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Association of food insecurity with the use of tobacco products and urine cotinine-measured smoking intensity: evidence from a population-based study in South Korea, 2019–2021

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ABSTRACT

Introduction This study explored the association between food insecurity and tobacco product use and urine cotinine-measured smoking intensity.

Methods This cross-sectional study included 13 705 adults representative of the Korean population. The 18-item Household Food Security Survey Module was administered to the primary food managers in households with the scores applied to household members. The use of three tobacco products—combustible cigarettes, heated tobacco products and electronic cigarettes (e-cigarettes)—was assessed. Based on the urine cotinine level, the smoking status of each participant was classified into one of three groups: non-smoker, low-intensity smoker and high-intensity smoker. Logistic regression analysis was used to determine the association between food insecurity and tobacco product use and urine cotinine-measured smoking intensity. ORs and 95% CIs were estimated.

Results Among the survey participants, 3.2% had mild food insecurity and 0.7% had moderate-to-severe food insecurity. Those with mild food insecurity (23.5%, OR: 1.38, 95% CI: 1.01 to 1.89) and those with moderate-to-severe food insecurity (45.1%, OR: 3.36, 95% CI: 1.87 to 6.03) compared with those with non-food insecurity (18.4%) were positively associated with combustible cigarette use. Those with moderate-to-severe food insecurity was positively associated with e-cigarette use (5.5%, OR: 3.49, 95% CI: 1.31 to 9.28). Compared with those with non-food security (7.9%), those with mild food insecurity (14.3%, OR: 1.61, 95% CI: 1.09 to 2.38) and moderate-to-severe food insecurity (22.1%, OR: 2.25, 95% CI: 1.04 to 4.86) were associated with high-intensity smoking.

Conclusion Food insecurity is associated with both combustible and e-cigarette use. Those with food insecurity are associated with engagement in high-intensity smoking.

INTRODUCTION

Food insecurity has emerged as a global public health concern.¹ According to a report by the Food and Agriculture Organization of the United Nations, approximately 9.2% of the global population were undernourished in 2022.² The recent COVID-19 pandemic has substantially affected the global food chain and economic stability, primarily exacerbating food insecurity among vulnerable populations with low socioeconomic status.³ While the impact of COVID-19 was limited and food

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Food insecurity refers to the restricted access to safe and nutritious food that meets their dietary requirements. While past research has indicated its association with cardiovascular and overall mortality, its associations with tobacco use and smoking intensity remain understudied in the current literature. Additionally, studies using an objective biomarker for nicotine are scarce in survey research.

WHAT THIS STUDY ADDS

⇒ This study revealed that food insecurity is linked to higher odds of both combustible and electronic cigarette use. Moreover, increased levels of food insecurity were associated with a greater likelihood of engaging in high-intensity smoking intensity.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Through the measurement of urine cotinine levels, we not only validated the association between food insecurity and smoking risk as reported in existing literature but also provided novel insights into the correlation with smoking intensity. Our findings underscore the importance of implementing comprehensive intervention programmes aimed at reducing tobacco product use among populations experiencing food insecurity.

security remained stable in Korea,² it is estimated that approximately 3.8–4.3% of the population experiences food insecurity.⁴

Studies have shown that food insecurity is associated with adverse health consequences. Individuals who experience food insecurity exhibit an increased risk of cardiovascular disease and overall mortality.^{5 6} Considering that tobacco product use is a major contributor to the onset of noncommunicable diseases understanding the association between food insecurity and tobacco product use is important to effectively address health disparities related to food security.⁷

Several studies have found that food insecurity is a risk factor for smoking. Individuals with lower socioeconomic status characterised by factors like low educational attainment and income level experience disproportionately higher rates of both food

insecurity and tobacco product use.⁷ Longitudinal studies in the USA showed that food insecurity is associated with increased odds of smoking.^{8,9} Recent cross-sectional studies have demonstrated that individuals who experience food insecurity are more likely to be current smokers.^{10–13} The association between food insecurity and high risk of smoking is believed to involve complex mechanisms. Experiencing food insecurity may increase anxiety and stress,¹⁴ leading individuals to rely on smoking as a coping strategy to alleviate negative emotions.⁷ Along with the psychological mechanism, studies have suggested that nicotine has appetite-suppressing effects.^{15,16} Therefore, individuals experiencing severe food insecurity, particularly those who suffer from hunger, may depend on tobacco products to mitigate their appetite and hunger.¹⁷ Additionally, the association between food insecurity and tobacco use can be bidirectional. Previous studies showed that expenditure on smoking can exacerbate food insecurity by diverting limited financial resources.^{18–21}

Although several studies have explored the link between food insecurity and tobacco use, the existing literature has several limitations. First, most studies have focused on combustible cigarette use, whereas the consumption of heated tobacco products and electronic cigarettes (e-cigarettes) has received limited academic attention.²¹ Second, most studies have relied on self-reported questionnaires to assess smoking status with objective measures such as serum or urine cotinine rarely being used.²² Urine cotinine which serves as a biomarker for nicotine exposure can effectively identify individuals who may be reluctant to self-report smoking in surveys.²³ Moreover, the urine cotinine level can provide information on smoking intensity.²⁴ Third, most of the existing evidence originates from Western countries with few studies investigating the relationship between food insecurity and tobacco use in Korea or other East Asian regions. Consequently, this study aimed to explore the association of

food insecurity with tobacco product use and smoking intensity as measured through the urine cotinine level using data from a nationally representative sample of Korean adults.

