

# Implications of electronic cigarette use for depressive mood

## A nationwide cross-sectional study

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### Abstract

Despite the controversy surrounding electronic cigarette (e-cigarette) safety, global consumption has been rapidly increasing. We investigated the relationship between e-cigarette use and mental health conditions in adults of various ages.

We conducted a secondary data analysis of adults aged 19 to 80 who participated in the first year of the 7th Korea National Health and Nutrition Examination Survey (2016). The total number of participants was 5469, including 3398 non-smokers, 1700 smokers who had never used e-cigarettes, and 371 smokers who had previously used e-cigarettes, selected based on self-report questionnaires. Mental health factors including stress status, depressive mood, suicide plan, and suicide attempt were assessed by self-reported questionnaire. The Patient Health Questionnaire (PHQ-9) was used to assess depressive mood, with a cut-off value of 10. The relationship between e-cigarette use and stress status with depressive mood were analyzed with adjustment for potential confounders.

Both male and female smokers who previously used e-cigarettes showed higher levels of stress than non-smokers or smokers who had never used e-cigarettes. The average PHQ-9 score was higher among previous e-cigarette-using smokers relative to non-smokers and smokers who had never used e-cigarettes, regardless of gender. The number of participants with depressive mood was significantly higher in the group of smokers who previously used e-cigarettes. In multivariable-adjusted logistic regression analyses, there was a significantly higher odds ratio for higher stress in male smokers who had previously used e-cigarettes and for depressive mood in female smokers who had previously used e-cigarettes, compared with non-smokers.

This study analyzed the association between adult e-cigarette use and mental health conditions, including stress and depressive mood, and showed that e-cigarette use was significantly related to both conditions in men and women.

**Abbreviations:** ANOVA = analysis of variance test, CI = confidence interval, e-cigarettes = electronic cigarettes, KCDC = Korean Centers for Disease Control and Prevention, KNHANES = Korea National Health and Nutrition Examination Survey, MHC = mental health conditions, OR = odds ratio, PHQ-9 = Patient Health Questionnaire, SD = standard deviation.

**Keywords:** depression, electronic nicotine delivery systems, mental health, patient health questionnaire, smoking

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The datasets generated during and/or analyzed during the current study are publicly available.

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## 1. Introduction

Smoking rates are higher among individuals with mental health conditions (MHC) than in the general population,<sup>[1]</sup> and people with MHC smoke more heavily and find it more difficult to quit than individuals without MHC.<sup>[2]</sup> Smoking is strongly associated with depression,<sup>[3]</sup> and the rate of smoking cessation failure among individuals with depression is higher than that of those without depression.<sup>[4]</sup>

Electronic cigarettes (e-cigarettes) are rapidly replacing conventional cigarettes; the global market was worth approximately \$3 billion in 2014, and the proportion of e-cigarettes among total tobacco products is expected to rise to 4% in 2050.<sup>[5,6]</sup> According to the first year of the 7th Korea National Health and Nutrition Examination Survey (KNHANES), the overall proportions of men and women aged 19 years or older who had ever used e-cigarettes were 18.2% and 2.4%, respectively.<sup>[7]</sup> Although e-cigarettes are popular, there are still questions about their use in relation to mental health.<sup>[8]</sup> Conventional cigarettes, which contain the addictive substance nicotine, are known to be highly related to MHC, but research on e-cigarettes, which also often contain nicotine, is insufficient.

The current study was conducted based on the assumption that e-cigarette use is related to MHC because of the presence of

nicotine, the depressive mood that leads to e-smoking behavior,<sup>[9]</sup> and mood change after use.<sup>[10]</sup> The purpose of the study was to examine the association between e-cigarette use and MHC, focusing especially on stress status and elevated depressive symptoms among men and women of all ages.

## 2. Method

### 2.1. Respondents and design

This secondary data analysis was conducted among men and women 19 to 80 years old who participated in the first year of the 7th KNHANES. KNHANES, conducted by the Korean Centers for Disease Control and Prevention (KCDC) since 1998, is an ongoing series of cross-sectional national surveys with a stratified, multistage cluster sampling method based on geographic area, gender, and age to secure a representation of the Korean population. The surveys consist of health and behavior interviews, health examinations, and nutrition surveys.

From the source population of 8150 individuals who participated in the 7th KNHANES, we first excluded the 2408 people whose responses to the study variables were missing. We then excluded 273 individuals who were diagnosed with myocardial infarction, stroke, renal failure, liver cirrhosis, chronic obstructive pulmonary disease, and any malignancy. This left a study population of 5469.

