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RESEARCH ARTICLE

Cigarettes, ENDS Use, and Chronic Obstructive Pulmonary Disease Incidence: A Prospective Longitudinal Study

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Introduction: Understanding the relationship between ENDS use and chronic obstructive pulmonary disease and other respiratory conditions is critical. However, most previous studies have not fully adjusted for cigarette smoking history.

Methods: Using Waves 1−5 of the U.S. Population Assessment of Tobacco and Health study, the association between ENDS use and self-reported incident chronic obstructive pulmonary disease was examined among adults aged 40+ years using discrete-time survival models. *Current ENDS use* was measured as a time-varying covariate, lagged by 1 wave, defined as established daily or some days of use. Multivariable models were adjusted for baseline demographics (age, sex, race/ethnicity, education), health characteristics (asthma, obesity, exposure to second-hand smoke), and smoking history (smoking status and cigarette pack years). Data were collected between 2013 and 2019, and the analysis was conducted in 2021−2022.

Results: Incident chronic obstructive pulmonary disease was self-reported by 925 respondents during the 5-year follow-up. Before adjusting for other covariates, time-varying ENDS use appeared to double chronic obstructive pulmonary disease incidence risk (hazard ratio=1.98, 95% CI=1.44, 2.74). However, ENDS use was no longer associated with chronic obstructive pulmonary disease (adjusted hazard ratio=1.10, 95% CI=0.78, 1.57) after adjusting for current cigarette smoking and cigarette pack years.

Conclusions: ENDS use did not significantly increase the risk of self-reported incident chronic obstructive pulmonary disease over a 5-year period once current smoking status and cigarette pack years were included. Cigarette pack years, by contrast, remained associated with a net increase in chronic obstructive pulmonary disease incidence risk. These findings highlight the importance of using prospective longitudinal data and adequately controlling for cigarette smoking history to assess the independent health effects of ENDS.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a chronic and progressive respiratory disease that encompasses emphysema and chronic bronchitis.[1] COPD is characterized by expiratory airflow limitation and abnormal airway inflammation, usually caused by exposure to noxious particles or gases.[2] COPD is the fourth cause of mortality in the U.S.[3] and is projected to lead to 9.42 million deaths and >$800 billion in direct medical costs by 2038.[4]

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Cigarette smoking is a major risk factor for COPD,[2,5] with >20% of people who use cigarettes long-term expected to develop COPD.[5,6] The risk of COPD is 200% higher in adults who currently smoke and 30% higher in adults who formerly smoked than in adults who do not smoke.[7] Furthermore, COPD incidence has been also associated with second-hand smoke (SHS) exposure,[8] and cigarette smoking duration and intensity are both important determinants of COPD risk.[9]

ENDS product use began to rise quickly in popularity starting around 2012,[10] with growing concern that ENDS use may increase the risk of respiratory disease.[11] There is evidence of ENDS-induced inflammatory responses and immune dysregulation,[12−15] and it is theoretically plausible that ENDS use may increase the risk of COPD. Preliminary epidemiologic evidence has begun to associate ENDS use with COPD risk,[16−19] but these findings have been based on prevalence studies using cross-sectional data, which have typically not included information on the timing of ENDS use or the COPD outcome. Moreover, most adults who use ENDS are either currently smoking cigarettes or formerly smoked cigarettes,[20,21] making it important to account for cigarette smoking histories, including duration and intensity, when assessing any potential independent effects of ENDS use on COPD risk.

In this study, 5 waves of a U.S. nationally representative longitudinal cohort are analyzed to examine the prospective association between ENDS use and self-reported diagnosed incident COPD among adults aged ≥40 years. This study (1) examines COPD incidence prospectively; (2) includes ENDS use as a 1-wave−lagged time-varying measure to ensure that ENDS use preceded COPD diagnosis; and (3) controls for the duration, intensity, and history of cigarette smoking.

