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Association between kimchi consumption and obesity based on BMI and abdominal obesity in Korean adults: a cross-sectional analysis of the Health Examinees study

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ABSTRACT

Objective Previous animal studies have shown the anti-obesity effect of kimchi-derived probiotic lactic acid bacteria. However, only a few epidemiological studies have investigated the association between kimchi consumption and obesity. Therefore, we aim to assess this relationship in Korean adults.

Design Cross-sectional study.

Setting The Health Examinees study was conducted from 2004 to 2013.

Participants This study analysed 115 726 participants aged 40–69 years enrolled in the Health Examinees study in Korea.

Primary and secondary outcome measures Obesity was defined as body mass index ≥25 kg/m^2, and abdominal obesity was defined as waist circumference ≥90 cm in men and ≥85 cm in women. Kimchi consumption was assessed by the validated food frequency questionnaire.

Results In men, total kimchi consumption of 1–3 servings/day was related to a lower prevalence of obesity (OR: 0.875 in 1–2 servings/day and OR: 0.893 in 2–3 servings/day) compared with total kimchi consumption of <1 serving/day. Also, men with the highest baechu kimchi (cabbage kimchi) consumption had 10% lower odds of obesity and abdominal obesity. Participants who consumed kkakdugi (radish kimchi) ≥median were inversely associated with 8% in men and 11% in women with lower odds of abdominal obesity compared with non-consumers, respectively.

Conclusions and relevance Consumption of 1–3 servings/day of total kimchi was associated with a lower risk of obesity in men. Baechu kimchi was associated with a lower prevalence of obesity in men, and kkakdugi was associated with a lower prevalence of abdominal obesity in both men and women. However, since all results showed a 'J-shaped' association, it is recommended to limit excessive kimchi intake.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study included a large number of participants (n=115 726) for cross-sectional analysis.
⇒ The ORs were adjusted for confounding variables to evaluate the independent relationship between kimchi consumption and obesity.
⇒ Body mass index might have limitations as an obesity measure.
⇒ A food frequency questionnaire may make it difficult to quantify the portion size of kimchi consumption.

INTRODUCTION

Obesity is a multifactorial disease related to nutrition, lifestyle and environmental factors.[1–3] To estimate the risk of obesity, the WHO defined obesity as a body mass index (BMI) ≥30 kg/m^2, and for the Asian population, the classification of obesity is BMI ≥25 kg/m^2.[4] According to the 2021 Obesity Fact Sheet in Korea, the prevalence of obesity in South Korea has steadily increased from 29.7% in 2009 to 36.3% in 2019, and the prevalence of abdominal obesity also steadily increased from 19.0% in 2009 to 23.9% in 2019. In particular, the prevalence of obesity in individuals in their 20s and 80s was lower than in other age groups but had increased steeply between 2009 and 2019.[5] Obesity is a major risk factor for chronic diseases such as type 2 diabetes, hyperlipidaemia, cardiovascular disease and chronic kidney disease,[6–9] and increased obesity was associated with increased medical expenditure.[10] Therefore, the prevention of obesity is a public health priority.

Kimchi is traditionally consumed as a side dish in Korea and manufactured by salting and fermenting vegetables with various flavouring and seasoning ingredients, including onion, garlic, red pepper powder, salted shrimp and fish sauce.[11] Cabbage and radish are usually the main vegetables in kimchi, and kimchi is low in calories and rich in dietary fibre, lactic acid bacteria (LAB), vitamins and polyphenols.[12 13] Despite these

healthy ingredients, there was concern about health risks because kimchi was one of the major food groups that contributed to dietary sodium intake.[14] According to the Korea National Health and Nutrition Examination Survey (KNHANES) 2019–2020, the daily sodium intake from kimchi consumption in adults aged over 19 years is 500.1 mg/day (15.1% of the total daily sodium intake).[15] Several studies suggested that a high sodium intake was associated with a high prevalence of obesity and hypertension.[16–19] However, previous studies have shown that the consumption of kimchi and fermented vegetables is associated with reduced body weight[20] and improved fasting blood glucose and total cholesterol level[21] but has no association with hypertension.[22]