METHODS

Study sample

Survey participants included in the eighth wave of the Korea National Health and Nutrition Examination Survey (KNHANES) which was conducted between 2019 and 2021 were selected as the study sample for our analysis.²⁵ In the initial year of the eighth wave of the KNHANES (2019), a survey questionnaire on the use of various types of tobacco products (combustible cigarettes, heated tobacco products and e-cigarettes) was introduced. The KNHANES is an annual nationwide survey conducted by the Korea Disease Control and Prevention Agency with the goal of gaining information on the health status of the general Korean population. To include a nationally representative sample of the Korean population, the KNHANES employs a stratified multistage cluster sampling design.²⁵ Annually, 192 enumeration districts in South Korea are selected as the primary sampling units and approximately 20 households in each district are invited to participate in the KNHANES. While all household members were invited to participate in the survey, 74% agreed to participate in the eighth wave of the KNHANES.²⁶ To mitigate non-response bias and improve the generalisability of the survey sample, survey weights were assigned to survey participants reflecting the sex, age and regional distribution of the Korean population.²⁷ Raw data from the KNHANES are available at <https://knhanes.kdca.go.kr/knhanes/eng/index.do>.

The selection process for the survey sample is shown in figure 1. Initially, 14 766 survey participants who were aged ≥ 19 and participants in the nutritional survey were included. In South

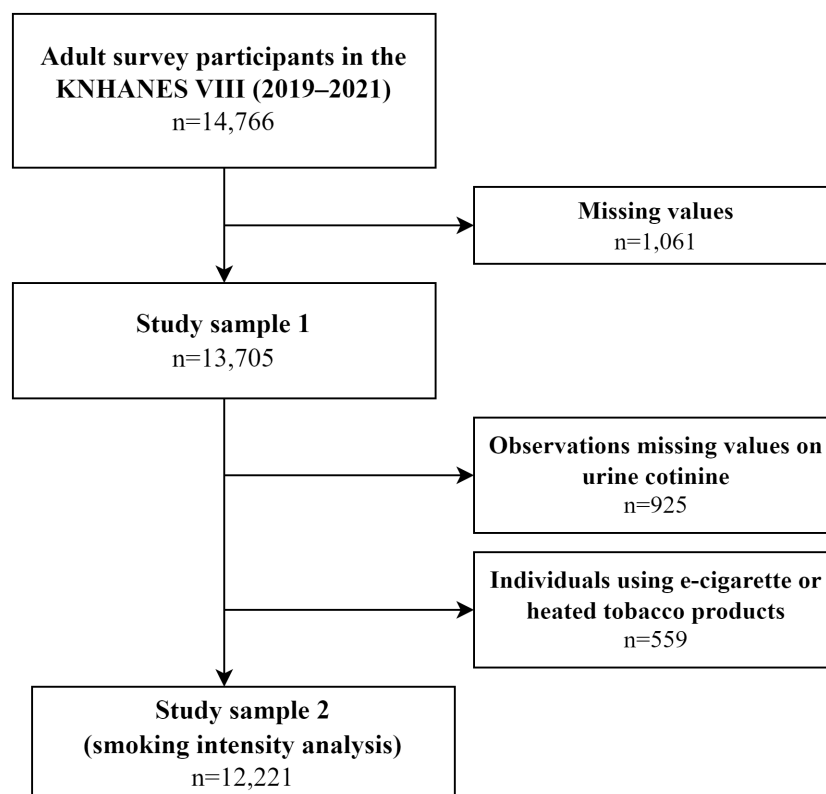


Figure 1 Selection process of study sample. KNHANES, Korea National Health and Nutrition Examination Survey.

Korea, the age of 19 is the legal threshold for adulthood and the minimum legal age for smoking. This criterion was also applied in the data collection process of the KNHANES survey. Subsequently, 1061 individuals with missing information regarding their sociodemographic characteristics and tobacco product use were excluded. Thus, 13 705 survey participants were included in the descriptive analyses and regression analysis of the association between food insecurity and the use of tobacco products. In the next step, an additional 925 individuals with missing information on urine cotinine or urine creatinine levels were excluded. Consequently, 12 780 individuals were included in the analysis of the association between food insecurity and urine cotinine-measured smoking status.

Variables

Food insecurity

Food insecurity was evaluated using the 18-item US Household Food Security Survey Module (HFSSM) which was adapted into the Korean version by Kim *et al.*²⁸ In line with the original US version, the Korean version of the HFSSM consists of 18 items that evaluate food insecurity based on the following three main domains: household-specific questions (three items), adult-specific questions (seven items) and child-specific questions (eight items). Each survey item assessed the difficulties experienced in acquiring or consuming food over the past 12 months scored on a scale of 0 or 1. The food insecurity survey questionnaire was answered by one household member who is primarily in charge of managing and purchasing food and the responses were applied to all individual household members. Only individuals with children in the household responded to child-specific questions, whereas those without children answered household-specific and adult-specific questions. The detailed questionnaires in the Korean version of the 18-item HFSSM have been elaborated on in previous literature.^{28 29} Therefore, individuals with children in the household had scores ranging from 0 to 18, whereas those without children or those in single-person households had scores ranging from 0 to 10. A higher score indicated greater food insecurity. The validity and reliability of the Korean version of the 18-item HFSSM have been established in previous studies.^{28 29} Based on the analysis guide provided in the previous literature,^{26 29 30} we categorised food insecurity according to the following criteria: (1) non-food insecurity: a score within the range of 0–2 for households with or without children; (2) mild food insecurity: a score within the range of 3–7 for households with children and 3–5 for households without children; and (3) moderate-to-severe food insecurity: a score within the range of 8–18 for households with children and 6–10 for households without children. Participants experiencing moderate or severe food insecurity were grouped together under a single category labelled ‘moderate-to-severe food insecurity’ owing to the limited number of households falling into the severe food insecurity group.³¹

