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Gender differences in the association between food costs and obesity in Korean adults: an analysis of a population-based cohort

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ABSTRACT

BACKGROUND/OBJECTIVES: Prior studies, mostly conducted in Western countries, have suggested that the low cost of energy-dense foods is associated with an increased risk of obesity. This study aimed to investigate the association between food costs and obesity risk among Koreans who may have different food cost and dietary patterns than those of Western populations.
SUBJECTS/METHODS: We used baseline data from a cohort of 45,193 men and 83,172 women aged 40–79 years (in 2006–2013). Dietary intake information was collected using a validated food frequency questionnaire. Prudent and Western dietary patterns extracted via principal component analysis. Food cost was calculated based on Korean government data and market prices. Logistic regression analyses were performed to investigate the association of daily total, prudent, and Western food cost per calorie with obesity.
RESULTS: Men in the highest total food cost quintile had 15% higher odds of obesity, after adjusting for demographic characteristics and lifestyle factors (adjusted odds ratio, 1.15; 95% confidence interval, 1.08–1.22; P-trend < 0.001); however, this association was not clear in women (P-trend = 0.765). While both men and women showed positive associations between prudent food cost and obesity (P-trends < 0.001), the association between Western food cost and obesity was only significant in men (P-trend < 0.001).
CONCLUSIONS: In countries in which consumption of Western foods is associated with higher food costs, higher food costs are associated with an increased risk of obesity; however, this association differs between men and women.

Keywords: Obesity; diet, healthy; diet, Western; cohort studies; Asian

INTRODUCTION

Obesity is one of the leading global public health problems, which substantially increases the risk of various chronic diseases including diabetes mellitus, hypertension, myocardial infarction, stroke, and several cancers [1]. World Health Organization estimated that about 39% and 13% of world's adult population were overweight and obese, respectively [2]. The prevalence of obesity in Korea is gradually increasing. Using Asian-Pacific body mass index

Conflict of Interest
The authors declare no potential conflicts of interests.

Author Contributions
Conceptualization: Park S, Kim J; Formal analysis: Park S; Investigation: Park S; Methodology: Park S, Kim J; Supervision: Kim J; Validation: Park S, Kim J; Writing - original draft: Park S; Writing - review & editing: Park S, Kim J.

(BMI) criteria of obesity (≥ 25 kg/m^2), the prevalence increased from 24.0% in 1998 to 33.8% in 2019 [3]. Notably, this trend is significant in men; the prevalence of obesity increased from 25.1% in 1998 to 41.6% in 2017. In contrast, the increase of obesity in women slowed down and showed plateaued pattern (approximately 26%) [4].

Food cost is an important factor guiding food selection and energy intake. Previous studies from Western countries, mostly the United States (US) or European countries, have suggested that the high (and rising) costs of healthy food (e.g., fruits and vegetables) relative to those of less healthy food items contribute to an inadequate intake of low-energy density diets [5-7]. These studies have reported that energy-dense foods, such as red and processed meat, sugar, and fast food, are affordable and accessible for low-income consumers, in turn, increasing their risk of obesity, compared to wealthier individuals [5-7]. Similarly, one review study noted negative associations between food cost and weight outcomes [8]. Although negative associations between food costs and weight outcomes are common in Western countries, this pattern may not persist in Asian countries, where energy-dense food items are relatively expensive. When analyzing the relative caloric prices for different food categories across 176 countries, healthy foods are typically expensive in most regions of the world [9]. However, animal-sourced food costs vary, being cheaper in the US and European countries and relatively expensive in East Asian countries [9]. While positive association between consumption and high cost in healthy food maybe universal, food cost differential in Western food indicates that the negative association between food cost and obesity may not be applicable in Asian countries such as Korea. Therefore, we hypothesize that consuming healthy, prudent foods may be related to higher food costs, linking to the decreased risk of obesity. On the other hand, consuming less healthy, Western foods may be related to higher food costs, which may be associated with the increased risk of obesity.

Studies suggest that there are gender differences in eating habits and food choices [10,11], which may lead to different food expenditures and obesity in men and women. To the best of our knowledge, no previous studies have examined the association between food costs and obesity in Korean men and women. Using baseline data from a population-based cohort of Korean adults, we investigated the associations between total daily food costs and the risk of obesity. Secondarily, we separated total food costs into prudent and Western food costs, and evaluated whether food cost per dietary pattern was associated with the risk of obesity.

