

Secondhand Exposure to Aerosols From Electronic Nicotine Delivery Systems and Asthma Exacerbations Among Youth With Asthma



Jennifer E. Bayly, BS; Debra Bernat, PhD; Lauren Porter, PhD; and Kelvin Choi, PhD

BACKGROUND: Current research suggests an association between the use of electronic nicotine delivery systems (ENDS) and asthma symptoms in youth, but little is known about the association of secondhand ENDS aerosol exposure and asthma control. The present study examines the relationship of secondhand ENDS aerosol exposure and asthma exacerbations among youth with asthma.

METHODS: Youth who participated in the 2016 Florida Youth Tobacco survey (aged 11-17 years) with a self-reported diagnosis of asthma (N = 11,830) reported asthma attacks in the past 12 months, demographic characteristics, cigarette use, cigar use, hookah use, ENDS use, past 30-day secondhand smoke exposure, and past 30-day secondhand ENDS aerosol exposure. Weighted multivariable logistic regression models were used to examine the association between secondhand ENDS aerosol exposure and past 12-month asthma attack status, adjusting for covariates.

RESULTS: Overall, 21% of youth with asthma reported having an asthma attack in the past 12 months, and 33% reported secondhand ENDS aerosol exposure. Secondhand ENDS aerosol exposure was associated with higher odds of reporting an asthma attack in the past 12 months, adjusting for covariates (adjusted OR, 1.27; 95% CI, 1.11-1.47).

CONCLUSIONS: Secondhand exposure to ENDS aerosols may be related to asthma symptoms in youth. Physicians may need to counsel youth with asthma regarding the potential risks of exposure. Future research is necessary to evaluate the longitudinal relationship between secondhand ENDS aerosol exposure and asthma control. CHEST 2019; 155(1):88-93

KEY WORDS: asthma; electronic cigarettes; electronic nicotine delivery systems; secondhand exposure

ABBREVIATIONS: e-cigarette = electronic cigarette; ENDS = electronic nicotine delivery systems; MSA = metropolitan statistical areas

AFFILIATIONS: From the Division of Intramural Research (Ms Bayly and Dr Choi), National Institute on Minority Health and Health Disparities, Bethesda, MD; Department of Epidemiology and Biostatistics (Dr Bernat), George Washington University, Washington, DC; and the Florida Department of Health (Dr Porter), Tallahassee, FL.

FUNDING/SUPPORT: The efforts of J. E. B. and K. C. on this study were supported by the Division of Intramural Research, National Institute on Minority Health and Health Disparities. The efforts of J. E. B. were also made possible through the National Institutes of Health Medical Research Scholars Program, a public-private partnership supported jointly by the National Institutes of Health and generous

contributions to the Foundation for the National Institutes of Health from the Doris Duke Charitable Foundation, the American Association for Dental Research, the Colgate-Palmolive Company, Genentech, Elsevier, and other private donors.

CORRESPONDENCE TO: Jennifer E. Bayly, BS, Division of Intramural Research, National Institute on Minority Health and Health Disparities, 9000 Rockville Pike, Bldg 3, 5E11, Bethesda, MD 20892; e-mail: jeb369@rwjms.rutgers.edu

Copyright © 2018 American College of Chest Physicians. Published by Elsevier Inc. All rights reserved.

DOI: <https://doi.org/10.1016/j.chest.2018.10.005>

The detrimental impact of secondhand smoke exposure on health in both children and adults is well documented, especially its association with asthma exacerbations among youth.¹ Less is known regarding the relationship between electronic nicotine delivery systems (ENDS), which include electronic cigarettes (e-cigarettes), and asthma. However, a recent report by the National Academies of Sciences, Engineering, and Medicine concluded there was moderate evidence for “increased cough and wheeze in adolescents who use e-cigarettes and an association with e-cigarette use and an increase in asthma exacerbations.”²

Although previous findings regarding ENDS use and asthma are suggestive, there is currently a lack of evidence regarding the relationship between secondhand or passive exposure to ENDS aerosols and asthma attacks. Few studies have directly studied the health effects of aerosols from ENDS; however, it does seem to contain biologically

active components, such as nicotine, formaldehyde, and metals.³ Furthermore, nonsmokers passively exposed to e-cigarettes have been found to absorb nicotine.⁴

