



Original Article

Gender Difference in the Association Between E-Cigarette Use and Depression among US Adults

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ABSTRACT

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Objectives: The objective of this study was to determine the association between e-cigarette use and depression and examine how this association is different by gender among US adults.

Methods: Data from the 2017 Behavioral Risk Factor Surveillance System and Selected Metropolitan/Micropolitan Area Risk Trends was used, and included 174,351 of 230,875 US adults aged 18 years and older. Data were analyzed using the multivariate logistic regression models.

Results: After adjusting for age, race, education, income, marital status, employment status, smoking status, and physical activity, firstly, “current daily e-cigarette users” (AOR = 2.487, $p < 0.001$), “current non-daily e-cigarette users” (AOR = 1.623, $p < 0.001$), and “former e-cigarette users” (AOR = 1.573, $p < 0.001$) were associated with increased odds of depression compared with “never e-cigarette users.” Secondly, women were associated with increased odds of depression compared with men (AOR = 1.797, $p < 0.001$). Finally, male “current daily e-cigarette users” (AOR = 1.366, $p < 0.01$) were associated with increased odds of depression compared with female “never e-cigarette users.”

Conclusion: Thus, even though women tend to be more vulnerable to depression compared with men, e-cigarette use was positively associated with depression among both men and women.

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Introduction

An e-cigarette is a handheld electronic nicotine delivery systems which delivers nicotine, and simulates cigarette smoking through vapors or aerosols [1,2]. The e-cigarette was invented by a Chinese pharmacist, Hon Lik, in 2003 [3]. Even though the prevalence of cigarette smoking has consistently decreased in the United States [4], the prevalence of e-cigarette use has rapidly increased since e-cigarettes were introduced into the US market in 2007 [5-7]. In 2016, about 10.8 million American adults were currently e-cigarette users, and 3.6 million American adults were currently daily e-cigarette users [8]. The e-cigarette is generally considered safer than tobacco cigarettes because e-cigarette users do not burn tobacco like in

a conventional cigarette with all the risks associated with this [9]. Some studies have documented the positive health effects of e-cigarettes. McNeill [10] in 2015 reported that e-cigarettes are presumed to be 95% less harmful than cigarette smoking. Overall, an e-cigarette contains lower levels of toxic chemicals than conventional cigarette [11-13]. However, the health effects of e-cigarette use are not currently conclusive. There are negative health effects of e-cigarettes. It has been reported that an e-cigarette contains the same or higher levels of toxic chemicals compared with a conventional cigarette [12,14,15]. Battista et al [16] in 2013 reported that inhalation of e-cigarette vapor yields the same patho-physiological cardiovascular effects as conventional cigarette smoking. Marini et al [17] in 2014 reported that e-cigarette vapor and conventional cigarette

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smoke have similar effects on human airways. Vardavas et al [18] in 2012 reported that short-term use of e-cigarettes has a similar negative effect on human airways compared with cigarette smoking.

In addition, e-cigarette use has been associated with depressive symptoms [19-22]. In 2016, in the US, people who currently used e-cigarettes were more likely to have depression than non-users (9.1% versus 4.5%) [8]. Mechanisms by which e-cigarette use increases the risk of depression have not been clearly defined, although chronic nicotine exposure has been proposed as a cause of impaired monoamine functioning and may facilitate depressive symptoms [23,24].

Major depressive disorders (MDD) are a inveterate and iterative conditions, particularly those characterized by poor general health, and detrimental effects on psychosocial skills [25]. Depression is considered major mental disorder [26]. In the United States, depression has become a major social issue. This is because economic uncertainty has a direct influence on depression, and despair leads to death; so called "death of despair" [27-29]. Most importantly, gender differences in the patterns of mental disorders exist. Specifically, women tend to be more vulnerable to internalizing mental depressive disorders such as depression and anxiety, whereas men tend to be more susceptible to externalizing mental depressive disorders such as substance abuse and antisocial disorders [30]. Women are nearly twice as likely as men to suffer depression, and this transcends race, nation, and culture [31,32]. According to a US national comorbidity survey (NCS), women are more likely to be diagnosed with depression than men (21.3% versus 12.7%) [33]. This predominance in depression in females generally appears after adolescence. Among preadolescent children, there are no gender differences in the prevalence of depression [34]. In 1 study, boys had a higher prevalence of depression than girls [34]. Thus, gender difference in depression is closely associated with adulthood.

