Ever Use of E-Cigarettes Among Adults in the United States: A Cross-Sectional Study of Sociodemographic Factors

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Abstract

E-cigarette use among adolescents is well-documented, but less is known about adult users of e-cigarettes. The purpose of this study was to examine associations between sociodemographic factors and e-cigarette use in a nationally representative sample of adults in the United States. Cross-sectional data from the National Health and Nutrition Examination Survey (NHANES) for years 2015-2016 were analyzed to assess e-cigarette use among 5989 adults aged ≥18 years. Multivariable logistic regression was conducted to examine associations between the sociodemographic exposures of age, sex, race, marital status, education level, employment status, and poverty-income ratio and the outcome of e-cigarette use. The weighted prevalence of ever use of e-cigarettes was 20%. Compared with adults aged ≥55 years, odds of e-cigarette use were 4.77 times (95% confidence interval [CI] = 3.63-6.27) higher among ages 18 to 34 years and 2.16 times (95% CI = 1.49-3.14) higher among ages 35 to 54 years. Higher odds of e-cigarette use were observed among widowed/divorced/separated participants compared with those who were married/living with a partner, among participants with less than high school (odds ratio [OR] = 1.47; 95% CI = 1.08-2.00) or high school/general educational development (GED) education (OR=1.41; 95% CI = 1.12-1.77) compared with those with college degrees/some college, and among those with incomes below the poverty level (OR=1.31; 95% CI = 1.01-1.69) compared with above the poverty level. For non-smokers of conventional cigarettes, higher odds of e-cigarette use were observed among males compared with females, Mexican Americans/Other Hispanics compared with non-Hispanic whites, and non-working participants compared with those who were working. Overall findings indicate that individuals who are widowed/divorced/separated, individuals with lower education, and with incomes below the poverty level are likely to report ever use of e-cigarettes. As increasing evidence demonstrates negative health consequences, e-cigarette initiation may ultimately contribute to additional smoking-related health inequalities even among non-smokers of conventional cigarettes.

Keywords

electronic nicotine delivery systems, tobacco products, smoking, health inequalities, cross-sectional studies

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What do we already know about this topic?
Studies have shown that e-cigarette use may encourage initiation of conventional cigarettes among non-smoking adolescents; in addition, prevalence studies among adults have indicated that current e-cigarette use is highest among young adults, men, multi-racial individuals, and conventional cigarette smokers.

How does your research contribute to the field?
This study investigates associations between additional sociodemographic factors such as education, income, and employment, and ever use of e-cigarettes using nationally representative data from the National Health and Nutrition Examination Survey from 2015 to 2016.

What are your research's implications toward theory, practice, or policy?
This study aids in identifying groups most likely in need of educational interventions to prevent e-cigarette use and potentially further use of conventional cigarettes; additionally, this study provides implications regarding further regulation of e-cigarettes and the potential to reduce health-related inequalities among sociodemographic groups most likely to be ever users.

Introduction

According to the Centers for Disease Control and Prevention (CDC), e-cigarettes are any electrical devices that can deliver nicotine or other substances to the individual inhaling them.[1] E-cigarettes are known by many different names: e-cigs, mods, vape pens, vapes, and electronic nicotine delivery systems or ENDS.[1] Although the mechanics of e-cigarettes can be manipulated by the consumer, they are typically composed of a battery, a heating component, and a cartridge containing nicotine.[2] E-cigarettes were initially advertised by the tobacco industry as a form of conventional cigarette cessation.[3] However, findings of previous studies on the use of e-cigarettes as a method of conventional smoking cessation have been mixed, with some studies indicating modest effectiveness[4,5] and others indicating ineffectiveness.[6-10] Furthermore, although the US Food and Drug Administration (FDA) has approved such smoking cessation aids as nicotine skin patches, nicotine gum, and bupropion, the FDA has not approved e-cigarettes as a smoking cessation aid.[11]

