HHS Public Access

Author manuscript

Prev Med. Author manuscript; available in PMC 2023 August 01.

Published in final edited form as:

Prev Med. 2022 August ; 161: 107137. doi:10.1016/j.ypmed.2022.107137.

Tests for Confounding with Cigarette Smoking in the Association of E-cigarette Use with Respiratory Disorder: 2020 National-Sample Data

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Abstract

Associations of e-cigarette use with respiratory disorder have been demonstrated but it has been unclear whether these are confounded by current or previous cigarette smoking. We address this question through studying different time frames for e-cigarette use and respiratory disorders in 2020 BRFSS data (N = 214,945). E-cigarette use and combustible cigarette smoking were classified into four categories: Participant never used either (Nonuse); used e-cigarettes/cigarettes but not in the past 30 days (Former Use), used in past 30 days on some days (Nondaily Use), or used past 30 days on all days (Daily Use). Contrasts for e-cigarette status and cigarette status (with nonuse as reference group) were entered with covariates in logistic regression with asthma or COPD as criterion. Stratified analyses of e-cigarette use were also performed for smokers and nonsmokers. In the total sample, results showed independent positive associations with both lifetime and current asthma for Former, Nondaily, and Daily e-cigarette use (mostly $p < 0.0001$) and the three cigarette indices. Significant positive associations with COPD were found for the three e-cigarette indices ($p < 0.0001$) and all the cigarette indices. Stratified analyses showed

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Contributors

Author tasks were: conceptualization of the research questions (TAW, KC), analysis of the data (TAW, PP, IP), interpretation of the results (TAW, PP, KC, IP), drafting of the manuscript (TAW), and review and revision of the manuscript for important intellectual content (TAW, KC, PP, IP).

Conflicts of Interest

No conflicts were reported by the authors of this paper.

Declaration of interests

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.

Ethics Approval

This research was approved by the Institutional Review Board for the University of Hawaii.

CREDIT statement

Thomas Wills: Conceptualization, Methodology, Formal Analysis, Writing Original Draft, Reviewing and Editing. **Kelvin Choi**: Conceptualization, Methodology, Reviewing and Editing. **Pallav Pokhrel**: Conceptualization, Methodology, Reviewing and Editing. **Ian Pagano**: Methodology, Dara Curation, Formal Analysis, Reviewing and Editing.

significant associations of e-cigarette use with respiratory disorder among nonsmokers as well as among smokers. We conclude that independent associations for former e-cigarette use (controlling for current/former smoking) and significant associations of e-cigarette use with respiratory disorder among nonsmokers indicate these associations are not confounded with cigarette smoking and suggest reverse causation is implausible. Findings for former use are discussed with reference to possible mechanisms including sensitization effects.

Keywords

e-cigarettes; combustible cigarettes; asthma; COPD; independent effects

Introduction

The use of electronic nicotine delivery systems (hereafter, e-cigarettes) has become increasingly prevalent among adolescents (Cullen, Gentzke, Sawdey, et al., 2019; Wang, Neff, Park-Lee, et al., 2020) and adults (Cornelius, Wang, Jamal, et al., 2020; Dai & Leventhal, 2019; Mayer, Reyes-Guzman, Grana, & Choi, 2020). This has raised concern about issues such as development of nicotine dependence (Klein, 2018; Thorndike, 2019; Vogel, Cho, McConnell, et al., 2020), transitions to cigarette smoking (Gaiha & Halpern-Felsher, 2020; Osibogun, Bursac, & Maziak, 2020; Pierce, Chen, Leas, et al., 2021), and adverse health consequences (Bush, Lintowsky, Mazur, et al., 2021; Di Cicco, Sepich, Beni, et al., 2022; Joshi, Duong, Kirkland, & Raina, 2021; Kathuria & Leone, 2021).

Recent research has demonstrated associations of e-cigarette use with asthma and COPD (Hickman & Jaspers, 2020; Kotoulas, Katsaounou, Riha, et al., 2021; Wills, Soneji, Choi, et al., 2021). Studies have assessed direct exposure to e-cigarette use (Gotts, Jordt, McConnell, & Tarran, 2019; Wills, Choi, & Pagano, 2020) and secondhand exposure to e-cigarette aerosol (Alnajem, Redha, Alroumi, et al., 2020; Bayly, Bernat, Porter, & Choi, 2019). However, criticisms have been made of this literature. Some commentators have argued that observed associations between e-cigarette use and respiratory disorder were confounded by prior cigarette smoking or may represent reverse causation, i.e., smokers using e-cigarettes to quit (Bates, 2021; Hajat, Stein, Shantikumar, et al., 2021; McNeill, Brose, Calder, Bauld, & Robson, 2018). Research and policy decisions would be influenced if these propositions are true, hence it is important to obtain clear evaluations of them.

