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Electronic cigarette (e-cigarette) use and frequency of asthma symptoms in adult asthmatics in California

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ABSTRACT

Introduction: Electronic cigarettes use is increasing in the United States. One motive for e-cigarette's popularity is that they wean from combustible cigarettes. Smokers perceive electronic cigarette products as healthier than cigarette smoking and as a useful tool for smoking cessation. However, research has indicated the use of electronic cigarettes may have harmful effects on respiratory function even with short-term use. Respiratory effects of e-cigarette use among asthmatics are little understood.

Objective: The aim of this study was to determine the association between e-cigarette use and frequency of asthma symptoms among adult asthmatics in California from 2015–2016.

Methods: This cross-sectional study included a total of 1277 adult asthmatics. The presence of asthma was based on an adult's self-reported doctor diagnosis. The analysis was controlled for age, education, sex, race, body mass index, and smoking status.

Results: E-cigarette use was associated with increased odds of having more frequent asthma symptoms (OR = 1.69, CI: 1.20–2.39, $p=0.002$; OR_{adj} = 1.65, CI: 1.09–2.49, $p=0.016$). Male e-cigarette users were more likely to have more frequent asthma symptoms compared to male nonusers (OR = 1.90, CI: 1.13–3.19, $p=0.015$; OR_{adj} = 2.42, CI: 1.28–4.55, $p=0.006$). No differences were found between female e-cigarette users and nonusers (OR = 1.43, CI: 0.86–2.37, $p=0.162$; OR_{adj} = 1.26, CI: 0.72–2.18, $p=0.162$).

Conclusion: Our findings suggest that e-cigarette use is associated with more frequent asthma symptoms and disproportionally affects male asthmatics.

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Introduction

Asthma is a disease that affects roughly 25 million people in the United States and this number continues to grow (1). As of 2018, 2,607,598 adults in California suffered from asthma (1). Asthma episodes vary in severity and frequency from person to person and can be debilitating as a result of the inflammation and swelling of airways. As a consequence, asthmatics can suffer repeated episodes of wheezing, breathlessness, chest tightness, and coughing (2). Multiple factors have been associated with the worsening of asthma including air pollution (3), smoking (4), and second-hand smoke (5).

Electronic cigarettes also known as e-cigarettes, vapes, or electronic nicotine delivery systems (ENDS) are devices that allow users to inhale an aerosol which typically contains nicotine, flavorings, and other additives (6). Electronic cigarettes contain materials that are respiratory irritants (7). Furthermore, exposure to

a variety of e-cigarette aerosols produces reactions such as amplified sensitization and exacerbation of asthma (8).

The use of electronic cigarettes is increasing in the U.S. In 2017, 2.8% of U.S. adults were current electronic cigarette smokers (9). One motive for e-cigarette's popularity is that they are thought to help reduce or eliminate the use of combustible cigarettes. Smokers perceive the electronic cigarette product as healthier alternative to cigarette smoking and they are useful for smoking cessation (10). Further, a study in the U.S. showed that current smokers with asthma and other comorbidities had higher odds of current e-cigarette use (11). However, research has indicated that using electronic cigarettes may have harmful effects on respiratory function even with short-term use (12). Since 2019, the California Department of Public Health received reports of 210 people in California who have a history of using electronic

cigarettes being hospitalized for severe breathing problems and lung damage along with 4 deaths (13).

A recent randomized controlled trial in Greece evaluated the acute effects of e-cigarette use on pulmonary function and airway inflammation in healthy and asthmatic participants. The study found that e-cigarette use produced significant alterations in the respiratory parameters and the inflammation markers in stable asthmatics with moderate asthma and not among healthy individuals (14). Another study found evidence that one single session of e-cigarette smoking produced immediate mechanical and inflammatory effects in healthy smokers and asymptomatic smokers with mild asthma, although these effects were more prominent among asthmatics (15).