The Research Ethics Review Board of the KCDC and Jeju National University Hospital (approval number: 2019-09-018) approved the study. Written informed consent to participate in the study was obtained from all participants. The study procedures were carried out in accordance with the Declaration of Helsinki.

### 2.2. Smokers, non-smokers, and e-cigarette use

When asked “What is the total number of cigarettes you have smoked in your lifetime?” those who answered “more than 5 packs” (100 cigarettes) were defined as smokers. Non-smokers were those who had not smoked 100 cigarettes or more. E-cigarette users were defined as those who answered “yes” to the question “Have you ever used an e-cigarette, in your entire life? According to the responses, we classified participants into 3 groups: non-smokers; smokers with no e-cigarette use; and smokers with previous e-cigarette use.

### 2.3. Mental health condition

The Patient Health Questionnaire (PHQ-9) is a widely used screening tool for major depressive disorder. Korean version of the PHQ-9 is a self-administered questionnaire, and it is translated and validation was performed.<sup>[11]</sup> The PHQ-9 contains 9 symptom items that measure the frequency of depressive symptoms over the preceding 2 weeks. The response options for each item are “not at all,” “on several days,” “on more than half of the days,” and “nearly every day.” Each item is scored from 0 to 3 points depending on the frequency of symptoms. A PHQ-9 score of  $\geq 10$  out of a total of 27 is considered indicative of a high risk of major depressive disorder.<sup>[12]</sup> In line with the aforementioned standards, in this study we categorized participants with PHQ-9 scores of  $\geq 10$  as the high-risk group for depression.

To assess other mental health-related factors, we used variables of the self-report questionnaire such as self-perceived stress, suicidal plan, suicide attempts, and mental health consultation.

Self-perceived stress was assessed by the question “How much stress do you usually feel in your daily life?” Participants who rated themselves as being “extremely stressed” or “quite stressed” were categorized as having self-perceived high stress, and those who reported being “a little bit stressed” or “hardly stressed” were classified as having no stress perception. Suicide plan and attempts were assessed by the question “In the last 12 months, did you plan or attempt committing suicide?” A positive response was considered to indicate suicidal plan and/or attempts. Suicidal plans and attempts were categorized based on the results of surveys about the previous year. Mental health consultation was assessed by the question “Over the past year, have you ever consulted a mental health professional about your own problems, through visits, phone calls, the Internet, etc.?”

### 2.4. Statistical analysis

Continuous variables were calculated by independent *t*-test and analysis of variance test (ANOVA) with Bonferroni correction; furthermore, categorical variables were analyzed by Chi-Squared tests. The data are presented as means  $\pm$  SD or as numbers (percentages) in tables. To compare the risk of high self-perceived stress and depressive mood in the 3 smoking groups, we used multivariable regression. We used multivariable logistic regression models with Firths penalized likelihood method to address issues of small sample size. All statistical analyses were performed using SPSS 22.0 for Windows (Armonk, NY, IBM Corporation) and STATA version 13.0 (Stata Corp., College Station, TX, USA). All *P* values were 2 tailed, and the significance level was set at  $< .05$ .

## 3. Results

A total of 5469 respondents were selected for this study, and 5.0% were at high risk for depression. Participants with depressive mood were older, and the proportion of women in the depressed group was higher than in the non-depressed group. Education level, income, occupation status, and comorbidities showed a difference between the 2 groups. There was a higher rate of current smokers ( $P < .001$ ) and past users of e-cigarettes ( $P = .001$ ) in the depressed group than in the non-depressed group. These results are shown in Table 1.

Table 2 shows the difference in MHC by conventional or e-cigarette use in men and women. Those who suffered high stress included smokers who had ever used e-cigarettes (40.1% of men and 54.5% of women,  $P < .001$ ). Similar patterns were observed related to depressed mood. The mean PHQ-9 scores were highest in smokers who had used e-cigarettes, compared to non-smokers and smokers who had never used e-cigarettes, regardless of gender (all  $P < .001$ ). Participants with depressed mood, defined as a PHQ-9 score above 10 points, were also higher in number in the group of people who had used e-cigarettes than in other groups ( $P = .001$  in men,  $P < .001$  in women). However, no similar trend was observed regarding suicide plans, suicide attempts, or mental health consultations.

