,421	100.0
Tobacco use status						
Never tobacco use	8,753	75.5	7,092	76.2	1,658	69.8
Current sole cigarette/cigar smoking	209	1.6	154	1.5	36	1.5
Current sole e-cigarette use	594	5.1	477	5.1	196	7.9
Dual use	171	1.4	132	1.4	52	2.0
Other tobacco use	2,021	16.5	1,567	15.9	479	18.7
Current cannabis use status						
No current cannabis use	11,199	95.6	9,004	95.7	2,244	93.3
Current cannabis use	549	4.4	418	4.3	177	6.7
Age						
12–14 years old	5,537	50.5	4,550	51.5	910	43.8
15–17 years old	6,211	49.5	4,872	48.5	1,511	56.2
Sex						
Male	6,097	50.9	4,805	50.1	1,357	55.3
Female	5,651	49.1	4,617	49.9	1,064	44.7
Race/ethnicity						
Non-Hispanic White	5,248	50.3	4,323	51.5	940	44.0
Non-Hispanic African American	1,480	12.4	1,071	11.2	418	17.5
Non-Hispanic Other	1,108	10.0	888	10.2	232	9.1
Hispanics	3,409	23.1	2,717	22.7	725	25.1
Unknown	503	4.2	423	4.4	106	4.3
Household income						
Less than \$10,000	805	5.9	596	5.5	222	7.6
\$10,000 to \$24,999	1,722	13.0	1,310	12.3	390	14.8
\$25,000 to \$49,999	2,590	20.3	2,071	20.1	585	23.2
\$50,000 to \$99,999	2,914	25.6	2,367	25.8	554	23.4
\$100,000 or more	3,322	31.8	2,760	32.7	594	27.7
Unknown	395	3.4	318	3.5	76	3.3
Parents' education						
Less than high school	1,599	11.3	1,282	11.2	342	12.6
GED or High school graduate	1,946	15.5	1,535	15.3	403	15.2
Some college (no degree) or associates degree	3,525	29.0	2,753	28.2	830	34.1
Bachelor's degree and above	4,678	44.2	3,852	45.3	846	38.1
Home tobacco rules						
Not allowed anywhere or at any time inside my home	8,794	74.3	7,113	75.0	1,773	72.6
Allowed in some/any places or at some/any times inside my home	2,954	25.7	2,309	25.0	648	27.4
Living with tobacco use						
Not living with anyone who uses tobacco	8,161	69.5	6,634	70.6	1,554	63.9
Living with someone who uses tobacco	3,462	29.4	2,690	28.4	833	34.8
Unknown	125	1.1	98	1.0	34	1.3
Had wheezing or whistling in the chest in the past 12 months						
Yes	1,441	12.3	N/A	N/A	N/A	N/A
No	10,307	87.7	N/A	N/A	N/A	N/A
Had a dry cough at night in the past 12 months						
Yes	2,035	17.4	N/A	N/A	N/A	N/A
No	9,713	82.6	N/A	N/A	N/A	N/A
Diagnosed asthma						
No	N/A	N/A	9,242	98.1	N/A	N/A
Yes	N/A	N/A	180	1.9	N/A	N/A
Asthma-related interference with activities						
None or little of the time	N/A	N/A	N/A	N/A	2,205	91.2
Some of the time	N/A	N/A	N/A	N/A	135	5.7
Most or all of the time	N/A	N/A	N/A	N/A	81	3.1

asthma interference most/all of the time and current dual use (AOR = 3.64, P = 0.04) was associated with asthma interference some of the time (Table 3).

The odds of reporting asthma-related interference with activities most/all or some of the time were significantly higher among Hispanic adolescents than NH White adolescents and were significantly lower among adolescents who lived in a household with annual household income ≥\$25,000 than the lowest income group (Table 3). In addition,

compared with the respective reference groups, the odds of reporting asthma-related interference with activities some of the time were significantly lower among adolescents aged 15–17 and adolescents who lived in a household with annual household income ≥\$25,000 per year, and were significantly higher among NH Black adolescents.