The present research uses data from a representative national sample, the 2020 Behavioral Risk Factor Surveillance Survey (BRFSS), to test for possible confounding in the association of e-cigarette use with diagnosed asthma and COPD. We tested directly whether associations of e-cigarette use with respiratory disorder are confounded with current or former cigarette smoking. If a statistical association of e-cigarette use with respiratory disorder is nonsignificant when control for smoking is included in analyses, this would support a confounding hypothesis. However, if e-cigarette use has significant associations with respiratory disorder with control for current smoking and smoking history, this would make the confounding hypothesis less plausible. Hence we tested for independent contributions for both prior and current use, hypothesizing that former as well as current e-cigarette use would

be significantly associated with respiratory disorder with control for both current and prior cigarette smoking, because measures of lifetime use tap longer-term exposures that may be relevant for development or recurrence of disorder

We tested the reverse causation hypothesis by performing separate analyses for smokers and nonsmokers. If e-cigarette use is significantly associated with respiratory disorder only among smokers, this could support a reverse causation process. However, if analyses show e-cigarette use significantly associated with respiratory disorder among nonsmokers, this would make a reverse causation hypothesis less plausible. Accordingly, we performed both total-sample and stratified analyses of e-cigarette use for asthma and COPD.

The hypotheses were tested in multivariable analyses including covariates that may be correlated with e-cigarette use and are relevant for respiratory disorder, including age, gender, race/ethnicity, and obesity (Schweitzer, Wills, Tam, et al., 2017; Wills et al., 2019; 2020). We also controlled for marijuana use because this has been found associated with asthma independent of e-cigarette use in several studies (Schweitzer et al., 2017; Wills et al., 2020).

Methods

The BRFSS is a telephone survey of US residents age 18 and older using a random-digit dial methodology to obtain a probability sample of households. Surveys are conducted through health departments in 50 states and three territories. Contacts are made through landlines or through cell phones using a dual-frame survey methodology to improve the reliability and representativeness of the data (Hu, Pierannunci, & Balluz, 2011). Informed consent was obtained. The present research was based on deidentified data and was designated as exempt by the Institutional Review Board for the University of Hawaii.

Data from methodological studies have supported the reliability and validity and reliability of the BRFSS survey measures (Li, Balluz, Ford, et al., 2012; Pierannunzi, Hu, & Balluz, 2013). In addition, the respiratory disease measures have been validated against direct clinical observation (Radeos, Cydulka, Rowe et al., 2009; Barr, Herbstman et al., 2003).

The 2020 BRFSS survey had a total of 401,958 respondents. The response rate by state ranged from 34.5% to 67.2% and the median across all states/territories was 47.9%, a figure that compares favorably with other similar surveys (Centers for Disease Control, 2020). The BRFSS protocol has a core section of items that are required for all states, along with optional modules that can be included through decisions by individual states. It should be noted that questions about e-cigarettes were in an optional module, only selected by 39 out of the 50 states surveyed.

Measures

The BRFSS includes measures of asthma and COPD, together with a separate section on e-cigarette use and cigarette smoking. Also included are detailed measures of demographic characteristics and body mass index.

E-cigarettes.—EVER USE: “Have you ever used an e-cigarette or other electronic vaping product, even just one time, in your entire life?” (Yes, No, Don’t know/not sure). CURRENT USE: “Do you now use e-cigarettes or other electronic vaping products every day, some days, or not at all?” (Every day, Some days, Not at all, Don’t know/not sure).

Cigarettes.—EVER SMOKED: “Have you smoked at least 100 cigarettes in your entire life?” (Note: 5 packs = 100 cigarettes.) (Yes, No, Don’t know/not sure). CURRENT SMOKING: “Do you now smoke every day, some days, or not at all?” (Every day, Some days, Not at all, Don’t know/not sure).

Asthma.—LIFETIME ASTHMA: “Has a doctor, nurse, or other health professional ever told you that you had asthma” (Yes, No, Not Sure). CURRENT ASTHMA: “Do you still have asthma?” (Yes, No, Not sure).

COPD.—“Has a doctor, nurse, or other health professional ever told you that you had chronic obstructive pulmonary disease, COPD, emphysema or chronic bronchitis.” (Yes, No, Not Sure).

Covariates

Sex: “What was your sex at birth? Was it male or female?” (Male, female, Don’t know/not sure). *Age*: 18–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80 or older. *Education*: “What is the highest grade or year of school you have completed?” (Grades 1–8, grades 9–11; grade 12 or GED; 1–3 years college or technical school; college graduate (4 years college or more). *Race/ethnicity*: White only, non-Hispanic; Black only; non-Hispanic; American Indian or Alaska Native only, non-Hispanic; Asian only, non Hispanic; Native Hawaiian or other Pacific Islander only, non-Hispanic; Other race only, non-Hispanic; Multiracial, non-Hispanic; Hispanic. *Body mass index* (coded from height/weight data): Underweight (BMI < 18), Normal Weight (BMI 18–25), Overweight (BMI 25–29), Obese (BMI 30 or over). *Marijuana*: “During the past 30 days, on how many days did you use marijuana or cannabis?” (None, Number of days, Don’t know / not sure). (There was no item for ever use of marijuana.)

Analysis Methods

Analyses were conducted in January 2022 using SAS version 9.4. Raw variables were recoded such that a higher value means more of the named attribute (e.g., using e-cigarettes, having asthma). For analysis, “Don’t know” or “Not Sure” responses were treated as missing. Weighted analyses using Proc SurveyFreq determined prevalence estimates for the study variables and univariate associations of e-cigarette use and cigarette smoking with the respiratory variables. For further analyses, binary items on ever and current e-cigarette use and cigarette smoking were recoded to four categories: Never Used (never used either e-cigarettes or cigarettes); Former Use (ever used but not currently); Nondaily Use (use currently on some days); and Daily Use (currently use every day).