METHODS

Study Sample

Data from Waves 1−5 (2013−2019) of the Population Assessment of Tobacco and Health (PATH) Study, a nationally representative longitudinal study of the non-institutionalized civilian U.S. population, were analyzed using the restricted-access PATH adult data files.[22] Further details on the survey design are described elsewhere.[23]

The analysis examined self-reported diagnosed COPD incidence over 4 waves of follow-up (Waves 2−5). Consistent with national COPD cohorts,[24,25] the analytic sample was restricted to respondents aged ≥40 years who reported no history of any COPD outcome (i.e., COPD, chronic bronchitis, and emphysema) at baseline (Wave 1) and who completed at least 1 follow-up interview. Respondents were censored at the time of their first self-reported COPD outcome. Those who did not report an outcome were censored at their last observation point. The final analytic sample consisted of 9,861 respondents. A flowchart summarizing the analytic sample is provided in the Appendix (Appendix Figure 1, available online).

Measures

Self-reported diagnosed COPD incidence was measured at each follow-up interview on the basis of the question, In the past 12 months, has a doctor, nurse, or other health professional told you that you had... (1) COPD, (2) chronic bronchitis, or (3) emphysema? Consistent with the COPD clinical definition, respondents who reported having any of these conditions were considered to have COPD.

The ENDS use exposure variable was based on self-reported everyday or someday use among adults with established use (ever fairly regularly used ENDS). This variable was measured at each wave and included as a time-varying exposure. To ensure that ENDS use preceded COPD incidence, the ENDS exposure was lagged by 1 wave (t-1).

To account for potential confounding by other tobacco product use, 3 covariates were included. First, a smoking status variable (nonsmoking, former smoking, current smoking) was created using established cigarette use (100 or more cigarettes smoked in a lifetime). Nonsmoking adults included those without established cigarette use and those who never smoked. *Former smoking* was defined as adults with established cigarette use who did not currently smoke. *Current smoking* was defined as adults with established cigarette use who currently smoked cigarettes every day or some days. Second, adults with established use of other combustible tobacco products (including traditional cigars, filtered cigars, cigarillos, hookah, and pipes) were included. Smoking status and other combustible tobacco use were both included as time-varying covariates, lagged by 1 wave (t-1) to ensure the exposures preceded the outcome. Third, cigarette pack years (CPY) was included as a measure of lifetime cigarette smoking at baseline. CPY was calculated by multiplying the reported years of cigarette smoking by the average number of packs per day while individuals smoked. CPY for adults without established cigarette use was coded as 0. Respondents who reported smoking >200 cigarettes per day (10 packs per day) were considered implausible and were set to missing. Preliminary analyses suggested that a log transformation of CPY best fits the data, which is the functional form included in models.

Age (continuous), sex (male, female), race/ethnicity (Hispanic, non-Hispanic [NH] White, NH Black, NH other), education (high school or less, some college, bachelor's degree/graduate degree), and health insurance status (some versus none) were included as baseline sociodemographic covariates. Obesity (BMI≥30 vs BMI<30) and asthma were included as baseline COPD risk factors. To capture variation in exposure to SHS, the number of hours respondents reported close exposure to SHS during the past 7 days (range=0−100) was included. SHS exposure was included as a time-varying covariate, lagged by 1 wave (t-1) to ensure that this exposure preceded the outcome.

Statistical Analysis

Descriptive statistics were first calculated for sociodemographic characteristics, smoking behaviors, and COPD risk factors at baseline. Sample characteristics were then calculated according to the respondent's cigarette/ENDS use at baseline. Next, lifetables were used to describe the distribution of self-reported diagnosed

incident COPD at follow-up (Waves 2−5). The discrete-time hazard estimates, provided in the lifetable, reflect the weighted conditional probability of COPD in the risk set at each discrete interval.

A series of multivariable discrete-time survival models predicting self-reported incident COPD at follow-up (Wave 2−5) were fitted. The 9,861 respondents in the analytic sample were restructured to an unbalanced person−period data set where each respondent *(N)* contributed a separate row of data for each discrete-time interval (*T*), with a maximum of 4 rows per respondent, until COPD diagnosis or right censoring. The person−period data set, constructed on the basis of *N x T*, had 33,679 observations and provided the data structure for the analyses. All discrete-time survival models were estimated using a complementary log-log link function on the person−period data set. Data were weighted using Wave 1 weights, including full-sample and 100 replicate weights, to ensure that results were representative of the non-institutionalized U.S. adult population at baseline.