Results from the pairwise comparisons (Table 4) indicate that the odds of reporting asthma-related interference with activities most/all of the time (vs. none/little of the time) were significantly lower for sole e-

Table 2

Odds of having wheezing/whistling in the chest, dry cough at night, or new diagnosed asthma by tobacco use status and other characteristics among U.S. youth: PATH Waves 4.5 (December 2017-December 2018) Youth file and Wave 5 (December 2018-November 2019) Youth and Adult files.

Outcome variable	Model 1: Wheezing/whistling in the chest in the past 12 months				Model 2: Dry cough at night in the past 12 months				Model 3: New diagnosed asthma in the past 12 months			
	Among youth who completed both wave 4.5 and wave 5 surveys (N = 11,748)				Among youth who completed both wave 4.5 and wave 5 surveys (N = 11,748)				Among youth who completed both wave 4.5 and wave 5 surveys and who never had asthma at wave 4.5 (N = 9,422)			
Study cohort	AOR	95 % CI	P	AOR	95 % CI	P	AOR	95 % CI	P	AOR	95 % CI	P
Tobacco use status												
Never tobacco use												
Current sole cigarette/cigar smoking	1.88	1.22	2.88	0.00	1.33	0.91	1.93	0.14	2.23	0.82	6.09	0.12
Current sole e-cigarette use	1.03	0.69	1.51	0.90	0.92	0.69	1.25	0.60	0.37	0.07	1.87	0.23
Dual use	1.70	0.99	2.90	0.05	1.15	0.75	1.78	0.52	1.47	0.30	7.16	0.63
Other tobacco use	1.02	0.87	1.19	0.81	0.94	0.80	1.10	0.42	1.91	1.25	2.92	0.00
Wheezing/whistling in the chest in the past 12 months												
No												
Yes	11.25	9.70	13.04	<0.0001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dry cough at night in the past 12 months												
No												
Yes	N/A	N/A	N/A	N/A	4.38	3.95	4.85	<0.0001	N/A	N/A	N/A	N/A
Current cannabis use status												
No current cannabis use												
Current cannabis use	1.41	1.00	1.99	0.05	1.05	0.78	1.42	0.74	0.56	0.20	1.52	0.25
Age												
12–14 years old												
15–17 years old	0.77	0.67	0.89	0.00	0.83	0.73	0.95	0.01	0.92	0.65	1.30	0.63
Sex												
Male												
Female	1.20	1.03	1.38	0.02	1.21	1.10	1.34	0.00	1.13	0.81	1.57	0.47
Race/ethnicity												
Non-Hispanic White												
Non-Hispanic African American	0.97	0.77	1.24	0.83	1.19	1.01	1.40	0.04	1.43	0.89	2.30	0.13
Non-Hispanic Other	0.99	0.77	1.26	0.92	1.16	0.96	1.41	0.12	1.17	0.64	2.12	0.61
Hispanics	0.90	0.75	1.07	0.23	1.05	0.90	1.22	0.55	0.98	0.58	1.66	0.95
Unknown	0.81	0.57	1.14	0.22	0.79	0.59	1.06	0.12	1.28	0.51	3.25	0.59
Household income												
Less than \$10,000												
\$10,000 to \$24,999	0.97	0.71	1.31	0.82	1.05	0.81	1.37	0.72	1.27	0.75	2.15	0.36
\$25,000 to \$49,999	0.91	0.68	1.23	0.55	0.97	0.75	1.26	0.84	0.68	0.36	1.28	0.23
\$50,000 to \$99,999	0.90	0.69	1.18	0.45	0.89	0.68	1.16	0.38	1.02	0.53	1.97	0.96
\$100,000 or more	0.92	0.67	1.26	0.59	0.87	0.66	1.15	0.32	0.68	0.33	1.39	0.29
Unknown	0.74	0.42	1.32	0.30	0.87	0.60	1.25	0.44	1.13	0.30	4.17	0.86
Parents' education												
Less than high school												
GED or high school graduate	0.98	0.77	1.24	0.86	0.95	0.77	1.17	0.62	1.08	0.68	1.71	0.76
Some college (no degree) or associates degree	1.06	0.81	1.37	0.69	1.05	0.85	1.29	0.64	0.73	0.44	1.22	0.22
Bachelor's degree and above	1.08	0.82	1.41	0.60	1.27	1.01	1.61	0.04	0.55	0.30	1.01	0.05
Home tobacco rules												
Not allowed anywhere or at any time inside my home												
Allowed in some/any places or at some/any times inside my home	1.11	0.91	1.35	0.32	1.02	0.89	1.18	0.77	1.08	0.72	1.61	0.72
Living with tobacco use												
Not living with anyone who uses tobacco												
Living with someone who uses tobacco	1.22	1.05	1.41	0.01	1.19	1.03	1.37	0.02	1.51	1.00	2.28	0.06
Unknown	1.07	0.41	2.84	0.88	1.40	0.85	2.33	0.19	1.87	0.54	6.55	0.32

