Association of mixed use of electronic and conventional cigarettes and exposure to secondhand smoke with prediabetes

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Abstract

Objective

To examine the association of mixed electronic and conventional cigarette use and exposure to secondhand smoke with prediabetes.

Methods

Data from the 2014–2018 Korean National Health and Nutrition Examination Survey were analyzed. Prediabetes was defined as an HbA1C of 5.7–6.4%. Participants were categorized according to type of cigarette use and secondhand smoke exposure. Multiple logistic regression analysis was performed.

Results

Of the 22,385 participants without diabetes, 6,735 had prediabetes. Mixed cigarette use was associated with a 1.57-fold increase in the odds of prediabetes when compared with never smoking without exposure to secondhand smoke (odds ratio [OR] = 1.57, 95% confidence interval [CI] = 1.31–1.87), and a 1.27-fold increase when compared with conventional cigarette use only (OR = 1.27, 95% CI = 1.09–1.49). Participants who were current non-smokers but mixed users in the past had an increased risk of prediabetes (OR = 1.54, 95% CI = 1.06–2.23). However, there was no significant association between current non-smoking but only conventional cigarette use in the past and prediabetes. Among never-smokers, exposure to secondhand smoke significantly increased the risk of prediabetes (OR = 1.15, 95% CI = 1.03–1.28).

Conclusions

Mixed use of electronic and conventional cigarettes and exposure to secondhand smoke increased the risk of prediabetes.

Introduction

In 2017, 425 million people were living with diabetes, a number that is expected to increase to 629 million by 2045 according to the latest estimates[1]. Diabetes can cause micro-vascular complications such as retinopathy, nephropathy, and neuropathy, as well as macro-vascular complications such as ischemic heart disease and stroke[2,3]. Therefore, the growing disease burden of diabetes is a major public health priority worldwide.

Previous studies have established that active smoking and exposure to secondhand smoke (SHS) are associated with an increased risk of insulin resistance and type 2 diabetes[4–7]. Although the smoking rate

is steadily declining worldwide, 22.8% of the world's population smoked tobacco in 2020, and more than 8 million people a year die from conditions related to tobacco use[8]. In Korea, the smoking rate was 22.3% in 2017, with 38.1% of men falling under the “current smoker” category according to the Korea National Health and Nutrition Examination Survey. In recent years, high rates of smoking conventional cigarettes (c-cigarettes) have been accompanied by continuous increases in the use of electronic cigarettes (e-cigarettes) and SHS exposure, thus representing a major public health problem[9–11].

E-cigarettes that heat a liquid to deliver (usually) aerosols of nicotine and other flavors are often promoted as a safer alternative to c-cigarettes that burn tobacco to produce the nicotine aerosol[12]. Adults use e-cigarettes to reduce cigarette consumption or quit smoking, and some studies have mentioned the positive role that e-cigarettes can play in smoking cessation[13]. However, the risks of e-cigarettes remain to be clearly established. Particularly, research regarding the association between e-cigarette use and the risk of developing incident diabetes is limited.

Prediabetes is defined by the American Diabetes Association as follows: a fasting plasma glucose of 100–125 mg/dL or 2-h plasma glucose value during a 75-g oral glucose tolerance test of 140–199 mg/dL, or hemoglobin A1c (HbA1c) levels of 5.7–6.4%[14]. Prediabetes is a state in which the patient is at high risk for diabetes, with higher glucose levels than normal, and about 5–10% of people with prediabetes become diabetic annually[15]. Furthermore, prediabetes has been associated with multiple comorbidities such as composite cardiovascular disease, coronary heart disease, stroke, and all-cause mortality[16]. Thus, screening for prediabetes among non-diabetic individuals and identifying risk factors for prediabetes is an important public health task.

The purpose of this study was to investigate the association of smoking behavior and exposure to SHS with prediabetes, which can aid in predicting the incidence of type 2 diabetes in people who have no known history of diabetes.