Fermented kimchi contains major species of LAB, such as *Leuconostoc* spp., *Lactobacillus* spp. and *Weissella* spp. Especially, *Lactobacillus* spp. is the dominant species of kimchi LAB in late fermentation.[23 24] In a cell-based experiment, kimchi LAB reduced lipid accumulation by regulating the adipogenesis-related and lipogenesis-related genes in 3T3-L1 adipocytes.[25] An animal study reported that *Lactobacillus plantarum* HACo1 derived from fermented kimchi reduced adipose tissue accumulation in mice.[26] A 12-week randomised controlled trial (RCT) showed that *Lactobacillus sakei* isolated from fermented kimchi was associated with decreased body fat mass and waist circumference (WC).[27]

There are currently a few epidemiology studies investigating the relationship between kimchi consumption and obesity in adults. There is a concern about the intake of kimchi due to the salt content of kimchi, but we focused on its health function as a fermented food. Therefore, we examined the association of kimchi consumption with obesity and abdominal obesity in South Korean adults.

MATERIALS AND METHODS

Study population

This cross-sectional study used the data from the Health Examinees (HEXA) study, a large, community-based prospective cohort study of the larger Korean Genome and Epidemiology Study designed to examine environmental and genetic risk factors for common chronic diseases in Korean adults aged over 40 years. The baseline examination for the HEXA study was conducted from 2004 to 2013. A detailed description of the study design and procedures for the HEXA study is provided in previous studies.[28 29] Among the 173 357 participants, those who were aged <40 years or >69 years (n=3627), who had no dietary information (n=2982), who had missing data of anthropometry measurements, including height, weight and WC (n=2214), who had a history of hypertension (n=29 508), diabetes (n=5405), hyperlipidaemia (n=6452), cardiovascular disease (n=1341), cerebrovascular disease (n=399) and cancer (n=3548), and who had implausible energy intakes in men (<800 or ≥4000 kcal/day, n=1192) and women (<500 or ≥3500 kcal/day, n=963) were excluded (figure 1). Therefore, this cross-sectional study included 115 726 participants (36 756 men and 78 970 women). Informed consent was confirmed (or waived) by the institutional review boards.

Patient and public involvement

Patients were not involved in this study.

Dietary assessment

Dietary intake for the previous year was assessed using a validated 106-item semiquantitative food frequency questionnaire (SQ-FFQ) completed by the participants.[30] Participants referred to accompanying photographs of