Tobacco products use and smoking intensity

Self-administered questionnaires were used to assess the use of tobacco products for each survey participant. First, the use of combustible cigarettes was assessed by the following question: ‘Do you currently smoke traditional cigarettes?’. The possible response options were ‘every day’, ‘occasionally’, ‘used to smoke in the past but currently do not smoke’, or ‘never’. If the respondents smoked occasionally, they were asked about the number of days they had smoked combustible cigarettes in the past month. Based on the response, those who smoked every day

or smoked ≥ 1 day in the past month were classified as currently using combustible cigarettes. Second, the use of heated tobacco products was assessed using the following question: ‘Do you currently use heated tobacco products (eg, IQOS, GLO, LIL, etc.)?’. The possible response options were ‘every day’, ‘occasionally’, ‘used to smoke in the past but currently do not smoke’ or ‘never’. If the respondents smoked occasionally, they were asked about the number of days they had smoked heated tobacco products in the past month. Based on the response, those who smoked every day or smoked ≥ 1 day in the past month were classified as currently using heated tobacco products. Third, the use of e-cigarettes was assessed using the following question: ‘Have you used nicotine-containing e-liquids in the past month?’. The possible answer options were ‘yes’ and ‘no’. Those who responded ‘yes’ were classified as currently using e-cigarettes.

The urine cotinine level was measured by high-performance liquid chromatography-mass spectrometry using an Agilent 1100 Series with API 4000 (AB Sciex, USA). The lower limit of detection (LOD) was 0.5 ng/mL. Urine creatinine was measured by a kinetic colorimetric assay using a LABOSPECT 008AS (Hitachi, Japan). The LOD was 1.0 mg/mL. Values below the LOD were substituted with half of the LOD value. Based on the previous literature,³² survey participants with a urine cotinine level of ≥ 50 ng/mL were defined as cotinine-verified smokers ($n=2014$). To isolate the impact of traditional cigarettes on smoking intensity, we included only participants who reported using traditional cigarettes in our measurement of smoking intensity. The urine cotinine-to-creatinine (Co/Cr) ratio was calculated with ng/mg as the units.³³ Based on the median value of the Co/Cr ratio (8.05 ng/mg), participants were classified as engaging in high-intensity smoking (Co/Cr ratio ≥ 8.05 ng/mg; $n=1007$) or low-intensity smoking (Co/Cr ratio < 8.05 ng/mg; $n=1007$). As a result, the urine cotinine-verified smoking status of each participant was classified into one of three groups: non-smoking, low-intensity smoking or high-intensity smoking.

Covariates

The following confounders were selected as covariates for our analysis: Sex (male, female), age (< 30 , 30–39, 40–49, 50–59, ≥ 60), educational attainment (elementary or below, middle school, high school, college or above), household income (Q1, Q2, Q3, Q4), employment status (employed, unemployed), marital status (married and having children, married and not having children, unmarried/others). Household income level was categorised into four groups based on the quartile values of monthly total household income for each year. Those who engaged in any economic activities whether as employed workers or self-employed workers were classified as ‘employed’.

Statistical analysis

The characteristics of the study sample according to food insecurity levels were presented in the descriptive analyses. We then examined the prevalence of the use of each tobacco product according to the study variables.

For the regression analysis, we first estimated the association between food insecurity and the use of combustible cigarettes, heated tobacco products or e-cigarettes using logistic regression models in which food insecurity served as an independent variable and tobacco product use served as a dependent variable. Second, we estimated the association between food insecurity and urine cotinine-measured smoking status using multinomial logistic regression in which non-smoking was the reference outcome group. In this step, 925 observations with missing data

Table 1 Distribution of characteristics according to food insecurity. Survey weights were adjusted

	Food insecurity			
	Overall (n=13 705)	None (n=13 073)	Mild (n=513)	Moderate-to-severe (n=116)
Sex				
Male	5871 (49.6)	5626 (49.8)	193 (43.8)	52 (51.7)
Female	7834 (50.4)	7447 (50.2)	323 (56.2)	64 (48.3)
Age group				
<30	1667 (17.7)	1609 (17.8)	45 (15.1)	13 (16.3)
30–39	1816 (16.9)	1773 (17.2)	30 (7.9)	13 (17.6)
40–49	2382 (19.4)	2296 (19.5)	78 (18.8)	8 (7.4)
50–59	2533 (19.9)	2428 (19.9)	82 (19.2)	23 (23.1)
≥60	5307 (26.0)	4967 (25.5)	281 (39.0)	59 (35.6)
Educational level				
Elementary or below	2599 (12.1)	2353 (11.5)	198 (27.5)	48 (30.1)
Middle school	1346 (7.6)	1258 (7.4)	74 (12.7)	14 (12.7)
High school	4542 (36.2)	4336 (36.1)	165 (39.6)	41 (41.2)
College or above	5218 (44.0)	5126 (45.0)	79 (20.2)	13 (15.9)
Household income				
Q1	3243 (17.2)	2844 (15.5)	304 (53.9)	95 (82.9)
Q2	3453 (24.5)	3320 (24.6)	117 (23.5)	16 (12.8)
Q3	3524 (28.4)	3446 (29.0)	73 (17.9)	5 (4.3)
Q4	3485 (29.9)	3463 (31.0)	22 (4.7)	0 (0.0)
Employment status				
Employed	8132 (63.3)	7844 (63.9)	239 (49.2)	49 (44.1)
Unemployed	5573 (36.7)	5229 (36.1)	277 (50.8)	67 (55.9)
Marital status				
Married (having children)	3207 (26.6)	3104 (26.8)	91 (22.5)	12 (10.2)
Married (not having children)	5990 (37.7)	5793 (38.1)	178 (28.8)	19 (16.2)
Unmarried/ others	4508 (35.8)	4176 (35.1)	247 (48.7)	85 (73.6)