Methods

Study population and data

This study used data obtained from the 2014 and 2018 Korean National Health and Nutrition Examination Survey (KNHANES). The KNHANES is a nationwide population-based survey designed to acquire information regarding the health and nutrition of people in South Korea. The survey is performed by the Korean Centers for Disease Control and Prevention (KCDC) and combines a health interview with a physical examination and nutrition survey. The KNHANES protocols were approved by the Institutional Review Board of the KCDC (IRB No. 2018-01-03-P-A), and the research complied with the tenets of the Declaration of Helsinki for medical research involving human subjects. Informed consent was obtained from all participants.

A total of 39,199 participants were involved in the 2014-2018 KNHANES. In this study, participants aged <19 years, diagnosed with diabetes based on fasting plasma glucose levels over 126 mg/dl, HbA1c levels over 6.5%, or the use of medication for diabetes were excluded. Furthermore, we excluded participants without data for the variables analyzed in this study. Finally, a total of 22,385 participants (9,490 men and 12,895 women) were selected for this study.

Presence of prediabetes

The presence of prediabetes was the primary outcome of this study. According to the definition of prediabetes as per the American Diabetes Association[17], participants with an HbA1c cut-off of 5.7–6.4% were defined as having prediabetes. Fasting blood samples were collected from participants, and HbA1c levels were assessed via high-performance liquid chromatography (HLC-723G7; Tosoh, Tokyo, Japan)[18]. Finally, patients with HbA1c <5.7% were classified into the normal group, while those with HbA1c of 5.7–6.4% were classified into the prediabetes group.

Smoking behavior and exposure to SHS

The main independent variables were tobacco smoking behaviors and exposure to SHS. Smoking behavior was divided into four categories based on responses to questions regarding use of e-cigarettes or c-cigarettes over one's lifetime and those regarding exposure to SHS. mixed user of e- and c-cigarettes, c-cigarette user only, never-smoker with exposure to SHS, and never-smoker without exposure to SHS. Exposure to SHS was evaluated based on three questions, "In the last 7 days, have you ever breathed smoke from someone other than you who was smoking indoors at work?", "In the last 7 days, have you ever breathed smoke from someone other than you who was smoking indoors at home?", and "In the last 7 days, have you ever breathed smoke from someone other than you who was smoking indoors in a public place (except in designated smoking areas)?" The answers to these questions consisted only of "yes" or "no". Those who answered "yes" to even one of the three questions were defined as those exposed to SHS.

Covariates

The covariates for this study included sex, age, region (rural and metropolitan), educational level (under high school and university degree or above), occupation (white, pink, or blue collar and none), monthly household income quartiles, marital status, alcohol consumption, body mass index, muscle strengthening activity, aerobic activity, and history of chronic disease (hypertension, dyslipidemia, stroke, angina, myocardial infarction). Age was categorized into 10-year periods of 19–29, 30–39, 40–49, 50–59, 60–69, and ≥70 years.

Statistical analysis

Chi-square tests were used to evaluate differences in the frequencies and proportions of categorical variables between participants with prediabetes and those without prediabetes. Multiple logistic

regression analysis was performed to examine the association of smoking behavior and exposure to SHS with HbA1c levels, after adjusting for covariates. The results are presented as odds ratios (ORs) and 95% confidence intervals (CIs). Subgroup analyses were performed using sex and other covariates. All analyses were performed using Statistical Analysis Software (SAS, version 9.4, SAS, Inc., Cary, NC, USA), and $p < 0.05$ was considered statistically significant.

Results

Table 1 presents the general characteristics of male and female participants with prediabetes. Among the 22,385 participants, 6,735 (30%) had prediabetes. The number of participants who used mixed cigarette types was 1,628 (7.3%), while the number who used c-cigarettes only was 6,954 (31.1%). Among the 1,628 participants with mixed use, 393 (24.1%) had prediabetes, compared to 2,303 (33.1%) among the 6,954 participants who used only c-cigarettes. Among the 7,829 participants exposed to SHS, 2,245 (28.7%) had prediabetes.