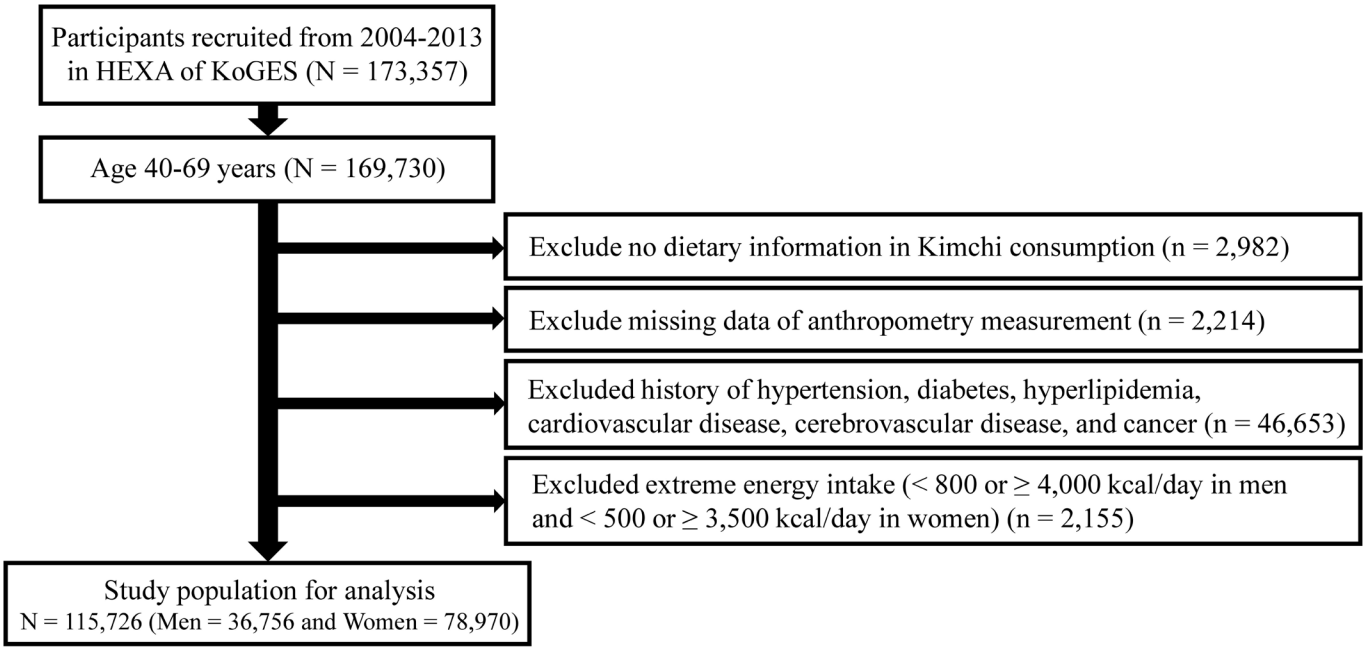

Figure 1 Flow chart of the study population. HEXA, Health Examinees.

each food to respond to questions about their frequency and amount of food consumption. The nine frequency categories are as follows: never or seldom, once a month, 2–3 times a month, 1–2 times a week, 3–4 times a week, 5–6 times a week, once a day, 2 times a day and 3 times a day. The serving size of kimchi consumption was categorised as 0.5, 1 or 2 servings. Total kimchi included baechu kimchi (cabbage kimchi), kkakdugi (radish kimchi), nabak kimchi and dongchimi (watery kimchi) and other kimchi (eg, green onion kimchi, Korean lettuce kimchi and mustard greens kimchi). One serving of baechu kimchi, kkakdugi and other kimchi is 50 g, and one serving of nabak kimchi and dongchimi is 95 g. The serving size of kimchi was obtained by multiplying the frequency of kimchi consumption by the amount of serving. Total kimchi consumption is categorised as follows: <1 serving/day, 1–2 servings/day, 2–3 servings/day, 3–5 servings/day and ≥5 servings/day. Nutrient intakes, such as macronutrients, sodium, fibre and potassium, were calculated by multiplying the frequency of each food intake by The Korean Food Composition Table prepared by the Rural Development Administration National Institute of Agricultural Sciences.[31]

Anthropometry and definition of obesity

Anthropometry measurements, including height, weight and WC, were measured by trained staff via standardised procedures. Height and weight were measured using a digital height and weight machine, and WC was measured at the midway between the ribs and the iliac ridge using a measuring tape. The definition of obesity was based on the guidelines of the Korean Society for the Study of Obesity.[32] BMI is calculated as weight divided by height in metres squared (kg/m^2). Obesity was divided into underweight (BMI<18.5 kg/m^2), normal (18.5 kg/m^2≤BMI<25.0 kg/m^2) and obese (BMI≥25 kg/m^2). Abdominal obesity was defined as WC ≥90 cm (men) or ≥85 cm (women).