Values are presented as n (%).

on urine cotinine or creatinine levels as well as 559 observations involving the use of e-cigarettes or heated tobacco products were additionally excluded to restrict the source of nicotine intake solely to cigarette smoking. ORs and their corresponding 95% CIs were estimated. R software V.4.2.3 (R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analysis. For both descriptive and regression analyses, the survey weights were adjusted to reflect the complex survey design of the KNHANES.³⁴

Following additional analyses were conducted. First, we explored the association between food insecurity and dual/poly use of tobacco products. Second, analyses were stratified by sex to account for differences in smoking patterns based on sex. We also examined disparities in self-reported and cotinine-verified smoking status by sex.

RESULTS

There were 5871 men and 7834 women in the study sample (table 1). Among the 13 705 survey participants, 96.1% had food security, 3.2% had mild food insecurity and 0.7% had moderate-to-severe food insecurity. Compared with the group with food security, those experiencing moderate-to-severe food insecurity

were characterised by a higher proportion of older individuals, individuals with lower educational and income levels, unemployed individuals and individuals with chronic conditions.

The survey-weighted prevalence of tobacco product use is presented in table 2. The prevalence of combustible cigarette use was 18.4% among those with food security, 23.5% among those with mild food insecurity and 45.1% among those with moderate-to-severe food insecurity. The prevalence of individuals using heated tobacco product was 4.4% among those with food security, 0.7% among those with mild food insecurity and 5.5% among those with moderate-to-severe food insecurity. The prevalence of individuals using e-cigarette was 2.6% for those with food security, 2.3% for those with mild food insecurity and 7.5% for those with moderate-to-severe food insecurity.

The associations between food insecurity and tobacco product use are shown in table 3. After adjusting for confounders, both mild (OR: 1.38, 95% CI: 1.01 to 1.89) and moderate-to-severe (OR: 3.36, 95% CI: 1.87 to 6.03) food insecurity, compared with food security, were associated with increased odds of combustible cigarette use. Moderate-to-severe food insecurity, compared with food security, was associated with increased odds of e-cigarette (OR: 3.49, 95% CI: 1.31 to 9.28). No clear association was observed between food insecurity and the use of heated tobacco products. Online supplemental table S1 shows that those with moderate-to-severe food insecurity were associated with dual/poly use of tobacco products (OR: 3.67, 95% CI: 1.45 to 9.29) compared with those without food insecurity.

The associations between food insecurity and urine cotinine-measured smoking status are presented in table 4. Compared with those with food security, those with mild and moderate-to-severe food insecurity were more likely to engage in high-intensity smoking (OR: 1.61, 95% CI: 1.09 to 2.38 for mild food insecurity and OR: 2.25, 95% CI: 1.04 to 4.86 for moderate-to-severe food insecurity).

Online supplemental table S2 and S3 show the sex-stratified associations between food insecurity and dependent variables. The association between food insecurity and combustible cigarette use was observed both in the male and female sample (online supplemental table S2). The association between food insecurity and high-intensity smoking was observed only in the male sample (online supplemental table S3). Online supplemental table S4 shows the disparities in self-reported and cotinine-verified smoking by sex revealing a large proportion of ‘hidden’ smoking among women. Finally, food insecurity showed no clear association with cotinine-verified current smoking among the female sample (online supplemental table S5).

DISCUSSION

In this study, we found that experiencing food insecurity was associated with an increased likelihood of combustible cigarette and e-cigarette use compared with those with non-food security. Additionally, food insecurity was associated with high-intensity smoking as determined by the urine cotinine level, a well-known nicotine metabolite.

Our findings indicate that the prevalence of food insecurity is lower in South Korea compared with high-income countries while the prevalence of tobacco product use is relatively high. This disparity can be attributed to various sociopolitical factors including the lack of robust anti-smoking policies for both traditional and e-cigarettes as well as the reported reluctance among many Koreans to engage in smoking cessation efforts.³⁵ Therefore, active policy efforts are required to promote anti-smoking

Table 2 Prevalence of the use of each tobacco product according to study characteristics. Survey weights were adjusted