Table 2 shows the factors associated with prediabetes. Compared to those who never smoked without exposure to SHS, those with mixed e- and c-cigarette use, those who used only c-cigarettes, and those who never smoked but had been exposed to SHS exhibited an increased risk of prediabetes (mixed use group, OR = 1.57, 95% CI = 1.31–1.87; c-cigarette use only group, OR = 1.23, 95% CI = 1.10–1.38; never-smoker with exposure to SHS, OR = 1.15, 95% CI = 1.03–1.28). Participants with mixed use of e- and c-cigarettes exhibited increased odds of prediabetes when compared to users of c-cigarettes only (OR = 1.27, 95% CI = 1.09–1.49, Fig. 1-A). The likelihood of developing prediabetes increased with age, body mass index (BMI), and muscle strengthening activity.

In the subgroup analysis of smoking behavior, participants who were current non-smokers but mixed users of e- and c-cigarettes in the past had significantly increased risk of prediabetes compared to participants who never smoked (OR = 1.54, 95% CI = 1.06–2.23). However, there was no significant association between current non-smoker status but past use of c-cigarettes and prediabetes (OR = 1.02, 95% CI = 0.90–1.16, Fig. 1-B).

Table 3 presents the association between place of SHS exposure and prediabetes among never-smokers. Exposure to SHS at the workplace was associated with prediabetes in men (OR = 1.58, 95% CI = 1.12–2.24), whereas exposure to SHS at home was associated with prediabetes in women (OR = 1.23, 95% CI = 1.00–1.53).

Table 4 shows the results of subgroup analysis stratified by independent variables. Men who were mixed users, c-cigarette users only, and never-smokers with exposure to SHS had a significantly higher risk of prediabetes than never-smokers without exposure to SHS (mixed users: OR = 1.75, 95% CI = 1.40–2.18; c-cigarettes only: OR = 1.53, 95% CI = 1.29–1.83; never-smokers with SHS exposure: OR = 1.30, 95% CI = 1.01–1.68). However, there was no significant association between smoking behavior and prediabetes among women. Participants who did not engage in aerobic activity with mixed use or use of c-cigarettes only had a higher risk of prediabetes than never-smokers (mixed users: OR = 1.60, 95% CI = 1.32–1.95; c-

cigarettes only: OR = 1.27, 95% CI = 1.12–1.44). Among participants with obesity and normal/underweight participants, mixed use and c-cigarette use only were associated with a higher risk of prediabetes than never smoking without exposure to SHS.

Discussion

In the present study, we investigated the association of smoking behavior and exposure to SHS with prediabetes in the general population. Our findings indicated that there was a higher risk of prediabetes in both participants using a mixture of e- and c-cigarettes and those using c-cigarettes only than in those who were never-smokers. Furthermore, mixed use of e- and c-cigarettes was associated with an increased risk of prediabetes when compared to use of c-cigarettes only. Interestingly, we observed that participants who did not currently smoke but had smoked a mixture of e- and c-cigarettes in the past had a significantly increased risk of prediabetes, whereas participants who did not currently smoke but smoked only c-cigarettes in the past did not.

Several longitudinal studies have demonstrated that smoking is associated with diabetes [19,20]. However, few studies have confirmed a link between e-cigarette use and prediabetes[21]. Considering that adults often use a mixture of e- and c-cigarettes to reduce or quit c-cigarettes rather than smoking e-cigarettes alone, our research shows the association of e-cigarettes with prediabetes.

Although the mechanism by which the risk of prediabetes increases in mixed-type users remains unclear, several possible mechanisms can be suggested. First, nicotine may have an effect on the increased incidence of prediabetes. E-cigarette aerosol also contains highly oxidizing free-base nicotine, and the concentration of nicotine varies from product to product[22,23]. The nicotine dependence triggered by using e-cigarettes to quit cigarette smoking may have led mixed type users to smoke more e-or c-cigarettes. Further studies are required to evaluate the dose-response relationship with regard to e- and c-cigarette use and prediabetes. Second, the e-liquid component of e-cigarettes can affect the relationship between mixed use and prediabetes. Sugars and aldehydes found in e-liquid may have induced the development of prediabetes[24]. A previous in vitro study reported that e-cigarettes can affect body metabolism, affecting blood levels of lipids and inflammatory factors, resulting in decreased insulin sensitivity[25]. Furthermore, another study demonstrated that even e-liquid without nicotine induces hyperglycemia in rats, and that this disruption in glucose metabolism differs from that induced by e-liquid containing nicotine and nicotine alone[26].