SUBJECTS AND METHODS

Study design and study population

The Korean Genome and Epidemiology Study_Health Examinees (KoGES_HEXA) is an on-going, population-based cohort study investigating the genetic and environmental etiology of common complex diseases in Koreans [12]. National Health Insurance Service invited its subscribers and their dependents aged ≥ 40 years to complete a biannual general health examination. Between 2004 and 2013, a total of 173,209 community residents aged 40–79 years were recruited. Participants provided written informed consent [13]. The Institutional Review Boards at the Korea Disease Control and Prevention Agency and Kyung Hee University (KHGIRB-19-398) approved the study protocol.

For this study, we excluded participants with extreme total energy intakes (< 800 or > 4,200 kcal/day men; < 500 or > 3,500 kcal/day women; n = 6,117), as well as those with a diagnosis of any cardiovascular disease (i.e., myocardial infarction, stroke, angina) or cancer (n = 10,967), because chronic diseases may change individual's dietary patterns. We excluded participants who completed the study between January 2004 and January 2006, when the first version of survey questionnaire was administered (n = 6,989). This survey questionnaire systematically did not include an item assessing monthly household income, one of the potential confounders that may influence the association between food cost and obesity. We then excluded participants with missing information on any variables included in the analysis (i.e., missingness on obesity, age, education level, occupation, marital status, physical activity, smoking and drinking status, and income; n = 20,771). Our final sample size was 128,365 (74.1% of original sample), encompassing 45,193 men and 83,172 women (**Supplementary Fig. 1**).

Measurements

Obesity

Trained staff at the national health examination centers obtained anthropometric information during the health examination. Using height and weight information, we calculated BMI (kg/m^2), and used BMI ≥ 25 kg/m^2 as a cut-off to define obesity [14].

Food cost

A validated 106-item food frequency questionnaire was used to assess participants' food and beverage intakes in the previous year. Participants reported the frequency and portion size of their food consumption. The reported portion size consumed per day was used as the measurement unit. After excluding 2 items that did not specify ingredients (i.e., soup, stew), the remaining 104 food items were categorized into 16 food groups (**Appendix 1**). To identify dietary pattern, we performed principal component analysis (PCA) on these food groups [15]. We retained factors based on having an eigenvalue ≥ 2, the scree plot, and their interpretability. The orthogonal rotation (varimax) procedure permitted factors to be uncorrelated, increasing interpretability. Food groups with factor loading ≥ |0.20| were considered to have an important contribution to the pattern. Based on the PCA results, we derived 2 patterns: prudent dietary pattern (including green and yellow vegetable; light colored vegetable; seafood; mushroom; kimchi and salted food; legume; and fruit) and Western dietary patterns (including red meat; white and other meat; processed meat; dairy; sweet; beverage; flour-based food; white rice; and grains) (**Supplementary Table 1**).

For each food item, we used the current or the most recent costs of food (retrieved in June 2021) to calculate total daily food cost; this was necessary since we were unable to obtain the cost of each food item at the time of the completion of the food frequency questionnaire. The costs of raw products (e.g., grain, vegetables, meat, or fish) were retrieved from the Korea Agro-fisheries & Food Trade Corporation (aT; www.at.or.kr), a public institution under the Ministry of Agriculture, Food, and Rural Affairs food industry. The prices of a few food items not reported by the aT (mostly processed foods) were obtained from supermarket prices. To calculate food cost, we first multiplied the cost of each food item by the consumed portion size on an average day, based on the participant's questionnaire responses. By summing up cost of each food item that belongs either to prudent or Western food that were derived from the PCA, we obtained prudent and Western food costs. Because only grains showed negative factor loadings, we weighted grains by multiplying the corresponding factor loading. Then, total daily food cost was calculated by summing up prudent and Western food costs. We used US$ as the unit of food cost (US$1 ≈ 1,000 Korean Won [KRW]).

Finally, we created 3 variables of food costs per calorie: 1) total food costs per calorie (i.e., total food costs divided by total energy intake), 2) prudent food costs per calorie (i.e., prudent food costs divided by energy intake from prudent food), and Western food costs per calorie (i.e., Western food costs divided by energy intake from Western food).