For multivariable analysis, three binary variables each were coded for e-cigarette use and cigarette smoking, contrasting Former, Nondaily, and Daily Use against Never Used as the

reference group. Asthma Status was coded as a three-level variable (Never Had Asthma, Had Asthma but not currently, Currently Have Asthma). A five-level variable for race/ethnicity (with sparsely populated cells dropped) was coded for analysis with four binary variables contrasting Black, Hispanic, Asian, and Multirace respondents against Whites as the reference group. Variables derived from body mass index were coded with two binary variables contrasting Overweight Status and Obese Status against Normal Weight as the reference group. A multinomial logistic regression analysis was performed with Asthma Status as the criterion, entering simultaneously three e-cigarette indices, three cigarette smoking indices, sex (dichotomous), age (ordinal, 12 levels), education (ordinal, 4 levels), race/ethnicity (4 binary variables), overweight (binary), and obesity (binary). For COPD, a logistic regression analysis was performed with the same predictors and covariates entered simultaneously and with a dichotomous measure for COPD as the criterion variable. These analyses were performed with listwise deletion. A stratified analysis using the same analytic models was conducted separately for groups of nonsmokers and smokers

To test for interaction, the cross-product of lifetime e-cigarette use and lifetime cigarette smoking was added to the main effects in logistic regression with asthma or COPD as the criterion. To test for additive effects, four groups were formed by crossing ever-use of e-cigarettes and cigarettes. Group status was coded with three binary variables contrasting E-Cigarette Only, Cigarette Only, and Dual Use (E-cigarettes + Cigarettes) with Never Used as the reference group. The three group codes were entered in logistic regression with asthma or COPD as the criterion and two planned contrasts tested whether the association for the Dual Use group differed significantly from the association for either of the exclusive-use groups.

For sensitivity analyses, 30-day marijuana use was included in similar (nonstratified) models for asthma and COPD, coded with two binary variables that contrasted Light Use (1–15 days) and Heavy Use (16–30 days) against No 30-day Use as the reference group. It should be noted that the marijuana item was in an optional module included in the survey in only 21 states (40% of the locales)., compared with 39 states (74% of the locales) for the e-cigarette measures.

Results

Preliminary analyses indicated that e-cigarette use was infrequent among respondents over 60 years of age. Accordingly, analyses for e-cigarettes and respiratory disorder were based on an analytic sample of respondents ages 18–59 years (N = 214,945). Prevalence estimates (Table 1) indicated the sample had reasonable distributions for gender, age, and education. For race/ethnicity the sample was majority White and had proportional representation of Black, Hispanic, and Asian-American respondents. Prevalence for overweight and obesity status was consistent with rates from other national studies.

In the analytic sample 69% of respondents had not used e-cigarettes, 25% had formerly used e-cigarettes, 4% had current nondaily use, and 3% had current daily use. Regarding cigarettes, 66% of the sample were nonsmokers, 18% were former smokers, 5% were current nondaily smokers, and 11% were current daily smokers. Regarding respiratory

disorder, 5% of respondents previously (but not currently) had asthma, 9% still had asthma, and 4% had ever been diagnosed by a health professional with COPD.

Univariate Associations with Asthma and COPD

Univariate associations of e-cigarettes and smoking with the respiratory variables (Table 2A) indicated asthma was overrepresented among persons with former, nondaily, and daily e-cigarette use. Associations were noted for current asthma and for previous asthma. COPD showed a similar pattern, being overrepresented among both former and nondaily e-cigarette users.

Univariate associations for cigarettes (Table 2B) showed asthma was overrepresented among daily smokers and nondaily smokers. Notably, asthma was also overrepresented among former smokers. COPD was overrepresented among current nondaily and daily smokers, and there was also an overrepresentation among former smokers.

There was a correlation between smoking and e-cigarette use. Among daily smokers, 67% had ever used e-cigarettes (11% current, 56% noncurrent). Among nondaily smokers, 61% had ever used e-cigarettes (18% current, 43% noncurrent). Hence subsequent analyses controlled for correlations between e-cigarette use and smoking and also controlled for demographic characteristics.

Multivariate Analyses

A multinomial analysis for asthma was performed with all predictors entered simultaneously and a three-level variable for Asthma Status as the criterion. The multinomial model provides separate tests for variables associated with current asthma and variables associated with lifetime (but noncurrent) asthma. For the multivariable analyses the analytic sample size was reduced owing to the age restriction, and data on e-cigarette use were only available for 136,378 participants because these items were not asked in all states (see Table 1). Analytic sample size was also reduced by missing data for variables such as cigarette smoking, race/ethnicity, and body mass index (Table 1).

Results from the multivariate analysis for asthma (Table 3, left column) showed that all three indicators for e-cigarette use had independent associations with asthma. Significant odds ratios were noted both for former e-cigarette use and for current nondaily and daily use. Comparable results were found both for current asthma and for lifetime asthma. Significant odds ratios were also noted for former smoking and daily smoking (for current asthma only) but results for nondaily smoking were nonsignificant. Thus all indicators of e-cigarette use are associated with asthma, controlling for current/former cigarette smoking and other covariates.