Even though previous studies documented the potential harmful effects of e-cigarette use in the pulmonary system, little is known about the association between e-cigarette use and the frequency of symptoms of asthma. We hypothesized that the use of e-cigarettes is associated with asthma symptoms among adult asthmatics. To test this hypothesis, we used cross-sectional survey data from the California Health Interview Survey (CHIS) and examined the relationship between e-cigarette use and the frequency of asthma symptoms among adult asthmatics in California during 2015 and 2016. We assessed this relationship accounting for the possible confounders of age, body mass index (BMI), and smoking status.

Materials and methods

Data and participants

Data was collected from the adult public use file of the 2015–2016 California Health Interview Survey (CHIS), the nation's largest state health survey (16). This publicly available data contains no personal identifiable information. CHIS collects information about the health status of California citizens by telephone and online of households in California. The adult sample of 2015–2016 contained 21,034 individuals of which 1277 adults were diagnosed with asthma by a doctor in the last 12 months and had asthmatic symptoms.

Variables

We used frequency of asthma symptoms as the outcome variable. The main exposure variable was e-cigarette use (“yes” or “no”). The analysis was controlled for sex (male and female), age (18–24, 25–34, 44, 45–64, 65 or above), BMI (weight (in kg) = height²

(in m)) (“underweight” a BMI < 18.5, “normal weight” BMI between 18.5 and 24.99, “overweight” BMI between 25.0 and 29.99 and “obese” BMI of 30 and above) and smoking status (smoker or non-smoker). Dual use of e-cigarette and tobacco product was not reported in CHIS.

Study design

A cross-sectional study was used that included a total of 1277 adult asthmatics for the study population. The presence of asthma was based on an adult's self-reported doctor diagnosis of asthma in the past 12 months and the presence of asthma symptoms.

Statistical analysis

We used ordered logistic regression methods to assess the relationship between e-cigarette use and the four-category measurement of asthma symptoms. The four categories of outcome variable frequency of asthma symptoms were “less than every month,” “every month,” “every week,” and “every day.” Ordered logistic regression uses proportional odds models, also called cumulative odds models (17–19). The proportional odds assumption of the ordered logistic regression assumes that the coefficients that describe the relationship between the lowest categories compared to higher categories of the response variable are the same as those that describe the relationship (20). Thus, the models are based on the cumulative distribution probabilities of the categories of frequency of asthma symptoms, instead of on their individual probabilities (21).

First, the bivariate relationship between the independent variables and frequency of asthma symptoms was estimated. The probability of having asthma symptoms less often versus more often with the independent variables was predicted. Second, we adjusted for confounders by estimating the effects of e-cigarette use on frequency of asthma symptoms controlling for age group, BMI, and smoking status. The confounders were chosen through stepwise ordered logistic regression. In addition, assessment was made after stratification by sex (male vs. female). We calculated crude odds ratios (OR) and adjusted odds ratios (OR_{adj}) with 95% confidence intervals (CIs). Statistical significance was considered for *p* values <0.05 (two-sided tests). We tested the proportional odds assumption using the likelihood-ratio test of proportionality and the Brant test; both yielded nonsignificant results (χ^2

= 18.01 and $\chi^2 = 19.14$, respectively) providing evidence that the assumption has not been violated (19).

Sample weights were used to account for the complex survey design. Sampling correcting procedures reduce the possibility of selection bias and ensure that the participants represent the population in California. All analyses were performed on the weighted data using STATA version 13. 1.

Results

Descriptive analysis of the study population

Of 1277 asthmatic adults in the 2015–2026 survey, 34% were men and 66% were female. The majority of the respondents described in Table 1 were adults older than 25 years of age (83%) and younger respondents were 17%. The percentage of non-Hispanic White participants was 45% of the population, followed by Hispanic participants that accounted for 32%. Non-hispanic Asians participants were 10%, non-Hispanic Black participants were 9% and other races/ethnicities were approximately 4%. According to their BMI, the majority of the respondents were either overweight (32%) or obese (40%). Overall, the majority of the respondents had a bachelor's degree or a higher degree (36%); followed by those that attended some college (28%). Only 16% of the respondents were currently combustible cigarette smokers while e-cigarette users were 23% of the respondents.