Covariates

Information on sociodemographic factors, cigarette smoking, physical activity, menopause status and history of chronic diseases such as hypertension, diabetes, hyperlipidaemia, cardiovascular disease and cerebrovascular diseases, was obtained from self-administered questionnaires with an interviewer. To investigate the general characteristics, age was categorised into 40s, 50s and 60s, and BMI was categorised into underweight (BMI<18.5 kg/m^2), normal (18.5 kg/m^2≤BMI<25.0 kg/m^2) and obese (25.0 kg/m^2≤BMI). Income level was classified as <1 million won (approximately 800 dollars), 1–1.99 million won, 2–2.99 million won and ≥3 million won. Education level, marital status, alcohol consumption, current smoking and physical activity were self-identified and reported as follows: education level (below middle school, high school and above college), marital status (married or other), alcohol consumption (non-drinker or current drinker), smoking status (never, past or current smoker), physical activity (active or inactive) and menopause status (premenopausal or post menopausal).

Statistical analyses

All statistical analyses were performed using SAS (V.9.4; SAS Institute). Participants were categorised into five groups according to their total kimchi consumption (<1 serving/day, 1–2 servings/day, 2–3 servings/day, 3–5 servings/day and ≥5 servings/day). Statistical analyses were conducted separately by sex to identify the association of kimchi consumption with obesity and abdominal obesity. To assess the differences in general characteristics in subjects according to total kimchi consumption, we used the χ^2 test for categorical variables and linear regression for continuous variables. A multivariable logistic analysis model was used to estimate the OR and 95% CI of obesity based on kimchi consumption, with the lowest consumption group as the reference, and the reference group of obesity was 18.5 kg/m^2≤BMI<25.0 kg/m^2. Sodium, fibre and potassium intake were adjusted for daily energy intake using the residual methods.[33] To assess whether kimchi consumption was independently associated with the prevalence of obesity and abdominal obesity, we adjusted for potential confounders, such as age, total energy intake, income level, education level, marital status, alcohol consumption, smoking status, physical activity, menopausal status, energy-adjusted sodium, potassium, and fibre intake, consumption of cooked rice (cooked rice included cooked white rice, cooked white rice with soybean, cooked white rice with other cereals, half & half cooked white rice and rice with soybean, and half & half cooked white rice and rice with other cereals), pickled radish, jangajji and other kimchi consumption (except for analysis of total kimchi consumption). A two-sided p<0.05 was considered statistically significant.

RESULTS

Participants' characteristics according to kimchi consumption

The study included a total of 115 726 participants (36 756 men and 78 970 women) with a mean age of 51.8±8.2 years in men and 50.8±7.4 years in women, and the prevalence of obesity (BMI ≥25 kg/m^2) was 28.2% (36.1% in men and 24.7% in women). Table 1 shows the baseline characteristics stratified by sex according to total kimchi consumption. Compared with participants who consumed total kimchi <1 serving/day, those who consumed total kimchi ≥5 servings/day had higher weight and WC and were more likely to be obese, below middle school educated, household income <1 million won and current drinkers in both men and women. Men participants who consumed total kimchi ≥5 servings/day tended to be younger, taller, smokers and active than those who consumed total kimchi <1 serving/day. In comparison to women who consumed total kimchi<1 serving/day, those who consumed total kimchi≥5 servings/day were older, shorter, married, non-smokers, inactive and post menopausal. The food and nutrient intakes of the study participants according

Table 1 General characteristics of the participants according to total kimchi consumption