Results for COPD (Table 3, right column) showed significant associations for e-cigarettes, with AORs ranging from 1.44 to 1.76. Again, these results were independent of cigarette smoking, which showed strong associations with COPD, notably for current regular smoking and light smoking but also for former smoking.

Significant findings were noted for several demographic characteristics. Current asthma and COPD were more prevalent for women but lifetime asthma was more common among men. Asthma was less likely with advancing age (i.e., inverse odds ratios) but COPD was more likely. Asthma and COPD were both more likely for persons who were obese. Current asthma was less likely for persons with higher education but more likely among persons with lower education; COPD was inversely associated with education. For race/ethnicity, significant odds ratios indicated Blacks and MultiRace respondents were more likely (relative to Whites) to have both current and lifetime asthma, whereas Asian-Americans and Hispanics were less likely to have current asthma. A similar patterning occurred for COPD.

Sensitivity analyses based on the same analytic models with 30-day marijuana use included as a covariate (Table 4) indicated Light Use and Heavy Use of marijuana were both significantly associated with asthma ($p < .0001$) and Heavy Use was significantly associated with COPD ($p < 0.0001$). Of previous results for e-cigarettes and smoking, for asthma 8/10 of the tests remained significant (the two tests for Regular Use were nonsignificant) and for COPD 6/6 of the tests remained significant. Thus controlling for marijuana use did not substantially alter the results.

Tests for Interaction and Additive Effects

In the multinomial analysis for asthma, the adjusted odds ratio for the cross-product of e-cigarettes and smoking for current asthma was 0.98 (CI 0.89–1.07), $p = .64$; and the AOR for previous asthma was 0.90 (0.81–1.03), $p = .15$. For COPD the AOR for the cross-product was 1.03 (0.88–1.22, $p = .70$. Thus the cross-product analyses did not show evidence for interaction.

Tests for additive effects were based on forming groups of Nonusers (N = 71,176, 52% of the sample), Exclusive E-cigarette Users (N = 13,287, 10%), Exclusive Cigarette Smokers (N = 24,490, 18%), and Dual Users (N = 27,022, 20%) and determining the association of the groups with respiratory illness in logistic regression for three binary group codes (Nonusers as reference group (Supplementary Table 1). Adjusted odds ratios showed likelihoods of respiratory illness for the three substance-using groups were all significantly greater than nonusers. The first planned contrast (E-cigarette Only vs. Dual User) was significant for asthma, (Wald chi-square (1 df) = 11.80, $p = .001$) and for COPD (214.58, $p < .0001$) both indicating an additive effect. The second planned contrast (Cigarette Only vs. Dual User) was significant for asthma, Wald chi-square (1 df) = 88.65, $p < .0001$, and for COPD, 352.10, $p <.0001$, both indicating an additive effect.

Stratified Analysis for Smokers and Nonsmokers

The stratified analysis was conducted with analytic samples of approximately 72,000 for nonsmokers and 44,000 for smokers. Results for nonsmokers (Table 5A) showed significant associations of e-cigarette use with asthma for 5 of the 6 multinomial tests. For COPD there was a significant association for Former e-cigarette use (AOR= 1.55, $p < .0001$) but Nondaily Use and Daily Use were nonsignificant. These analyses support the hypothesis of an association of e-cigarette use with respiratory disease among nonsmokers.

Among smokers (Table 5B), five of the six tests for e-cigarettes showed significant associations with asthma. All three tests for COPD showed significant associations. Though odds ratios for COPD tended to be larger among smokers compared with nonsmokers, the cross-product tests were nonsignificant, indicating lack of evidence for a synergistic interaction between e-cigarette use and cigarette smoking.

Discussion

The primary aim of this research was to test for confounding with cigarette smoking in associations of e-cigarette use with respiratory disorder. Although e-cigarette use and smoking were correlated, multivariable analyses including covariates and controlling for smoking showed e-cigarette use significantly associated with both asthma and COPD, consistent with prior studies of adolescents and adults (Wills et al., 2021). Our analyses showed hypothesized independent associations for both former and current e-cigarette use, controlling for important demographic characteristics including age, gender, and race/ethnicity. Moreover, we found significant associations of e-cigarette use with asthma and COPD among nonsmokers. Both approaches support the proposition that associations of e-cigarette use with respiratory conditions are not confounded with prior history of cigarette smoking. We did find evidence for additive effects, that is, e-cigarette use adds to the odds of illness among smokers, so dual use is not harm free from a health standpoint.

Our sensitivity analyses indicated that associations of e-cigarette use with respiratory disorder were independent of marijuana use, though this conclusion is tentative because the sample size for the sensitivity analyses was lower than that for the main analyses (because of the lesser availability of data on marijuana). The observed association of marijuana use with respiratory disease is noteworthy because many states in the US have passed regulations legalizing the medicinal and recreational use of marijuana.