	Combustible cigarette		Heated tobacco products		E-cigarette	
	Yes (n=2163)	No (n=11 542)	Yes (n=411)	No (n=13 294)	Yes (n=246)	No (n=13 459)
Food insecurity						
None	2015 (18.4)	11 058 (81.6)	402 (4.4)	12 671 (95.6)	232 (2.6)	12 841 (97.4)
Mild	105 (23.5)	411 (76.5)	3 (0.7)	513 (99.3)	8 (2.3)	508 (97.7)
Moderate-to-severe	43 (45.1)	73 (54.9)	6 (5.5)	110 (94.5)	6 (7.5)	110 (92.5)
Sex						
Male	1772 (31.8)	4099 (68.2)	330 (7.2)	5541 (92.8)	201 (4.3)	5670 (95.7)
Female	391 (5.8)	7443 (94.2)	81 (1.4)	7753 (98.6)	45 (0.9)	7789 (99.1)
Age group						
<30	344 (21.7)	1323 (78.3)	92 (6.1)	1575 (93.9)	94 (6.0)	1573 (94.0)
30–39	361 (23.3)	1455 (76.7)	132 (8.4)	1684 (91.6)	64 (4.6)	1752 (95.4)
40–49	445 (21.1)	1937 (78.9)	126 (6.4)	2256 (93.6)	48 (2.3)	2334 (97.7)
50–59	429 (19.0)	2104 (81.0)	47 (2.2)	2486 (97.8)	18 (0.9)	2515 (99.1)
≥60	584 (11.7)	4723 (88.3)	14 (0.2)	5293 (99.8)	22 (0.6)	5285 (99.4)
Educational level						
Elementary or below	257 (11.4)	2342 (88.6)	3 (0.2)	2596 (99.8)	3 (0.1)	2596 (99.9)
Middle school	235 (20.5)	1111 (79.5)	16 (1.4)	1330 (98.6)	11 (1.3)	1335 (98.7)
High school	937 (23.4)	3605 (76.6)	160 (4.5)	4382 (95.5)	115 (3.4)	4427 (96.6)
College or above	734 (16.5)	4484 (83.5)	232 (5.7)	4986 (94.3)	117 (2.9)	5101 (97.1)
Household income						
Q1	486 (19.0)	2757 (81.0)	42 (2.0)	3201 (98.0)	32 (1.8)	3211 (98.2)
Q2	616 (20.7)	2837 (79.3)	89 (3.9)	3364 (96.1)	64 (2.6)	3389 (97.4)
Q3	602 (20.3)	2922 (79.7)	158 (5.8)	3366 (94.2)	71 (2.9)	3453 (97.1)
Q4	459 (15.4)	3026 (84.6)	122 (4.5)	3363 (95.5)	79 (2.9)	3406 (97.1)
Employment status						
Employed	1518 (21.7)	6614 (78.3)	334 (5.6)	7798 (94.4)	180 (3.1)	7952 (96.9)
Unemployed	645 (13.5)	4928 (86.5)	77 (2.0)	5496 (98.0)	66 (1.8)	5507 (98.2)
Marital status						
Married (having children)	506 (18.2)	2701 (81.8)	151 (5.8)	3056 (94.2)	58 (2.2)	3149 (97.8)
Married (not having children)	773 (14.9)	5217 (85.1)	89 (2.3)	5901 (97.7)	50 (1.3)	5940 (98.7)
Unmarried/others	884 (23.1)	3624 (76.9)	171 (5.2)	4337 (94.8)	138 (4.3)	4370 (95.7)

Values are presented as n (weighted %).

initiatives, raise awareness about the risks of smoking and support smoking cessation programmes for Korean residents.

The findings of our study are consistent with those of previous studies showing that food insecurity is closely associated with cigarette smoking and e-cigarette use. Cross-sectional studies have consistently shown that food insecurity is associated with cigarette smoking.^{10 36 37} A recent cross-sectional study in the USA showed that e-cigarette use is associated with experiencing food insecurity.²¹ Moreover, a longitudinal study in the USA demonstrated that the transition from food security to food insecurity is associated with a 1.9-fold increase in the odds of engagement in smoking.⁹ They found a positive association between food insecurity and self-reported smoking intensity.⁹ A longitudinal study also found that food insecurity was prospectively associated with the likelihood of smoking at a 2-year follow-up.¹⁹ Another cohort study by Kim *et al* demonstrated that severe food insecurity was associated with increased odds of smoking at follow-up among the homeless or women with unstable housing.⁸ Methodologically, a US cross-sectional study showed that food insecurity is associated with increased odds of both firsthand and second-hand smoke exposure as confirmed by the serum cotinine level among pregnant and postpartum women.²² This finding aligns with our results indicating a positive association between food insecurity and smoking status as measured using urine cotinine.

Several mechanisms may explain the observed association between food insecurity and tobacco product use. First, food insecurity can serve as a primary stressor that contributes to chronic stress for individuals.¹⁴ Specifically, stress triggered by hunger, anxiety regarding future food consumption and concerns regarding the well-being of family members such as partners or dependent household members may lead individuals to rely on tobacco products and higher-intensity nicotine consumption as coping strategies. Previous studies have shown that chronic stress can reduce the capacity to manage cravings leading to increased nicotine dependence.^{38 39} Second, previous studies have shown that nicotine has an appetite-suppressing effect.^{17 40} Particularly in resource-constrained households where individuals may experience food insecurity, this effect, coupled with addiction, may influence the prioritisation of tobacco purchases over essential food items.⁴¹ A biological mechanism underlying this pathway involves the activation of proopiomelanocortin neurons which contributes to the nicotine-induced decrease in food intake and hunger.⁴⁰ Third, another important mechanism is the potential for reverse causation where tobacco product use may contribute to food insecurity by diverting funds from purchasing food. For instance, a longitudinal study demonstrated that ceasing smoking is linked to a decreased risk of food insecurity as it

Table 3 Association between food insecurity and use of tobacco products on logistic regression models (n=13 705)