Covariates

Participants completed a structured questionnaire to report their relevant demographic information (i.e., age, sex, education level, employment status, marital status, income) and lifestyle factors (i.e., physical activity, smoking, alcohol use). Education level was categorized into '≤ middle school graduate,' 'high school graduate,' and '≥ some college.' Employment status was dichotomized into 'employed' (participants who listed any paid occupation) and 'unemployed' (including housewives and 'no occupation'). Marital status was dichotomized into 'with a partner' (including married and living with a partner) and 'without a partner.' Physical activity was assessed as whether the participant had regularly exercised enough to sweat. Smoking and alcohol use was categorized as 'never,' 'former,' and 'current' user, respectively. Total energy intake per day was calculated using a food composition table developed from the Korean Nutrition Society [16]. Monthly household income was categorized into 'low' (< US$2,000), 'middle' (US$2,000–3,999), and 'high' (≥ US$4,000) (US$1 ≈ 1,000 KRW).

Statistical analysis

All analyses were performed separately for men and women. Participant characteristics, categorized by quintiles of total food costs per calorie, were described using means and standard deviations (SDs) or percentages. The differences across quintiles were assessed using analysis of variance (ANOVA) tests (for continuous variables) and χ^2 tests (for categorical variables). We also reported effect size estimates which indicate the practical significance of differences by accounting for the sample size. Cramér's *V* (with χ^2 test), and omega-squared (ω^2; with ANOVA test) were used to measure the degree of difference. Cramér's $V < 0.1$ represents a negligible association, whereas > 0.1, > 0.2, > 0.4 indicate weak, moderate, and relatively strong associations, respectively [17,18]. For ω^2, 0.01, 0.06, 0.14 represent small, medium, and large effect sizes, respectively [19-21].

Two nested logistic regression analysis models were constructed to understand whether an increase in the quintiles of total food cost per calorie was linked to obesity. Model 1 minimally adjusted for total energy intake and age. Model 2 additionally adjusted for education, employment status, marital status, physical activity, smoking status, alcohol use, and income. We repeated the same series of logistic regression models for quintiles of prudent and Western food costs per calorie in relation to obesity. Using restricted cubic splines with 4 knots (5^{th}, 35^{th}, 65^{th}, and 95^{th} percentiles), we also tested linear trends across total, prudent, and Western food cost quintiles in the association with obesity [22]. After eliminating the extreme values (< 0.05^{th} or > 99.5^{th} percentiles) and setting the reference point at the 5^{th} percentile, logistic regression models were adjusted for age, sex, education level, employment status, marital status, physical activity, smoking status, alcohol use, total energy intake, and monthly household income.

For the sensitivity analysis, we implemented Multivariate Imputation using Chained Equations (MICE) to the values that had missing information on any variables included in the analysis (n = 20,771; total sample size n = 149,163, 86.1% of total population) [23]. We created 20 imputations and set a random seed number for reproducibility [24]. Then, we

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conducted the same logistic regression analyses, controlling for demographic information and lifestyle factors.

All statistical tests were 2-sided, with statistical significance set at $P < 0.05$. Stata version 15.1 (StataCorp, College Station, TX, USA) was used for all analyses.

RESULTS

Participant characteristics, according to food cost quintile

The average total daily food cost/1,000 kcal was higher for women ($6.5) than men ($6.1). Men in the highest food cost quintile were more likely to be obese, have a high education level, live with a partner, be physically active, be current smokers or drinkers (*P*-value's < 0.001), but the effect sizes were negligible (*V*'s < 0.1) (**Table 1**). Men in the high food cost quintiles tended to have high energy intake, with moderate to strong effect size ($P < 0.001$, $\omega^2 = 0.09$). Women in the highest quintile tended to be unemployed, live with a partner, be physically active, have never been smokers, but be current drinkers (*P*-value's < 0.001) with negligible effect sizes (*V*'s ≤ 0.1). Women in the high quintiles were more likely to have high energy intake with moderate effect size ($P < 0.001$, $\omega^2 = 0.06$). For both men and women who were in the higher quintiles were more likely to have higher income levels with moderate to strong effect sizes ($\omega^2 = 0.08$ for men; and $\omega^2 = 0.09$ for women).

Association between food cost and obesity

Food cost was positively associated with obesity in men (*P*-trend < 0.001; **Table 2**). Men in the highest food cost quintile had 15% increased odds of obesity, compared with those in the lowest quintile, adjusting for covariates (adjusted odds ratio $[aOR]_{Q5}$, 1.15; 95% confidence interval [CI], 1.08–1.22). This association was not observed among women in the fully-adjusted model (*P*-trend = 0.765). There was a strong linear relationship between food cost and obesity in men, but not in women (**Fig. 1A**).

