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E-cigarette use and asthma in a multiethnic sample of adolescents

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ABSTRACT

There is minimal evidence from epidemiological studies on how e-cigarette use is related to health indices in adolescence. We hypothesized that e-cigarette use would be associated with asthma, controlling for demographics and cigarette smoking. The hypothesis was tested with cross-sectional data from a statewide sample of school students. Surveys were administered in classrooms in 2015 to adolescents in 33 high schools throughout the State of Hawaii. The sample (N = 6,089) was 50% female and mean age was 15.8 years. Data were obtained on demographics; ever use and current (past 30 days) use of e-cigarettes, combustible cigarettes, and marijuana; ever being diagnosed with asthma; and currently having asthma. Multinomial regression examined the association between e-cigarette use and asthma controlling for cigarette smoking, marijuana use, and six demographic covariates. Current e-cigarette use was associated with currently having (vs. never having) asthma (adjusted odds ratio [aOR] = 1.48, CI 1.26 - 1.74) and with previously having (vs. never having) asthma (aOR = 1.22, CI 1.07 - 1.40). This was independent of cigarette smoking, marijuana use, and other covariates. Smoking and marijuana were nonsignificant in the multivariate analysis. Blacks, Native Hawaiians, other Pacific Islanders, and Filipinos had higher rates of asthma compared with Asian Americans and Caucasians. We conclude that e-cigarette use by adolescents is independently associated with asthma. This finding is consistent with recent laboratory research on pulmonary effects from e-cigarette vapor. Implications for public health should be considered.

BACKGROUND

The use of electronic cigarettes (e-cigarettes) among adolescents has increased substantially over the past five years. Recent US data show prevalence estimates for current e-cigarette use (i.e., any use in the last 30 days) of 14%-16% in high school populations (Jamal et al., 2017; Miech et al., 2017a). Similar prevalence estimates have been noted in other countries (Dutra and Glantz, 2014; Goniewicz et al., 2014; White et al., 2015). However, there is little evidence available from human studies on how e-cigarettes are related to indices of health status. Researchers have noted that findings from laboratory studies of short-term e-cigarette effects on biological processes can be of uncertain relevance for human health, and there have been few epidemiological studies testing whether e-cigarette use is related to respiratory symptoms in human populations (Pisinger and Døssing, 2014).

Asthma has been prevalent among children and adolescents in the US and is linked to significant health, social, and financial morbidity (Akinbami et al., 2016; Kopel et al., 2014). Although levels of toxicants in e-cigarette vapor are lower than in smoke from combustible cigarettes (Goniewicz et al., 2014), health concerns have been raised because of the unregulated levels of nicotine itself and constituents that have no safe lower limit (Grana et al., 2014). E-cigarette vapor contains substantial levels of fine particles (Fuoco et al., 2014; Zhang et al., 2013), which have previously been implicated in pulmonary disease linked to cigarette smoke and air pollution (Brook et al., 2010). In addition, there is evidence that e-cigarette vapor can produce oxidative stress and inflammation in airways (Lerner et al., 2015; Wu et al., 2014), which presents a possible concern for pulmonary disease.

Two previous reports have examined the relation between e-cigarette use and asthma. An investigation from Korea (Cho and Paik, 2016) studied a large sample of high school students and found that e-cigarette use was related to higher likelihood of having been diagnosed with asthma and to more days absent from school because of asthma. An American investigation (Choi and Bernat, 2016) reported data from a 2012 survey of Florida high school students that showed a higher prevalence of current asthma among those who used e-cigarettes. Analogous results were found for self-reported respiratory symptoms (cough or phlegm persisting for 3 months) with Chinese secondary school students in Hong Kong (Wang et al., 2016) and with high school students in California (McConnell et al., 2017).