Several sensitivity analyses were conducted. First, discrete-time models were estimated using the all waves weights, which restricted the analysis to the longitudinal cohort of respondents who participated in all waves of the PATH study. Second, the outcome was restricted to respondents who reported the COPD outcome and reported seeing a doctor during the past year. Third, frequent E-cigarette use (measured as 10+ days in the past 30 days) was included as the exposure. Fourth, because chronic bronchitis and emphysema are phenotypically different, discrete-time models were re-estimated, with these outcomes disaggregated. Finally, this analysis was extended to include adult respondents aged 25+ years at baseline. For all analyses, variances were computed using the balanced repeated replication methods, with Fay's adjustment set to 0.3 as recommended by the PATH study.[26] All analyses were conducted using Stata 17.1.

RESULTS

Baseline sociodemographic characteristics, COPD risk factors, and tobacco variables for the analytic sample (*n*=9,861) are outlined in Table 1. At baseline (Wave 1, 2013−2014), respondents had a mean age of 57.4 years (SD=11.9), 53% were female, 70.4% were NH White, 11.2% were NH Black, and 11.4% were Hispanic. Regarding education, 60.6% had at least some college education, whereas 39.4% reported completing a high school education or less. Approximately one third of respondents had a BMI of 30 kg/m^2 or more (33.5%), whereas 8.7% reported a lifetime diagnosis of asthma. Every day or someday use of ENDS was reported by 1.4% of respondents at baseline. Most respondents reported never established cigarette smoking at baseline (63.0%), whereas 23.2% reported former smoking, and 13.8% reported current cigarette smoking. Among those who currently or formerly smoked, the average cigarette pack years at baseline was 23.9 (SD=26.4). In terms of exposure to SHS, 41% reported past 7-day SHS exposure, with an average of 10.1 hours (SD=22.2) exposure.

Table 2 presents the lifetables describing self-reported COPD incidence, reflecting the conditional probability of COPD diagnosis at each discrete time interval. In total, there were 925 self-reported incident COPD cases, with an average annualized incidence of 1.97% (range=1.4%−2.4%) during the 5-year follow-up period.

Table 3 presents the results examining self-reported COPD incidence across the 5-year follow-up period. Before adjusting for other covariates (Model 1), time-varying ENDS use appeared to nearly double the risk COPD incidence (hazard ratio=1.98, 95% CI=1.44, 2.74). However, ENDS use was no longer significantly associated with COPD risk (adjusted hazard ratio [AHR]=1.17, 95% CI=0.83, 1.66) after adjusting for current cigarette smoking in Model 3 and adjusting for cigarette pack years in Model 4 (AHR=1.10, 95% CI=0.78, 1.57).

Multivariable associations between other variables and COPD can also be found in Model 4 (Table 3). Self-reported COPD incidence increased with the log of cigarette pack years (AHR=1.79, 95% CI=1.46, 2.19) and was higher for respondents who were older (AHR=1.03, 95% CI=1.02, 1.04), were female (AHR=1.79, 95% CI=1.50, 2.13), had a high-school degree or less (AHR=1.72, 95% CI=1.31, 2.26), and had baseline asthma (AHR=3.05, 95% CI=2.33, 4.00) or obesity (AHR=1.41, 95% CI=1.16, 1.71). SHS exposure was also associated with COPD incidence because every 10 hours of exposure increased the risk of COPD by 9.0% (AHR=1.09, 95% CI=1.04, 1.14). Current smoking status remained significant after adjusting for the log of cigarette pack years in Model 4 (AHR=1.64, 95% CI=1.17, 2.29).

The confounding effect of smoking on the association between ENDS use and self-reported COPD incidence can be seen in Table 4. Most adults who used ENDS at each wave were either currently (range=49.7%−61.4%, decreasing by wave) or formerly (range=30.7%−46.7%, increasing by wave) smoking, whereas <8% were adults without established cigarette use (range=3.4%−7.9%, decreasing by wave). Conversely, most adults who did not use ENDS were adults without established cigarette use (range=60.5%−63.8%). Moreover, most adults who used ENDS had significantly higher baseline cigarette pack years and higher levels of SHS exposure than adults who did not use ENDS.