Although the national prevalence of secondhand ENDS aerosol exposure is unclear, it is likely that a substantial number of youth with asthma are exposed given that the prevalence of ENDS use has grown. In the United States, current ENDS use ranges from 4% among adults⁵ to 11% among high school students.⁶ Furthermore, almost 10% of US adolescents reported living with an ENDS user in 2014,⁷ and a study among youth in Florida found almost one-third reported secondhand ENDS aerosol exposure.⁸ Given that youth with asthma are likely exposed to these aerosols, it is important to understand if and how these exposures affect health. The goal of the present study was to examine the associations between secondhand ENDS aerosol exposure and asthma exacerbations among youth with asthma.

Subject and Methods

Sample

The Florida Youth Tobacco Survey is an annual school-based cross-sectional survey conducted by the Florida Department of Health.⁹ During even years, county-level data of the sampled schools are collected. A two-stage cluster probability sampling procedure was used. In the first stage, a random sample of public middle and high schools was selected, and in the second stage, a random sample of classrooms was selected from within each sampled school. Within each selected class, all students were asked to participate in the paper-and-pencil survey. This analysis utilized data from the 2016 survey. The sampling frame included all public high schools and middle schools in Florida’s 67 counties, and the sample comprised 753 of 756 selected schools. All counties required parental consent.

In 2016, a total of 33,558 high school students and 36,082 middle school students participated (71% and 78% participation rates, respectively).⁹ Analyses were restricted to youth between the ages of 11 and 17 years with a self-reported diagnosis of asthma (N = 11,830). This study is a secondary data analysis on de-identified data and thus was determined by the National Institutes of Health Office of Human Subject Research Protection to be exempt from review by the institutional review board.

Measures

Dependent Variables: All participants in the sample answered yes when asked, “Has a doctor or nurse ever told you that you have asthma?” (The response options were yes, no, or not sure). Asthma exacerbations were assessed by asking participants, “During the past 12 months, did you have an asthma attack?” (The response options were: I have never had asthma, yes, no, not sure, or I no longer have asthma.) These answers were recoded into yes (yes) and no (all other responses). Participants who responded that they never had asthma were excluded from the study.

Independent Variable: Participants were considered exposed to aerosols from ENDS if they answered yes to one or both of the following questions: “During the past 30 days, were you in the same room with someone who was using electronic vapor products?”;

“During the past 30 days, did you ride in a car with someone smoking electronic vapor products?”

Covariates: Demographic variables included age, sex, race/ethnicity, metropolitan status, and housing type. Age was categorized as 11 to 13 years old and 14 to 17 years old. Participants were asked if they were Hispanic or Latino (yes/no), as well as which category best described them (American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or other Pacific Islander, white, or other). Race/ethnicity was categorized by recoding responses to these questions into seven categories (Hispanic, non-Hispanic American Indian/Alaskan Native, non-Hispanic Asian, non-Hispanic black, non-Hispanic Native Hawaiian or other Pacific Islander, non-Hispanic white, and non-Hispanic other).

For metropolitan status, the 2013 National Center for Health Statistics Urban-Rural Classification Scheme for Counties was utilized, which divides counties into six categories based on their metropolitan statistical areas (MSA) and micropolitan statistical areas.¹⁰ Of Florida’s 67 counties, five were large central metro (MSA of 1 million population that contains the entire population of the largest principal city of the MSA, or are completely contained within the largest principal city of the MSA, or contain at least 250,000 inhabitants of any principal city of the MSA); 11 were large fringe metro (MSA of at least 1 million population that does not qualify as large central); 19 were medium metro (MSA of 250,000-999,999 population); nine were small metro (counties in MSAs < 250,000 population); seven were micropolitan (counties in micropolitan statistical areas); and 17 were noncore (counties not in micropolitan statistical areas). Housing status was assessed by asking participants what type of building they live in (stand-alone single-family, trailer/mobile home, townhouse/duplex, condominium/apartment, or other).