E-cigarettes first appeared in the US tobacco market in 2007 and are dramatically rising in sales each year.[12] Due to the manner in which e-cigarettes are advertised, many individuals believe that e-cigarettes are a safe alternative to conventional cigarettes.[13-16] However, multiple laboratory-based studies have demonstrated the presence of carcinogens and other potentially carcinogenic compounds both in e-cigarette vapor and in measured biomarkers of e-cigarette users, such as urine and saliva.[17-21] E-cigarettes can be harmful in a variety of ways. For example, hundreds of different e-cigarette liquids are available and many of them include components such as diacetyl, the butter flavoring used on microwave popcorn, that has been shown to cause "popcorn lung," an irreversible loss of pulmonary function which may necessitate treatment via lung transplant.[22] Furthermore, a recent study has shown that when e-juice is heated within the tank system, toxic metals, such as lead, nickel, and chromium, are transferred from the heating coil into both the liquid and resulting aerosol, thereby being inhaled by the e-cigarette user.[23] In addition, many tobacco companies have advertised e-juices containing 0% nicotine; however, laboratory tests have confirmed the presence of nicotine in some of the "nicotine-free" e-juices.[3]

The long-term health effects remain to be seen,[24] but a recent study showed that dual use of e-cigarettes and conventional cigarettes was associated with 36% higher odds of cardiovascular disease compared with conventional smoking alone.[25] Proponents of the precautionary principle, which involves taking preventive action irrespective of current uncertainty,[26] recommend extending existing indoor smoke-free laws to include prohibiting the use of e-cigarettes.[27,28] With the rationale of protecting non-users of e-cigarettes, the World Health Organization Framework Convention on Tobacco Control recommends banning use of e-cigarettes indoors and in areas where conventional cigarette use is prohibited.[29] In the United States, 12 states and 615 local areas have set restrictions on e-cigarette smoking in indoor public establishments where conventional cigarette use is also prohibited.[28]

Although e-cigarette use among adolescents is well-documented, less is known about adult ever use of e-cigarettes. For example, several studies have shown that the use of e-cigarettes may encourage initiation and subsequent use of conventional cigarettes among non-smoking adolescents.[24,28,30-33] Perhaps most strikingly, a recent systematic review and meta-analysis demonstrated that ever use of e-cigarettes among adolescents and young adults was consistently associated with initiation of conventional cigarette smoking.[34] Further evidence is needed to determine whether ever use of e-cigarettes among adults is also prevalent among non-smokers of conventional cigarettes.

Recent prevalence studies among adults have indicated that current e-cigarette use is highest among young adults, men, individuals who are multi-racial, and conventional cigarette smokers.[35,36] From a primary prevention perspective, understanding the associations between sociodemographic factors and ever use of e-cigarettes is important to identify groups most likely in need of educational interventions to prevent e-cigarette use and potentially further use of conventional cigarettes. This study may also inform whether further regulation of e-cigarettes has the potential to reduce health-related inequalities among sociodemographic groups most likely to be ever users. Therefore, the purpose of this study was to examine the association between sociodemographic factors and e-cigarette use in a nationally representative sample of adults in the United States.

Methods

Data Source and Study Population

Data were acquired from the National Health and Nutrition Examination Survey (NHANES) for years 2015-2016.[37] The exposures of interest were the sociodemographic factors of age, sex, race, marital status, education level, employment, and poverty-income ratio. The outcome of