When we divided total food costs into prudent and Western food costs, prudent food costs were positively associated with obesity in men and women (*P*-trends < 0.001; **Table 3**). In Model 2, men and women in the highest prudent food quintile were linked to 1.15- and 1.24-times higher odds of obesity, compared to those in the lowest quintile (aOR_{Q5}, 1.15; 95% CI, 1.08–1.22 men; and aOR_{Q5}, 1.24; 95% CI, 1.18–1.30 women). However, men and women showed distinct relationship between Western food cost and obesity. Western food cost was positively associated with obesity in men (*P*-trend < 0.001), and men in the highest Western food quintile showed 25% increase in odds of obesity (aOR_{Q5}, 1.25; 95% CI, 1.17–1.34). Adjusting only for energy intake and age, the association between Western food cost and obesity was negative in women (Model 1; *P*-trend < 0.001). In Model 2, the relationship between Western food cost and obesity was not significant ($P = 0.062$), suggesting that other factors, such as education level, physical activity, or income, may have significant role in this association. Strong linear relationship was observed between prudent food cost and obesity both in men and women (**Fig. 1B**). However, the relationship between Western food cost and obesity showed linear relationship only in men (**Fig. 1C**).

After implementing MICE (50,820 men and 98,316 women), we conducted the sensitivity analysis. The associations between food costs and obesity were largely consistent with those of the main analysis, adjusting for covariates. Total food costs were positively associated with

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Table 1. Participant characteristics according to quintiles of food cost (n = 128,365)

Characteristics	Quintiles of total food cost per calorie					*P*-value	Effect size
	1 (Lowest)	2	3	4	5 (Highest)		
Men (n = 45,193, 35.2%)							
No. of sample size	9,039	9,039	9,038	9,039	9,038	-	-
Daily food cost (US$)/1,000 kcal	3.5 ± 0.8	5.0 ± 0.3	5.9 ± 0.3	7.0 ± 0.4	9.2 ± 1.7	-	-
Obesity	37.0	38.5	39.5	41.2	42.8	< 0.001	0.04
Age (yrs)	53.7 ± 8.9	53.2 ± 8.7	52.9 ± 8.6	53.1 ± 8.6	53.6 ± 8.5	< 0.001	0.00
Education						< 0.001	0.06
≤ Middle school graduate	26.8	22.5	20.0	19.3	17.6		
High school graduate	34.0	33.5	33.4	34.2	33.3		
≥ Some college	39.2	43.9	46.6	46.6	49.1		
Employed	80.5	82.9	83.8	83.7	82.5	< 0.001	0.03
Living with a partner	91.8	93.7	95.0	95.1	95.4	< 0.001	0.06
Physically active	51.6	54.2	56.0	59.7	62.9	< 0.001	0.08
Smoking status						< 0.001	0.03
Never smoker	30.9	27.7	27.2	25.9	26.7		
Former smoker	38.9	39.6	39.4	40.9	39.7		
Current smoker	30.2	32.8	33.5	33.2	33.5		
Alcohol use						< 0.001	0.04
Never drinker	22.2	19.6	19.5	17.8	17.6		
Former drinker	7.7	6.4	5.5	5.5	5.7		
Current drinker	70.1	74.0	75.0	76.7	76.6		
Total energy intake (kcal/d)	1,646.0 ± 438.9	1,795.6 ± 445.8	1,892.3 ± 468.9	2,003.3 ± 517.9	2,093.8 ± 608.7	< 0.001	0.09
Monthly household income						< 0.001	0.08
US$ < 2,000	35.0	27.3	24.7	23.9	22.0		
US$2,000–3,999	43.4	45.4	45.3	46.1	44.9		
US$ ≥ 4,000	21.7	27.3	30.0	30.0	33.2		
Women (n = 83,172, 64.8%)							
No. of sample size	16,635	16,634	16,635	16,634	16,634	-	-
Daily food cost (US$) /1,000 kcal	3.7 ± 0.8	5.3 ± 0.3	6.4 ± 0.3	7.5 ± 0.4	9.8 ± 1.7	-	-
Obesity	29.1	28.4	28.1	27.7	27.5	< 0.001	0.01
Age (yrs)	53.1 ± 8.4	52.2 ± 8.2	51.8 ± 7.9	52.0 ± 7.8	52.1 ± 7.4	< 0.001	0.00
Education						< 0.001	0.08
≤ Middle school graduate	47.0	39.1	35.0	32.9	31.1		
High school graduate	33.8	37.0	39.3	40.1	42.2		
≥ Some college	19.3	23.9	25.6	27.0	26.7		
Employed	42.5	42.9	42.1	39.8	38.5	< 0.001	0.03
Living with a partner	83.2	86.0	87.4	88.3	88.4	< 0.001	0.06
Physically active	42.5	47.0	50.6	53.0	57.4	< 0.001	0.10
Smoking status						< 0.001	0.01
Never smoker	96.7	96.6	96.6	96.3	95.7		
Former smoker	1.3	1.2	1.1	1.2	1.5		
Current smoker	2.1	2.2	2.3	2.5	2.8		
Alcohol use						< 0.001	0.04
Never drinker	70.1	66.7	64.8	64.5	62.1		
Former drinker	2.2	1.8	1.7	1.7	2.0		
Current drinker	27.8	31.5	33.5	33.8	35.9		
Total energy intake (kcal/d)	1,514.2 ± 401.0	1,683.1 ± 434.6	1,774.8 ± 483.9	1,847.3 ± 535.8	1,834.7 ± 601.4	< 0.001	0.06
Monthly household income						< 0.001	0.09
US$ < 2,000	44.4	35.7	32.5	30.5	28.0		
US$2,000–3,999	38.4	41.3	42.8	44.4	44.4		
US$ ≥ 4,000	17.2	23.0	24.6	25.1	27.6		