	Total kimchi consumption							
	Men (n=36 756)				Women (n=78 970)			
	<1 serving/day	2–3 servings/day	≥5 servings/day	P value	<1 serving/day	2–3 servings/day	≥5 servings/day	P value
N	5081 (13.8)	5816 (15.8)	5881 (16.0)		14 376 (18.2)	12 314 (15.6)	9188 (11.6)	
Age, years	52.4±8.1	51.3±8.1	51.5±8.2	<0.0001	50.8±7.4	50.4±7.3	51.0±7.5	<0.0001
Age								
40s	1969 (38.8)	2620 (45.1)	2644 (45.0)	<0.0001	6698 (46.6)	5918 (48.1)	4168 (45.4)	<0.0001
50s	1976 (38.9)	2098 (36.1)	2053 (34.9)		5618 (39.1)	4833 (39.3)	3599 (39.2)	
60s	1136 (22.4)	1098 (18.9)	1184 (20.1)		2060 (14.3)	1563 (12.7)	1421 (15.5)	
BMI*, kg/m^2†	24.1±2.7	24.1±2.7	24.4±2.7	<0.0001	23.1±2.8	23.2±2.8	23.8±2.9	<0.0001
Obesity								
Underweight	76 (1.5)	89 (1.5)	74 (1.3)	<0.0001	402 (2.8)	290 (2.4)	169 (1.8)	<0.0001
Normal	3140 (61.8)	3665 (63.0)	3516 (59.8)		10 782 (75.0)	9147 (74.3)	6254 (68.1)	
Obese	1865 (36.7)	2062 (35.5)	2291 (39.0)		3192 (22.2)	2877 (23.4)	2765 (30.1)	
Abdominal obesity†	1263 (24.9)	1453 (25.0)	1647 (28.0)	<0.0001	2270 (15.8)	1998 (16.2)	2008 (21.9)	<0.0001
Anthropometric measurements								
Height, cm	168.8±5.7	169.1±5.7	169.1±5.8	<0.0001	156.8±5.3	156.9±5.2	156.5±5.3	<0.0001
Weight, kg	68.7±9.0	69.0±9.1	69.8±9.2	<0.0001	56.9±7.3	57.2±7.3	58.2±7.7	<0.0001
Waist circumference, cm	84.7±7.3	84.9±7.4	85.4±7.4	<0.0001	76.8±7.8	77.2±7.7	78.5±8.0	<0.0001
Monthly income level								
<1 million won	297 (6.9)	274 (5.4)	351 (7.2)	<0.0001	1416 (11.9)	904 (8.7)	852 (12.1)	<0.0001
1–1.99 million won	833 (19.3)	789 (15.6)	850 (17.4)		2423 (20.3)	1958 (18.9)	1448 (20.5)	
2–2.99 million won	1049 (24.2)	1163 (23.0)	1250 (25.6)		2614 (21.9)	2345 (22.6)	1701 (24.1)	
≥3 million won	2149 (49.7)	2821 (55.9)	2432 (49.8)		5463 (45.9)	5170 (49.8)	3057 (43.3)	
Education level								
Below middle school	1087 (21.7)	1047 (18.3)	1365 (23.6)	<0.0001	4905 (34.5)	3698 (30.5)	3412 (37.9)	<0.0001
High school	2070 (41.3)	2283 (39.9)	2400 (41.5)		6281 (44.2)	5547 (45.7)	4068 (45.2)	
Above college	1861 (37.1)	2397 (41.9)	2017 (34.9)		3018 (21.3)	2892 (23.8)	1521 (16.9)	
Marital status								
Married	4613 (91.2)	5363 (92.6)	5494 (93.8)	<0.0001	12 066 (84.5)	10 683 (87.1)	7989 (87.4)	<0.0001
Others	443 (8.8)	427 (7.4)	363 (6.2)		2222 (15.6)	1576 (12.9)	1148 (12.6)	
Alcohol consumption								