Our findings indicated that exposure to SHS among never-smokers was associated with a 1.15-fold increase in the risk of prediabetes when compared with non-exposure to SHS in both men and women. Our result is in line with the findings of previous studies showing that exposure to SHS is associated with the development of diabetes[27,28]. In addition, we observed differences in the places in which men and women are exposed to SHS. This result suggests that exposure to SHS in a space where people spend more of daily life may affects the risk of prediabetes. Future studies should examine the association of prediabetes according to the duration of exposure to SHS.

In a subgroup analysis stratified by aerobic activity level, among those reporting aerobic inactivity, mixed use exhibited a stronger association with the risk of prediabetes than other types of use or exposure. Considering that there were no differences among the strata in the subgroup analysis of muscle strengthening activity level, aerobic exercise and mixed use of e- and c-cigarettes may exert a synergistic effect on the development of prediabetes. Our study is in line with a previous study reporting that structured exercise training, including aerobic exercise, is associated with a reduction of HbA1c levels in patients with type 2 diabetes mellitus[29,30].

This study has several limitations. First, the causal relationship between mixed use of e- and c-cigarettes and prediabetes should be interpreted cautiously, as our study was cross-sectional in nature. Second, the dose-response relationship for smoking and prediabetes could not be confirmed because the frequency of e-cigarette vaping and concentration of nicotine were not investigated in the survey. Third, data related to smoking behavior, exposure to SHS, and some covariates were collected through a self-reported survey, indicating that there may have been recall bias. Fourth, the effect of exposure to e-cigarette smoking on prediabetes has not been evaluated. Finally, we did not include a group of participants who used e-cigarettes only.

Despite these limitations, this study has strengths. First, we investigated the association of smoking behavior and exposure to SHS with patients without diabetes who had a high probability of developing diabetes using HbA1c levels, which reflect the average plasma glucose levels over the last 8–12 weeks. Since HbA1c was tested through blood samples, the information provided can be considered reliable and valid. In addition, to the best of our knowledge, the present study is the first to evaluate the association of mixed use of e- and c-cigarettes and SHS with prediabetes. Lastly, our study is based on a nationally representative survey and random cluster sampling. This makes the data more reliable and representative of the Korean population. In addition, the results of the current study can be used as baseline motivators to establish nationalized policies or programs.

Conclusion

Despite many previous studies on the association between smoking and diabetes, the effects of e-cigarette and SHS on insulin sensitivity or glucose metabolism have not been fully elucidated. In the current study, mixed use of e- and c-cigarettes was significantly associated with prediabetes when compared to use of c-cigarettes only. Additionally, among never-smokers, exposure to SHS increased the probability of developing prediabetes.

Further longitudinal and biological studies are required to evaluate the adverse health effects of this emerging way of smoking (“vaping” of e-cigarettes) and SHS. If the association between e-cigarette use and the risk of prediabetes is causal, regulation or education on e-cigarettes may help to reduce the risk of prediabetes, which can in turn reduce the worldwide burden of type 2 diabetes.

Declarations

Data Availability

All the KNHANES data used this study are available to the public and can be seen in the KNHANES official website (http://knhanes.cdc.go.kr/).

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Author Contributions

SHK and SIJ were responsible for the conception and design of the study. SHK performed the data curation and made contributions to analysis and interpretation of the data. SHK was drafted the manuscript. MP, GRK and SIJ were performed writing review and editing, and all authors read and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