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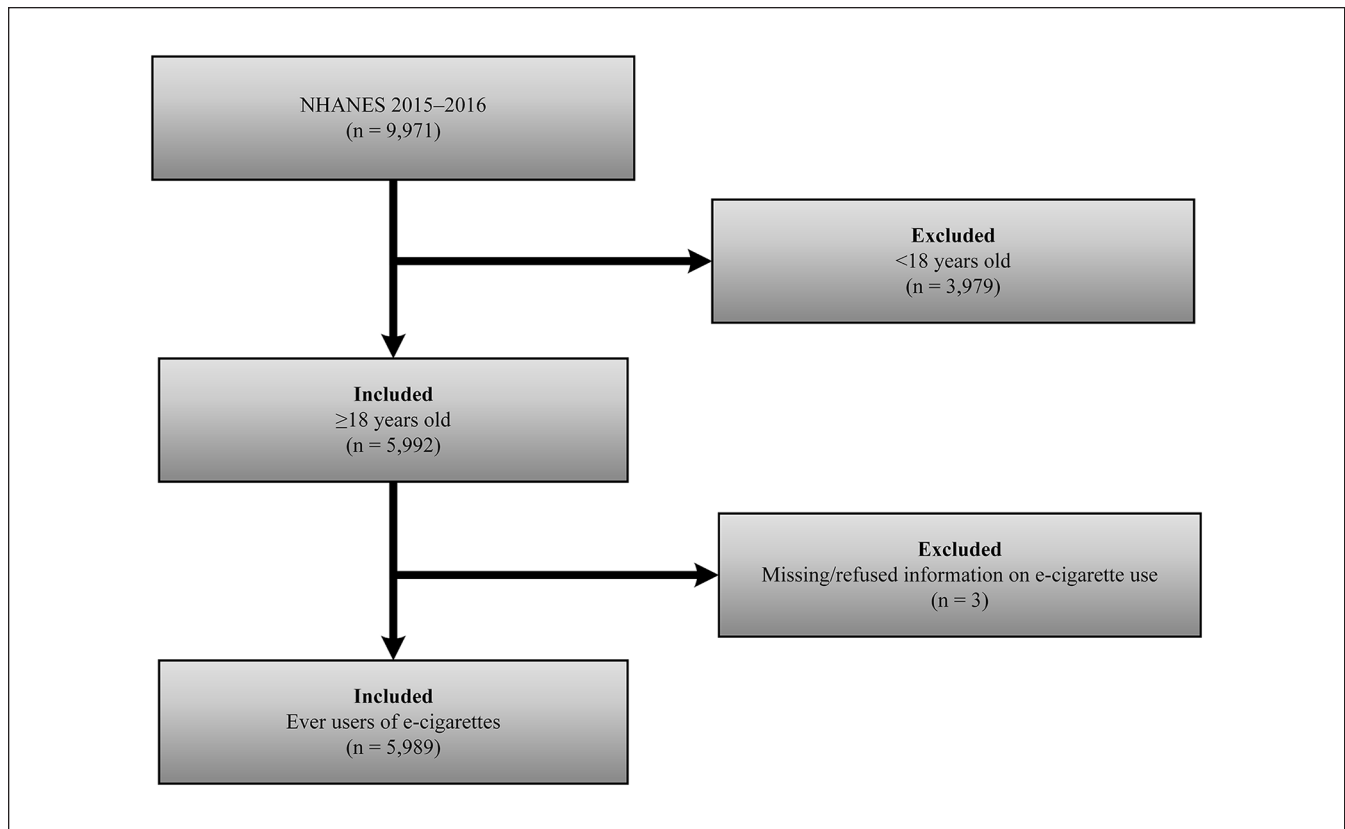Email: s.stallings-smith@unf.edu

Figure 1. Selection of study participants from NHANES 2015 to 2016 to investigate the association between sociodemographic factors and ever use of e-cigarettes.
Note. NHANES = National Health and Nutrition Examination Survey.

interest was self-reported ever use of e-cigarettes (ie, "Have you EVER used an e-cigarette EVEN ONE TIME?"). The information for these variables was collected by NHANES representatives via self-reported participant questionnaire. A hand card of examples was provided for each study participant to view when responding to the question about ever use of e-cigarettes. De-identified sociodemographic data were merged with e-cigarettes data based on participant identification number. All missing data were excluded. The process for determining the final study population is presented in Figure 1.