The previous studies on asthma are primarily from populations outside the US or based on data from an early stage of the e-cigarette phenomenon. In the present research we analyze data

from a 2015 survey of adolescents in Hawaii, a population that has a substantial prevalence of e-cigarette use (Wills et al., 2015) and known risk factors for asthma (Min et al., 2014; Tam et al., 2016). The analyses controlled for demographics, cigarette smoking, and several covariates linked to asthma, such as overweight status. We hypothesized that e-cigarette use among adolescents would be associated with asthma independent of cigarette smoking. We used data from the 2015 Hawaii Youth Risk Behavior Survey (HYRBS) because the sample is multiethnic and the survey contains items on 30-day use of e-cigarettes and other substances and current asthma status, which are not included in some other surveys (e.g., national YRBS).

METHODS

Procedure and participants

The HYRBS is administered every 2 years by the University of Hawaii to students in public middle and high schools throughout the state of Hawaii. The present research uses data from high school students (9th grade - 12th grade) in the 2015 HYRBS. The 99-item survey was self-administered by students in classrooms, supervised by project staff, in 33 randomly selected high schools during the spring of 2015. Out of 43 high schools in Hawaii, participating schools were selected using a three-stage sample stratified by racial/ethnic concentration and metropolitan statistical area status to produce a representative sample of students in grades 9–12. Intact classes of a required subject or intact classes during a required period (e.g., second period) were selected randomly. All students in sampled classes were eligible to participate. Procedures involved passive consent from parents and affirmative assent from students. The overall response rate was 78% and surveys were obtained from 6,089 participants. Procedures were approved by the Institutional Review Board for the University of Hawaii at Manoa.

The sample was 50% female and the mean age was 15.8 years (SD = 1.2). Grade level was 27% 9th grade, 25% 10th grade, 24% 11th grade, and 23% 12th grade. For primary ethnicity, 2% of the participants were American Indian or Alaska Native; 3% were Black or African American, 29% were Filipino, 39% were Native Hawaiian or Other Pacific Islander, 16% were Japanese or Other Asian, and 11% were Caucasian. For an item on intention for obtaining further education post-high school, responses were 12% definitely would not, 9% probably would not, 31% probably would, and 49% definitely would.

Measures

The YRBS measures have been previously tested for reliability and validity (Brener et al., 1995; Centers for Disease Control and Prevention, 2013). “Not sure” responses for the items on

asthma and educational intentions were treated as missing.

Demographics. Participants responded first to items about their gender (dichotomous), age (7 categories, 12-18 years), and grade level (4 categories, 9^{th}-12^{th} grade). Race was assessed by the question "What is your race?" (8 categories, multiple responding allowed). Grades were assessed by "During the past 12 months, how would you describe your grades in school?" (5 categories, mostly A's to mostly F's). Body mass index (BMI) was assessed with write-in questions about height and weight. For multiple responses on ethnicity a coding procedure with override rules (Glanz et al., 2005; Kaholokula et al., 2006; Wills et al., 2013) was used to index primary ethnicity. (Results on asthma prevalence were similar for a subsample with monoethnicity.) Because educational attitudes and vocational track are correlates of e-cigarette use (Kinnunen et al., 2014; Wills et al., 2015) we included the item "How likely is it that you will complete a post high school program such as a vocational training program, military service, community college, or 4-year college?" (4 response options: definitely will not to definitely will).

Substance use items. Cigarette smoking was assessed by "Have you ever tried cigarette smoking, even a few puffs?" (No/Yes) and "During the past 30 days, on how many days did you smoke cigarettes?" (7 response options: 0 days to all 30 days). E-cigarette use had the lead-in instruction, "The next two questions ask about electronic vapor products, such as blu, NJOY, or Starbuzz. Electronic vapor products include e-cigarettes, e-cigars, vape pipes, e-hookahs, and hookah pens." The items were "Have you ever used an electronic vapor product?" (No/Yes) and "During the past 30 days, on how many days did you use an electronic vapor product?" (7 response options, same as for cigarettes). Marijuana use was assessed with "How old were you when you tried marijuana for the first time?" (7 responses: Never tried to 17 years or older) and "During the past 30 days, how many times did you use marijuana?" (6 response options: 0 times to 40 or more times). The item on age of first marijuana use was recoded to never tried vs. tried at any age, providing an index for ever use of marijuana.