As the analyses were based on cross-sectional data, several issues are relevant for interpretation. One is the question of reverse causation, that is, could positive associations of e-cigarette use with respiratory outcomes reflect a process in which persons who develop respiratory disease take up e-cigarette use to stop smoking. This interpretation would be inconsistent with the present findings showing significant associations of e-cigarette use with respiratory disease among nonsmokers (see also Osei, Mirbolouk, Orimoloye, et al., 2020; Perez, Atuegwu, Oncken, et al., 2019; Wills, Pagano, Schweitzer, & Tam, 2019). In addition, it would be inconsistent with findings from prospective studies that have shown e-cigarette use related to incident respiratory disease among initially disease-free persons (Bhatta & Glantz, 2020; Reddy, Schwamm, Kalkhoran, et al., 2021; Xie, Kathuria, Galiatsatos et al., 2020). Thus we think reverse causation is not a very plausible interpretation for the results.

A second issue is the time frame for disease development. Recent data have shown that there is a considerable amount of asthma onset in adulthood; the review by Tan, Walters, Peret, et al. (2015) noted that among persons who have asthma in middle adulthood, approximately 50% started as children but 50% initially presented with asthma as adults. Asthma is a condition characterized by exacerbations and remissions (Hickman & Jaspers,

2020; Kotoulas et al., 2021). Thus asthma that began in childhood or adolescence (e.g., Schweitzer et al., 2017) could still be present in adulthood if symptoms were exacerbated by e-cigarette use, even if there had been earlier remission.

There is also a question about how exposure to e-cigarettes could be related to COPD, which conventionally is regarded as only manifesting at 40–50 years of age and requiring a history of 20 years of cigarette smoking as a predictor (Postma & Rabe, 2015). The question of whether asthma contributes to development of COPD or whether symptoms of asthma and COPD sometimes occur together is not fully resolved (Bujarski, Parulekar, Sharafkhaneh, & Hanania, 2015; deMarco, Pesce, Marson et al., 2013; Mirabelli, Beavers, & Chatterjee, 2014; Postma & Rabe, 2015), but prospective studies have shown that having asthma precedes the development of COPD in time, hence is a true risk factor (e.g., Silva, Sherrill, Guerra, & Barbee, 2004). Thus a variable that contributed to asthma could also be a risk factor for development of COPD, which, like asthma, is a disease with exacerbations and remissions (Bujarski et al., 2015; Postma & Rabe, 2015).

Finally there is a question about how a common conception of ever use as having used e-cigarettes only one or two times (McNeill et al., 2018) could be relevant for respiratory disease. Data actually show that the majority of ever users have used e-cigarettes a number of times (Schweitzer et al., 2017; Wills et al., 2020), and laboratory studies with both animal and human models have shown that even brief exposure to e-cigarette aerosol activates biological processes such as oxidative stress that are relevant to respiratory disease (Gordon, Karey, Rebuli, et al., 2022; Kelesidis, Tram, Nguyen, et al., 2021; Wills et al., 2021). Thus it is biologically plausible that a long history of e-cigarette use is not necessary for contributing to disease development or exacerbation (Hickman & Jaspers, 2020; Postma & Rabe, 2015; Rounds & Lu, 2020).

Limitations

While the present research had a large representative sample and analyses with multiple covariates, some aspects could be noted as possible limitations. The data were cross-sectional and do not provide definitive inferences about temporal relations between variables. This research is based on self-reported disease status and the results might be influenced by recall or misclassification errors (though see Ball et al., 2002; Radeos et al., 2009). The BRFSS survey had limited information about the type of e-cigarette device used, the frequency and intensity of lifetime e-cigarette and marijuana use, and the inclusion of flavorings. Also, the BRFSS survey does not include information on other causes of asthma such as environmental pollution and second-hand smoke exposure. However, other studies have shown significant associations of e-cigarette use with respiratory outcomes controlling for second-hand smoke exposure and marijuana use (Schweitzer et al., 2017; Wills et al., 2019; Wills et al., 2020).

Conclusions

This research adds to evidence showing significant associations of e-cigarette use with respiratory disorders (Wills et al., 2021) and demonstrates that prior smoking history cannot account for the findings. Moreover, we found that former e-cigarette use was

associated with respiratory disorder independent of current use, which could lend support to a sensitization mechanism (Rounds & Lu, 2020). We conclude that e-cigarettes may be a factor in respiratory disorder among adults, i.e., they are not harmless (Gordon et al., 2022; Hickman & Jaspers, 2020, Kotsoulas et al., 2021). Thus there is a good rationale for including material about e-cigarettes and respiratory disease in preventive education programs (Owusu, Massey, & Popova, 2020; Rohde, Noar, Mendel, et al., 2020).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding

This research was supported by grant P30 CA071789 from the National Cancer Institute (Wills, Pagano) and grants R01 CA202277 and R01 CA228905 from the National Cancer Institute (Pokhrel). Dr. Choi's effort was supported by the Division of Intramural Research, National Institute on Minority Health and Health Disparities. Conclusions and opinions expressed here are those of the authors and do not necessarily reflect those of the U.S. Government, Department of Health and Human Services, National Institutes of Health, National Institute on Minority Health and Health Disparities. The study sponsors had no role in the design of the research; collection, analysis, and interpretation of the data; writing of the report; or decision to submit the manuscript for publication.