Unadjusted and adjusted models

Table 2 shows the OR and OR_{adj} for e-cigarette use and frequency of asthma symptoms. Adults with asthma that were e-cigarette users had higher odds of having asthma symptoms more often compared to non-e-cigarette users (OR = 1.69, CI: 1.20–2.39, $p = 0.002$). After adjusting for demographic variables, the odds were still statistically significant (OR_{adj} = 1.65, CI: 1.09–2.49, $p = 0.016$). Another characteristic that showed statistical significance was smoking status. Smokers had higher odds of having more frequent asthma symptoms compared to nonsmokers (OR = 1.75, CI: 1.22–2.51, $p = 0.002$); however, the effect of smoking was not statistically significant after adjustment for all other characteristics (OR_{adj} = 1.31, CI: 0.86–2.00, $p = 0.201$).

Stratification by sex

“The stratified analysis by sex is shown in Table 3. Male e-cigarette users had higher odds of having

Table 1. Characteristics of the population sample composed of adult asthmatics (California Health Interview Survey, 2015–2016; $N = 1277$).

	Unweighted, N (%)	Weighted % (95% CI)
Total, no. (%)	1277 (100)	
Sex, no. (%)		
Male	394 (30.85)	34.36 (28.50–40.22)
Female	883 (69.15)	65.63 (59.77–71.49)
Age, no. (%)		
18–24	181 (14.17)	16.86 (12.43–21.27)
25–44	320 (25.06)	38.09 (31.17–44.99)
45–64	731 (57.24)	43.03 (37.42–48.63)
65 and older	45 (3.52)	2.03 (0.65–03.40)
Education, no. (%)		
Less than high school	141 (11.04)	13.08 (8.65–17.50)
High school or GED	320 (25.06)	22.90 (18.81–26.99)
Some college or associate degree	384 (30.07)	27.97 (22.76 – 33.19)
Bachelor's degree or higher	432 (33.83)	36.03 (31.17–40.89)
Race, no. (%)		
NH White	708 (55.52)	45.00 (39.31–50.69)
NH Black	128 (10.02)	9.10 (5.96–12.24)
NH Asian	56 (4.39)	9.54 (5.25–13.86)
NH Other	77 (6.03)	3.95 (2.04–5.86)
Hispanic	307 (24.04)	32.39 (26.56–38.22)
BMI categories, no. (%)		
Underweight	15 (1.17)	0.85 (0.16–01.53)
Normal weight	335 (26.23)	27.34 (20.83–33.85)
Overweight	382 (29.91)	31.56 (25.43–37.69)
Obese	545 (42.68)	40.23 (33.77–46.69)
Smoking status, no. (%)		
Smoker	241 (18.87)	15.96 (79.82–88.26)
Non-smoker	1036 (82.15)	84.04 (11.73–20.17)
E-cigarette use, no. (%)		
User	259 (20.28)	22.98 (17.19–28.78)
Non-user	1018 (79.72)	77.01 (71.21–82.80)

BMI, body mass index (kg/m^2).

more frequent asthma symptoms compared to male non-e-cigarette users (OR = 1.90, CI: 1.13–3.19, $p = 0.015$; OR_{adj} = 2.42, CI: 1.28–4.55, $p = 0.006$). No differences were found between female e-cigarette users and nonusers. (OR = 1.43, CI: 0.86–2.37, $p = 0.162$; OR_{adj} = 1.26, CI: 0.72–2.18, $p = 0.162$). Noteworthy, women ages 25 to 44 years old had lower odds of having more frequent asthma symptoms compared to the reference group (OR = 0.52, CI: 0.29–0.93, $p = 0.029$; OR_{adj} = 0.47, CI: 0.26–0.87, $p = 0.017$). However, female smokers had increased odds of having more frequent asthma symptoms compared to nonsmokers (OR = 1.78, CI: 1.08–2.94, $p = 0.024$). After adjustment for other factors the effect of smoking was not statistically significant (OR_{adj} = 1.58, CI: 0.88–2.81, $p = 0.121$).

