



Investigation of the Association Between Smoking Behavior and Metabolic Syndrome Using Lipid Accumulation Product Index Among South Korean Adults

Sung Hoon Jeong a,b, Bich Na Jang a,b, Seung Hoon Kim b,c, Sung-In Jang b,c and Eun-Cheol Park b,c*

^aDepartment of Public Health, Graduate School, Yonsei University
^bInstitute of Health Services Research, Yonsei University
^cDepartment of Preventive Medicine, Yonsei University College of Medicine

INTRODUCTION

- The prevalence of metabolic syndrome (MetS) is increasing worldwide and is known to negatively affect health in many ways
- The mechanisms involved in MetS have not yet been identified, but it is well known that various environments and lifestyles, including smoking, lack of exercise, and unbalanced eating habits, are risk factors for MetS.
- Electronic cigarette vaping has recently been chosen as a smoking alternative for those who want to quit smoking, but some of the electronic cigarette users use both conventional and electronic cigarettes (dual smoking) without stopping smoking.
- The health effects of dual smoking are not yet fully known, it has been found that smoking cessation motives and the likelihood of successful cessation are reduced and tobacco dependence may occur
- Furthermore, although there are quantitative prior studies on the health effects of e-cigarettes or conventional smoking, research on the effects of dual smoking is limited and is still in its infancy.
- Therefore, this study investigated the relationship between various smoking behaviors, including dual smoking, single smoking, and previous smoking, with lipid accumulation product(LAP), an index useful for predicting MetS in the general population.

MATERIALS AND METHODS

- **Data source:** Our present study extracted data collected by the Korea National Health and Nutrition Examination Survey (KNHANES VII) between 2016 and 2018 and was the secondary analysis of a large data set.
- **Study population:** Our study was carried out on data derived from the KNHANES on 14,607(6142 males and 8465 females) respondents aged ≥19 years after exclusion of those with missing values.
- **Outcome variables:** The outcome variable LAP was calculated as [waist circumference (cm) – 65] × [triglyceride concentration (mM)] for males, and [waist circumference (cm) – 58] × [triglyceride concentration (mM)] for females.
- **Interesting variables:** The Interesting variable was the smoking behavior of participants who used both conventional and e-cigarettes. In the KNHANES survey, all subjects were asked whether they currently use conventional or e-cigarettes or whether they have been using these products for a long time or in the past. Based on this, we categorized our subjects in to four categories: dual smokers (both conventional and e-cigarettes), single smokers (only conventional cigarettes), ex-smokers (previous smokers), and non-smokers.
- **Covariates:** Socio-economic and health-related characteristics were all included as control variables. General characteristics included: age, education level, household income and occupational status. Health-related variables included: body mass index(BMI), alcohol consumption, physical activity, number of chronic diseases, pack-year and caloric intake.
- **Statistical analysis:** A univariate linear regression analysis was conducted to investigate the general characteristics of the study population. Prior to multiple linear regression analysis, we performed a log-transformation of the LAP to ensure normality. Multiple linear regression analysis was performed to examine the association between smoking behavior pattern and log-transformed LAP, after considering the potential confounding variables, including sociodemographic, economic, and health-related characteristics. All statistical analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, NC, USA). A $p < 0.05$ was considered statistically significant.

RESULTS

Table 1. General characteristics of the study population.

Variables	Lipid Accumulation Product index (LAP)										
	Total			Male			Female				
	N	%		N	%		N	%			
Total	14,607	100.0		6142	100.0		8465	100.0			
Smoking Behavior											
Dual smoker	222	1.5		187	3.0		35	0.4			
“Single” smoker	2222	15.2		1850	30.1		372	4.4			
Ex-use	3111	21.3		2618	42.6		493	5.8			
Non-use	9052	62.0		1487	24.2		7565	89.4			

- In Table 1, the total 14,607 participants, 6142 were males (42.0%) and 8465 were females (58.0%). Of the 6142 males, 187 (3.0%) were dual smokers, 1850 (30.1%) were single smokers, 2618 were ex-smokers (42.6%), and 1487 (24.2%) were non-smokers. Of the 8465 females, 35 (0.4%) were dual smokers, 372 (4.4%) were single smokers, 493 (5.8%) were ex-smokers, and 7565 (89.4%) were non-smokers.

Table 2. Association between Smoking Behavior and Log-transformed Lipid Accumulation Product index.

Variables	Lipid Accumulation Product Index (Log-Transformed Model)					
	Male			Female		
	β	SE	p-Value	β	SE	p-Value
Smoking Behavior						
Dual smoker	0.27	0.06	<0.0001	0.11	0.11	0.2878
“Single” smoker	0.18	0.03	<0.0001	0.21	0.04	<0.0001
Ex-use	0.03	0.03	0.1788	0.07	0.03	0.0175
Non-use	Ref.			Ref.		

- In Table2, among males, dual smokers ($\beta = 0.27$, standard error (SE) = 0.06, $p < 0.0001$) and single smokers ($\beta = 0.18$, SE = 0.03, $p < 0.0001$) were found to be statistically associated with LAP, whereas in females, statistical associations were found only in single smokers ($\beta = 0.21$, SE = 0.04, $p < 0.0001$).

RESULTS

Table 3. Subgroup analysis stratified by independent variables.