Note: Bold indicates p < 0.05.

cigarette use (AOR = 0.14, P = 0.03) than sole cigarette/cigar smoking and were significantly higher for dual use than sole e-cigarette use (AOR = 11.11, P < 0.01) and other tobacco use (AOR = 4.84, P < 0.01). There was no statistically significant difference in asthma-related interference with activities between dual use and sole cigarette/cigar smoking, between sole cigarette/cigar smoking and another tobacco use pattern, and between sole e-cigarette use and another tobacco use pattern.

4. Discussion

This study found evidence of short-term respiratory health impacts from cigarette/cigar smoking and indirect effects on quality of life from cigarette/cigar smoking alone or in combination with e-cigarettes in adolescence. Adolescents who smoked cigarettes/cigars were more

likely to report subsequent wheezing or whistling a year later compared to peers who never used tobacco, although not dry cough or diagnosed asthma. Furthermore, we found that both sole cigarette/cigar smoking and dual use of cigarette/cigars and e-cigarettes increased the odds of substantial asthma-related interference with activities, suggesting that tobacco use exacerbates the negative impacts of asthma on quality of life for adolescents.

Our study contributes to the literature by examining the combined role of cigarette smoking and cigar smoking — the third most prevalent tobacco product used by adolescents (Gentzke et al., 2020; Cooper et al., 2022; Wang et al., 2018; Gentzke et al., 2019; Gentzke et al., 2022) — in the association with subsequent respiratory symptoms. Moreover, we detect this effect after adjusting for baseline respiratory symptoms, consistent with a causal relationship between smoking/vaping and

Table 3

Model 4: Determinants of asthma-related interference with activities in the past 30 days among U.S. youth who were ever diagnosed with asthma (N = 2,421), PATH Wave 5 (December 2018–November 2019) Youth file.

Factors	Most or all of the time vs. none or little of the time				Some of the time vs. none or little of the time			
	AOR	95 % CI	P		AOR	95 % CI	P	
Tobacco use status								
Never tobacco use	Reference				Reference			
Current sole cigarette/cigar smoking	8.49	2.59	27.81	0.00	2.10	0.37	11.97	0.40
Current sole e-cigarette use	1.17	0.26	5.34	0.84	1.39	0.63	3.09	0.41
Dual use	13.07	5.00	34.16	<0.0001	3.64	1.07	12.38	0.04
Other tobacco use	2.70	1.58	4.64	0.00	1.15	0.70	1.88	0.58
Current cannabis use status								
No current cannabis use	Reference				Reference			
Current cannabis use	0.82	0.35	1.93	0.65	0.73	0.31	1.72	0.47
Age								
12–14 years old	Reference				Reference			
15–17 years old	0.77	0.42	1.44	0.41	0.56	0.37	0.86	0.01
Sex								
Male	Reference				Reference			
Female	0.77	0.47	1.26	0.29	1.18	0.77	1.82	0.44
Race/ethnicity								
Non-Hispanic White	Reference				Reference			
Non-Hispanic African American	2.02	0.91	4.50	0.09	1.96	1.10	3.49	0.02
Non-Hispanic Other	1.07	0.30	3.85	0.91	1.21	0.53	2.72	0.65
Hispanics	2.52	1.26	5.04	0.01	1.34	0.80	2.25	0.26
Unknown	2.79	0.72	10.79	0.14	0.89	0.24	3.39	0.86
Household income								
Less than \$10,000	Reference				Reference			
\$10,000 to \$24,999	0.80	0.35	1.80	0.58	0.53	0.24	1.13	0.10
\$25,000 to \$49,999	0.37	0.17	0.83	0.02	0.35	0.18	0.67	0.00
\$50,000 to \$99,999	0.29	0.11	0.73	0.01	0.44	0.21	0.92	0.03
\$100,000 or more	0.18	0.05	0.67	0.01	0.25	0.11	0.62	0.00
Unknown	1.37	0.38	4.98	0.63	0.41	0.08	2.16	0.29
Parents' education								
Less than high school	Reference				Reference			
GED or high school graduate	1.44	0.73	2.82	0.29	0.69	0.39	1.22	0.20
Some college (no degree) or associates degree	1.24	0.60	2.54	0.56	1.21	0.70	2.11	0.49
Bachelor's degree and above	0.94	0.39	2.27	0.89	1.18	0.59	2.35	0.63
Home tobacco rules								
Not allowed anywhere or at any time inside my home	Reference				Reference			
Allowed in some/any places or at some/any times inside my home	1.57	0.90	2.74	0.11	1.36	0.88	2.12	0.16
Living with tobacco use								
Not living with anyone who uses tobacco	Reference				Reference			
Living with someone who uses tobacco	1.36	0.81	2.29	0.24	1.28	0.85	1.93	0.23
Unknown	<0.001	<0.001	0.04	0.01	0.73	0.10	5.07	0.74