Typically, studies have focused on the unilinear association between e-cigarette use and depression. Little is known about gender difference in the association between e-cigarette use and depression among US adults. Considering the social and health implications of e-cigarette use and depression, more research is needed to examine the effect of gender on the association between e-cigarette use and depression. Therefore, the objective of this study was to determine whether there was gender association between e-cigarette use and depression among US adults.

Materials and Methods

1. Data

This study used data from the 2017 Behavioral Risk Factor Surveillance System (BRFSS) and Selected Metropolitan/Micropolitan Area Risk Trends (SMART). This study analyzed 174,351 of 230,875 US adults aged 18 years and older (SMART BRFSS data is secondary data, which includes missing cases). The BRFSS conducted a telephone survey, which used a Random Digit Dialing (RDD) technique for both landlines and cell phones to collect state-level data on US residents concerning their health-related risk behaviors, chronic health conditions, and use of preventive services [response rates: landline (45.3%) and cell phone (44.5%)] [35]. In 1984, the BRFSS was conducted in 15 states, whilst now the BRFSS gathers data in 50 states, the district of Columbia, and 3 United States territories (Puerto Rico, Virgin Islands, and Guam) [35]. The BRFSS conducts a survey of more than 400,000 adults each year and is the largest conducted repeat health survey system in the world [35]. SMART BRFSS data provides health-related risk behaviors, chronic health conditions, and socio-demographic information in the U.S. metropolitan areas and their surrounding counties (MMSAs) [35]. This study did not require approval from the institutional review board because the SMART BRFSS data was secondary data which did not include personal information.

2. Measures

2.1. Dependent variable (depression)

Depression, as a variable was converted to a binary index variable (No:0, Yes:1), based on responses to the following item: (Ever told) you have a depressive disorder (including depression, major depression, dysthymia, or minor depression)?

2.2. Independent variables (e-cigarette use, and gender)

Respondents were first asked "Have you ever used an e-cigarette in your lifetime? Those who responded "no" were categorized as "never e-cigarette user." Respondents who responded "yes" were categorized into 1 of 3 groups: (1) Respondents who reported having used e-cigarette in their lifetime and now use e-cigarettes every day were categorized as "current daily e-cigarette user." (2) Respondent who reported having used e-cigarettes in their lifetime and now use e-cigarettes some days were categorized as "current non-daily e-cigarette users." (3) Respondents who reported having used e-cigarettes in their lifetime and currently do not use e-cigarettes were categorized as "former e-cigarette user."

Gender was categorized into (male and female).

2.3. Control variables (age, race, education, income, marital status, employment status, smoking status, and physical activity)

Age was categorized into (18-34, 35-44, 45-54, 55-64, 65+ years). Race was categorized into (Non-Hispanic White, Black, AIAN/Pacific Islander, Asian, Other race, Multiracial, Hispanic). The education level was categorized into (\leq high school diploma, some college, technical school, \geq Bachelor's degree). The household income level was categorized into ($<$ \$ 25,000, \$ 25,000 - \$ 74,999, \geq \$ 75,000). Marital status was categorized into (married, divorced, widowed, separated, never married, cohabitation). Employment status was categorized into (employed, self-employed, unemployed, student, retired). Smoking status was categorized into (current smoker, former smoker, never smoker). Physical activity was categorized into (took physical activity or exercise in the last 30 days or had no physical activity or exercise in the last 30 days).

3. Statistical analysis

The SMART BRFSS data provided design weighting and recurrent proportional fitting to guarantee representativeness of the data [36]. This weighting methodology was applied to the statistical analysis. After presenting descriptive statistics using chi-square test (Table 1), multivariate logistic regression was performed to analyze the influence of gender on the association between e-cigarette use and depression among US adults (Table 2). Model 1 only included independent variables such as e-cigarette use and gender. Model 2 included covariates as well as independent variables. Model 3 included interaction terms as well as covariates (Figure 1).

All statistical analyses were conducted using STATA (Version 15.0, StataCorp LLC., College Station, TX, USA).

Results

Descriptive statistics of US adults according to depression ($N = 174,351$) are shown in Table 1. The percentage of participants who had a depressive episode was 14.97% for men and 24.85% for women. Current daily e-cigarette users who had a depressive episode was 29.66% for men and 50.17% for women. Current non-daily e-cigarette users who had a depressive episode was 26.73% for men and 47.44% for women. Former e-cigarette users who had a depressive episode was 23.27% for men and 41.26% for women. Never e-cigarette users who had a depressive episode was 12.91% for men and 22.04% for women.