Values are presented as mean ± SD or percentage. US$1 ≈ 1,000 Korean Won (KRW).

obesity in men (aOR_{Q5}, 1.16; 95% CI, 1.09–1.23; *P*-trend < 0.001), but not in women (*P*-trend = 0.135) (**Supplementary Table 2**).

Table 2. Association between quintiles of total food cost and obesity, stratified by gender

Gender	Quintiles of total food cost per calorie					*P*-trend
	1 (Lowest)	2	3	4	5 (Highest)	
Men (n = 45,193, 35.2%)						
Crude	Ref.	1.06 (0.99–1.12)	**1.10 (1.04–1.17)**	**1.19 (1.12–1.26)**	**1.29 (1.21–1.37)**	< 0.001
Model 1[1)]	Ref.	1.02 (0.95–1.07)	1.05 (0.98–1.11)	**1.11 (1.04–1.18)**	**1.19 (1.11–1.26)**	< 0.001
Model 2[2)]	Ref.	1.01 (0.95–1.07)	1.02 (0.96–1.09)	**1.08 (1.01–1.15)**	**1.15 (1.08–1.22)**	< 0.001
Women (n = 83,172, 64.8%)						
Crude	Ref.	0.96 (0.92–1.01)	**0.93 (0.89–0.98)**	**0.94 (0.90–0.98)**	**0.91 (0.87–0.95)**	< 0.001
Model 1[1)]	Ref.	0.99 (0.94–1.04)	0.96 (0.92–1.01)	**0.95 (0.90–1.00)**	**0.92 (0.87–0.97)**	0.009
Model 2[2)]	Ref.	1.03 (0.98–1.08)	1.02 (0.97–1.07)	1.03 (0.98–1.08)	1.01 (0.96–1.07)	0.765

Values are presented as odds ratio (95% confidence interval). Bolded texts represent statistically significant coefficients. Obesity was defined as body mass index ≥ 25 kg/m^2.
1)Model 1 was adjusted for total energy intake and age.
2)Model 2 was adjusted for total energy intake, age, education, employment status, marital status, physical activity, smoking status, alcohol use, and monthly household income.

DISCUSSION

In this study, higher food cost was significantly associated with a higher risk of obesity among Korean men, but not in women. When we analyzed prudent and Western food costs separately, higher cost from prudent foods was positively related to higher odds of obesity in men and women. However, higher cost from Western foods was positively associated with increased risk of obesity in men, but not in women. These findings remained largely consistent in the sensitivity analyses conducted with larger sample size using MICE.

Previous studies that investigated the relationship between food cost per calorie and obesity have produced inconsistent findings. Goldman *et al.* [25] reported a negative association between food price and BMI among the US population, in which a 10% reduction in price per calorie was associated with a 0.26-unit or 0.77% increase in BMI within 2 years. In contrast, Lopez *et al.* [26] noted a positive association between price per calorie and weight gain in a Spanish cohort; higher daily food cost was associated with a 20% increased risk of gaining at least 0.6 kg/year during the maximum 6 years of follow-up time. Although different measures of body weight or obesity may produce varied association directions, our findings demonstrated a positive link between food cost per calorie and the risk of obesity among Korean men.