After adjusting for age, education level, income, hypertension, and diabetes, compared with non-smokers, male smokers who had never used e-cigarettes had 1.62-fold (95% CI, 1.25–2.07) higher odds of reporting a high stress status, while male smokers who had used e-cigarettes had 2.43-fold (95% CI, 1.79–3.29) higher odds. Among women, we found graded higher odds of reported high stress in those smokers who had no e-cigarette use

**Table 1**

**Baseline characteristics according to depressive mood.**

	Non-Depressed (n = 5197)		Depressed (n = 272)		P value <sup>a</sup>
	Mean (SD)	n (%)	Mean (SD)	n (%)	
Age (years)	50.39 (16.60)		53.45 (18.46)		.008
Gender					<.001
Men		2314 (44.5%)		90 (33.1%)	
Women		2883 (55.5%)		182 (66.9%)	
Educational level					<.001
≤ Elementary School		1010 (19.5%)		107 (39.3%)	
Middle School		519 (10.0%)		30 (11.0%)	
High School		1688 (32.5%)		71 (26.1%)	
≥ College		1975 (38.0%)		64 (23.5%)	
Monthly income					<.001
Low		893 (17.2%)		103 (37.9%)	
Low-Middle		1268 (24.5%)		77 (28.3%)	
High-Middle		1462 (28.2%)		64 (23.5%)	
High		1562 (30.1%)		28 (10.3%)	
Occupation		3207 (61.7%)		112 (41.2%)	<.001
Married		813 (15.6%)		53 (19.5%)	.108
Self-Rated Health		891 (17.1%)		125 (46.0%)	<.001
Obesity		1800 (34.9%)		103 (38.0%)	.579
Hypertension		1173 (22.6%)		87 (32.0%)	.003
Diabetes		459 (8.8%)		58 (21.3%)	<.001
Current Smoker		935 (18.0%)		78 (28.7%)	<.001
History of Electronic Cigarette Use		343 (6.6%)		28 (10.3%)	.001
Alcohol Consumption		2858 (55.0%)		141 (51.8%)	.337
Physical Activity		2358 (45.4%)		108 (39.7%)	.072
EQ-5D Index	0.96 (0.09)		0.82 (0.20)		<.001
Self-perceived Stress		1197 (23.0%)		199 (73.2%)	<.001
PHQ-9 Score <sup>b</sup>	1.89 (2.28)		13.75 (3.54)		<.001
Suicide Plan		53 (1.0%)		24 (8.8%)	<.001
Suicide Attempt		14 (0.3%)		7 (2.6%)	<.001
Mental Health Consultation		73 (1.4%)		22 (8.1%)	<.001

<sup>a</sup> P-value by independent t-test (continuous variables) or Chi-Squared test (categorical variables).

<sup>b</sup> PHQ-9 = Patient Health Questionnaire.

**Table 2**

**Comparison of mental health characteristics according to conventional and electronic cigarette use.**

	Men						P value <sup>a</sup>
	Non-Smoker (n = 615, 25.6%)		Smoker, No EC <sup>‡</sup> Use (n = 1462, 60.8%)		Smoker, Previous EC Use (n = 327, 13.6%)		
	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	
Self-Perceived High Stress		118 (19.2)		325 (22.2)		131 (40.1)	<.001 <sup>b</sup>
PHQ-9 <sup>‡</sup> Score	1.5 (2.4)		2.0 (3.2)		2.6 (3.4)		<.001 <sup>b</sup>
Depressive Mood <sup>†</sup>		8 (1.3)		66 (4.5)		16 (4.9)	.001
Suicide Plan		10 (1.6)		19 (1.3)		6 (1.8)	.734
Suicide Attempt		1 (0.2)		7 (0.5)		1 (0.3)	.790
Mental Health Consultation		10 (1.6)		22 (1.5)		4 (1.2)	.941
	Women						P <sup>a</sup>
	Non-Smoker (n = 2783, 90.8%)		Smoker, No EC Use (n = 238, 7.8%)		Smoker, Previous EC Use (n = 44, 1.4%)		
	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	
Self-Perceived High Stress		696 (25.0)		102 (42.9)		24 (54.5)	<.001 <sup>b</sup>
Mean PHQ-9 <sup>‡</sup> Score	2.7 (3.5)		4.4 (4.7)		6.8 (6.3)		<.001 <sup>b</sup>
Depressive Mood		137 (4.9)		33 (13.9)		12 (27.3)	<.001 <sup>b</sup>
Suicide Plan		36 (1.3)		5 (2.1)		1 (2.3)	.281
Suicide Attempt		9 (0.3)		3 (1.3)		0 (0.0)	.096
Mental Health Consultation		46 (1.7)		12 (5.0)		1 (2.3)	.003

<sup>a</sup> P-value by analysis of variance test (continuous variables) or Chi-Squared test, Fishers exact test (categorical variables).