ENDS user status was assessed by asking participants, “Have you ever used an electronic vapor product?” (yes/no) and “During the past 30 days, on how many days did you use an electronic vapor product?” Participants were then categorized as never users (answered no to ever using and indicated no ENDS use in the past 30 days); ever, noncurrent ENDS users (answered yes to ever using but none in the past month); and current ENDS users (participants who used ENDS for 1 or more days in the past month). The same process was used to

categorize participants' use of cigarettes, cigars, and hookah. Participants were considered exposed to secondhand smoke if they answered yes to one or both of the following questions: "During the past 30 days, were you in the same room with someone who was using cigarettes;" "During the past 30 days, did you ride in a car with someone smoking cigarettes?"

Statistical Analysis

Analyses were weighted to be representative of middle and high school students in Florida and to account for clustered sampling. Analyses

were performed by using survey procedures in SAS version 9.4 (SAS Institute, Inc).

Weighted χ^2 tests and logistic regression models were used to test the hypothesis that youth with self-reported asthma who were exposed to aerosols from ENDS would be more likely to report asthma exacerbations (past-year asthma attacks) compared with unexposed youth with asthma, adjusting for all covariates listed earlier. Significance was set at $P < .05$.

Results

Overall, about one-half of the study sample was female, and two-thirds were aged 11 to 13 years (Table 1). Regarding race/ethnicity, about one-third self-identified as Hispanic, another one-third self-identified as non-Hispanic white, and slightly more than one-fifth self-identified as non-Hispanic black. Three-quarters of the sample resided in large or medium metropolitan areas and close to two-thirds lived in stand-alone homes. Between 4% and 6% of the sample reported current cigarette smoking, cigar smoking, or hookah use. In contrast, almost 12% reported current ENDS use. Almost one-half of the youth were exposed to secondhand smoke, and one-third were exposed to secondhand ENDS aerosols.

Table 2 shows the weighted distribution of the sample according to asthma exacerbations. Overall, 21% of youth with asthma reported an asthma attack within the past 12 months. In a weighted χ^2 test, exposure to secondhand ENDS aerosols was associated with reporting an asthma attack ($P < .01$). In a multivariable logistic regression model, the association between secondhand exposure to ENDS aerosols and asthma exacerbations remained significant (adjusted OR, 1.27; 95% CI, 1.11-1.47) after controlling for demographic characteristics, individual tobacco product use (cigarettes, cigars, hookah, and ENDS), and secondhand smoke exposure. Results from the multivariable logistic regression model also showed that asthma exacerbations were more prevalent among female (vs male), non-Hispanic other (vs non-Hispanic white), current cigarette users (vs never users), and those exposed to secondhand smoke ($P < .05$). In contrast, asthma exacerbations were less prevalent among youth aged 14 to 17 years (vs those aged 11-13 years) and Hispanic/non-Hispanic black subjects (vs non-Hispanic white subjects; $P < .05$). Results of additional interaction tests between secondhand ENDS aerosol exposure, secondhand smoke exposure, and current tobacco use were not significant ($P > .42$).

Discussion

The present study found an association between secondhand exposure to ENDS aerosols and asthma

exacerbations among youth with asthma independent of individual tobacco product use, including cigarettes and ENDS, as well as exposure to secondhand smoke. Although there are only a few studies that have examined associations between ENDS and asthma, several have linked ENDS use with pulmonary symptoms and asthma in youth. For instance, McConnell et al¹¹ found e-cigarette use increased the likelihood of chronic bronchitis symptoms among youth in California, whereas another study found that past 30-day e-cigarette use was associated with past-year asthma attacks among youth with asthma.¹² In South Korea, researchers found that youth who used e-cigarettes had a higher likelihood of having an asthma diagnosis and missing school due to asthma-related symptoms.¹³ However, to the best of our knowledge, no studies have evaluated the longitudinal relationship between ENDS use and asthma or extended these analyses to include secondhand exposure to ENDS aerosols and asthma.