In most regions of the world, healthy foods are typically expensive [9], which was also the case in Korea. Prior studies consistently reported negative association between healthy food intake and weight gain [27,28]. One study conducted in the US identified that 1% increase in household fruit and vegetable expenditure share was associated with 9% decrease in incidence of adult obesity [29], Unlike these studies, our findings demonstrated that spending more money on prudent food was significantly associated with increased risk of obesity both in men and women. One possible explanation for this positive relationship may be the fact that some less-healthy foods could not have been separated from more-healthy food (e.g., fruit juices were included to fruit category) in the dataset. Further research is warranted to understand mechanism of this unique relationship.

Our findings suggest a clear gender difference in the association between Western food cost and obesity. This positive association among men may be due to their positive attitude or perception toward the specific Western foods. As 'masculinity' is often linked with meat consumption [30,31], Korean men indicated higher levels of healthy image and preference

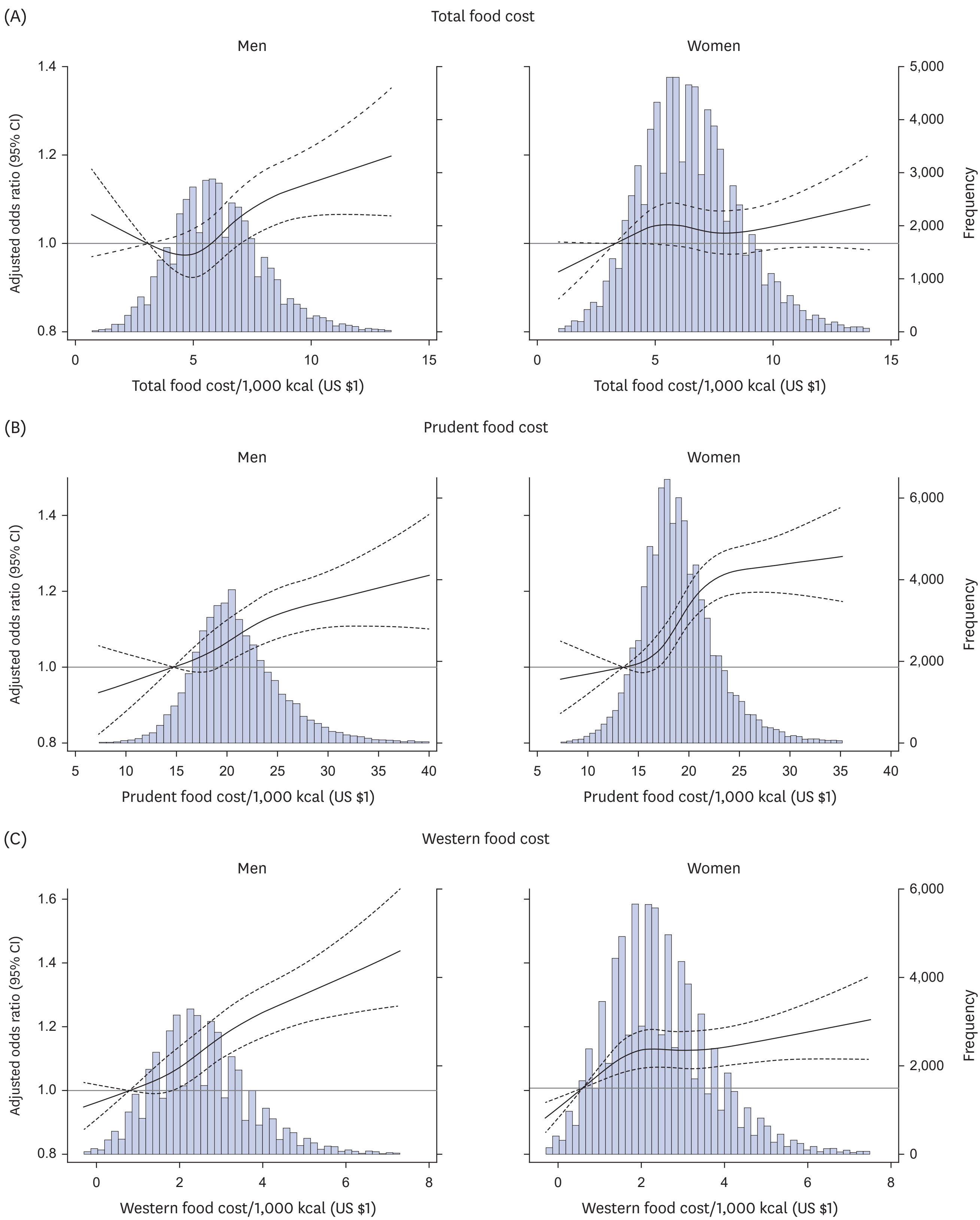

Fig. 1. Adjusted association for obesity according to the food cost per calorie, stratified by gender. The histogram in gray shows the distribution of total daily food cost (/1,000 kcal, US$). The ORs were adjusted for age, sex, education level, employment status, marital status, physical activity, smoking status, alcohol use, total energy intake, and monthly household income. (A) Total food cost. (B) Prudent food cost. (C) Western food cost.