Continued

Table 1 Continued

	Total kimchi consumption							
	Men (n=36 756)				Women (n=78 970)			
	<1 serving/day	2–3 servings/day	≥5 servings/day	P value	<1 serving/day	2–3 servings/day	≥5 servings/day	P value
Non-drinker	1302 (25.7)	1260 (21.7)	1247 (21.3)	<0.0001	9393 (65.7)	7744 (63.1)	5987 (65.4)	<0.0001
Current drinker	3770 (74.3)	4544 (78.3)	4618 (78.7)		4913 (34.3)	4529 (36.9)	3165 (34.6)	
Current smoking status								
Never	1599 (31.6)	1578 (27.2)	1619 (27.6)	<0.0001	13 714 (95.8)	11 756 (95.9)	8837 (96.7)	<0.0001
Past smoker	1869 (36.9)	2171 (37.4)	2071 (35.3)		232 (1.6)	170 (1.4)	103 (1.1)	
Current smoker	1598 (31.5)	2058 (35.4)	2170 (37.0)		364 (2.5)	336 (2.7)	202 (2.2)	
Physical activity								
Active	1610 (32.0)	1851 (32.0)	1921 (32.9)	0.2158	4953 (34.8)	4145 (33.9)	3003 (33.0)	0.0003
Inactive	3424 (68.0)	3935 (68.0)	3915 (67.1)		9269 (65.2)	8077 (66.1)	6090 (67.0)	
Menopausal status								
Premenopausal					6510 (48.3)	5865 (50.4)	3985 (47.2)	<0.0001
Post menopausal					6964 (51.7)	5777 (49.6)	4464 (52.8)	

Values are mean±SD or n (%); p values were calculated using χ^2 tests for categorical variables and general linear regression for continuous variables.
*BMI, body mass index: underweight (BMI<18.5 kg/m²), normal (18.5 kg/m²<BMI<25 kg/m²) and obese (≥25 kg/m²).
†Abdominal obesity: WC ≥90 cm in men and ≥85 cm in women.
BMI, body mass index; WC, waist circumference.

to kimchi consumption are provided in online supplemental table 1. The higher consumption of kimchi was associated with higher consumption of jangajji, pickled radish and cooked rice in both men and women (all p<0.0001). The average nutrient intake in each group of kimchi consumption showed that total energy intake, carbohydrate, protein, fat, sodium, potassium and fibre were significantly higher in the highest kimchi intake than in the lowest kimchi intake.

Association between kimchi consumption and obesity

Tables 2 and 3 present the ORs of obesity according to kimchi consumption by sex. After adjustment for confounding covariates, men who consumed 1–2 servings/day and 2–3 servings/day of total kimchi had a lower prevalence of obesity (OR: 0.875; 95% CI 0.808 to 0.947 in 1–2 servings/day, and OR: 0.893; 95% CI 0.817 to 0.978 in 2–3 servings/day) compared with those who consumed <1 serving/day. In men, there was a significant association that consuming baechu kimchi ≥3 servings/day was associated with a 10% lower prevalence in both obesity (OR: 0.904; 95% CI 0.832 to 0.982) and abdominal obesity (OR: 0.903; 95% CI 0.825 to 0.989) compared with participants who consumed baechu kimchi <1 serving/day. In women, compared with the lowest baechu kimchi consumption (<1 serving/day), the consumption of baechu kimchi 2–3 servings/day was associated with an 8% (95% CI 0.865% to 0.981%) lower prevalence of obesity, and 1–2 servings/day was associated with a 6% (95% CI 0.889% to 0.994%) lower prevalence of abdominal obesity. For kkakdugi consumption, participants who consumed kkakdugi <median were associated with lower prevalence of obesity in both men (OR: 0.908; 95% CI 0.842 to 0.979) and women (OR: 0.895; 95% CI 0.855 to 0.938). Those who consumed kkakdugi more than the median (25.0 g/day in men and 10.7 g/day in women) were less likely to have abdominal obesity in both men and women than non-consumers (OR: 0.915; 95% CI 0.840 to 0.996 in men and OR: 0.889; 95% CI 0.842 to 0.939 in women). Additionally, some groups of nabak kimchi+dongchimi, other kimchi and baechu kimchi+kkakdugi consumption showed an inverse association with obesity, but mostly, there were no significant associations with obesity (online supplemental tables 2–4).