Other studies have postulated the mechanisms linking the constituents of ENDS to lung function and asthma. A review by Clapp and Jaspers¹⁴ discusses how aerosolized propylene glycol and vegetable glycerin, nicotine, and flavoring agents, all found in ENDS, have each been linked to physiological activity in the lungs that may have implications for asthma. For instance, although propylene glycol and vegetable glycerin are classified by the US Food and Drug Administration as generally recognized as safe for oral consumption, they have been less studied in their aerosolized forms. However, they are commonly found in theatrical smokes and fogs, and research has found chronically exposed workers in these occupations to have decreased lung function and increased self-reported respiratory symptoms.¹⁵ There is also concern that aerosolization of these compounds at high temperatures can lead to reactive compounds that are known to be pulmonary irritants.¹⁴ Finally, some research has shown aerosols from ENDS contain varying amounts of these constituents, including nicotine⁴ and propylene glycol and vegetable glycerin.¹⁶ Thus, it is plausible that exposure to ENDS aerosols due to direct use or secondhand use has implications for lung health.

TABLE 1] Weighted Characteristics of the Sample, 2016 Florida Youth Tobacco Survey (N = 11,830)

Characteristic	Overall No. (Weighted %)
Age, y	
Age 11-13	7,257 (67.2)
Age 14-17	4,573 (32.8)
Sex	
Female	5,965 (49.9)
Male	5,701 (50.1)
Race/ethnicity	
Hispanic	2,930 (33.0)
Non-Hispanic American Indian or Alaskan Native	178 (0.7)
Non-Hispanic Asian	280 (1.9)
Non-Hispanic black	2,190 (23.3)
Non-Hispanic Native Hawaiian or Other Pacific Islander	55 (0.3)
Non-Hispanic other	480 (2.6)
Non-Hispanic white	5,385 (38.3)
Metropolitan status	
Large central metro	1,006 (12.3)
Large fringe metro	2,431 (25.7)
Medium metro	3,885 (37.6)
Small metro	1,693 (6.5)
Micropolitan	1,063 (7.8)
Noncore	1,752 (10.2)
Housing	
Stand alone	7,402 (66.0)
Trailer/mobile home	1,583 (7.1)
Townhouse/duplex	753 (8.7)
Condo/apartment	1,041 (12.0)
Other	854 (6.3)
Cigarette use	
Never used	9,668 (83.4)
Ever, noncurrent use	1,465 (11.5)
Current use	579 (4.1)
Undetermined	118 (1.0)
Cigar use	
Never used	10,341 (87.7)
Ever, noncurrent use	806 (6.7)
Current use	535 (4.3)
Undetermined	148 (1.3)
Hookah use	
Never used	9,879 (80.3)
Ever, noncurrent use	1,049 (11.5)
Current use	618 (5.8)
Undetermined	284 (2.3)

(Continued)

TABLE 1] (Continued)

Characteristic	Overall No. (Weighted %)
ENDS use	
Never used	8,503 (70.4)
Ever, noncurrent use	1,788 (16.6)
Current use	1,382 (11.8)
Undetermined	157 (1.2)
Exposed to secondhand smoke	
Yes	5,611 (45.4)
No	5,817 (54.6)
Exposed to secondhand ENDS aerosols	
Yes	3,812 (32.8)
No	7,613 (67.2)

Due to missing values, total responses do not always add up to the total sample size. ENDS = electronic nicotine delivery system.

Although our findings need to be confirmed by future longitudinal studies, it may be beneficial for health professionals to consider screening for and documenting ENDS use and secondhand ENDS aerosol exposure among youth with asthma. Health professionals may also consider including ENDS aerosol exposure as a possible trigger in asthma self-management/action plans and updating asthma home environment assessments to include exposure to ENDS aerosols.

Our study has several limitations. The cross-sectional study design limits our ability to determine the temporal sequences between secondhand exposure to ENDS aerosols and asthma exacerbations, and causality therefore cannot be established. The sample included students attending public schools in Florida, and thus the results may not be generalizable to youth not attending public schools or to youth nationwide. Furthermore, our data are limited by being based on self-reported data. Not all youth may be aware of their asthma status and secondhand exposures, and recall biases may exist. In addition, secondhand exposure to ENDS aerosols was measured in the past 30 days, whereas asthma attacks were measured within the past 12 months. It is plausible that asthma exacerbations could lead to increased exposure to ENDS aerosols, such as if family members switched from using combustible products to using ENDS when around youth with asthma. However, it is also possible that past 30-day secondhand exposure to ENDS aerosols represents current exposure beyond this time frame. Certainly, future longitudinal studies are needed to elucidate the temporal relationship between these