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Tables

Table 1. General characteristics of study participants

	Prediabetes (5.7≤HbA1c≤6.4)						
	Total		Yes		No		*P*-value
	N	%	N	%	N	%	
Total (n=22,385)	22,385	100	6,735	30	15,650	70	
Smoking behavior							<0.0001
Mixed user (e-cig. & c-cig.)	1,628	7.3	393	24.1	1,235	75.9	
Only c-cig. user	6,954	31.1	2,303	33.1	4,651	66.9	
Never smoker with exposure to SHS	4,181	18.7	1,106	26.5	3,075	73.5	
Never smoker w/o exposure to SHS	9,622	43.0	2,933	30.5	6,689	69.5	
Sex							0.484
Male	9,490	42.4	2,879	30.3	6,611	69.7	
Female	12,895	57.6	3,856	29.9	9,039	70.1	
Age							<0.0001
19~29	3,141	14.0	166	5.3	2,975	94.7	
30~39	4,016	17.9	613	15.3	3,403	84.7	
40~49	4,419	19.7	982	22.2	3,437	77.8	
50~59	4,394	19.6	1,681	38.3	2,713	61.7	
60~69	3,541	15.8	1,755	49.6	1,786	50.4	
70+	2,874	12.8	1,538	53.5	1,336	46.5	
Region							0.7876
Rural	9,791	43.7	2,955	30.2	6,836	69.8	
Metropolitan	12,594	56.3	3,780	30.0	8,814	70.0	
Educational level							<0.0001
Under high school	13,662	61.0	4,920	36.0	8,742	64.0	
College	8,723	39.0	1,815	20.8	6,908	79.2	
Job							<0.0001
White collar	5,951	26.6	1,192	20.0	4,759	80.0	
Pink collar	2,994	13.4	865	28.9	2,129	71.1	
Blue collar	5,093	22.8	1,914	37.6	3,179	62.4	
None	8,347	37.3	2,764	33.1	5,583	66.9	
Household income							<0.0001
Low	3,517	15.7	1,455	41.4	2,062	58.6	
Middle low	5,382	24.0	1,752	32.6	3,630	67.4	
Middle high	6,539	29.2	1,774	27.1	4,765	72.9	
High	6,947	31.0	1,754	25.2	5,193	74.8	
Marital status							<0.0001
No	6,790	30.3	1,615	23.8	5,175	76.2	
Yes	15,595	69.7	5,120	32.8	10,475	67.2	
Alcohol consumption							<0.0001
2 ~ 4 times / week	4,921	22.0	1,280	26.0	3,641	74.0	
2 ~ 4 times / month	5,291	23.6	1,289	24.4	4,002	75.6	
Never or occasionally	12,173	54.4	4,166	34.2	8,007	65.8	
Obesity status (BMI)							<0.0001
Obesity (≥25)	7,065	31.6	2,922	41.4	4,143	58.6	
Overweight (23-24.9)	5,176	23.1	1,633	31.5	3,543	68.5	
Normal (<23)	10,144	45.3	2,180	21.5	7,964	78.5	
Muscle strengthening activity							<0.0001

No	17,770	79.4	5,495	30.9	12,275	69.1	
Yes	4,615	20.6	1,240	26.9	3,375	73.1	
Aerobic activity							<0.0001
No	18,222	81.4	5,587	30.7	12,635	69.3	
Yes	4,163	18.6	1,148	27.6	3,015	72.4	
Chronic disease[1]							<0.0001
≥2	2,692	12.0	1,396	51.9	1,296	48.1	
1	5,985	26.7	2,538	42.4	3,447	57.6	
0	13,708	61.2	2,801	20.4	10,907	79.6	

[1] Defined as diagnosed diseases: hypertension, hyperlipidemia, stroke, and myocardial infarction or angina. The number of chronic diseases is the sum of the number of above diseases diagnosed.

Abbreviations: e-cig., electronic cigarette; c-cig., conventional cigarette; SHS, Secondhand smoke; w/o, without; BMI, body mass index