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Highlights

- E-cigarette use has been related to respiratory disorder in previous studies.
- However, it has been unclear whether this is related to previous cigarette smoking.
- We tested if e-cigarette use was related to asthma and COPD controlling for smoking.
- We found that associations of e-cigarette use were not attributable to smoking.

Table 1

Prevalence Estimates (%) for Analysis Variables

Variable	Unweighted n	Estimate (%)
Sex		
Female	111,597	54.2
Male	103,348	45.8
Total	214,945	100
Age group		
18–29 years	46,559	29.6
30–39 years	48,900	25.3
40–49 years	52,157	21.8
50–59 years	67,329	23.4
Total	214,945	100
Overweight Status		
Normal	124,177	66.0
Overweight	65,420	34.0
Total	189,597	100
Obesity Status		
Normal	124,538	67.0
Obese	65,059	33.0
Total	189,597	100
Race/ethnicity		
White NH	144,246	56.4
Black NH	17,862	12.8
Hispanic	28,174	22.2
Asian NH	7,556	7.0
Multi NH	5,715	1.5
Total	203,553	100
Education		
< High school	13,831	11.9
HS graduate	55,954	27.6
Some college	59,484	30.6
College grad	84,728	29.8
Total	213,997	100
E-cigarette status		
Never used	96,005	68.7
Former use	31,784	24.0
Nondaily use	4,845	4.1
Daily use	3,744	3.2
Total	136,378	100

Variable	Unweighted n	Estimate (%)
Cigarette status		
Never used	128,336	65.9
Former use	40,728	18.3
Nondaily use	9,681	4.9
Daily use	24,677	11.0
Total	203,422	100
Asthma status		
Never had	182,508	85.6
Had previous	9,304	4.9
Still have	21,600	9.4
Total	213,412	100
COPD status		
Never had	204,727	96.2
Have	9,509	3.8
Total	214,236	100

Note: NH = nonHispanic, HS = high school. Analysis performed for respondents ages 18–59 years. Weighted analyses include adjustment for stratum and clustering. Weighted N's are approximately 177,000,000, with slight variation across variables.

Table 2

Cell N and Row % for Cross-tabulation of E-cigarette Status and Combustible Cigarette Status with Respiratory Variables

A. ANALYSIS FOR E-CIGARETTES							
	Asthma status				**COPD status**		
E-cigarette status	**Never had**	**Previous had**	**Currently have**	**Marginal n/(%)**	**Never had**	**Have now**	**Marginal n/(%)**
Never used	82927 (86.8%)^{D}	3551 (3.7%)^{D}	9012 (9.4%)^{D}	95490 (70.5%)	92402 (96.5)%^{D}	3350 (3.5%)^{D}	95752 (70.4%)
Former use	25918 (82.4%)^{D}	1813 (5.8%)^{D}	3704 (11.8%)^{D}	32435 (23.2%)	29096 (91.9%)^{D}	2566 (8.1%)^{D}	31662 (23.3%)
Current nondaily use	3837 (80.1%)^{D}	327 (6.8%)^{D}	624 (13.0%)^{D}	4788 (3.5%)	4480 (93.0%)	337 (7.0%)^{D}	4817 (3.5%)
Current daily use	3036 (82.1%)^{A}	224 (6.1%)^{D}	438 (11.8%)^{C}	3698 (2.7%)	3529 (94.6%)	203 (4.4%)^{A}	3732 (2.7%)
Marginal n/(%)	115718 (85.4%)	5915 (4.4%)	13778 (10.2%)	135411 (95.2%)	129507 (95.2%)	6456 (4.8%)	135963 (100.0%)
B. ANALYSIS FOR CIGARETTES							
	Asthma status				**COPD status**		
Combustible cigarette status	**Never had**	**Previous had**	**Currently have**	**Marginal n/(%)**	**Never had**	**Have now**	**Marginal n/(%)**
Never smoked	110308 (86.5%)^{D}	5378 (4.2%)^{C}	11857 (9.3%)^{D}	127543 (63.1%)	125579 (98.1%)^{D}	2436 (1.9%)^{D}	128015 (63.1%)
Former smoker	34220 (84.6%)	1925 (4.8%)^{C}	4278 (10.6%)^{A}	40423 (20.0%)	38251 (94.2%)^{B}	2340 (5.8%)^{D}	40591 (20.0%)
Current nondaily smoker	8025 (83.6%)^{A}	488 (5.1%)^{C}	1083 (11.3%)^{C}	9596 (4.7%)	8806 (91.3%)^{D}	834 (8.7%)	9640 (4.8%)
Current daily smoker	19930 (81.7%)^{D}	1093 (4.5%)	3386 (13.9%)^{D}	24409 (12.1%)	21064 (85.9%)^{D}	3466 (14.1%)^{D}	24530 (12.1%)
Marginal	172483	8884	20604	201971	193700	9076	202776
n/(%)	(85.4%)	(4.4%)	(10.2%)	(100.0%)	(95.5%)	(4.5%)	(100.0%)

Note: Analysis based on respondents 18–59 years of age. Superscripts indicate cell departure from expectation.