Measures

All sociodemographic exposures were self-reported by study participants. The poverty-income ratio is based on income thresholds established by the US Census Bureau according to the size and composition of the family that the income supports. The variable is calculated as the ratio of actual income to the family's established poverty threshold with values ≥1.00 indicating that the family's income is at or above the poverty level and values <1.00 indicating that the family lives in poverty.[37]

To further explore the factors associated with e-cigarette use, stratified analyses were conducted by conventional cigarette smoking status, which was based on participant responses to the question: "Have you smoked at least 100 cigarettes in your lifetime?" Smoking status was operationalized as a dichotomous variable with a value of 0 designated for non-smokers and a value of 1 designated for smokers. The additional variable "Do you now smoke cigarettes?" could not be used in analyses due to the number of missing responses.

Statistical Analysis

Multivariable logistic regression was used to examine associations between the sociodemographic exposures of age, sex, race, marital status, education level, employment status, and poverty-income ratio and the outcome of e-cigarette use. To prevent the introduction of overadjustment bias into the statistical models, potential confounders were included when there was probability of affecting both the exposure and the outcome.[38] Specifically, demographic exposures such as age, sex, and race are considered to be non-modifiable factors.[39-41] As such, no statistical adjustment is required for the association between these demographic factors and any outcome.

However, socioeconomic factors such as level of education, marital status, employment status, and poverty have been shown to be influenced by age,[42,43] sex,[44,45] and race.[46,47] In addition, because traditional cigarette use is influenced by socioeconomic factors,[48-52] it is logical that these factors would also translate to the use of e-cigarettes. Therefore, the statistical models with marital status, education level, employment status, and poverty-income ratio as exposures were adjusted for the sociodemographic factors of age, sex, and race. Furthermore, NHANES sample weights were included in all statistical models to address the differential likelihood of participant selection, non-response, and non-coverage during the primary data collection. All analyses were conducted with SAS statistical software version 9.4.

Results

The study population consisted of 5989 adults aged ≥18 years (Table 1). The majority of the study population was 65 years of age and older (36%). Among the study participants, 52% were female and 48% were male. Most study participants were non-Hispanic white (63%), followed by 16% Mexican American and Other Hispanic, 11% non-Hispanic black, and 10% Other Races, including Multi-Racial. The majority of study participants were married or living with a partner (34%). The education level of the study population was primarily represented by the completion of some college/college degree (65%), followed by 21% high school graduates/general educational development (GED) equivalent, and 14% of study participants had less than a high school education. Regarding employment status, 64% stated that they were working whereas 36% indicated that they were either not working or were looking for work. Most of the study population lived above the federal poverty level (85%). Conventional cigarette smoking was observed among 43% of study participants and 20% of the study population stated that they had ever used e-cigarettes.

As displayed in Table 2, odds of e-cigarette use among ages 18 to 34 years were 4.77 times (odds ratio [OR] = 4.77; 95% confidence interval [CI] = 3.63-6.27) that of adults aged ≥55 years; in addition, odds of e-cigarette use among ages 35 to 54 years were 2.16 times (95% CI = 1.49-3.14) that of adults aged ≥55 years. When compared with females, males had higher odds of e-cigarette use (OR = 1.43; 95% CI = 1.24-1.65). Study participants who were Mexican American/Other Hispanic were less likely to use e-cigarettes when compared with non-Hispanic whites (OR = 0.76; 95% CI = 0.61-0.96), but no other racial/ethnic differences were detected. Participants who were widowed, divorced, or separated were 2.10 (95% CI = 1.65-2.67) times more likely to ever use e-cigarettes when compared with participants who were married or living with a partner. In comparison with individuals who had a college degree or some college, higher odds of e-cigarette use were observed among participants with a high school/GED equivalent education level (OR =

Table 1. Characteristics of the Study Population, National Health and Nutrition Examination Survey, 2015-2016.