Table 3. Association of quintiles of prudent and Western food cost with obesity, stratified by gender

Food groups and gender	Quintiles of food cost per calorie					*P*-trend
	1 (Lowest)	2	3	4	5 (Highest)	
Prudent food						
Men (n = 45,193, 35.2%)						
Crude	Ref.	1.02 (0.96–1.08)	1.05 (0.99–1.11)	1.06 (1.00–1.13)	**1.12 (1.05–1.19)**	< 0.001
Model 1[1)]	Ref.	1.01 (0.95–1.07)	1.05 (0.99–1.11)	**1.07 (1.01–1.14)**	**1.14 (1.07–1.21)**	< 0.001
Model 2[2)]	Ref.	1.01 (0.95–1.07)	1.05 (0.99–1.11)	**1.07 (1.01–1.14)**	**1.15 (1.08–1.22)**	< 0.001
Women (n = 83,172, 64.8%)						
Crude	Ref.	1.05 (1.00–1.10)	**1.15 (1.09–1.20)**	**1.22 (1.16–1.28)**	**1.30 (1.24–1.36)**	< 0.001
Model 1[1)]	Ref.	1.05 (1.00–1.10)	**1.16 (1.10–1.21)**	**1.24 (1.18–1.30)**	**1.33 (1.27–1.40)**	< 0.001
Model 2[2)]	Ref.	1.03 (0.98–1.08)	**1.12 (1.06–1.17)**	**1.18 (1.12–1.24)**	**1.24 (1.18–1.30)**	< 0.001
Western food						
Men (n = 45,193, 35.2%)						
Crude	Ref.	**1.13 (1.07–1.21)**	**1.18 (1.11–1.25)**	**1.29 (1.22–1.37)**	**1.43 (1.35–1.52)**	< 0.001
Model 1[1)]	Ref.	**1.09 (1.02–1.15)**	**1.10 (1.03–1.17)**	**1.17 (1.10–1.25)**	**1.26 (1.18–1.35)**	< 0.001
Model 2[2)]	Ref.	**1.08 (1.01–1.15)**	**1.09 (1.03–1.16)**	**1.17 (1.09–1.24)**	**1.25 (1.17–1.34)**	< 0.001
Women (n = 83,172, 64.8%)						
Crude	Ref.	**0.94 (0.90–0.99)**	**0.86 (0.82–0.90)**	**0.83 (0.79–0.87)**	**0.76 (0.73–0.80)**	< 0.001
Model 1[1)]	Ref.	1.02 (0.97–1.07)	0.97 (0.93–1.02)	0.98 (0.93–1.03)	**0.92 (0.88–0.97)**	0.003
Model 2[2)]	Ref.	**1.06 (1.01–1.11)**	1.04 (0.99–1.10)	**1.08 (1.02–1.13)**	**1.05 (1.00–1.11)**	0.062

Values are presented as odds ratio (95% confidence interval). Bolded texts represent statistically significant coefficients. Obesity was defined as body mass index ≥ 25 kg/m^2.
[1)]Model 1 was adjusted for total energy intake and age.
[2)]Model 2 was adjusted for total energy intake, age, education, employment status, marital status, physical activity, smoking status, alcohol use, and monthly household income.

for beef, pork, chicken, and sausage, compared to women [32]. Although many Western food items including meat and fast food are considered relatively expensive in Korea [9,33], high cost may be a less important factor than preference for food selection. The fact that the low cost of less healthy food becomes a driver of food selection, increasing the risk of obesity may only be applicable to some Western countries. In contrast, our study demonstrated unclear association between food cost and obesity in women. Future studies are needed to understand factors that influence the association between Western food cost and obesity in women.

In countries where Western food items are relatively cheap, people with lower socioeconomic status (SES) are more likely to consume higher quantities of red and processed meat, fats, and sugars [30,34-36]. In contrast, if this relationship is positive, it may also be possible that people with higher SES consume more Western foods, compared to those with lower SES. Although the relationship between SES and dietary patterns has rarely been investigated among Koreans, some studies reported that Koreans with high SES consumed more ultra-processed foods (e.g., meat and fish products, and sugar-sweetened beverages) or fast food, compared to those with low SES [37,38]. Similarly, our participants in the higher food cost quintiles (who may have a relatively high SES, with a high education level and income) were more likely to spend on Western foods, in addition to spending more on prudent foods. Further research investigating the influence of SES on the association between food costs and obesity is needed.