Table 2. Factors associated with prediabetes

	Prediabetes(5.7≤HbA1c≤6.4)			
	AOR	95% CI		
Smoking behavior				
Mixed user (e-cig. & c-cig.)	1.57	(1.31	-	1.87)
Only c-cig. user	1.23	(1.10	-	1.38)
Never smoker with exposure to SHS	1.15	(1.03	-	1.28)
Never smoker w/o exposure to SHS	**1.00**		-	
Sex				
Male	1.00	(0.89	-	1.11)
Female	**1.00**		-	
Age				
19~29	0.06	(0.05	-	0.08)
30~39	0.19	(0.16	-	0.22)
40~49	0.29	(0.25	-	0.34)
50~59	0.54	(0.47	-	0.62)
60~69	0.79	(0.70	-	0.90)
70~	**1.00**		-	
Region				
Rurals	0.85	(0.78	-	0.93)
Metropolitans	**1.00**		-	
Educational level				
Under high school	1.11	(1.01	-	1.23)
College	**1.00**		-	
Job				
White	0.99	(0.88	-	1.10)
Pink	1.14	(1.01	-	1.29)
Blue	1.13	(1.01	-	1.26)
None	**1.00**		-	
Household income				
Low	0.95	(0.84	-	1.08)
Middle low	1.06	(0.95	-	1.19)
Middle high	1.01	(0.92	-	1.12)
High	**1.00**		-	
Marital status				
No	0.95	(0.86	-	1.05)
Yes	**1.00**		-	
Drink				
2 ~ 4 times / week	0.71	(0.65	-	0.79)
2 ~ 4 times / month	0.95	(0.86	-	1.05)
Never or occasionally	**1.00**		-	
Obesity Status (BMI)				
Obesity (≥25)	2.25	(2.06	-	2.47)
Overweight (23-24.9)	1.31	(1.18	-	1.45)
Normal (<23)	**1.00**		-	
Muscle strengthening activity				
No	1.11	(1.01	-	1.23)

Yes	1.00		-		
Aerobic activity					
No	1.07	(0.97	-	1.18)	
Yes	1.00		-		
Chronic disease					
≥2	1.76	(1.56	-	1.98)	
1	1.44	(1.31	-	1.58)	
0	1.00				

[1] Defined as diagnosed diseases: hypertension, hyperlipidemia, stroke and myocardial infarction or angina. The number of chronic diseases is the sum of the number of diagnosed above diseases.

Abbreviations: e-cig., electronic cigarette; c-cig., conventional cigarette; SHS, Secondhand smoke; w/o, without; BMI, Body Mass Index;

Table 3. Association between place of secondhand smoke exposure and prediabetes among never smokers

Variables	Prediabetes(5.7≤HbA1c≤6.4)								
	Total			Male			Women		
	AOR	95% CI		AOR	95% CI		AOR	95% CI	
Secondhand smoke									
Workplace	1.33	(1.11 -	1.60)	1.58	(1.12 -	2.24)	1.22	(0.99 -	1.50)
Home	1.28	(1.03 -	1.59)	2.30	(0.91 -	5.82)	1.23	(1.00 -	1.53)
Public	1.09	(0.94 -	1.25)	1.07	(0.75 -	1.53)	1.12	(0.96 -	1.30)
Never	1.00			1.00			1.00		