As sensitivity analyses, discrete-time models were estimated using the longitudinal cohort who participated in all waves of follow-up (Appendix Table 1, available online), with the COPD outcome restricted to those who also reported seeing a healthcare professional during the past 12 months in Waves 2 and 3, consistent with the definition in Waves 4 and 5 (Appendix Table 2, available online); with E-cigarette use as 10+ days in the past 30 days rather than every day or someday use (Appendix Table 3, available online); with chronic bronchitis and

Table 1. Weighted Sociodemographic Characteristics, Smoking Behaviors, and Clinical Risk Factors for Adult Respondents (Aged 40+ Years), Population Assessment of Tobacco and Health Study (Wave 1, 2013–2014)

Variables	*n*	% or mean[a]	95% CI
Age (mean in years, SD)	9,861	57.4 (11.9)	
Sex			
Female	4,860	53	52.2–53.8
Male	5,001	47	46.2–47.8
Race/ethnicity			
NH White	6,589	70.4	70.4–72.3
Hispanic	1,209	11.4	10.6–12.2
NH Black	1,517	11.2	10.6–11.7
NH other	546	6	5.6–6.6
Education			
High school or less	4,080	39.4	38.7–40.2
Some college	3,151	29.2	28.5–29.8
Bachelor or higher	2,630	31.4	30.7–32.1
Health insurance status			
Some insurance	8,438	89.5	88.7–90.2
No health insurance	1,423	10.5	9.9–11.3
Baseline risk factors			
Asthma diagnosis			
No	9,002	91.3	90.5–91.9
Yes	859	8.7	8.1–9.5
Obesity (BMI≥30)			
No	6,511	66.5	65.2–67.8
Yes	3,350	33.5	32.2–34.8
Tobacco product exposure			
Other' combustible tobacco product use			
No	9,368	97.9	97.7–98.1
Yes	493	2.1	1.9–2.3
ENDS[c] use			
No	9,502	98.6	98.4–98.9
Yes	359	1.4	1.3–1.6
Smoking status			
Nonestablished or never smoking	4,512	63	61.4–64.5
Formerly established smoking	1962	23.2	22.0–24.5
Current established smoking	3,387	13.8	13.2–14.4
Pack years among people currently/ formerly smoking (mean, SD)	5,349	23.9 (26.4)	
Past 7-day second-hand smoke exposure			
No	4,205	59	57.5–60.6
Yes	5,656	41	39.4–42.5
Past 7-day second-hand smoke exposure (mean number of hours, SD)	5,656	10.1 (22.2)	

NH, non-Hispanic.
[a]Percentages were calculated using Wave 1 weights.

emphysema modeled separately (Appendix Tables 4 and 5, available online); and with the analytic sample extended to include adult respondents aged ≥25 years at baseline (Appendix Table 6, available online). Across all sensitivity analyses, the substantive results were nearly identical because the effect of ENDS use on COPD was no longer significant after adjusting for cigarette smoking status, other combustibles, and cigarette pack years.

DISCUSSION

This study examined the prospective association between established and time-varying ENDS use and self-reported COPD incidence over a 5-year follow-up period. Before adjusting for current and historical cigarette use, ENDS use appeared to be associated with increasing COPD risk in U.S. adults. This unadjusted estimate is consistent with findings from several prevalence studies using cross-sectional data.[16–19,27] Aside from not accounting for the relative timing of ENDS use and COPD outcomes, these studies typically adjusted for current smoking status but not for cigarette smoking duration or intensity. High levels of smoking exposure are needed for COPD to develop,[9,28] and not controlling for this exposure may conflate the effect of ENDS use with individual smoking histories. In this study, once time-varying smoking status and baseline smoking history were included, ENDS use was no longer associated with COPD incidence. This finding is not surprising because >90% of adults who used ENDS aged ≥40 years in the study sample either currently or formerly smoked cigarettes at each time interval. Moreover, the average pack years of adults who used ENDS and simultaneously smoked cigarettes was significantly higher than the average pack-years values for adults who smoked cigarettes and did not use ENDS. These findings, considered together, show the importance of adjusting for both smoking status and smoking histories when studying the health effects of ENDS products.