Asthma status items. Asthma status was assessed by the items "Has a doctor or nurse ever told you that you have asthma?" (no/yes/not sure) and "Do you still have asthma?" (4 response options: I have never had asthma (no/yes/not sure).

Analysis methods

Prevalence estimates for asthma and substance use were computed with weighted analyses using SAS Proc SURVEYFREQ, accounting for stratum and school clustering. Correlation analyses examined the intercorrelation of the asthma indices and the other study

variables. A binary index for ever had asthma (vs. never) was derived from the first asthma item and two binary indices were derived from the second asthma item (previously had asthma vs. never and currently have asthma vs. never). For substance use variables we compared correlations using a scaled score (e.g., frequency of e-cigarette use in last 30 days) with correlations based on a binary variable (e.g., any e-cigarette use in last 30 days). The binary variables had somewhat larger correlations with asthma based on phi coefficients; hence binary variables were utilized for further analyses.

Multivariate analyses were performed in logistic and multinomial regression using Proc SURVEYLOGISTIC with an asthma index as the criterion and with binary codes for e-cigarette use, cigarette smoking, marijuana use, and the demographic variables entered simultaneously as predictors, with adjustment for stratum and school clustering. This controls for any correlation of e-cigarette use and cigarette smoking with the covariates and with each other. Variance inflation factors were less than 2 for all analyses, indicating that multicollinearity was not an issue. To have comparable coefficients in the multivariate analysis (Stoolmiller et al., 2012; Wills et al., 2017) participant age, body mass index (age-sex percentile), and educational intentions were entered as binary variables (14-16 vs. 17-18, lowest terciles vs. upper tercile), and No/Little intention vs. Some/Much intention. For entering ethnicity we dropped one small group (Native Americans) and simplified the analytic model by constructing two binary indices, one that contrasted the two highest-rate asthma groups (Blacks and Native Hawaiians) and one that contrasted the two intermediate-rate groups (Filipinos and Pacific Islanders), each against the three lowest-rate groups (Japanese, Other Asians, and Whites) as the reference group. (Results were essentially identical with a procedure using 6 contrasts entered for all the ethnic groups.)

To test for interaction in prediction of asthma, we entered the cross-product of e-cigarette use and cigarette smoking in regression models together with their main effects and the covariates. Because there were appreciable rates of missing data for the predictors entered to the multivariate analyses, we conducted a full-information analysis using multiple imputation for the predictors (Rubin, 1987) so as to maximize sample size and minimize potential bias. This was performed using the SAS 9.4 Proc MI procedure with 20 imputations based on the Markov Chain Monte Carlo method (Schafer and Graham, 2002), so the multivariate analyses were based on sample sizes of 4,880 for ever had asthma and 4,601 for have asthma now. For a sensitivity analysis we report results with listwise deletion as supplemental material.

RESULTS

Prevalence for substance use and asthma

Prevalence estimates (Table 1) showed 25% of the participants had ever smoked cigarettes and 10% had smoked in the past 30 days (i.e., current use). These estimates are comparable to national studies (Jamal et al., 2017; Miech et al., 2017a). In contrast, e-cigarette prevalence estimates of 45% for ever use and 25% for current use are both higher than national rates (Jamal et al., 2017; Miech et al., 2017a). Ever-use of marijuana was reported by 33% of the participants and a substantial proportion of participants had used marijuana on multiple occasions.

Prevalence estimates for self-reported asthma indicated a substantial prevalence in this sample; 34% of the participants had ever been diagnosed with asthma and 22% currently had asthma (Table 1). These prevalence estimates are higher than the national average of 7.8% from the 2015 National Health Interview Survey (Centers for Disease Control and Prevention, 2015), but are close to rates reported from Hong Kong and Florida (Choi and Bernat, 2016; Wang et al., 2016). We note that the prevalence of never having asthma differed for the two asthma items (66% vs. 56%) possibly because participants interpreted the two items differently, the criterion being a doctor's diagnosis for the first item but their personal experience for the second item.