<sup>b</sup> Bonferroni correction was applied to the post hoc analysis. EC users who smoked showed significantly higher values compared with smokers who never used ECs and non-smokers.

<sup>†</sup> Defined as more than 10 points in the PHQ-9 screening exam.

<sup>‡</sup> EC = electronic cigarettes, PHQ-9 = Patient Health Questionnaire.

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and those with previous e-cigarette use compared with non-smokers (smokers with no e-cigarette use: odds ratio [OR] = 2.05; 95% CI, 1.55–2.69; smokers with previous e-cigarette use: OR = 2.68; 95% CI, 1.46–4.89; Table 3).

Similar estimates were observed when multivariable-adjusted logistic regression analyses were used to examine the association between conventional and e-cigarette use and depressive mood (Table 4). Compared with non-smoking men, men who reported smoking but had never used e-cigarettes had 3.54-fold (95% CI, 1.68–7.45) higher odds of reporting depressive mood, while male smokers who had used e-cigarettes had 3.80 (95% CI, 1.62–8.92) higher odds. Similarly, female smokers who had never used e-cigarettes and women who had used e-cigarettes were more likely to report depressive mood compared with non-smoking women (smokers with no e-cigarette use: OR = 2.80; 95% CI, 1.84–4.25; smokers with previous e-cigarette use: OR = 7.64; 95% CI, 3.76–15.53).

#### 4. Discussion

In this cross-sectional analysis of various-aged adults in Korea, we found that e-cigarette use was related to MHC. Smokers who had previously used e-cigarettes suffered more from high stress and depressive mood than non-smokers or smokers who had never used e-cigarettes.

These results are similar to those of most previous reports. A study on American adolescents found that rates of depression, panic disorder, and anhedonia were higher among e-cigarette users than non-users.<sup>[13]</sup> Another study involving American adolescents showed that continuing use of e-cigarettes was related to increases in the rate of depressive symptoms, and a higher frequency of e-cigarette use was related to greater severity of depressive symptoms.<sup>[14]</sup> In a study on American college students, e-cigarette use was linked with depressive symptoms and mental health problems, and college students with depression were more likely to use e-cigarettes relative to those without depression.<sup>[15]</sup> In contrast, however, 1 study from 2017 reported that the association between e-cigarettes and depression in adolescents was barely discernible.<sup>[16]</sup> The researchers argued that e-cigarettes were less risky than conventional smoking because a group using only e-cigarettes showed fewer psychiatric

symptoms than a group using only conventional cigarettes or dual users. In addition, the relationship with alcohol and drug problems was minimal, and the authors stated that the sole use of e-cigarettes could improve smoking-related problems. However, that study did not compare students who were non-smokers with e-cigarette users. Thus, it is difficult to conclude that e-cigarettes are safe based only on this study.

We believe that e-cigarette use is associated with depressive affect through 2 mechanisms. First, the substances contained in e-cigarettes contribute to this association. The e-cigarette delivery system involves the heating of propylene glycol, with the addition of flavorings, and plant-based glycerin liquid, for vaporization and inhalation.<sup>[17]</sup> Furthermore, although e-cigarettes have manufacturer-related variations, like conventional cigarettes they usually contain the addictive substance nicotine, which is known to be highly correlated with depression.<sup>[18]</sup> Neurobiological research supports the hypothesis that people with depression smoke as a means of “self-medicating” to strengthen the short-term delivery of nicotine to brain cells in response to depressive symptoms. Chronic use of nicotine can contribute to exacerbating or maintaining depression by damaging long-term monoamine function, creating a vicious cycle.<sup>[19]</sup>

Second, a depressive mood often results from trying to quit smoking and people often use e-cigarettes when attempting to quit smoking traditional cigarettes. The number of people who want to quit smoking is increasing in the current social climate; designated smoking areas make smoking physically more difficult, and the cost of smoking creates an economic burden for smokers. E-cigarettes are often seen as a smoking cessation aid. According to a 2012 Korean national report,<sup>[20]</sup> users reasons for smoking e-cigarettes were to “aid in smoking cessation” (64%) and help to “reduce the number of conventional cigarettes smoked” (47%). According to this observational study, e-cigarette users were more likely to attempt smoking cessation relative to those who smoked conventional cigarettes. Moreover, e-cigarette users tended to use more smoking cessation aids than conventional smokers did.<sup>[21]</sup> In fact, since their introduction in South Korea, e-cigarettes have been advertised as a tool to aid smoking cessation, even though their safety has not been demonstrated.<sup>[22]</sup> Depressive symptoms can temporarily occur when people attempt to quit smoking, because high stress