^{A}indicates $p < .05$;

^{B}$p < .01$;

^{C}$p < .001$;

^{D}$p < .0001$.

Table 3

Adjusted Odds Ratio (AOR) and Confidence Interval (CI) for Covariates, E-cigarette Status, and Combustible Cigarette Status, Asthma and COPD as Criterion Variables

	Asthma (multinomial)			COPD (logistic)	
Variable	**Asthma status**	**AOR**	**(CI)**	**AOR**	**(CI)**
Sex (male)	Current	0.46	(0.44–0.48) ****	0.56	(0.55–0.62) ****
	Lifetime	1.11	(1.05–1.18) ***		
Age	Current	0.98	(0.97–0.99) ****	1.33	(1.31–1.35) ****
	Lifetime	0.88	(0.87–0.89) ****		
Overweight	Current	1.22	(1.16–1.28) ****	1.00	(0.92–1.08)
	Lifetime	1.10	(1.02–1.18) **		
Obese	Current	1.84	(1.76–1.94) ****	1.70	(1.58–1.83) ****
	Lifetime	1.29	(1.20–1.39) ****		
Black	Current	1.09	(1.02–1.17) **	0.95	(0.86–1.05)
	Lifetime	1.16	(1.05–1.28) **		
Hispanic	Current	0.78	(0.76–0.85) ****	0.58	(0.52–0.66) ****
	Lifetime	0.93	(0.84–1.02)		
Asian American	Current	0.57	(0.49–0.66) ****	0.46	(0.34–0.62) ****
	Lifetime	0.94	(0.80–1.10)		
MultiRace	Current	1.51	(1.37–1.66) ****	1.27	(1.10–1.47) ***
	Lifetime	1.56	(1.36–1.79) ****		
Education	Current	0.93	(0.90–0.95) ****	0.67	(0.65–0.69) ****
	Lifetime	1.05	(1.02–1.09) ***		
Smoke Former	Current	1.09	(1.03–1.15) ***	2.12	(1.96–2.30) ****
	Lifetime	1.17	(1.09–1.27) ****		
Smoke Nondaily	Current	1.10	(1.00–1.21) *	3.38	(3.01–3.79) ****
	Lifetime	1.09	(0.96–1.24)		
Smoke Daily	Current	1.35	(1.27–1.44) ****	4.60	(4.22–4.50) ****
	Lifetime	1.04	(0.94–1.14)		
E-cig Former	Current	1.22	(1.15–1.28) ****	1.65	(1.54–1.77) ****
	Lifetime	1.36	(1.27–1.46) ****		
E-cig Nondaily	Current	1.41	(1.28–1.56) ****	1.76	(1.54–2.02) ****
	Lifetime	1.54	(1.35–1.76) ****		
E-cig Daily	Current	1.20	(1.06–1.35) **	1.44	(1.21–1.71) ****
	Lifetime	1.22	(1.04–1.43) **		

Note: Multivariate analysis, all predictors entered simultaneously. Smoke = combustible cigarette smoking, E-cig = e-cigarette use; nonuse is reference group for both. N for analysis = 116,585 for asthma and 117,063 for COPD. Asthma status is 3-level variable (never had asthma; had asthma but not now, still have asthma); contrasts for asthma status use "never had asthma" as reference group. COPD criterion is dichotomous (never had COPD vs. have COPD).

*
p < .05;

**
p < .01;

***
p < .001;

****
p < .0001.

Table 4

Adjusted Odds Ratios (CI) for E-cigarette Status and Combustible Cigarette Status, Asthma and COPD as Criterion Variables, Including Marijuana Control

	Asthma (multinomial)			COPD (logistic)	
Variable	**Asthma status**	**AOR**	**(CI)**	**AOR**	**(CI)**
Smoke Former	Current	1.04	(0.96–1.12)	2.00	(1.78–2.24) ****
	Lifetime	1.12	(1.00–1.25) *		
Smoke Nondaily	Current	1.08	(0.95–1.24)	3.24	(2.75–3.83) ****
	Lifetime	1.21	(1.01–1.46) *		
Smoke Daily	Current	1.27	(1.16–1.38) ****	4.54	(3.87–4.91) ****
	Lifetime	0.98	(0.85–1.13)		
E-cig Former	Current	1.17	(1.09–1.26) ****	1.59	(1.44–1.76) ****
	Lifetime	1.32	(1.19–1.47) ****		
E-cig Nondaily	Current	1.27	(1.10–1.47) ***	1.76	(1.45–2.15) ****
	Lifetime	1.39	(1.14–1.70) ***		
E-cig Daily	Current	1.13	(0.95–1.34)	1.59	(1.26–2.02) ****
	Lifetime	1.23	(0.98–1.54)		
Marijuana Light	Current	1.21	(1.09–1.38) ***	1.11	(0.95–1.30)
	Lifetime	1.01	(0.86–1.18)		
Marijuana Heavy	Current	1.44	(1.29–1.60) ****	1.51	(1.32–1.72) ****
	Lifetime	1.18	(1.10–1.38) *		

Note: Results are from multivariate analysis, all predictor variables entered simultaneously with demographic covariates as in Table 3. Smoke = cigarette smoking, E-cig = e-cigarette use; nonuse as reference group for both e-cigarette status and smoking status variables. Marijuana status variable has no 30-day use as reference group. N for analysis = 56,008 for asthma and 56,248 for COPD. Results for demographic variables were similar but are omitted because of differing analytic sample.