The results of the multivariate logistic regression models of gender difference in the association between e-cigarette use and depression among US adults are shown in Table 2.

Adjusted odds ratio from the first multivariate logistic

regression model indicated that firstly, current daily e-cigarette users (AOR = 3.683, $p < 0.001$), current non-daily e-cigarette users (AOR = 2.563, $p < 0.001$), and former-e-cigarette users (AOR = 2.190, $p < 0.001$) were associated with increased odds of depression compared with never e-cigarette users. Secondly, women were associated with increased odds of depression compared with men (AOR = 2.019, $p < 0.001$).

Adjusted odds ratio from the second multivariate logistic regression model after adjusting for age, race, education, income, marital status, employment status, smoking status, and physical activity indicated that firstly, current daily e-cigarette users (AOR = 2.487, $p < 0.001$), current non-daily e-cigarette users (AOR = 1.623, $p < 0.001$), and former-e-cigarette users (AOR = 1.573, $p < 0.001$) were associated with increased odds of depression compared with never e-cigarette users. Secondly, women were associated with increased odds of depression compared with men (AOR = 1.797, $p < 0.001$).

Adjusted odds ratio from the final multivariate logistic regression model after adjusting for age, race, education, income, marital status, employment status, smoking status, and physical activity indicated that firstly, current daily female e-cigarette users (AOR = 2.681, $p < 0.001$) were associated with increased odds of depression compared with never female e-cigarette users. Secondly, current non-daily female e-cigarette users (AOR = 1.610, $p < 0.001$) were associated with increased odds of depression compared with never female e-cigarette users. Thirdly, former female e-cigarette users (AOR = 1.728, $p < 0.001$) were associated with increased odds of depression compared with never female e-cigarette users. Fourthly, current daily male e-cigarette users (AOR = 1.366, $p < 0.01$) were associated with increased odds of depression compared with never female e-cigarette users. Fifthly, former male e-cigarette users (AOR = 0.821, $p < 0.001$) were associated with decreased odds of depression compared with never female e-cigarette users. Sixthly, never male e-cigarette users (AOR = 0.584, $p < 0.001$) were associated with decreased odds of depression compared with never female e-cigarette users.

Discussion

The main finding of this study was that both current and former e-cigarette users were more likely to be associated with an increased risk of depression compared with never e-cigarette users. This finding was consistent with previous studies [19-22]. The mechanism through which e-cigarette use increases the risk of depression has not yet been clearly defined. Some possible mechanisms have been proposed suggesting that chronic nicotine exposure may lead to impaired monoamine functioning, and contribute to facilitating depressive symptoms [23,24]. Specifically, smokers are more

Table 1. Descriptive statistics of US adults according to depression disorder (N=174,351).