Adjusted for covariates

Abbreviations: AOR, adjusted odds ratio

Table 4. Subgroup analysis stratified by independent variables

Variables	Prediabetes (5.7≤HbA1c≤6.4)								
	Smoking behavior								
	Never smoker w/o SHS	Never smoker with SHS			Only c-cig. user			Mixed user (e- and c-cig.)		
	AOR	AOR	95%CI		AOR	95%CI		AOR	95%CI	
Sex										
Male	1.00	1.30	(1.01	1.68)	1.53	(1.29	1.83)	1.75	(1.40	2.18)
Female	1.00	1.17	(1.04	1.33)	1.05	(0.86	1.27)	1.28	(0.85	1.94)
Age										
19~29	1.00	2.04	(1.29	3.24)	2.16	(1.27	3.68)	1.68	(0.92	3.05)
30~39	1.00	0.92	(0.68	1.25)	0.93	(0.70	1.26)	1.24	(0.87	1.78)
40~49	1.00	1.11	(0.88	1.40)	1.37	(1.07	1.74)	1.37	(0.98	1.94)
50~59	1.00	1.15	(0.95	1.39)	1.29	(1.01	1.64)	2.05	(1.35	3.12)
60~69	1.00	1.27	(1.00	1.61)	1.38	(1.03	1.84)	1.40	(0.78	2.50)
70~	1.00	1.29	(0.93	1.78)	1.53	(1.16	2.02)	2.63	(1.31	5.30)
Region										
Rurals	1.00	1.27	(1.08	1.50)	1.22	(1.03	1.44)	1.46	(1.12	1.90)
Metropolitans	1.00	1.08	(0.94	1.23)	1.24	(1.05	1.45)	1.63	(1.28	2.08)
Educational level										
Under high school	1.00	1.15	(1.01	1.31)	1.31	(1.14	1.52)	1.53	(1.20	1.96)
College	1.00	1.13	(0.94	1.36)	1.08	(0.89	1.31)	1.53	(1.19	1.98)
Job										
White	1.00	1.15	(0.90	1.45)	1.19	(0.95	1.49)	1.38	(1.02	1.87)
Pink	1.00	1.35	(1.04	1.74)	0.95	(0.69	1.31)	1.64	(1.06	2.53)
Blue	1.00	1.27	(1.01	1.60)	1.58	(1.24	2.01)	1.72	(1.20	2.46)
None	1.00	1.01	(0.86	1.20)	1.14	(0.94	1.39)	1.71	(1.14	2.55)
Household income										
Low	1.00	1.11	(0.84	1.48)	1.29	(0.98	1.71)	2.09	(1.20	3.63)
Middle low	1.00	1.29	(1.04	1.59)	1.39	(1.12	1.73)	1.80	(1.27	2.55)
Middle high	1.00	1.00	(0.82	1.22)	1.20	(0.97	1.49)	1.26	(0.91	1.73)
High	1.00	1.16	(0.97	1.40)	1.07	(0.85	1.34)	1.48	(1.08	2.04)
Marital status										
No	1.00	1.29	(1.02	1.62)	1.33	(1.06	1.67)	1.85	(1.36	2.53)
Yes	1.00	1.11	(0.98	1.25)	1.19	(1.04	1.36)	1.44	(1.15	1.79)
Drink										
2 ~ 4 times / week	1.00	1.24	(0.88	1.73)	1.41	(1.09	1.82)	1.47	(1.06	2.04)
2 ~ 4 times / month	1.00	1.39	(1.10	1.75)	1.18	(0.94	1.48)	1.48	(1.08	2.02)
Never or occasionally	1.00	1.07	(0.94	1.22)	1.24	(1.06	1.45)	1.91	(1.40	2.62)
Obesity Status (BMI)										
Obesity (≥25)	1.00	1.12	(0.93	1.34)	1.25	(1.04	1.51)	1.59	(1.21	2.08)
Overweight (23-24.9)	1.00	1.18	(0.95	1.46)	1.12	(0.88	1.43)	1.35	(0.94	1.92)
Normal (<23)	1.00	1.15	(0.97	1.36)	1.32	(1.09	1.59)	1.59	(1.18	2.14)
Muscle strengthening activity										

No	1.00	1.15	(1.02	-	1.29)	1.17	(1.03	-	1.34)	1.55	(1.26	-	1.90)
Yes	1.00	1.14	(0.88	-	1.46)	1.46	(1.15	-	1.86)	1.52	(1.05	-	2.20)
Aerobic activity													
No	1.00	1.20	(1.07	-	1.35)	1.27	(1.12	-	1.44)	1.60	(1.32	-	1.95)
Yes	1.00	0.94	(0.73	-	1.20)	1.11	(0.84	-	1.47)	1.41	(0.89	-	2.24)
Chronic disease													
≥2	1.00	1.07	(0.80	-	1.42)	1.20	(0.88	-	1.62)	1.41	(0.87	-	2.28)
1	1.00	1.19	(0.98	-	1.44)	1.31	(1.08	-	1.60)	1.45	(1.06	-	1.98)
0	1.00	1.15	(1.00	-	1.33)	1.22	(1.04	-	1.43)	1.62	(1.30	-	2.03)

Abbreviations: AOR, adjusted odds ratio; e-cig., electronic cigarette; c-cig., conventional cigarette; SHS, Secondhand smoke; w/o, without; BMI, Body Mass Index;