For demographic items the missing-data rates were from 1% to 3%, and for substance use items the rates of missing data were from 3% to 7%. However, 11% of cases were missing the asthma items and 10% were missing the educational intentions item. These items were at the end of the questionnaire whereas items for the other variables were at the beginning of the survey.

Table 1

Prevalence estimates (%) for asthma and substance use variables

Asthma index	
Has a doctor or nurse ever told you that you have asthma?	
No	66
Yes	34
Do you still have asthma?	
Never had	56
Had, but not now	22
Have asthma now	22

Substance use index	E-cigarettes	Cigarettes	Marijuana
Ever use			
Never used	55	75	67
Ever used	45	25	33
Use in past 30 days[A]			
None	75	90	81
Used 1-2 days (1-2 times)	11	4	6
Used 3-5 days (3-9 times)	5	2	5
Used 6-9 days (10-19 times)	3	1	3
Used 10-19 days (20-39 times)	3	1	2
Used 20-29 days (∃40 times)	1	1	3
Used all 30 days	2	1	n.a.

Note: n.a. = not applicable. Weighted Ns for asthma items are 35,224 and 34,441, respectively; unweighted Ns are 5,001 and 4,889. Weighted Ns for substance ever-use items are 39,960, 39,468, and 40,945 for e-cigarettes, cigarettes, and marijuana, respectively; unweighted Ns are 5,724, 5,675, and 5,897. For 30-day use items, weighted Ns are 41,175, 41,214, and 40,810; unweighted Ns are 5,916, 5,933, and 5,872. [A] Marijuana question has a different scale, response values are in parentheses.

Correlations of study variables

Correlations of the two asthma indices with the study variables, accounting for stratum and school clustering, indicated several significant associations (Table 2). As predicted, having asthma (ever or current) was associated significantly with both e-cigarette use and cigarette smoking and was also associated with marijuana use. Asthma was positively associated with Native Hawaiian ethnicity and overweight status and was inversely associated with the educational intentions variable. It should be noted that the effect sizes for e-cigarette use and cigarette smoking were similar to those for other significant covariates (e.g., overweight status). E-cigarette use and combustible cigarette smoking were correlated with a number of the other study variables. For example, all types of substance use were inversely correlated with the educational intentions variable and were positively correlated with Native Hawaiian ethnicity. Obesity was correlated with Native Hawaiian ethnicity but not with other Pacific Islander ethnicity. E-cigarette use, cigarette smoking, and marijuana use were all significantly intercorrelated. Thus, there were several potential confounding relationships and these were addressed in a multivariate analysis.

Table 2. Correlations among Study Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Ever had asthma	.xx														
2. Previous asthma	**.30**	.xx													
3. Current asthma	**.66**	.n.a.	.xx												
4. Gender	.03	*.07*	.02	.xx											
5. Age	-.02	.03	.02	.02	.xx										
6. Black/Nat. Hawaiian	**.14**	.03	**.13**	.04	-.03	.xx									
7. Filipino/Pac. Islander	-.01	.02	-.05	.01	-.01	-.57	.xx								
8. Educ. intentions	**-.11**	.00	-.04	**-.11**	.02	**-.08**	.02	.xx							
9. Overweight **.09**	.03	*.06*	**.09**	-.03	**.16**	.05	-.04	.xx							
10. Ever used e-cigs	**.09**	*.06*	**.08**	.05	**.08**	**.27**	*-.05*	**-.10**	*.07*	.xx					
11. Current e-cig use	**.08**	.06	**.10**	**.10**	*.06*	**.13**	-.04	**- .10**	*.07*	**.61**	.xx				
12. Ever smoked	**.09**	.03	**.09**	.00	**.07**	**.13**	*-.07*	**-.11**	*.07*	**.42**	**.37**	.xx			
13. Current smoking	**.08**	.04	*.06*	.05	.04	**.09**	-.04	**-.17**	.05	**.28**	**.35**	**.53**	.xx		
14. Ever used marijuana	**.08**	.04	**.08**	.00	**.12**	**.40**	**-.12**	**-.11**	.01	**.48**	**.48**	**.50**	**.38**	.xx	
15. Current marijuana	*.07*	.03	*.07*	.01	*.05*	**.30**	**-.11**	**-.14**	.01	**.48**	**.35**	**.38**	**.40**	**.68**	.xx