	Tobacco products (outcome)			
	Combustible cigarette OR (95% CI)	Heated tobacco products OR (95% CI)	E-cigarette OR (95% CI)	Any type* OR (95% CI)
Food insecurity				
None	Reference	Reference	Reference	Reference
Mild	1.38 (1.01 to 1.89)	0.23 (0.06 to 0.80)	1.27 (0.57 to 2.86)	1.45 (1.07 to 1.98)
Moderate-to-severe	3.36 (1.87 to 6.03)	1.63 (0.56 to 4.75)	3.49 (1.31 to 9.28)	3.31 (1.85 to 5.92)
Sex				
Male	Reference	Reference	Reference	Reference
Female	0.13 (0.11 to 0.15)	0.21 (0.16 to 0.27)	0.23 (0.16 to 0.34)	0.13 (0.11 to 0.15)
Age group				
<30	Reference	Reference	Reference	Reference
30–39	1.52 (1.18 to 1.95)	1.21 (0.80 to 1.84)	0.87 (0.55 to 1.39)	1.56 (1.23 to 1.99)
40–49	1.38 (1.07 to 1.78)	0.92 (0.61 to 1.39)	0.47 (0.29 to 0.75)	1.32 (1.03 to 1.69)
50–59	1.07 (0.84 to 1.36)	0.32 (0.18 to 0.55)	0.16 (0.08 to 0.33)	0.97 (0.77 to 1.23)
≥60	0.48 (0.38 to 0.62)	0.05 (0.02 to 0.11)	0.16 (0.07 to 0.35)	0.46 (0.36 to 0.59)
Educational level				
Elementary or below	Reference	Reference	Reference	Reference
Middle school	1.31 (1.03 to 1.68)	2.64 (0.61 to 11.37)	6.13 (1.71 to 22.02)	1.36 (1.07 to 1.73)
High school	0.97 (0.76 to 1.25)	3.14 (0.78 to 12.62)	6.41 (1.42 to 28.97)	1.00 (0.78 to 1.27)
College or above	0.55 (0.42 to 0.72)	3.12 (0.77 to 12.63)	5.35 (1.19 to 23.95)	0.57 (0.44 to 0.75)
Household income				
Q1	Reference	Reference	Reference	Reference
Q2	0.92 (0.75 to 1.12)	0.92 (0.59 to 1.42)	1.02 (0.62 to 1.68)	0.89 (0.73 to 1.08)
Q3	0.87 (0.69 to 1.08)	1.08 (0.69 to 1.69)	1.04 (0.61 to 1.78)	0.89 (0.71 to 1.10)
Q4	0.62 (0.49 to 0.78)	0.83 (0.52 to 1.33)	1.05 (0.61 to 1.80)	0.66 (0.53 to 0.82)
Employment status				
Employed	Reference	Reference	Reference	Reference
Unemployed	0.76 (0.67 to 0.87)	0.63 (0.47 to 0.86)	0.73 (0.50 to 1.07)	0.77 (0.68 to 0.88)
Marital status				
Married (having children)	Reference	Reference	Reference	Reference
Married (not having children)	1.00 (0.82 to 1.21)	1.08 (0.76 to 1.54)	1.25 (0.70 to 2.23)	1.04 (0.86 to 1.26)
Unmarried/others	1.45 (1.18 to 1.77)	1.00 (0.70 to 1.42)	1.45 (0.96 to 2.19)	1.49 (1.23 to 1.82)

*Use of any types of combustible cigarette or heated tobacco products or e-cigarette.

reduces expenditure on cigarettes.²⁰ A recent study showed that the use of both combustible cigarettes and e-cigarettes was associated with increased odds of food insecurity.²¹ The relationship between food insecurity and the use of tobacco products can be bidirectional;¹⁹ thereby, instead of construing our findings as indicative of a unidirectional causal effect of food insecurity on tobacco product use, it should be considered

within the framework of reciprocal influence. The prevalence of tobacco product use and food insecurity is concentrated among households with low socioeconomic status. For example, community programmes responsible for providing food assistance should also consider supporting smoking cessation efforts to prevent the diversion of household funds to tobacco products.⁷ From a research perspective, future strategies should

Table 4 Association between food insecurity and urinary cotinine-verified smoking status on multinomial logistic regression models (n=12 221)

	Urinary cotinine-measured smoking intensity (reference outcome: non-smokers)			
	Low-intensity smoking		High-intensity smoking	
	Case/N	OR (95% CI)	Case/N	OR (95% CI)
Food insecurity				
None	960/11 657 (8.2%)	Reference	919/11 657 (7.9%)	Reference
Mild	39/469 (8.3%)	1.35 (0.88 to 2.05)	67/469 (14.3%)	1.61 (1.09 to 2.38)
Moderate-to-severe	8/95 (8.4%)	1.30 (0.55 to 3.08)	21/95 (22.1%)	2.25 (1.04 to 4.86)

1484 observations with missing data on urine cotinine or creatinine levels or those using heated tobacco products or e-cigarettes were excluded.

Survey participants with a urine cotinine level of <50 ng/mL were defined as cotinine-verified non-smokers (n=10 207). Participants were classified as high-intensity smokers (Co/Cr ratio ≥8.05 ng/mg; n=1007) or low-intensity smokers (Co/Cr ratio <8.05 ng/mg; n=1007).

Models adjusted for sex, age, educational level, household income, employment status and marital status.

Co/Cr ratio, cotinine-to-creatinine ratio.

include prospective studies designed to explore whether food insecurity predicts the initiation of tobacco product use and vice versa.

One novel finding of our study is that food insecurity is associated with high-intensity smoking. A previous study showed that food insecurity is positively associated with self-reported smoking intensity; however, this intensity did not increase with higher levels of food insecurity.⁹ In contrast, our study demonstrated that a higher level of food insecurity was associated with greater odds of engaging in high-intensity smoking. Measuring intensity using cotinine levels can offer the advantages of being less susceptible to recall bias and providing greater precision compared with self-reporting.²⁴ Individuals experiencing greater food insecurity may resort to smoking as a coping strategy for hunger or stress potentially leading to increased nicotine intake. Furthermore, higher smoking intensity can divert more household funds away from purchasing food and meals contributing a greater food insecurity.⁴² Another novel approach of our study was to explore the association between food insecurity and the use of e-cigarettes and heated tobacco products as well as combustible cigarettes. The findings of our study have significant policy implications particularly in light of the rising prevalence of alternative smoking products.⁴³ As these products gain popularity,⁴⁴ policy considerations should address their co-existence with food insecurity, taking into account the potential influence of food insecurity on their use as well as the possibility of these products exacerbating food insecurity. However, the small number of cases involving heated tobacco products limited our ability to establish a conclusive association with food insecurity necessitating future large-scale investigations.