Research examining the longitudinal association between ENDS use and COPD incidence has begun to emerge. Paulin et al.[27] examined the association between 12 mutually exclusive categories of current tobacco product use, including exclusive ENDS use, and COPD incidence using data from Waves 1 through Wave 5 of the PATH Study and Poisson regression models. Consistent with this study, Paulin and colleagues[27] found that the association between exclusive past 30-day ENDS use and COPD incidence was attenuated once they adjusted for cigarette pack years. However, conflicting evidence was found in another study using PATH Waves 1 through 4 because Xie et al.[29] concluded that exclusive

Table 2. Life Tables Describing the Incidence of Self-Reported COPD Among Adults (Aged 40+ Years), Population Assessment of Tobacco and Health Study (Waves 1–5, 2013–2019)

Interval	Total	COPD diagnosis	Censored	Survivor estimate[a]	Hazard estimate[b]
Period 1 (Waves 1 and 2)	9,861	314	646	0.968	0.024
Period 2 (Waves 2 and 3)	8,901	252	719	0.941	0.021
Period 3 (Waves 3 and 4)	7,930	158	785	0.922	0.014
Period 4 (Waves 4 and 5)	6,987	201	6,785	0.896	0.019

COPD, chronic obstructive pulmonary disease.
[a]Survival estimates were based on unweighted data.
[b]Hazard estimates were calculated with the replicate weights.

ENDS use increased COPD risk. There are several reasons that might explain these different findings. First, this study examined the prospective association between time-varying ENDS use and COPD incidence, adjusting for time-varying cigarette smoking status. Conversely, Xie and colleagues[29] looked at the association between baseline ENDS use and 5-year risk of COPD incidence. This means that they did not account for patterns of ENDS use or cigarette smoking that occurred after baseline and before COPD incidence. It is established that current cigarette use is a major COPD risk factor,[7] and with more than half of people who used ENDS at

Table 3. Discrete Time Survival Analysis Predicting Incidence of Self-Reported COPD for Respondents Aged ≥40 Years, Population Assessment of Tobacco and Health Study (Waves 1–5, 2013–2019)

Variables	Model 1[a]		Model 2[b]		Model 3[c]		Model 4[d]	
	Hazard	95% CI	Hazard	95% CI	Hazard	95% CI	Hazard	95% CI
Time-varying ENDS use	**1.98*** **	1.44, 2.74	**1.70** **	1.21, 2.40	1.16	0.82, 1.65	1.1	0.78, 1.56
Age (years)[e]			**1.03*** **	1.02, 1.03	**1.03*** **	1.02, 1.04	**1.03*** **	1.02, 1.04
Sex (female=1)			**1.59*** **	1.34, 1.88	**1.70*** **	1.42, 2.03	**1.80*** **	1.51, 2.15
Race/ethnicity								
NH White			Ref	Ref	Ref	Ref	Ref	Ref
Hispanic			0.94	0.73, 1.21	1.06	0.82, 1.36	1.18	0.92–1.52
NH Black			1.21	0.99, 1.49	1.16	0.94, 1.44	**1.27***	1.03, 1.58
NH other			0.94	0.59, 1.49	0.99	0.63, 1.56	1	0.64, 1.59
Education								
High school or less			**2.19*** **	1.67, 2.88	**1.83*** **	1.40, 2.40	**1.72*** **	1.31, 2.26
Some college			**1.57** **	1.17, 2.10	1.40*	1.05, 1.88	**1.33***	1.0, 1.78
Bachelor's degree or higher			Ref	Ref	Ref	Ref	Ref	Ref
Uninsured			1.32	0.99, 1.76	1.18	0.88, 1.56	1.16	0.88, 1.55
Baseline risk factors								
Asthma			**2.95*** **	2.26, 3.84	**2.98*** **	2.29, 3.89	**3.04*** **	2.32, 3.98
Obesity (BMI>30)			**1.34** **	1.11, 1.63	**1.43*** **	1.18, 1.73	**1.41** **	1.16, 1.71
Time-varying second-hand smoke exposure[f]			**1.19*** **	1.15, 1.23	**1.11*** **	1.07, 1.16	**1.09*** **	1.04, 1.14
Other' combustible tobacco product use					1.26	0.94, 1.68	1.25	0.94, 1.65
Time-varying smoking status indicator								
Nonestablished or never smoking					Ref	Ref	Ref	Ref
Formerly established smoking					**1.50** **	1.17, 1.94	0.85	0.59, 1.23
Current established smoking					**3.13*** **	2.55, 3.83	**1.63** **	1.16, 2.27
Log cigarette pack years[f]							**1.79*** **	1.46, 2.19