Note: Educ. = educational; e-cig = e-cigarette. Values are phi coefficients. **BOLD** indicates $p < .0001$; *Italic* indicates $p < .001$.

Multivariate analysis for e-cigarettes

The multinomial regression analysis (Table 3) indicated that current e-cigarette use showed significant associations with current asthma (adjusted odds ratio [aOR] = 1.48, CI 1.24-1.78) and with previous asthma (aOR = 1.20, CI 1.00-1.44), but there were no significant effects for cigarettes or marijuana in this model. There was a significant association of ever e-cigarette use with currently having asthma (compared to never) and a marginal association for previously having asthma. Ever-smoking was associated with currently having asthma but the effect for previous asthma was not significant. The covariate effects indicated Blacks and Native Hawaiians as more likely to currently have asthma, whereas Filipinos, Other Pacific Islanders, and males were more likely to have had asthma previously but not currently. In the multivariate models, males were more likely to previously have asthma and overweight status was significantly related to current asthma, but educational intentions did not have any significant effects net of the other covariates.

Results for tests of interactions were nonsignificant for ever e-cigarette/cigarette use and ever-asthma, ever-use and current asthma, and current substance use and current asthma. The interaction term for current use and ever-asthma was significant, but this effect was based on one small cell and is probably not reliable. These results together indicate there are additive effects of e-cigarette use and cigarette smoking for prediction of asthma but no synergism.

Table 3

Adjusted odds ratio (aOR) for two contrasts in multinomial regression with previous/current asthma as criterion variable, with ever use and current use for substance use predictors

		Substance use index			
	Asthma	Ever used		Current use [B]	
Variable	contrast	AOR	CI	AOR	CI
E-cigarette use	Current vs. never	1.22	1.01 - 1.47	1.48	1.24 - 1.78
	Previous vs. never	1.19	0.99 - 1.43	1.20	1.00 - 1.44
Cig. smoking	Current vs. never	1.27	1.05 - 1.54	1.23	0.92 - 1.64
	Previous vs. never	1.01	0.82 - 1.24	1.17	0.88 - 1.54
Marijuana use	Current vs. never	1.04	0.87 - 1.24	1.01	0.84 - 1.20
	Previous vs. never	1.10	0.90 - 1.34	1.07	0.85 - 1.35
Gender (male)	Current vs. never	1.06	0.92 - 1.22	1.04	0.90 - 1.19
	Previous vs. never	1.29	1.13 - 1.47	1.27	1.12 - 1.45
Age	Current vs. never	0.85	0.71 - 1.02	0.86	0.72 - 1.03
	Previous vs. never	1.15	0.93 - 1.42	1.16	0.94 - 1.44
Black/NH[A]	Current vs. never	1.54	1.22 - 1.95	1.57	1.24 - 1.99
	Previous vs. never	1.16	0.94 - 1.44	1.19	0.96 - 1.47
Filipino/PI[A]	Current vs. ever	1.03	0.83 - 1.29	1.03	0.83 - 1.28
	Previous vs. never	1.17	0.97 - 1.41	1.17	0.97 - 1.41
Ed. intentions	Current vs. never	0.97	0.81 - 1.16	0.96	0.81 - 1.15
	Previous vs. never	1.04	0.86 - 1.26	1.05	0.87 - 1.27
Overweight	Current vs. never	1.22	1.02 - 1.45	1.22	1.02 - 1.46
	Previous vs. never	1.07	0.92 - 1.26	1.07	0.91 - 1.26

Note: Cig. = cigarette; NH = Native Hawaiian; PI = Pacific Islander; Ed. = educational. AOR=adjusted odds ratio; CI=confidence interval. All predictors are entered simultaneously and analyses adjust for stratum and school clustering.