Characteristic	N	Weighted %
Total	5989	100
Age		
18-34 years	1749	30
35-64 years	1906	34
≥65 years	2334	36
Sex		
Male	2885	48
Female	3104	52
Race		
Mexican American/Other Hispanic	1862	16
Other Races, including Multi-Racial	951	10
Non-Hispanic black	1264	11
Non-Hispanic white	1912	63
Marital status[a]		
Never married	1227	18
Widowed/divorced/separated	1048	18
Married/living with partner	3439	64
Education level[b]		
Less than high school	1363	14
High school graduate/GED equivalent	1236	21
Some college/college degree	3113	65
Employment status		
Not working/looking for work	2544	36
Working	3435	64
Poverty income ratio[c]		
<1.00	1220	15
≥1.00	4095	85
Conventional smoking status		
Smoker	2422	43
Non-smoker	3559	57
E-cigarette use		
Yes	1064	20
No	4925	80

Note. GED = general educational development.
[a]Data not available for 275 participants.
[b]Data not available for 277 participants.
[c]Data not available for 674 participants.

1.60; 95% CI = 1.39-1.84) and among participants with less than a high school education (OR = 1.47; 95% CI = 1.08-2.00). Unemployed individuals were less likely (OR = 0.81; 95% CI = 0.69-0.95) to ever use e-cigarettes compared with individuals who were working. Participants with an income below the poverty level were 1.52 (95% CI = 1.18-1.95) times more likely to ever use e-cigarettes when compared with participants above the poverty level.

When stratified by conventional cigarette smoking status, odds of e-cigarette ever use were highest among ages 18 to 34 years for both conventional cigarette smokers (OR = 12.20; 95% CI = 8.00-18.61) and non-smokers (OR = 19.45; 95% CI = 6.00-62.98) when compared with the reference group composed of individuals aged ≥55 years. In comparison with

Table 2. Weighted Logistic Regression Analysis of the Association Between Sociodemographic Factors and Use of E-Cigarettes Among Adult Participants Aged ≥18 Years in the National Health and Nutrition Examination Survey, 2015-2016.

	E-cigarette use		
	Overall	Smokers	Non-smokers
Sociodemographic characteristic	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Age			
18-34 years	4.77 (3.63-6.27)	12.20 (8.00-18.61)	19.45 (6.00-62.98)
35-54 years	2.16 (1.49-3.14)	3.22 (2.09-4.96)	3.89 (1.38-11.02)
≥55 years	Reference	Reference	Reference
Sex			
Male	1.43 (1.24-1.65)	0.95 (0.78-1.15)	1.52 (1.07-2.14)
Female	Reference	Reference	Reference
Race			
Mexican American/Other Hispanic	0.76 (0.61-0.96)	0.98 (0.67-1.42)	1.59 (1.02-2.48)
Other Races, including Multi-Racial	0.91 (0.63-1.31)	0.81 (0.59-1.12)	1.41 (0.93-2.16)
Non-Hispanic black	0.96 (0.73-1.25)	1.33 (0.82-2.15)	1.00 (0.60-1.69)
Non-Hispanic white	Reference	Reference	Reference
Marital status[a]			
Never married	1.20 (0.94-1.53)	0.87 (0.61-1.23)	0.79 (0.57-1.10)
Widowed/divorced/separated	2.10 (1.65-2.67)	1.33 (0.92-1.93)	1.71 (0.64-4.54)
Married/living with partner	Reference	Reference	Reference
Education level[a]			
Less than high school	1.47 (1.08-2.00)	1.09 (0.81-1.47)	0.53 (0.23-1.21)
High school graduate/GED equivalent	1.83 (1.62-2.06)	1.41 (1.12-1.77)	0.91 (0.67-1.24)
Some college/college degree	Reference	Reference	Reference
Employment status			
Not working/looking for work	0.81 (0.69-0.95)	0.67 (0.48-0.95)	1.52 (1.05-2.20)
Working	Reference	Reference	Reference
Poverty income ratio[a]			
<1.00	1.52 (1.18-1.95)	1.31 (1.01-1.69)	0.77 (0.45-1.31)
≥1.00	Reference	Reference	Reference

Note. CI = confidence interval; GED = general educational development.
[a]Adjusted for age (continuous), sex, and race.