Notes: Boldface indicates statistical significance (*p<0.05, **p<0.01, and ***p<0.001).
Person n=9,861; risk n=33,679.
NH, non-Hispanic.
[a]ENDS exposure.
[b]Sociodemographic variables added.
[c]Smoking status added.
[d]Cigarette pack years added.
[e]Age mean centered for models.
[f]Variable rescaled to reflect intervals of 10 hours.

Table 4. Time-Varying ENDS Use by Smoking Status, Cigarette Pack Years, and Second-Hand Smoke Exposure, Population Assessment of Tobacco and Health Study (Waves 1–5, 2013–2019)

Smoking Variables	Wave 1					Wave 2				
	No ENDS use		ENDS use			No ENDS use		ENDS use		
	% or mean	95% CI	% or mean	95% CI	*p*-Value	% or mean	95% CI	% or mean	95% CI	*p*-Value
Prevalence of ENDS use	98.6	98.4, 98.7	1.4	1.2, 1.6		98.3	98.0, 98.5	1.7	1.5, 2.0	
Time-varying smoking status indicator					***					***
Proportion nonestablished or never smoking (%)	63.8	62.2, 65.3	7.9	5.5, 11.1		61.6	60.0, 63.1	4.1	2.4, 7.1	
Proportion former smoking (%)	23.1	21.9, 24.4	30.7	25.3, 36.7		25.2	23.9, 26.6	37.5	31.8, 43.7	
Proportion current smoking (%)	13.1	12.5, 13.7	61.4	55.9, 66.7		13.2	12.6, 13.8	58.4	52.6, 63.9	
Baseline cigarette pack years (mean, SD)	24.5 (26.1)		27.4 (32.4)		*	23.7 (25.5)		29.2 (32.7)		**
Time-varying second-hand smoke exposure (mean hours, SD)	4.0 (12.7)		12.3 (34.4)		***	3.5 (11.8)		13.1 (35.7)		***

XXX	Wave 3					Wave 4				
	No ENDS use		ENDS use			No ENDS use		ENDS use		
	% or mean	95% CI	% or mean	95% CI	*p*-Value	% or mean	95% CI	% or mean	95% CI	*p*-Value
Prevalence of ENDS use	98.3	98.1, 98.5	1.7	1.5–1.9		98.6	98.3–98.8	1.4	1.2–1.7	
Time-varying smoking status indicator					***					***
Proportion non-established or never smoking (%)	60.7	59.0, 62.3	3.4	1.8, 6.2		60.5	58.7,62.3	3.6	1.6, 7.8	
Proportion former smoking (%)	26.3	24.9, 27.8	40.8	34.7,47.2		27.2	25.6,28.8	46.7	39.6, 54.0	
Proportion current smoking (%)	13	12.3, 13.6	55.8	49.7,61.8		12.3	11.6,13.1	49.7	42.4, 57.1	
Baseline cigarette pack-years (mean, SD)	22.9 (24.7)		28.5 (32.9)		**	22.3 (24.1)		30.9 (35.5)		**
Time-varying second-hand smoke exposure (mean hours, SD)	3.1 (10.8)		11.2 (31.4)		***	2.9 (10.3)		9.9 (29.6)		***