TABLE 2] Weighted Prevalence and aORs of Past-Year Asthma Attacks Among Youth Diagnosed With Asthma, 2016 Florida Youth Tobacco Survey (N = 11,830)

Characteristic	No. Reported Past-Year Asthma Attacks (Weighted %)	aOR (95% CI)
Age, y		
11-13	1,062 (22.9)	1.00
14-17	1,569 (20.2)	0.77 (0.68-0.87) ^a
Sex		
Female	1,592 (26.0)	1.68 (1.48-1.90) ^a
Male	991 (16.0)	1.00
Race/ethnicity		
Hispanic	571 (19.0)	0.79 (0.68-0.93) ^a
Non-Hispanic American Indian or Alaskan Native	48 (27.4)	1.35 (0.84-2.18)
Non-Hispanic Asian	60 (19.1)	0.85 (0.59-1.24)
Non-Hispanic black	447 (18.7)	0.80 (0.67-0.95) ^a
Non-Hispanic Native Hawaiian or Other Pacific Islander	19 (42.8)	2.53 (1.20-5.30) ^a
Non-Hispanic other	117 (20.8)	0.83 (0.62-0.95) ^a
Non-Hispanic white	1,302 (24.0)	1.00
Metropolitan status		
Large central metro	215 (20.9)	1.00
Large fringe metro	542 (21.4)	1.09 (0.86-1.39)
Medium metro	872 (21.6)	1.07 (0.86-1.33)
Small metro	395 (21.7)	0.96 (0.75-1.24)
Micropolitan	222 (19.1)	0.97 (0.71-1.33)
Noncore	365 (19.6)	0.94 (0.72-1.21)
Housing		
Stand alone	1,621 (21.3)	1.00
Trailer/mobile home	366 (21.6)	0.94 (0.76-1.15)
Townhouse/duplex	156 (19.0)	0.95 (0.75-1.20)
Condo/apartment	230 (19.7)	1.02 (0.83-1.25)
Other	215 (24.1)	1.21 (0.94-1.56)
Cigarette use		
Never used	2,083 (20.4)	1.00
Ever, noncurrent use	345 (22.6)	1.23 (0.99-1.52)
Current use	169 (30.0)	1.92 (1.28-2.68) ^a
Undetermined	34 (22.7)	1.47 (0.76-2.86)
Cigar use		
Never used	2,302 (21.0)	1.00
Ever, noncurrent use	159 (20.4)	0.78 (0.60-1.03)
Current use	132 (22.1)	0.84 (0.60-1.18)
Undetermined	38 (25.1)	2.40 (1.25-4.63) ^a
Hookah use		
Never used	2,163 (21.0)	1.00
Ever, noncurrent use	243 (21.4)	1.01 (0.81-1.25)
Current use	155 (20.9)	0.76 (0.56-1.06)
Undetermined	70 (22.6)	0.81 (0.49-1.31)
ENDS use		
Never used	1,883 (21.0)	1.00

(Continued)

TABLE 2] (Continued)

Characteristic	No. Reported Past-Year Asthma Attacks (Weighted %)	aOR (95% CI)
Ever, noncurrent use	377 (20.6)	1.01 (0.81-1.25)
Current use	336 (22.6)	0.90 (0.71-1.15)
Undetermined	25 (17.9)	0.84 (0.42-1.69)
Exposed to secondhand smoke		
Yes	1,410 (23.7)	1.19 (1.05-1.35) ^a
No	1,163 (18.8)	1.00
Exposed to secondhand ENDS aerosols		
Yes	989 (24.2)	1.27 (1.11-1.47) ^a
No	1,560 (19.5)	1.00

aOR = adjusted odds ratio. See Table 1 legend for expansion of other abbreviation.

^a*P* < .05.

variables. Future studies also need to examine the role of respiratory virus infections, an important factor for asthma exacerbations, in the association between secondhand ENDS aerosol exposure and asthma exacerbations. Our study does have several strengths, such as having a large, diverse, state-representative sample, as well as the ability to capture both secondhand ENDS aerosol and secondhand smoke exposures.