females, non-smoking males were more likely to use e-cigarettes (OR = 1.52; 95% CI = 1.07-2.14). When compared with non-Hispanic white participants, non-smoking Mexican American/Other Hispanic participants were more likely to use e-cigarettes (OR = 1.59; 95% CI = 1.02-2.48). No other differences were observed by race/ethnicity. For marital status, no differences were observed in e-cigarette ever use when stratified by conventional cigarette smoking. When compared with individuals with some college/college degree, high school graduates/GED equivalent participants were more likely to use e-cigarettes if they were already conventional cigarette smokers (OR = 1.41; 95% CI = 1.12-1.77). Conventional cigarette smoking participants who were not working or were looking for work had 33% lesser odds (OR = 0.67; 95% CI = 0.48-0.95) of ever having used e-cigarettes when compared with smoking participants who were currently working. In contrast, non-smokers of conventional cigarettes who were not working or were looking for work had 52% higher odds (OR = 1.52; 95% CI = 1.05-2.20) of

ever having used e-cigarettes when compared with non-smoking participants who were currently working. When compared with individuals living above the poverty level, participants with a poverty-income ratio <1.00 were more likely to use e-cigarettes if they were already conventional cigarette smokers (OR = 1.31; 95% CI = 1.01-1.69).

Discussion

Overall, higher odds of e-cigarette ever use were observed among younger adults compared with older adults, among males compared with females, among individuals who were widowed/divorced/separated compared with those who were married or living with a partner, among individuals with less than high school or high school/GED equivalent education compared with those with a college degree/some college, and among individuals with an income below the poverty level compared with individuals with an income above the poverty level. Among non-smokers of conventional cigarettes, higher

odds of e-cigarette ever use were observed for younger adults compared with older adults, among males compared with females, among Mexican American/Hispanic study participants compared with non-Hispanic whites, and among individuals who were not working or were looking for work compared with individuals who were working. These overall findings indicate that individuals who are potentially socioeconomically vulnerable are likely to report ever use of e-cigarettes. As increasing evidence demonstrates the harmfulness of e-cigarette use on health,[24] initiation of e-cigarette use may ultimately contribute to additional smoking-related health inequalities, even among those who are not conventional cigarette smokers.[53,54]

A potential explanation for the finding that the population with the highest e-cigarette use is young adults, 18 to 34 years of age, is that tobacco companies market e-cigarettes to the same target populations that are most susceptible to using conventional cigarettes. Younger generations are more commonly focused on fulfilling societal norms and seeking acceptance from peers.[55] For these young adults, conventional cigarettes are viewed as more negative and unhealthy when compared with e-cigarettes, which are more socially acceptable.[55] In addition, e-cigarette liquids come in a variety of nicotine content levels, aromas, and flavors such as cherry crush, iced berry, cupcake, milk chocolate, and fruit squirts, which are produced to grab the attention of young adults.[22] In fact, prior evidence has shown that young adults who are non-smokers are more likely to initiate the use of flavored e-cigarettes.[56] In this study, stratification by conventional cigarette smoking status demonstrated that ever use of e-cigarettes was higher among the younger adult age groups of 18 to 34 years and 35 to 54 years when compared with participants aged ≥55 years for both smokers and non-smokers of conventional cigarettes.

According to the CDC, among current e-cigarette users in 2015 aged ≥45 years, more than half were current or former users of conventional cigarettes.[1] In contrast, 40% of e-cigarette users aged 18 to 24 years were neither conventional cigarette smokers nor had they ever been smokers.[1] A recent clinical study of adult smokers showed that smoking urge was reduced by use of both conventional cigarettes and e-cigarettes, but craving symptoms were not as attenuated with e-cigarettes when compared with conventional cigarettes.[2] Each individual user of e-cigarettes will have a different puff topography, which means that the same chemicals are inhaled, but in different amounts.[57] When addicted to nicotine, users are looking for a higher volume to satisfy their craving or what some smokers call a "throat hit."[58] With the majority of e-cigarette users in the older age groups having previously been conventional cigarette users, their bodies are craving increasingly higher nicotine intakes when compared with the younger age groups who were not previously conventional cigarette smokers.[59] When failing to satisfy the need of the nicotine high, many adults are either abandoning

e-cigarettes and returning to conventional cigarette use or are likely to maintain dual use.[60-63]