Figures

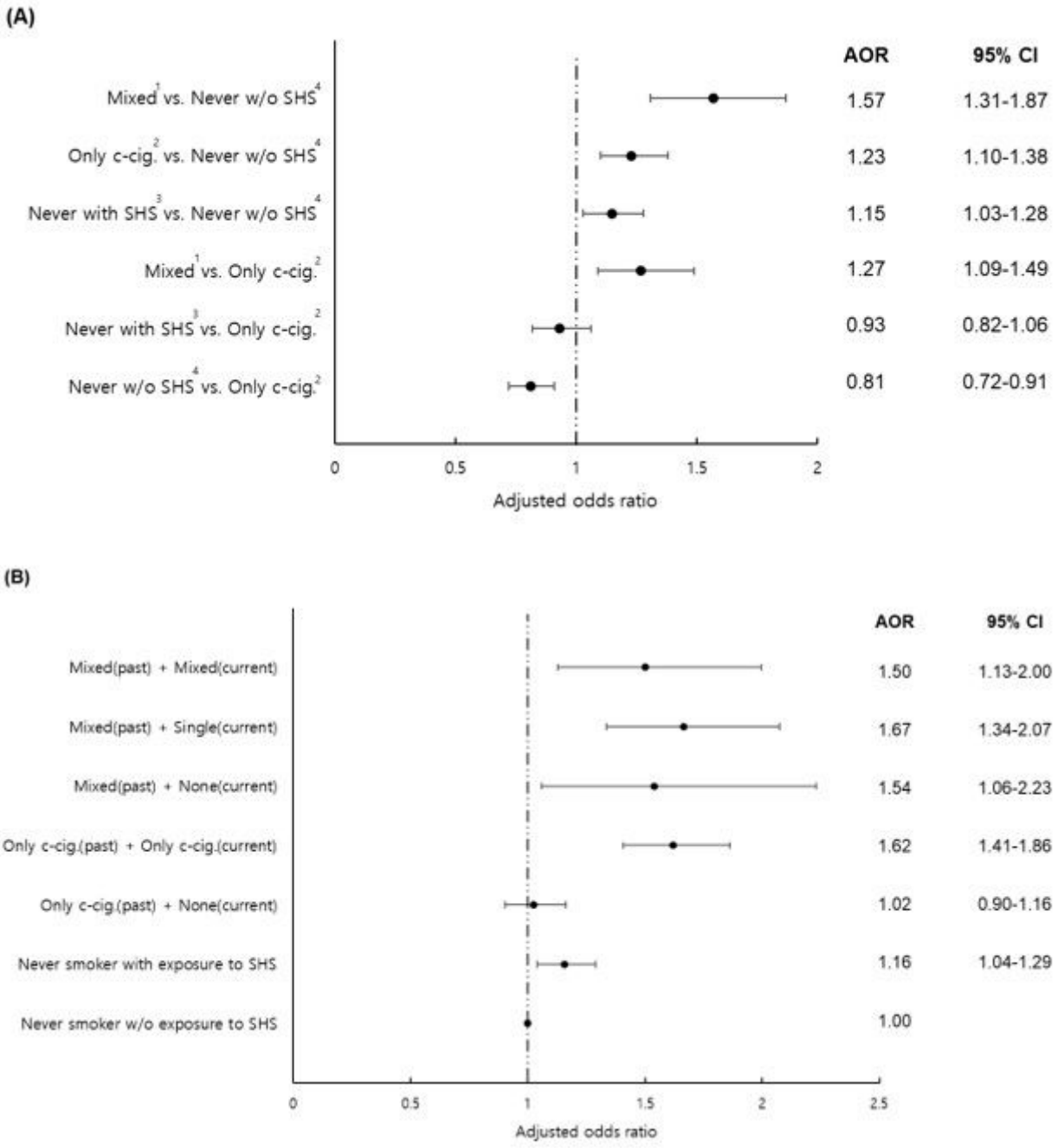

Figure 1

(A) Multivariate association between smoking behavior and prediabetes. (B) subgroup analysis of the main independent variable. w/o, without; c-cig., conventional cigarette; e-cig., electronic cigarette.1 Mixed user of electronic and conventional cigarette; 2 only conventional cigarette user; 3 Never smoker with secondhand smoke; 4 Never smoker without secondhand smoke. SHS: secondhand smoke.