**Table 3**  
Association between self-perceived high stress and conventional smoking with electronic cigarette use.

	Unadjusted		Adjusted*	
	OR <sup>†</sup> (95% CI) <sup>‡</sup>	P	OR (95% CI)	P value
Total				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	1.07 (0.93–1.22)	.331	1.18 (1.03–1.36)	.016
Smoker, Previous EC Use	2.29 (1.83–2.85)	<.001	1.83 (1.46–2.30)	<.001
Men				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	1.21 (0.95–1.53)	.115	1.62 (1.25–2.07)	<.001
Smoker, Previous EC Use	2.83 (2.09–3.81)	<.001	2.43 (1.79–3.29)	<.001
Women				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	2.27 (1.73–2.97)	<.001	2.05 (1.55–2.69)	<.001
Smoker, Previous EC Use	3.59 (1.98–6.49)	<.001	2.68 (1.46–4.89)	.001

\* Adjusted for age, educational level, income, hypertension, and diabetes.

<sup>†</sup> Odds ratios (95% confidence intervals) were calculated by Firths penalized maximum likelihood logistic regression.

<sup>‡</sup> CI = confidence interval, EC = electronic cigarette, OR = odds ratio.

**Table 4****Association between depressive mood and conventional smoking with electronic cigarette use.**

	Unadjusted		Adjusted*	
	OR (95% CI)	P value	OR (95% CI)	P value
Total				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	1.39 (1.07–1.80)	.014	1.42 (1.08–1.85)	.011
Smoker, Previous EC Use	1.85 (1.22–2.81)	.004	2.08 (1.34–3.23)	.001
Men				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	3.40 (1.65–6.99)	.001	3.54 (1.68–7.45)	.001
Smoker, Previous EC Use	3.77 (1.63–8.72)	.002	3.80 (1.62–8.92)	.002
Women				
Non-Smoker	1 (ref)		1 (ref)	
Smoker, No EC Use	3.14 (2.09–4.70)	< .001	2.80 (1.84–4.25)	< .001
Smoker, Previous EC Use	7.37 (3.75–14.47)	< .001	7.64 (3.76–15.53)	< .001

\* CI = confidence interval, OR = odds ratio, EC = electronic cigarette.

and depressed mood may be a withdrawal symptom after smoking cessation. However, depressive withdrawal sometimes persists longer in those who have a history of depression.<sup>[2,3]</sup> Stress, anxiety, and depression can occur even after successfully quitting smoking, as withdrawal symptoms and repeated attempts to quit smoking can adversely affect mental health.<sup>[10]</sup>

This study had some limitations. For example, the cross-sectional design limited causal inferences regarding the relationship between depressive symptoms and e-cigarette use. However, according to previous research, depressive symptoms predicted the initiation of smoking and increased the rate of smoking; moreover, smoking predicted increases in depressive symptoms.<sup>[10]</sup> Thus, e-cigarette use and depression appear to have a bidirectional relationship. In addition, we did not investigate the amount and duration of smoking or nicotine dependence when analyzing e-cigarette use. The Fagerström Nicotine Addiction Test can be used to assess addiction levels in future studies.<sup>[24]</sup> The third limitation is that we assessed smoking status by questionnaire without testing. However, research has shown multiple cases in which the prevalence of smoking was underestimated based on self-report measures because participants concealed their smoking habit.<sup>[25]</sup> Therefore, biochemical markers such as cotinine are needed in future tests for assessing smoking status. In spite of these limitations, this study had an advantage over past research, which was conducted mainly among adolescents, students, and individuals with substance abuse disorders. Our research included a large number of adults from 19 to 80 years old. Moreover, we used the PHQ-9, an established standard screening tool for depressive disorder.

## 5. Conclusion

In this study, we analyzed the association between e-cigarette use and MHC in adults aged 19 to 80. The results demonstrated that e-cigarette use, levels of stress, and depressed mood were closely related, regardless of gender. In the future, longitudinal studies should be conducted and include detailed information such as the duration, amount, and pattern of e-cigarette use. Furthermore, social regulations regarding e-cigarettes, which are often perceived to be relatively safer than conventional cigarettes, must be established based on empirical research about the association between e-cigarettes and health outcomes.

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## Author contributions

Yunhwan Oh, Hyeonju Kim, Mihee Kong, and Jihyun Moon designed the study. Jihyun Moon analyzed the data. Sumin Lee, and Jihyun Moon wrote the paper. Yunhwan Oh, Hyeonju Kim, Mihee Kong, and Jihyun Moon reviewed Edited the manuscript. All authors read and approved the manuscript.

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