Conclusions

This study documents an association between secondhand exposure to ENDS aerosols and asthma exacerbations among youth with asthma. Families may believe exposure to aerosols from ENDS to be benign. However, while this relationship is further elucidated, health professionals may wish to counsel youth with asthma and their families regarding the potential risks of ENDS use and exposure to ENDS aerosols.

Acknowledgments

Author contributions: L. P. collected the data. J. E. B. conducted the analysis and drafted the manuscript. K. C., D. B., and L. P. critically reviewed and revised the manuscript. All authors interpreted the results, designed the study, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work. The comments and opinions expressed in this article are the authors' own and do not necessarily represent those of the U.S. Government, the Department of Health and Human Services, the National Institutes of Health, the National Institute on Minority Health and Health Disparities, or the Florida Department of Health.

Financial/nonfinancial disclosures: None declared.

Role of sponsor: The funding sources played no role in the conceptualization and implementation of the study, or in the analysis and reporting of its findings.

References

- Office on Smoking and Health. *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General*. Atlanta, GA: Centers for Disease Control and Prevention; 2006.
- National Academies of Sciences Engineering and Medicine. *Public Health Consequences of E-Cigarettes*. Washington, DC: The National Academies Press; 2018.
- Hess IM, Lachireddy K, Capon A. A systematic review of the health risks from passive exposure to electronic cigarette vapour. *Public Health Res Pract*. 2016;26(2).
- Ballbe M, Martinez-Sanchez JM, Sureda X, et al. Cigarettes vs. e-cigarettes: passive exposure at home measured by means of airborne marker and biomarkers. *Environ Res*. 2014;135:76-80.
- QuickStats. Cigarette smoking status among current adult e-cigarette users, by age group—National Health Interview Survey, United States, 2015. *MMWR Morb Mortal Wkly Rep*. 2017;66(33):892.
- Jamal A, Gentzke A, Hu SS, et al. Tobacco use among middle and high school students—United States, 2011-2016. *MMWR Morb Mortal Wkly Rep*. 2017;66(23):597-603.
- Fischer F, Kraemer A. Secondhand smoke exposure at home among middle and high school students in the United States—does the type of tobacco product matter? *BMC Public Health*. 2017;17(1):98.
- Bayly J, Bernat D, Choi K. Prevalence and characteristics of secondhand smoke and secondhand vapor exposure among youth. *Tob Control*. In press. doi: <https://doi.org/10.1136/tobaccocontrol-2018-054265>.
- Florida Department of Health. 2016 Florida Youth Tobacco Survey. <http://www.floridahealth.gov/statistics-and-data/survey-data/florida-youth-survey/florida-youth-tobacco-survey/index.html>. Accessed December 6, 2017.
- National Center for Health Statistics. 2013 Urban-Rural Classification Scheme for Counties. https://www.cdc.gov/nchs/data_access/urban_rural.htm. Accessed November 30, 2017.
- McConnell R, Barrington-Trimis JL, Wang K, et al. Electronic cigarette use and respiratory symptoms in adolescents. *Am J Respir Crit Care Med*. 2017;195(8):1043-1049.
- Choi K, Bernat D. E-cigarette use among Florida youth with and without asthma. *Am J Prev Med*. 2016;51(4):446-453.
- Cho JH, Paik SY. Association between electronic cigarette use and asthma among high school students in South Korea. *PLoS One*. 2016;11(3):e0151022.
- Clapp PW, Jaspers I. Electronic cigarettes: their constituents and potential links to asthma. *Curr Allergy Asthma Rep*. 2017;17(11):79.
- Varughese S, Teschke K, Brauer M, Chow Y, van Netten C, Kennedy SM. Effects of theatrical smokes and fogs on respiratory health in the entertainment industry. *Am J Ind Med*. 2005;47(5):411-418.
- Geiss O, Bianchi I, Barahona F, Barrero-Moreno J. Characterisation of mainstream and passive vapours emitted by selected electronic cigarettes. *Int J Hyg Environ Health*. 2015;218(1):169-180.