In the sex-stratified analysis, we observed a high incidence of false negative self-reported smokers, particularly among women and no clear association between food insecurity and cotinine-measured smoking status in women. First, due to the influence of Confucian culture, smoking is considered a social taboo for women in Korea leading to social desirability bias where participants are reluctant to report their smoking status.²³ This bias is also likely to apply to e-cigarettes and heated tobacco products as well necessitating caution in interpretation. Women, who often manage household food supplies, may be more likely than men to avoid diverting funds to smoking when experiencing food insecurity. This behaviour could significantly mitigate the association between food insecurity and smoking status in the female sample.

This study had some limitations. First, as this was a cross-sectional study, we could not consider the temporal sequence between food insecurity and tobacco use. As mentioned previously, the relationship between food insecurity and tobacco use may be bidirectional. While food insecurity can serve as a risk factor for smoking initiation, a number of studies indicated that tobacco product use contributes to future food insecurity by diverting funds from food purchases.^{7 10 19–21} Therefore, rather than interpreting the results of our study as indicating the impact of food insecurity on tobacco product use, it should be interpreted as showing the association between food insecurity and tobacco product use encompassing the potential influence of tobacco product use on food insecurity. Further longitudinal studies should be conducted to elucidate the reciprocal relationship between how food insecurity can induce the use of various types of tobacco products and increase the smoking intensity and vice versa. Second, although urine cotinine is a widely used biomarker in epidemiological studies to assess nicotine exposure and smoking intensity, it was measured only once in this study; therefore, it should be acknowledged that it may not fully reflect

the usual smoking patterns of study participants. Therefore, repeated measurements of urine cotinine can be employed in future studies to evaluate the smoking status of survey participants more precisely. Third, most variables used in this study, except for urine cotinine, were self-reported which can lead to potential measurement biases such as recall bias. Fourth, the observed number of individuals with moderate-to-severe food insecurity and heated tobacco products and e-cigarette users was relatively small which precluded us from performing more in-depth analyses including stratified analyses by socioeconomic status.

Nevertheless, our study contributes positively to the literature in several ways. First, the use of a population-based sample enhances the generalisability of our findings. Second, to the best of our knowledge, this study is among the few to consider various types of tobacco use including heated tobacco products and e-cigarettes and their associations with food insecurity. Considering the recent increase in the use of tobacco products other than traditional cigarettes, this study provides valuable insights. Third, by measuring the urine cotinine level, we not only validated the association between food insecurity and smoking risk reported in the existing literature but also offered novel insights into the association with smoking intensity.

CONCLUSION

In this study, we found that food insecurity is associated with an increased likelihood of using both combustible cigarettes and e-cigarettes among Korean adults. Furthermore, greater food insecurity is associated with higher odds of high-intensity smoking as confirmed by the urine cotinine level. While further longitudinally-designed investigations are required to disentangle the temporal and bidirectional relationship between food insecurity and tobacco product use, our study suggests that policymakers should consider the coexistence of food insecurity and tobacco product use.