Moreover, dual use of both conventional and e-cigarettes has been shown to be associated with higher odds of cardiovascular disease when compared with sole use of conventional cigarettes.[25] In addition to dual use of e-cigarettes and conventional cigarettes, e-cigarettes are often used with other substances; for example, marijuana is sometimes used in the same vaping device by both adolescents[64,65] and adults.[66] Consistent with findings related to conventional cigarette use, e-cigarette use is also associated with problematic alcohol consumption;[65,67] in fact, former smokers of conventional cigarettes who transition to e-cigarette use report higher alcohol consumption than those who do not use e-cigarettes.[68]

High prevalence of e-cigarette use among young adults is concerning for health professionals in many aspects. Nicotine, which is present in the e-juice, is a compound known to alter healthy brain development, a process that can continue into an individual's early 30s.[55,69] In addition, a recent study found that out of 51 different flavored e-cigarette liquids tested, 47 of those liquids contained flavoring chemicals such as diacetyl, 2,3-pentanedione, and acetoin which are associated with severe respiratory illness.[22] A recent systematic review concluded that e-cigarettes are a pertinent source of hazardous trace metals which are found in higher concentrations in e-cigarettes when compared with conventional cigarettes.[70] The longer-term implications of e-cigarette use will continually need to be assessed, especially considering that the negative health effects of carcinogenic substances can take between 30 and 50 years to be observed.[71,72]

Although males were more likely to use e-cigarettes than females, this finding was only observed among non-smokers in stratified analyses by conventional cigarette smoking status. Interestingly, it was observed that Mexican American/Other Hispanic study participants were less likely to use e-cigarettes than non-Hispanic white participants overall; however, stratified analyses by conventional cigarette use indicated that Mexican American/Other Hispanic participants who were non-smokers were more likely to use e-cigarettes when compared with their non-Hispanic white counterparts. This indicates that the observed differences in e-cigarette use by sex and race/ethnicity were modified by conventional cigarette smoking status with non-smoking Mexican American/Other Hispanic participants being more likely than non-Hispanic white participants to engage in e-cigarette use, but this was not the case for Mexican American/Other Hispanic participants who were conventional cigarette smokers.

When examined by marital status, individuals who were widowed/divorced/separated had higher odds of e-cigarette use compared with individuals who were married or living with a partner. This finding is consistent with patterns of conventional cigarette use, wherein smoking rates are

higher for unmarried and divorced individuals compared with married individuals;[73,74] furthermore, being single, divorced, or widowed has been shown to be associated with lower odds of former smoking status compared with that among married individuals.[75] Ultimately, these trends result in differing risks for negative health outcomes such as cardiovascular disease.[76]

The association between education level and ever use of e-cigarettes indicated that when compared with their more educated counterparts, individuals with a high school education or less were more likely to engage in e-cigarette use. In addition, individuals living below the federal poverty level were more likely to be ever users of e-cigarettes. These findings are in contrast to those of previous data from the annual US HealthStyles survey, a consumer-based Web survey that includes adults aged ≥18 years, which showed that adults with at least some college education were more likely to be ever users of e-cigarettes when compared with individuals who had less than a high school education.[77] The same study also showed no variations in ever use of e-cigarettes by household income from 2010 to 2013.[77] One potential explanation for these differences in findings may be the additional public knowledge that has been released in subsequent years about the potential harms of e-cigarettes. It is also plausible that the trajectory of e-cigarette use may follow that of conventional cigarette use, wherein initial use was common across all sociodemographic levels, but was followed by cessation and abstinence among individuals with a higher education and income status.[78-80] In addition, in just 1 year, from 2013 to 2014, the expenditures of tobacco industry e-cigarette advertising expanded from $75 million to $115 million,[3] and it has been shown that e-cigarette advertisements are concentrated near the socioeconomically disadvantaged.[81,82]