Discussion

We investigated the association between e-cigarette use and the frequency of asthma symptoms among adult asthmatics in California during 2015–2016. To our knowledge, this is the first study conducted in

Table 2. Associations between e-cigarette use and frequency of asthma attacks among adult asthmatics.

	Unadjusted model			Adjusted model		
	OR ^a	<i>p</i>	95% CI	OR _{adj} ^b	<i>p</i>	95% CI
Age						
18–24	c			c		
25–44	0.72	0.162	0.46–1.13	0.64	0.055	0.40–1.00
45–64	1.11	0.612	0.73–1.70	1.09	0.686	0.70–1.69
65 and older	0.96	0.942	0.33–2.78	1.02	0.957	0.37–2.84
BMI categories						
Normal weight	c			c		
Underweight	1.79	0.418	0.43–7.39	0.64	0.528	0.35–2.58
Overweight	1.46	0.067	0.97–2.21	1.58	0.113	0.92–2.14
Obese	1.34	0.143	0.90–1.99	1.34	0.179	0.87–1.98
Smoking status						
Non-smoker	c			c		
Smoker	1.75	0.002**	1.22–2.51	1.31	0.201	0.86–2.00
E-cigarette use						
Non-user	c			c		
User	1.69	0.002**	1.20–2.39	1.65	0.016*	1.09–2.49

Note. ^aUnadjusted odds ratio; ^badjusted odds ratio; ^creference category.

p* < 0.05; *p* < 0.01; ****p* < 0.001.

OR, odds ratio; BMI, body mass index (kg/m²).

Table 3. Associations between e-cigarette use and frequency of asthma attacks among adult asthmatics by sex.

	Male		Female	
	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age				
18–24	a	a	a	a
25–44	0.28 (0.55–2.43)	0.98 (0.45–2.11)	0.52 (0.29–0.93)*	0.47 (0.26–0.87)*
45–64	0.37 (0.93–3.98)	2.10 (1.00–4.40)	0.85 (0.50–1.44)	0.80 (0.45–1.41)
65 and older	0.43 (0.48–1.05)	2.03 (0.66–2.09)	0.58 (0.17–1.89)	0.56 (0.18–1.76)
BMI categories				
Normal weight	a	a	a	a
Underweight	3.52 (0.58–2.19)	4.15 (0.56–3.40)	0.47 (0.05–3.09)	0.32 (0.03–2.89)
Overweight	1.32 (0.63–2.76)	1.04 (0.46–2.33)	1.50 (0.91–2.45)	1.46 (0.88–2.44)
Obese	1.53 (0.76–3.05)	1.23 (0.58–2.62)	1.22 (0.76–1.97)	1.29 (0.79–2.10)
Smoking status				
Non-smoker	a	a	a	a
Smoker	1.61 (0.93–2.77)	0.93 (0.47–1.83)	1.78 (1.08–2.94)*	1.58 (0.88–2.81)
E-cigarette use				
Non-user	a	a	a	a
User	1.90 (1.13–3.19)*	2.42 (1.28–4.55)**	1.43 (0.86–2.37)	1.26 (0.72–2.18)

Note. ^aReference category.

p* < 0.05; *p* < 0.01; ****p* < 0.001.

OR, odds ratio; BMI, body mass index (kg/m²).

California that investigated the effect of e-cigarette use on the symptoms of previously diagnosed asthmatics. California is among the top five states in the U.S. affected by asthma (1). The severity and frequency of symptoms can determine the quality of life for individuals that suffer from asthma (21,22). Frequent asthma symptoms can be debilitating. Asthmatics that experience symptoms frequently are more likely to miss work and school (23); and are more likely to suffer depression and anxiety (24,25). Thus, management of the symptoms is a significant intervention (26).