Note: Bold indicates p < 0.05.

Table 4

Model 4: Pairwise comparisons for the association with asthma-related interference with activities across tobacco use status categories among U.S. youth (N = 2,421), PATH Wave 5 (December 2018–November 2019) Youth file.

	Most or all of the time vs. none or little of the time				Some of the time vs. none or little of the time			
	AOR	95 % CI	P		AOR	95 % CI	P	
Current sole e-cigarette use vs. current sole cigarette/cigar smoking (reference)	0.14	0.87	0.02	0.03	0.66	4.03	0.11	0.65
Dual use vs. current sole cigarette/cigar smoking (reference)	1.54	6.21	0.38	0.54	1.73	13.16	0.23	0.60
Current other tobacco use vs. current sole cigarette/cigar smoking (reference)	0.32	1.14	0.09	0.08	0.55	3.11	0.10	0.50
Dual use vs. current sole e-cigarette use (reference)	11.11	55.56	2.19	0.00	2.62	10.20	0.67	0.17
Current other tobacco use vs. current sole e-cigarette use (reference)	2.31	10.20	0.52	0.27	0.83	1.83	0.37	0.64
Dual use vs. other tobacco use (reference)	4.84	1.97	11.89	0.00	3.16	0.88	11.42	0.08

Note: Bold indicates p < 0.05.

whistling/wheezing.

Our finding that neither sole e-cigarette use nor dual use was associated with dry cough is inconsistent with two previous adolescents studies (McConnell et al., 2017; Wang, n.d.). This discrepancy may be explained by differences in outcome measures and geographic study site. While we measured dry cough in the past 12 months, Wang and colleagues (Wang, n.d.) measured having cough or phlegm for 3 consecutive months in the past year, which eliminates statistical noise due to confounding from common colds (Wang, n.d.). While we used a nationally representative U.S. sample, Wang and colleagues used data from

Hong Kong and McConnell and colleagues (McConnell et al., 2017) used data from southern California.

Consistent with literature (Mattingly et al., 2023) which examined the causal impact of long-term tobacco use on asthma onset using the PATH Study Youth Waves 1–5 data, we found that sole e-cigarette use and dual use were not associated with newly diagnosed asthma a year later. Our finding that cigarette/cigar smoking was not associated with asthma onset is inconsistent with literature (Mattingly et al., 2023) which found that dual use of cigarettes and other combustible tobacco was associated with incident asthma among adolescents. Our measure of

combustible tobacco use included some youth who only smoked one combustible product; if dual use presents higher risk, these youth might have diluted the overall effect.