Measure	Men (N=79,103)			Women (N=95,248)			
	Yes	No	p	Yes	No	p	
	Total	11,843 (14.97)		67,260 (85.03)	23,673 (24.85)		71,575 (75.15)
E-cigarette use	Current daily e-cigarette user	379 (29.66)	899 (70.34)	< 0.001	434 (50.17)	431 (49.83)	< 0.001
	Current non-daily e-cigarette users	491 (26.73)	1,346 (73.27)		796 (47.44)	882 (52.56)	
	Former e-cigarette user	2,609 (23.27)	8,603 (76.73)		4,325 (41.26)	6,157 (58.74)	
	Never e-cigarette user	8,364 (12.91)	56,412 (87.09)		18,118 (22.04)	64,105 (77.96)	
Age (y)	18-34	2,414 (16.05)	12,629 (83.95)	< 0.001	3,812 (26.51)	10,567 (73.49)	< 0.001
	35-44	1,534 (14.78)	8,847 (85.22)		3,169 (26.22)	8,916 (73.38)	
	45-54	2,120 (16.19)	10,972 (83.81)		4,282 (27.36)	11,369 (72.64)	
	55-64	2,736 (16.37)	13,976 (83.63)		5,865 (28.53)	14,691 (71.47)	
	65+	3,039 (12.73)	20,836 (87.27)		6,545 (20.09)	26,032 (79.91)	
Race	Non-Hispanic White	9,237 (15.36)	50,905 (84.64)	< 0.001	18,714 (26.35)	52,307 (73.65)	< 0.001
	Black	818 (12.51)	5,719 (87.49)		1,968 (18.32)	8,775 (81.68)	
	AIAN/Pacific Islander	216 (22.11)	761 (77.89)		293 (29.27)	708 (70.73)	
	Asian	148 (6.68)	2,068 (93.32)		203 (12.02)	1,486 (87.98)	
	Other	79 (17.83)	364 (82.17)		104 (24.07)	328 (75.93)	
	Multiracial	339 (22.44)	1,172 (77.56)		522 (31.67)	1,126 (68.33)	
Education level	Hispanic	1,006 (13.82)	6,271 (86.18)	< 0.001	1,869 (21.45)	6,845 (78.55)	< 0.001
	≥ Bachelor's degree	4,625 (12.83)	31,437 (87.17)		9,098 (21.91)	32,434 (78.09)	
	College, technical school	3,456 (17.15)	16,690 (82.85)		7,558 (27.72)	19,709 (72.28)	
Income level	≤ High school	3,762 (16.43)	19,133 (83.57)	< 0.001	7,017 (26.53)	19,432 (73.47)	< 0.001
	≥ \$75,000	3,580 (10.52)	30,438 (89.48)		6,212 (18.96)	26,552 (81.04)	
	\$25,000 - \$74,999	4,629 (15.26)	25,700 (84.74)		9,062 (24.17)	28,428 (75.83)	
Marital status	< \$25,000	3,634 (24.63)	11,122 (75.37)	< 0.001	8,399 (33.60)	16,595 (66.40)	< 0.001
	Married	5,110 (11.28)	40,184 (88.72)		9,877 (21.36)	36,361 (78.64)	
	Divorced	2,134 (22.86)	7,200 (77.14)		4,916 (33.22)	9,883 (66.78)	
	Widowed	688 (15.50)	3,751 (84.75)		3,009 (21.31)	11,110 (78.69)	
	Separated	375 (24.93)	1,129 (75.07)		850 (38.57)	1,354 (61.43)	
	Never married	2,968 (19.25)	12,453 (80.75)		4,101 (27.78)	10,661 (72.22)	
Employment status	Cohabitation	568 (18.26)	2,543 (81.74)	< 0.001	920 (29.43)	2,206 (70.57)	< 0.001
	Employed	4,722 (11.98)	34,707 (88.02)		9,041 (22.29)	31,527 (77.71)	
	Self-employed	1,015 (11.39)	7,896 (88.61)		1,228 (20.09)	4,885 (79.91)	
	Unemployed	2,944 (38.41)	4,720 (61.59)		7,175 (38.28)	11,570 (61.72)	
	Student	374 (16.48)	1,895 (83.52)		584 (24.36)	1,813 (75.64)	
Smoking status	Retired	2,788 (13.38)	18,042 (86.62)	< 0.001	5,645 (20.58)	21,780 (79.42)	< 0.001
	Current smoker	2,825 (24.47)	8,719 (75.53)		4,908 (41.27)	6,984 (58.73)	
	Former smoker	4,105 (16.28)	21,107 (83.72)		6,787 (27.92)	17,520 (72.08)	
Physical activity	Never smoked	4,913 (11.60)	37,434 (88.40)	< 0.001	11,978 (20.28)	47,071 (79.72)	< 0.001
	Took physical activity or exercise in the last 30 days	8,295 (13.65)	52,477 (86.35)		15,773 (22.66)	53,843 (77.34)	
	Had no physical activity or exercise in last 30 days	3,548 (19.36)	14,783 (80.64)		7,900 (30.82)	17,732 (69.18)	

Data are presented as n (%).

Table 2. Multivariate logistic regression models of gender difference in the association between e-cigarette use and depression disorder among US adult smokers (N=174,351).

Variables	Categories	Adjusted odds ratio [95% Confidence Interval]		
		Model 1	Model 2†	Model 3‡
Independent variables				
E-cigarette use	Never e-cigarette user	Reference	Reference	
	Current daily e-cigarette user	3.683*** [3.115, 4.355]	2.487*** [2.096, 2.951]	
	Current non-daily e-cigarette users	2.563*** [2.242, 2.930]	1.623*** [1.401, 1.880]	
	Former e-cigarette user	2.190*** [2.053, 2.335]	1.573*** [1.458, 1.696]	
Gender	Male	Reference	Reference	
	Female	2.019*** [1.912, 2.131]	1.797*** [1.698, 1.902]	
Interaction effect				
Gender* e-cigarette use	Female * never e-cigarette user			Reference
	Female * current daily e-cigarette user			2.681*** [2.077, 3.460]
	Female * current non-daily e-cigarette users			1.610*** [1.318, 1.966]
	Female * former e-cigarette user			1.728*** [1.565, 1.909]
	Male * current daily e-cigarette user			1.366** [1.092, 1.707]
	Male * current non-daily e-cigarette users			0.942 [0.770, 1.151]
	Male * former e-cigarette user			0.821*** [0.744, 0.907]
	Male * never e-cigarette user			0.584*** [0.546, 0.624]

* p < 0.05, ** p < 0.01 *** p < 0.001.