Our findings expand the evidence that e-cigarette use compromises respiratory health. We verified the hypothesis that e-cigarette use is associated with asthma symptoms among adult asthmatics. We found

that e-cigarette use increased odds of having more frequent asthma symptoms; and the effect of e-cigarette use was still significant after controlling for other factors, however, at a lower level. This is consistent with research that has found e-cigarette fluids act as respiratory irritants and distress the respiratory function (22). There is evidence indicating that exposure to e-cigarette aerosols results in sensitization and exacerbation of asthma (8). Other studies have demonstrated that e-cigarette use increased airway resistance (12,27–29). Similar effects were found in mice, where inhalation of e-cigarette fluids increased airway inflammation, hyperresponsiveness and inflammatory cytokines (30). Furthermore, these consequences vary depending on their level of toxicity (31). A recent

systematic review on 27 case reports concluded that e-cigarette use can cause negative health effects on previously healthy individuals and exacerbate preexisting conditions (32). Six case studies reported the negative effects on the lower respiratory tract (33–38). Cross-sectional studies support this evidence as well. In South Korea, a study in high school students reported that e-cigarette use may be a risk factor for asthma (39). Another study in multiethnic cohort had similar results (40). Our findings are consistent with this evidence, and individuals with a compromised respiratory system such as asthmatics may be more affected by e-cigarette use.

Asthma affects males and females differently throughout their life (41–43). It is believed that hormonal differences (44), immune response (45), and intrinsic pulmonary characteristics account for this variation (46). Thus, we decided to further assess the use of e-cigarette among males and females and frequency of asthma symptoms. Our findings showed that male e-cigarette users were more likely to have more frequent asthma symptoms compared to male nonusers. Nonetheless, female e-cigarette users showed no significant difference compared to nonusers. Previous health conditions may explain these differences. For instance, a study found that males were more likely to initiate e-cigarette use to quit smoking due to health concerns more often than females (47). The liquid in e-cigarettes is a combination of propylene glycol, glycerin, nicotine and other trace additives. It is likely that sex differences in susceptibility and toxicity to these chemicals exist, as it has been demonstrated for a large variety of toxicants (48,49).

Strengths and limitations

This is the first study investigating the effect of using e-cigarette in asthmatic adults in California. Few studies on the effects of e-cigarette use have been done in the U.S.; and most of these studies were case reports on previously healthy individuals. The effect of e-cigarette on people with chronic respiratory conditions such as asthma is still scarce.

This study has limitations. The study relied on self-reports and lacks validation of the asthma diagnosis by medical assessment and confirmatory tests (i.e. spirometry and pulmonary function test). Individuals may not accurately report their asthma diagnosis, asthma symptoms and e-cigarette use. Therefore, the study may be subject of recall bias and may produce different estimates than diagnostic codes. Nonetheless, the estimates of diagnosed asthma reported in CHIS

are similar to the prevalence reported on the asthma surveillance data reported by the Centers for Disease Control and Prevention (CDC) during 2015 (50). Another limitation of the study is the lack of information about the different phenotypes of asthma and current asthma treatment. The use of medications to control asthma symptoms may modify the response to asthma triggers. This information could aid further to clarify the association between e-cigarette use and asthma symptoms. The participants did not report the frequency and the amount of e-cigarette use; therefore, a dose-response analysis was not performed in this study. In addition, the participants did not report the dual use status, defined as current use of both e-cigarettes and combustible cigarette.

Conclusion

Limiting e-cigarette use can be crucial for asthma management. Our findings indicate that e-cigarette use is linked to increased frequency of asthma symptoms among adults in California. And male cigarette users are disproportionately affected. Additional studies are needed to quantify the amount and the level of toxicity of e-cigarettes for individuals with prior respiratory disease.

We encourage health providers to routinely ask asthmatic patients about e-cigarette habits and warn them of the potential harmful effects of e-cigarette use for those that look for an alternative to tobacco smoking.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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