[A] Reference group is Asian-Americans and Caucasians. [B] The referent group is persons who do not report current use.

In the logistic regression analysis with ever being diagnosed with asthma as criterion, the temporal status of the results could be ambiguous in some cases (e.g., if asthma occurred in childhood). Accordingly, these are presented as supplemental material (see Supplemental Table 1). There were significant positive associations of ever having asthma with ever-use of e-cigarettes and cigarettes. Current e-cigarette use and current cigarette smoking also showed significant independent associations with asthma. Effects for the covariates were similar to those for the other analysis.

Sensitivity analyses (Supplemental Table 2) showed that results from the full-information analysis were generally similar to results from analyses based on listwise deletion. However, there were more significant effects for smoking in the full-information models, which we attribute to the larger sample size.

DISCUSSION

This research investigated the association between e-cigarette use and asthma in a multiethnic sample of adolescents in Hawaii surveyed in 2015. Our analytic approach controlled for the correlation of e-cigarette use with cigarette smoking and with other variables that were significantly related to asthma in this population. E-cigarette use was associated with higher odds of asthma, independent of cigarette smoking, marijuana use, and the covariates, with an effect size comparable to that of recognized risk factors for asthma. This association was most prominent among adolescents who currently used e-cigarettes in the past 30 days but was also significant for those who had ever used e-cigarettes (cf. McConnell et al., 2017). The present study is consistent with previous findings showing associations of asthma with cigarette smoking and overweight status (Cho and Paik, 2016; Gennuso et al., 1998; von Mutius et al., 2001) and with a study showing e-cigarette use and smoking to have additive effects in relation to likelihood of asthma (Cho and Paik, 2016). Our findings add to the literature on racial/ethnic differences (Akinbami et al., 2014; Kit et al., 2013) by showing differentials in prevalence of asthma for several Pacific Islander groups.

We note that in this sample the prevalence of cigarette smoking was relatively low whereas the prevalence of e-cigarette use was relatively high. The low rate of smoking in Hawaii has been attributed to high taxation and consistent enforcement concerning retail sales (Edwards et al., 2010; Williams et al., 2014). The higher rate of e-cigarette use may be attributable to aggressive marketing to teenagers (Duke et al., 2014), favorable price policies due to no tobacco tax on e-cigarettes in contrast to a high tax on combustible cigarettes, and the attractiveness of

"local" flavors such as pineapple and mango. We note that US studies have shown smoking rates decreasing while e-cigarette use is increasing (Jamal et al., 2017; Miech et al., 2017a), so the data we observed in the present study may be increasingly common in other locales.

When cigarette smoking was entered together with e-cigarette use in multivariate analyses, it sometimes did not have a significant unique effect (Table 3). We think this is attributable to statistical issues because e-cigarette use and cigarette smoking were substantially correlated and had similar levels of correlation with the asthma items (Table 2). In such situations the significant unique effect will go to the variable that has a slightly higher correlation with the criterion, though the shared variance will be substantial (Cohen and Cohen, 1988). This does not mean that cigarette smoking is irrelevant for asthma, and in fact some analyses showed significant independent effects. The additive contribution of e-cigarette use and cigarette smoking for predicting likelihood of asthma is relevant because e-cigarette use has been related in several studies to onset of cigarette smoking (Barrington-Trimis et al., 2016; Miech et al., 2017b; Soneji et al., 2017) and the two processes could reinforce each other.