This study encompasses several limitations. First, only population aged ≥ 40 was invited to a biannual health examination offered by the National Health Insurance Service, and those who voluntarily completed the health examination were included in the study. These participants may have a healthier lifestyle and better try to maintain good health, compared to those who did not pursue a general health examination. Further, twice more of women completed the health examination than men. Therefore, our findings may not be applicable to the general Korean population. Second, food cost may vary by season or year, and it may also vary by a wide range of food choices; however, we were only able to use an average

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of the most recent food costs available in markets or supermarkets. Although the cost of eating outside of the home is greater than that of eating at home, we could not account for this because information on eating out habits was not collected in the original survey. Nonetheless, we tried to incorporate the higher price for food items that are commonly consumed when eating out. For example, pork or beef intestines, included in the meat bypass category, are typically eaten away from home or consumed through meal kits; thus, we included the food cost of meal kits sold in supermarkets rather than using the raw food cost for meat intestines. Third, this was a cross-sectional study; we could only use baseline data from a cohort study. Therefore, we cannot infer the causal relationship between food costs and obesity. Further longitudinal studies will contribute to establishing the direction of the association. Lastly, there may have been residual confounding.

Despite these limitations, the strengths of our study include the large sample size from a population-based cohort, which enabled us to have greater power and precise estimates. In terms of expanding the literature examining the association between dietary patterns and obesity, our study is novel in that it includes food costs with a unique focus on Koreans, a population that is undergoing a rapid nutrition transition from traditional to Western diets. Our findings highlight that the associations between food costs and the risk of obesity may differ from the relationships commonly observed in Western populations.

In summary, food cost was positively associated with obesity in men, but not in women. Specifically, spending more money on Western food was associated with increased risk of obesity in men. Future research confirming the longitudinal association between food costs and obesity among Koreans is warranted. Furthermore, additional studies with other ethnic populations that are similarly undergoing nutrition transitions may provide new insight into the complex relationship of food costs, and health outcomes, thereby preventing obesity.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Factor loadings for individual food groups according to dietary patterns in Korean adults (n = 128,365)

Click here to view

Supplementary Table 2

Association between food cost and obesity, stratified by gender with multiple imputation (n = 149,136)

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Supplementary Fig. 1

Participant flowchart in Korean Genome and Epidemiology Study_Health Examinees (KoGES_HEXA).

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Appendix 1. Food groups used in dietary pattern analysis among Korean adults

Food or food group	Food items
Green and yellow vegetable	Carrot, zucchini, chili/pepper, cucumber, lettuce, perilla leaf, salad, spinach, other green leaf, pumpkin, crown daisy/chive/water parsley, pepper leaves/chamnamul/chwinamul, seaweed, kelp
Light colored vegetable	Radish, napa cabbage, bean sprout, bracken fern, onion, burdock/bellflower root, potato, sweet potato, tomato
Seafood	Sashimi, mackerel, belt fish, eel, croaker, pollack, anchovy, tuna, squid, fishcake, clam, oyster, crab, shrimp, salted fish
Mushroom	Oyster mushroom, other mushroom
Kimchi and salted food	Napa cabbage kimchi, radish kimchi, water kimchi, other kimchi, pickled vegetable
Legume	Soybean paste, bean, tofu, soymilk, nut, jellied nut
Fruit and fruit juice	Strawberry, melon, watermelon, peach, banana, persimmon, mandarin, pear, apple, orange, grape
Red meat	Fried pork belly, sauteed pork belly, pork bulgogi, beef bulgogi/steak, dogmeat
White and other meat	Chicken soup/fried chicken, meat byproduct
Processed meat	Ham/sausage
Dairy	Egg, milk, yogurt, ice cream, cheese, cream
Sweet	Cake, cookie, chocolate, sugar, jam/honey/margarine
Beverage	Coffee, green tea, sugar sweetened beverage, other beverage
Flour-based food	Instant noodle, handmade noodle, Chinese noodle, glass noodle, cold noodle, white bread, other bread, steamed bun, dumpling, pizza/hamburger
White rice	White rice, white rice cake, other rice cake
Grains	White bean rice, white mixed rice, bean rice, mixed rice, mixed grain powder

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