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REFERENCES

- Burki T. Food security and nutrition in the world. *Lancet Diabetes Endocrinol* 2022;10:622.
- FAO. *The State of Food Security and Nutrition in the World 2023*. Rome: FAO: FAO, 2023:6–11.
- Bloem JR, Farris J. The COVID-19 pandemic and food security in low- and middle-income countries: a review. *Agric & Food Secur* 2022;11:55.
- Choi JH. Food Insecurity Is Associated with Dietary Consumption during the COVID-19 Pandemic: Data from the Korea National Health and Nutrition Examination Survey 2019–2020. *Nutrients* 2023;15:772.
- Parekh T, Xue H, Cheskin LJ, et al. Food insecurity and housing instability as determinants of cardiovascular health outcomes: A systematic review. *Nutr Metab Cardiovasc Dis* 2022;32:1590–608.
- Sun Y, Liu B, Rong S, et al. Food Insecurity Is Associated With Cardiovascular and All-Cause Mortality Among Adults in the United States. *JAHA* 2020;9.
- Kim-Mozeleski JE, Pandey R. The Intersection of Food Insecurity and Tobacco Use: A Scoping Review. *Health Promot Pract* 2020;21:1245–1385.
- Kim JE, Flentje A, Tsoh JY, et al. Cigarette Smoking among Women Who Are Homeless or Unstably Housed: Examining the Role of Food Insecurity. *J Urban Health* 2017;94:514–24.
- Sheira LA, Frongillo EA, Hahn J, et al. Relationship between food insecurity and smoking status among women living with and at risk for HIV in the USA: a cohort study. *BMJ Open* 2021;11:e054903.
- Kang SY, Cho HJ. Association Between the Use of Tobacco Products and Food Insecurity Among South Korean Adults. *Int J Public Health* 2022;67:1604866.
- Pengpid S, Peltzer K. Food insecurity and health outcomes among community-dwelling middle-aged and older adults in India. *Sci Rep* 2023;13:1136.
- Chai X, Mei J. Investigating food insecurity, health lifestyles, and self-rated health of older Canadians living alone. *BMC Public Health* 2022;22:2264.
- Kim-Mozeleski JE, Chagin KM, Sehgal AR, et al. Food insecurity, social needs, and smoking status among patients in a county hospital system. *Prev Med Rep* 2022;29:101963.
- Pourmotabbed A, Moradi S, Babaei A, et al. Food insecurity and mental health: a systematic review and meta-analysis. *Public Health Nutr* 2020;23:1778–90.
- Bloom EL, Farris SG, DiBello AM, et al. Smoking-related weight and appetite concerns and use of electronic cigarettes among daily cigarette smokers. *Psychol Health Med* 2019;24:221–8.
- Schwartz A, Bellissimo N. Nicotine and energy balance: a review examining the effect of nicotine on hormonal appetite regulation and energy expenditure. *Appetite* 2021;164.
- Leeman RF, O'Malley SS, White MA, et al. Nicotine and food deprivation decrease the ability to resist smoking. *Psychopharmacol (Berl)* 2010;212:25–32.
- Mohammed K, Batung E, Kansanga MM, et al. Alcohol misuse as a social determinant of food insecurity among smallholder farmers. *Soc Sci Med* 2024;340:116489.
- Kim-Mozeleski JE, Poudel KC, Tsoh JY. Examining Reciprocal Effects of Cigarette Smoking, Food Insecurity, and Psychological Distress in the U.S. *J Psychoact Drugs* 2021;53:177–84.
- Berry KM, Drew JAR, Brady PJ, et al. Impact of smoking cessation on household food security. *Ann Epidemiol* 2023;79:49–55.
- Gu D, Max WB, Yao T, et al. Association between e-cigarette use and food insecurity among low-income adults. *Tob Control* 2023;32:e212–9.
- Sanjeevi N, Sachdev PK. Household food insecurity and in-utero and early life smoke exposure: Data from NHANES 2003–2016. *Prev Med* 2021;150:106710.
- Park MB, Kim C-B, Nam EW, et al. Does South Korea have hidden female smokers: discrepancies in smoking rates between self-reports and urinary cotinine level. *BMC Womens Health* 2014;14:156.
- Thomas CE, Wang R, Adams-Haduch J, et al. Urinary Cotinine Is as Good a Biomarker as Serum Cotinine for Cigarette Smoking Exposure and Lung Cancer Risk Prediction. *Cancer Epidemiol Biomarkers Prev* 2020;29:127–32.
- Kweon S, Kim Y, Jang M, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol* 2014;43:69–77.
- Korea Disease Control and Prevention Agency. Analysis Guideline for Using Raw Data for the Korea National Health and Nutrition Examination Survey Osong: Korea Disease Control and Prevention Agency. 2023.
- Oh K, Kim Y, Kweon S, et al. Korea National Health and Nutrition Examination Survey, 20th anniversary: accomplishments and future directions. *Epidemiol Health* 2021;43:e2021025.
- Kim K, Hong SA, Kwon SO, et al. Development of Food Security Measures for Korean National Health and Nutrition Examination Survey. *Korean J Nutr* 2011;44:551.
- Kim K, Hong SA, Kwon SO, et al. Validation of Food Security Measures for the Korean National Health and Nutrition Examination Survey. *Korean J Community Nutr* 2011;16:771.
- Rabbitt MP, Hales LJ, Burke MP, et al. *Household Food Security in the United States in 2022*. Washington, DC: US Department of Agriculture, Economic Research Service, 2023:4.
- Kim HJ, Oh K. Household food insecurity and dietary intake in Korea: results from the 2012 Korea National Health and Nutrition Examination Survey. *Public Health Nutr* 2015;18:3317–25.
- Benowitz NL, Iii PJ, Ahijevych K, et al. Biochemical verification of tobacco use and cessation. *Nicotine & Tobacco Research* 2002;4:149–59.
- Park MB. Comparison of secondhand smoking exposure between self-report and creatinine-corrected urine cotinine: Result from Korean NHANES 2009–2018. *J Formos Med Assoc* 2024;123:218–27.
- Lumley T. Analysis of Complex Survey Samples. *J Stat Soft* 2004;9:1–19.
- Gunter R, Szeto E, Jeong S-H, et al. Cigarette Smoking in South Korea: A Narrative Review. *Korean J Fam Med* 2020;41:3–13.
- Kim JE, Tsoh JY. Cigarette Smoking Among Socioeconomically Disadvantaged Young Adults in Association With Food Insecurity and Other Factors. *Prev Chronic Dis* 2016;13:E08.
- Bergmans RS, Coughlin L, Wilson T, et al. Cross-sectional associations of food insecurity with smoking cigarettes and heavy alcohol use in a population-based sample of adults. *Drug Alcohol Depend* 2019;205:107646.
- Hobkirk AL, Krebs NM, Muscat JE. Income as a moderator of psychological stress and nicotine dependence among adult smokers. *Addict Behav* 2018;84:215–23.
- Carim-Todd L, Mitchell SH, Oken BS. Impulsivity and Stress Response in Nondependent Smokers (Tobacco Chippers) in Comparison to Heavy Smokers and Nonsmokers. *Nicotine Tob Res* 2016;18:547–56.
- Mineur YS, Abizaid A, Rao Y, et al. Nicotine decreases food intake through activation of POMC neurons. *Science* 2011;332:1330–2.
- Guillaumier A, Bonevski B, Paul C. "Cigarettes are priority": a qualitative study of how Australian socioeconomically disadvantaged smokers respond to rising cigarette prices. *Health Educ Res* 2015;30:599–608.
- Swarnata A, Kamilah FZ, Wisana IDGK, et al. Crowding-out effect of tobacco consumption in Indonesia. *Tob Control* 2024;33:s81–7.
- Kim SJ, Park BY. Changes in smoking patterns and characteristics of Koreans using the Korea National Health and Nutrition Examination Survey 2013–2021 data. *Public Health (Fairfax)* 2024;227:259–66.
- Ju H, Lee H, Choi J, et al. The online promotion strategies of e-cigarette and heated tobacco product retailers in South Korea following the COVID-19 pandemic: Implications for regulation. *Tob Induc Dis* 2024;22.