Potential mechanisms

The mechanism of possible e-cigarette effects on pulmonary function currently is not well understood. However, the present findings are consistent with clinical studies showing that e-cigarette use causes inflammation and increased airway resistance, in some cases at levels similar to effects of cigarette smoking (McConnell et al., 2017; Schweitzer et al., 2017). Moreover, recent laboratory studies have found indicators of oxidative stress from e-cigarette use (Carnevale et al., 2016), and have found that e-cigarette vapor produces inflammatory responses and increased susceptibility to infection (Hwang et al., 2016; Lerner et al., 2015; Martin et al., 2016; Sussan et al., 2015; Wu et al., 2014). The convergence of the present results with laboratory evidence on e-cigarette effects, as well as reports on associations of e-cigarette use with respiratory symptoms and asthma-related absence from school in human populations (Cho and Paik, 2016; Choi and Bernat, 2016; McConnell et al., 2017), suggests more attention to possible health consequences of e-cigarette use among adolescents. Further research will be necessary to test for linkages of asthma as observed in epidemiological samples with processes delineated in laboratory studies.

The temporal relation between e-cigarette use and asthma is not established in the present cross-sectional data and this raises issues for interpretation. We think a reverse-causation argument (i.e., having asthma causes adolescents to smoke cigarettes or use e-cigarettes) is

implausible. An interpretation that adolescent smokers switched to e-cigarettes when they got asthma seems unlikely because the base rates of the behaviors are quite different, with 45% of the population using e-cigarettes while only 10% smoked. In some cases, it is possible that the asthma developed before high school, but e-cigarette use in high school could exacerbate an existing condition (cf. Cho and Paik, 2016). Considering all the issues together, we think the interpretation that e-cigarette use has a contributory role for asthma is plausible, but the issue of temporal ordering needs to be examined in further research with retrospective follow-back assessments and prospective research designs. Obtaining repeated assessments on the frequency and intensity of e-cigarette use and cigarette smoking would be desirable to test for possible threshold or dose-response effects in relation to onset or recurrence of asthma symptoms.

Study Limitations

Though our analyses had a large sample and multivariate controls, some aspects of this research could be noted as limitations. The data on asthma were based on self-reports and further research should corroborate these with medical records, clinical assessment measures (e.g., spirometry and fractional exhaled nitric oxide), or direct examination by physicians. There was missing data for the asthma measures and this should be considered for interpretation of the results. Although the educational intentions variable was a significant covariate, additional indices of socioeconomic status and more extensive data on residential context and family hardship (Beck et al., 2014) would be desirable. Finally, the present study was cross-sectional and longitudinal research would be desirable to examine effects of e-cigarette use on health indices over time.

CONCLUSION

This research adds to knowledge about e-cigarette use and health indices among adolescents. E-cigarette use was shown to be significantly associated with asthma when controlling for several variables in the multivariate analysis. The findings provide a new perspective on e-cigarettes and suggest attention to possible respiratory effects from e-cigarette use and mechanisms of how e-cigarette use could affect health-related variable, as well as behavioral variables (Cho and Paik, 2016; Lerner et al., 2015; Soneji et al., 2017). Public health specialists may be involved in making parents and youth more aware of both potential risks and benefits of e-cigarette use (U.S. Department of Health and Human Services, 2016).

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Contributors

RJS obtained the data set, conceptualized the manuscript, co-wrote the first draft, and reviewed drafts of the manuscript critically for important intellectual content. TAW assisted with conceptualizing the manuscript, performed the initial data analyses, co-wrote the first draft, and reviewed drafts of the manuscript critically for important intellectual content. EKT assisted with conceptualization of the manuscript and reviewed drafts of the manuscript critically for important intellectual content. IP assisted with performance of the statistical analyses and reviewed drafts of the manuscript for appropriateness and completeness of the analyses. KC consulted about the statistical analyses and reviewed drafts of the manuscript critically for important intellectual content.

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Conflicts of interest

None

Ethics approval

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

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HIGHLIGHTS

- E-cigarette use is associated with a higher likelihood of asthma.
- Findings are independent of cigarette smoking, marijuana use, and other covariates.
- Native Hawaiians, other Pacific Islanders, Filipinos had higher rates of asthma.
- Research on the health implications of e-cigarette use is needed.