Our work extends research about the impact of tobacco use on adolescent respiratory health by connecting those impacts to quality of life, reporting that tobacco use might exacerbate asthma's impact on daily activities for adolescents. We found that sole cigarette/cigar smoking increased the risks of substantial asthma-related interference with activities. We also found that dual use increased odds of reporting asthma-related interference with activities than sole e-cigarette use. This finding is consistent with evidence that dual use is more harmful than vaping alone, increasing exposure to high concentrations of toxic substances (Ginsburg et al., 2014) and increasing risk of developing respiratory symptoms (Reddy et al., 2021). Tobacco cessation programs for adolescents should target dual use to reduce asthma-related interference with quality of life.

Our study contributes to the growing literature demonstrating proximal consequences of tobacco use for young people. We found that sole e-cigarette use was not associated with respiratory symptoms, had lower odds of reporting asthma-related interference with activities most/all of the time than sole cigarette/cigar smoking, and was not associated with having asthma-related interference with daily activities compared to never tobacco use. There is limited literature on the causal relationship between e-cigarette use and asthma onset among youth. A growing number of studies (Centers for Disease Control and Prevention, n.d.; Global allergy & airways patient platform, n.d.; Allergy and asthma network, n.d.) have shown that the main chemicals in e-cigarettes (such as propylene glycol) can increase inflammation in the airways, cough, and chest tightness. All of these can intensify asthma symptoms and trigger asthma attacks which might lead to asthma-related interference with activities for adolescents. Given the evolving evidence about the health risks of e-cigarette use, (Bates, 2021; Kathuria and Leone, 2021; Balfour et al., 2021) our findings should be interpreted narrowly and in context. For example, because of data limitations, neither Mattingly's (Mattingly et al., 2023) nor our e-cigarette measure differentiated by intensity, frequency, and history. A study of U.S. adults reported an association between e-cigarette use and asthma onset (Bhatta and Glantz, 2020). It may be that asthma will develop among youth who vape with high intensity or after more years of exposure. Furthermore, e-cigarette use might have an indirect effect on respiratory health and subsequent impact on activities by encouraging initiation of combustible tobacco product use, (Berry et al., 2019; Soneji et al., 2018) which we do find negatively impacts respiratory health and asthma's interference with quality of life.

Despite low cigarette and cigar smoking prevalence among adolescents, [6] our finding of the negative consequences of sole cigarette/cigar smoking on wheezing and asthma-related interference with activities at work, school, or home supports the need for continuing efforts to reduce adolescent cigarette/cigar smoking. Tobacco control programs such as those limiting access to appealing tobacco products, reducing exposure to advertising, and providing evidence-based behavioral counseling and other cessation support could be effective in reducing asthma-related interference with activities by reducing adolescents' combustible tobacco use (U.S. Department of Health, 2022).

Findings should be interpreted considering a few limitations. First, our outcome measures are self-reported and might be subject to recall bias. However, self-reported health conditions have been shown to have reasonable validity compared with health professional diagnoses (Hel-lovaara et al., 1993; Edwards et al., 1994). Second, the prevalence of e-cigarette use is lower in the PATH Study than in other nationally representative surveys such as the Monitoring the Future Survey (Boyd et al., 2020). If the PATH Study misclassified some youth who use tobacco as nonusers, we might underestimate the relationship between tobacco use, respiratory health, and related well-being.

In summary, we found that adolescent cigarette/cigar smoking was associated with greater odds of experiencing subsequent wheezing or

whistling a year later compared to never tobacco use, and adolescent cigarette/cigar smoking and dual use of cigarettes/cigars and e-cigarettes were also associated with reporting worse impacts of asthma on activities. Our findings suggest that reducing combustible tobacco use and dual use among adolescents may reduce respiratory symptoms and allow adolescents with asthma to participate more fully in activities at work, school, and home, potentially promoting well-being in both the short and long term.

5. Data availability statement

SAS files and code are available upon written request to the corresponding author and with the execution of a data use agreement.

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CRediT authorship contribution statement

Tingting Yao: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Shannon Lea Watkins:** Writing – review & editing, Methodology, Conceptualization. **Hai-Yen Sung:** Writing – review & editing, Methodology, Conceptualization. **Yingning Wang:** Writing – review & editing, Conceptualization. **Dian Gu:** Writing – review & editing. **Joanne Chen Lyu:** Writing – review & editing. **James Lightwood:** Writing – review & editing. **Wendy Max:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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