† Adjusted for age, race, education, income, marital status, employment status, smoking status, and physical activity.

Model 1: $\log \left(\frac{P}{1-P} \right) = \beta_0 + \beta_1(\text{e-cigarette use}) + \beta_2(\text{gender})$

Model 2: $\log \left(\frac{P}{1-P} \right) = \beta_0 + \beta_1(\text{e-cigarette use}) + \beta_2(\text{gender}) + \beta_3(\text{age}) + \beta_4(\text{race}) + \beta_5(\text{education}) + \beta_6(\text{income}) + \beta_7(\text{marital status}) + \beta_8(\text{employment status}) + \beta_9(\text{smoking status}) + \beta_{10}(\text{physical activity})$

Model 3: $\log \left(\frac{P}{1-P} \right) = \beta_0 + \beta_1(\text{gender}) * (\text{e-cigarette use}) + \beta_2(\text{age}) + \beta_3(\text{race}) + \beta_4(\text{education}) + \beta_5(\text{income}) + \beta_6(\text{marital status}) + \beta_7(\text{employment status}) + \beta_8(\text{smoking status}) + \beta_9(\text{physical activity})$

likely to develop depression than non-smokers [37,38]. In addition, it has been reported that an e-cigarette contains the same or higher levels of toxic chemicals compared with a conventional cigarette [12,14,15]. It can be assumed that an e-cigarette is just as dangerous as a conventional cigarette because e-cigarettes also contain large amounts of the nicotine like conventional cigarettes. Therefore, public health authorities need to increase their efforts to make policies on e-cigarette which are designed to restrict access to e-cigarettes especially among people with depression. Carefully designed e-cigarette brochures or mass media campaigns that underscore the negative health effects of e-cigarette may reduce the use of e-cigarettes.

Figure 1. The formulas for logistic regression models.

It was determined that women were more likely to be associated with an increased risk of depression compared with men. This finding was consistent with previous studies [30-33]. Due to the dominant gender conceptions, women tend to be more vulnerable to internalizing mental health disorders such as depression and anxiety, whereas men tend to be more susceptible to externalizing mental health disorders such as substance abuse and antisocial disorders [30,31]

In terms of interaction effects of gender on the association between e-cigarette use and depression, male current daily e-cigarette users had increased odds of depression compared with female never e-cigarette users. Indicating the negative association between males and depression decreased for the current daily e-cigarette user group. Thus, e-cigarette use was positively associated with depression among both men and women. Therefore, public health authorities should not overlook the risk of depression among male heavy smokers.

This study had several limitations. Firstly, the temporal causal relationship between independent variables and depression could not be determined because the study design was cross-sectional. For this reason, there may be a bidirectional effect between e-cigarette use and depression. So, people who have symptoms of depression may be more likely to use an e-cigarette than those who do not have symptoms of depression. Therefore, follow-up studies of prospective longitudinal design necessary. Secondly, this study was based on self-reported symptoms and status of use of e-cigarette. It is possible that participants were not able to answer their socio-economic status, and e-cigarette use precisely, which may have led to inaccurate estimations of status. Finally, SMART BRFSS data provided health-related risk behaviors, chronic health conditions, and socio-demographic information of people in the U.S. in metropolitan areas and their surrounding counties (MMSAs). Therefore, some cities and counties were excluded from SMART BRFSS data.

Despite these limitations, this study examined gender differences in the association between e-cigarette use and depression. In summary, e-cigarette use was associated with an increased risk of depression. Women were more likely to be associated with an increased risk of depression compared with men. However, this negative association between males and depression decreased for the current daily e-cigarette user group. Male current daily e-cigarette users were more likely to be associated with an increased risk of depression than female never e-cigarette users. Thus, even though women tended to be more vulnerable to depression compared with men, e-cigarette use was positively associated with depression among both men and women.

Conflicts of Interest

The author declared no potential conflicts of interest with respect to this research, authorship, and/or publication of this article.

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