The overall findings from this study indicated that participants who were not working or were looking for work were less likely to be ever users of e-cigarettes compared with participants who were currently working. This result is consistent with that of a recent study which observed a higher prevalence of current and former e-cigarette use among employed individuals compared with unemployed individuals.[83] However, in this study, this association was only maintained among participants who were conventional smokers. In contrast, for individuals who were non-smokers of conventional cigarettes, participants who were not working or were looking for work were more likely to have ever used e-cigarettes compared with those who were currently working. This finding is particularly interesting as e-cigarettes are commonly framed as harm-reducing products for current smokers of conventional cigarettes. In this case, e-cigarette ever use introduced potential harm to the vulnerable non-smoking population who were currently unemployed.

The overall findings from this study were consistent with those of the US Surgeon General's Report on e-cigarette use among young adults, which determined that males, non-Hispanic whites, Hispanics, and those with lower educational status were more likely to use e-cigarettes when compared with females, non-Hispanic blacks, and those with higher levels of education, respectively.[84] Findings have been inconsistent regarding the association between socioeconomic status and e-cigarettes. For example, a recent study using data from the National Health Interview Survey showed that individuals with low socioeconomic status were more likely to be dual users of e-cigarettes, whereas individuals with higher socioeconomic status were more likely to be exclusive e-cigarette users.[85] Another study using data from the American Heart Association Tobacco Regulatory and Addiction Center (A-TRAC) adult vaping survey showed that both higher educational and income statuses were associated with e-cigarette use.[83] In contrast, a study of US adults using data from a consumer-based survey showed that low education was associated with ever use of e-cigarettes.[86] Similarly, a study conducted among adolescents demonstrated that free/reduced lunch status was associated with ever use of e-cigarettes.[87] The differences in these findings may relate to the outcomes of ever use versus frequency of use, with individuals of low socioeconomic status more likely to be ever or dual users and individuals of higher socioeconomic status more likely to maintain e-cigarette use.

A few limitations of this study should be addressed. The NHANES data only provided valid information about ever use of e-cigarettes among the general US adult population. Although additional queries about current use of e-cigarettes, frequency of use, and use within the past 5 days were present in the survey, the number of missing responses prevented inclusion in analyses. In addition, missing data prevented the classification of conventional cigarette smokers based on both history of cigarette smoking and current smoking status. As such, sufficient information was not available regarding whether ever users of e-cigarettes are also current cigarette smokers. Furthermore, the cross-sectional nature of these data prevents causal interpretation of findings.

This study offered a comprehensive, recent analysis of available data on ever use of e-cigarettes among the general population in the United States. This 2-year survey cycle from 2015 to 2016 was the first time that NHANES has included a question about ever use of e-cigarettes; therefore, to the authors' current knowledge, this is the first study to present an analysis of this outcome. All sociodemographic analyses were adjusted for factors that are likely to affect both the exposure and the outcome, which included age, sex, and race/ethnicity. Stratified analyses were conducted to determine whether the resulting effects were heterogeneous between smokers and non-smokers of conventional cigarettes and revealed that non-smoking members of certain vulnerable socioeconomic groups, such as those who were not working or were currently looking for work, were more likely to ever use e-cigarettes compared with those who were currently working; thus, use of e-cigarettes may increase the

burden of smoking-related health inequalities for those who were formerly not at risk.

Public health practitioners and policy makers should consider the full evidence when making decisions about e-cigarette regulation. Consideration should be given to the evidence of harm introduction to the non-smoking population rather than only focusing on the potential harm reduction among smokers of conventional cigarettes. Long-term use of e-cigarettes may ultimately contribute to additional smoking-related inequalities in morbidity and mortality among vulnerable socioeconomic groups. As such, comprehensive smoke-free legislation should also include regulations for e-cigarettes.

Declaration of Conflicting Interests

Funding

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