Lipid Accumulation Product Index (Log-Transformed Model) *										
Variables	Smoking Behavior									
	None	Dual Smoker			"Single" Smoker			Ex-Use		
	ß	ß	SE	p-Value	ß	SE	p Value	ß	SE	p-Value
Male BMI										
Normal	Ref.	0.36	0.09	<0.0001	0.18	0.04	<0.0001	0.03	0.04	0.3529
Under	Ref.	0.26	0.63	0.6764	0.32	0.21	0.1339	0.36	0.22	0.1339
Over	Ref.	0.14	0.07	0.0445	0.15	0.04	0.0001	0.01	0.04	0.7977
Alcohol consumption										
No	Ref.	0.17	0.20	0.4004	0.23	0.06	0.0004	0.10	0.05	0.0523
Yes	Ref.	0.33	0.06	<0.0001	0.23	0.03	<0.0001	0.07	0.03	0.0074
Physical activity										
Inadequate	Ref.	0.35	0.08	<0.0001	0.16	0.04	<0.0001	0.07	0.04	0.0736
Adequate	Ref.	0.20	0.08	0.0090	0.21	0.04	<0.0001	0.01	0.04	0.8370
Female BMI										
Normal	Ref.	0.10	0.13	0.4360	0.11	0.05	0.0367	0.05	0.04	0.2106
Under	Ref.	0.10	0.46	0.4907	0.003	0.18	0.9860	0.22	0.14	0.1090
Over	Ref.	0.09	0.18	0.6086	0.39	0.06	<0.0001	0.06	0.05	0.2763
Alcohol consumption										
No	Ref.	0.26	0.35	0.4614	0.26	0.09	0.0043	0.001	0.06	0.9888
Yes	Ref.	0.14	0.11	0.2145	0.24	0.04	<0.0001	0.12	0.03	0.0005
Physical activity										
Inadequate	Ref.	0.26	0.14	0.0463	0.21	0.05	<0.0001	0.09	0.04	0.0289
Adequate	Ref.	0.07	0.17	0.6891	0.20	0.06	0.0015	0.05	0.05	0.3291

* Adjusted for other covariates

- In Table 3, in males, in cases of normal BMI (dual smokers: $\beta = 0.36$, SE = 0.09, $p = 0.001$; single smokers: $\beta = 0.18$, SE = 0.04, $p < 0.0001$), alcohol consumption (dual smokers: $\beta = 0.33$, SE = 0.06, $p < 0.0001$; single smokers: $\beta = 0.23$, SE = 0.06, $p = 0.0004$), and inadequate physical activity (dual smokers: $\beta = 0.35$, SE = 0.08, $p < 0.0001$; single smokers: $\beta = 0.16$, SE = 0.04, $p < 0.0001$), dual or single smokers showed the strongest association with LAP compared to non-smokers.
- In case of females, only when the physical activity was inadequate (dual smokers: $\beta = 0.26$, SE = 0.14, $p = 0.0463$; single smokers: $\beta = 0.21$, SE = 0.05, $p < 0.0001$), dual or single smokers showed the strongest association with LAP compared to non-smokers.

DISCUSSION

- The results of the study confirmed that in male, dual and single smokers had higher LAP than non-smokers, and in female, dual and single smokers had higher LAP than non-smokers, but only single smokers confirmed statistically significant values. These results suggest that dual or single smoking may be a risk factor for MetS.
- There is no clear mechanism indicating that smoking increases visceral and abdominal fat. However, it is reported that non-smokers lose weight when they smoke, but show an increase in the WHR and the risk of developing MetS. This also applies to single and dual smokers, as indirectly implied by the current results.
- Additionally, we confirmed that smoking behavior and LAP are mostly related to lifestyle, including BMI, alcohol consumption, and inadequate physical activity. This is consistent with previous studies that, regardless of BMI, smoking can increase the accumulation of fat around tissues. Furthermore, alcohol consumption and inadequate physical activity significantly increase the body’s visceral fat and can lead to serious metabolic abnormalities through a lethal combination with smoking.
- There were several limitations in our study. First, we used cross-sectional data for this study. Therefore, causality and directionality of the observed relationship could not be established. Second, for the KNHANES data used in this study, data on smoking behavior and socioeconomic and health-related variables may have been over or underestimated because the survey was collected through self-reporting, and some surveys may have a recall bias. Third, electronic cigarettes are still a relatively new technology and the respondents rarely used them.
- Despite these limitations, our research has several strengths. First, the analyzed KNHANES is a nationwide survey based on a random cluster sampling conducted by the Korea Disease Control and Prevention Agency(KDCA) and is a reliable statistic that evaluates the health and nutritional status of Koreans according to Article 16 of the National Promotion Act. Therefore, our results reflect the overall health condition of Korean adults. Second, we used the highly predictive LAP as a tool for evaluating MetS. According to previous studies, LAP was a better predictor of MetS than TyG, TG/HDL-C, BMI, and WC measurement. Third, the LAP was measured through clinical trials, making it more reliable and clear.

CONCLUSION

- Our present study’s findings suggested that smoking behaviors such as conventional cigarette smoking and dual smoking are negatively affected health in adults in South Korea.
- E-cigarettes are a preferred option for people trying to quit smoking. However, they deliver nicotine just like conventional cigarettes, thereby suggesting that dual smoking may not be an appropriate method to quit smoking as it could adversely affect health.
- Therefore, the implication of our findings can help develop interventions and policies to prevent the adverse health effects of dual smoking.
- However, it is not clear whether the independent use of e-cigarettes is associated with MetS or affects other health outcomes.
- Hence, further research specifically investigating the negative effects of e-cigarettes on health and the adverse health effects of dual smoking is required.