Notes: Boldface indicates statistical significance (*p<0.05, **p<0.01, and ***p<0.001).

baseline reporting continued cigarette smoking at follow-up, it is not possible to parse out the impact of continued cigarette smoking at follow-up from baseline ENDS use. Second, although this study included continuous cigarette pack years for both current and former cigarette smoking, Xie et al.[29] created a crude categorical pack-years measure for current cigarette smoking (<5, 5−20, and 20+ pack years) but did not include a pack-years measure for former cigarette smoking. By not adjusting for cigarette pack years among people who formerly smoked, who comprised nearly one third of baseline ENDS use, Xie and colleagues[29] did not account for the considerable smoking history among those who formerly smoked. Third, this study defined ever *E-cigarette* use as those who reported ever using E-cigarettes fairly regularly at each wave, whereas Xie et al.[29] defined ever *E-cigarette use* as those who reported ever using E-cigarettes even 1 or 2 times for their main analysis. This distinction is important because Xie and colleagues'[29] definition included those who tried E-cigarettes only once or twice. Fourth, the analytic sample in this study was restricted to adults aged ≥40 years at baseline, reflecting the ages at which COPD diagnoses are most likely associated with exposure to noxious particles or gases.[2] In contrast, Xie et al.[29] included all adults aged ≥18 years in their study. COPD is rare among younger age groups, especially among those aged between 18 and 24 years, and younger age has been associated with a greater likelihood of misdiagnosis.[30]

Although ENDS use was not associated with incident COPD risk, consistent with other emerging literature,[5,7,27] this study found evidence of a strong association between cigarette smoking status and COPD, with higher risk among adults who currently smoked than among adults who smoked in the past or never smoked.[7] However, smoking status by itself is limited because it does not account for exposure level. Long-term smoking is required to develop COPD,[31] and these findings confirm that cigarette pack years are independently associated with the risk of COPD incidence. Similar to other research,[8] this study also found that time-varying SHS exposure was predictive of self-reported COPD incidence. Thus, incorporating measures of both direct and indirect smoking exposure is important to more fully understand the smoking−COPD relationship.

Limitations

There are several limitations. First, the findings were based on approximately 5 years of data, and a longer follow-up may be required to fully understand the role of ENDS use on the risk of COPD, a chronic and long-term condition. If similar exposure time is required for ENDS as for cigarettes, it is possible that the downstream consequences of ENDS use may not be observable until far into the future.[31] Not only are ENDS products relatively new to the tobacco marketplace, but they also continue to evolve, and more recent generations of ENDS products have more efficient nicotine delivery. This study did not adjust for nicotine level or product type. Future studies should account for ENDS product characteristics as longer-term longitudinal data become available. Second, ENDS use was only reported by a small number of respondents, potentially limiting the power to detect an association between ENDS use and COPD. PATH is a nationally representative sample of the U.S. population, so ENDS use prevalence reflects the use patterns of the population. However, ENDS use is more prevalent among youth and young adults,[32,33] and although we included an analysis of adults aged 25+ years as a sensitivity analysis, further analyses of PATH data are warranted as more data become available. Third, the nonrandomized data analyzed in this study means that the results could be affected by unmeasured confounding, and future research would benefit from adjusting for a more comprehensive series of COPD risk factors. Fourth, the study results are based on self-reported COPD diagnosis and not based on evidence from a spirometry test. This is a limitation of the PATH data, but the COPD prevalence estimates are generally consistent with those from the National Health and Nutritional Examination Survey,[27] and previous studies have shown the concurrent validity of other self-reported health outcomes using PATH.[34]

CONCLUSIONS

Using nationally representative prospective data, time-varying ENDS use during a 5-year period did not increase the risk of self-reported COPD incidence once current cigarette use and cigarette pack years were considered. Most adults who used ENDS either currently or formerly smoked cigarettes, highlighting the need to control for cigarette smoking history to assess any potential independent health effects of ENDS use on COPD.

CREDIT AUTHOR STATEMENT

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SUPPLEMENTAL MATERIAL

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