* p < .05;

** p < .01;

*** p < .001;

**** p < .0001.

Table 5

Adjusted Odds Ratios (CI in Parentheses) for E-cigarettes, Asthma and COPD as Criterion Variables; (A) for Nonsmokers, (B) for Smokers.

(A) ANALYSIS FOR NONSMOKERS					
	Asthma (multinomial)			**COPD (logistic)**	
Variable	**Asthma status**	**AOR**	**(CI)**	**AOR**	**(CI)**
Sex (male)	Current	0.52	(0.49–0.55)****	0.70	(0.62–0.78)****
	Lifetime	1.13	(1.05–1.22)***		
Age	Current	0.96	(0.95–0.97)****	1.20	(1.17–1.23)****
	Lifetime	0.88	(0.87–0.90)****		
Overweight	Current	1.27	(1.18–1.36)****	1.13	(0.96–1.33)
	Lifetime	1.11	(1.01–1.22)**		
Obese	Current	1.94	(1.82–2.07)****	2.20	(1.90–2.54)****
	Lifetime	1.38	(1.26–1.51)****		
Black	Current	1.07	(0.98–1.24)	1.38	(1.10–1.49)***
	Lifetime	1.10	(0.98–1.24)		
Hispanic	Current	0.74	(0.68–0.81)****	0.74	(0.62–0.89)***
	Lifetime	0.87	(0.77–0.98)**		
Asian American	Current	0.52	(0.44–0.62)****	0.46	(0.29–0.72)***
	Lifetime	0.95	(0.79–1.13)		
Multi-race	Current	1.50	(1.30–1.72)****	1.48	(1.11–1.99)**
	Lifetime	1.62	(1.34–1.95)****		
Education	Current	0.99	(0.96–1.02)	0.68	(0.64–0.72)****
	Lifetime	1.06	(1.02–1.11)**		
E-cig Former	Current	1.19	(1.10–1.29)****	1.55	(1.31–1.83)****
	Lifetime	1.41	(1.29–1.56)****		
E-cig Nondaily	Current	1.32	(1.11–1.58)***	1.18	(0.74–1.88)
	Lifetime	1.67	(1.39–2.03)****		
E-cig Daily	Current	1.48	(1.14–1.90)**	1.16	(0.57–2.36)
	Lifetime	1.26	(0.90–1.77)		
(B) ANALYSIS FOR SMOKERS					
	Asthma (multinomial)			**COPD (logistic)**	
Variable	**Asthma status**	**AOR**	**(CI)**	**AOR**	**(CI)**
Sex (male)	Current	0.38	(0.36–0.41)****	0.54	(0.50–0.58)****
	Lifetime	1.07	(0.97–1.17)		
Age	Current	1.02	(1.00–1.03)**	1.40	(1.37–1.42)****

	Lifetime	0.87	(0.85–0.89)****		
Overweight	Current	1.16	(1.07–1.26)***	0.93	(0.84–1.02)
	Lifetime	1.07	(0.95–1.20)		
Obese	Current	1.73	(1.61–1.87)****	1.46	(1.34–1.58)****
	Lifetime	1.18	(1.06–1.32)**		
Black	Current	1.17	(1.05–1.31)**	0.83	(0.72–0.94)**
	Lifetime	1.26	(1.06–1.49)**		
Hispanic	Current	0.97	(0.86–1.08)	0.47	(0.40–0.55)****
	Lifetime	1.06	(0.90–1.23)		
Asian American	Current	0.73	(0.55–0.98)*	0.47	(0.31–0.71)****
	Lifetime	0.92	(0.66–1.26)		
MultiRace	Current	1.55	(1.34–1.78)****	1.24	(1.05–1.46)**
	Lifetime	1.49	(1.22–1.83)****		
Education	Current	0.83	(0.81–0.86)****	0.62	(0.60–0.64)****
	Lifetime	1.05	(1.00–1.11)*		
E-cig Former	Current	1.29	(1.21–1.38)****	2.05	(1.91–2.21)****
	Lifetime	1.27	(1.15–1.41)****		
E-cig Nondaily	Current	1.54	(1.36–1.74)****	2.30	(1.99–2.65)****
	Lifetime	1.38	(1.16–1.65)****		
E-cig Daily	Current	1.19	(1.04–1.36)**	1.43	(1.20–1.71)****
	Lifetime	1.18	(0.98–1.42)		

Note: Results are from multivariate analysis, all predictors entered simultaneously. N for analysis for nonsmokers is 72,260 for asthma and 72,558 for COPD; for smokers, analytic N is 44,379 for asthma and 44,558 for COPD. E-cig = e-cigarette use. For e-cigarette contrasts, reference group = never used. Asthma status is 3-level variable (never had asthma; had asthma but not now, still have asthma); contrasts for asthma status use “never had asthma” as reference group. COPD criterion is dichotomous (never had COPD vs. have COPD).

* p < .05;

** p < .01;

*** p < .001;

**** p < .0001.