DISCUSSION

In this cross-sectional study, we analysed the data from the HEXA cohort study in Korea to investigate the association between kimchi consumption and obesity among Korean adults. The present study showed that total kimchi consumption of 1–3 servings/day is inversely associated with the risk of obesity in men. Also, in men, a higher intake of baechu kimchi was related to a lower prevalence of obesity and abdominal obesity. A higher consumption of kkakdugi was associated with lower prevalence of abdominal obesity in both men and women.

Previous studies reported an association between kimchi intake and obesity. A previous RCT involving 22 patients with obesity showed that both fresh kimchi (1-day-old kimchi) and fermented kimchi (10-day-old kimchi) significantly reduced body weight, BMI and body fat, and fermented kimchi consumption decreased waist-to-hip ratio, total cholesterol and leptin levels.[20] In a cohort study of 20 066 participants with obesity aged 40–69 years old, the average intake of kimchi of 2–3 servings/day was associated with changing to a normal weight group.[34] This may be because the white rice and kimchi dietary pattern is characterised by high consumption of processed food. In the results of the scoping review including two RCT studies, intake of fresh kimchi (before fermented) showed a decrease in WCs and body fat percentage.[35]

Previous studies have shown that ingestion of probiotic LAB genera during kimchi fermentation decreases body weight, BMI and WC in adults with overweight or obesity.[36–38] Moreover, the beneficial impact of kimchi-derived probiotic LAB on obesity has been demonstrated.[25 27 39] *L. brevis* and *L. plantarum* isolated from kimchi had an anti-obesity effect in a cell-based experiment, suppressing adipocyte differentiation and, thereby, lipid accumulation by downregulating the expression of adipogenesis-related genes.[25 39] Moreover, in diet-induced obese mice fed with *L. plantarum* for 12 weeks, serum and liver TG levels were reduced, and gains in adipose tissue and body weight were suppressed.[39] Similar findings have been reported for kimchi. For instance, kimchi markedly decreased the TG levels and reduced the adipogenesis/lipogenesis-related genes, including peroxisome proliferator-activated receptor gamma (PPAR)CCAAT/enhancer-binding protein-alpha, and fatty acid synthase in 3T3-L1 adipocytes and diet-induced obese mice.[40 41]

Kimchi was prepared using brined kimchi cabbage and radish, which are liberally seasoned with red pepper powder, garlic, onion, ginger, radish, scallion, *saeujeot* (a salt-fermented shrimp sauce), *aekjeot* (a fermented fish sauce) and glutinous rice.[11] Previous studies show that the common spices of kimchi including garlic, onion and ginger have an anti-obesity effect.[42–45] Intake of garlic could reduce WC and BMI, mainly reducing body weight and fat mass, and previous animal study shows that consumption of garlic compound decreased cells' lipid accumulation in adipocytes 3T3-L1.[43] Onion included quercetin, one of the flavonoids, and intake of quercetin can reduce adipocyte hyperplasia.[44] Ginger and its major component, 6-shogaol, also reduced adipogenic conversion during adipogenesis.[45]

In our results, a non-linear J-shaped curve was observed for kimchi consumption and obesity. Although not statistically significant, increased kimchi intake over 5 servings/day was associated with a high prevalence of obesity. In this study, increased total kimchi consumption was associated with higher intake of total energy, carbohydrates, protein, fat, sodium and cooked rice, and this might lead to increased weight. Also, in women, the higher kimchi consumption

Table 2 ORs (95% CI) for the association between obesity and total kimchi, baechu kimchi and kkakdugi consumption in men

	Kimchi consumption					
Total kimchi consumption	**<1 serving/day**	**1–2 serving/day**	**2–3 servings/day**	**3–5 servings/day**	**≥5 servings/day**	**p for trend**
Median (range), serving/day	0.53 (0.00–0.99)	1.43 (1.00–1.98)	2.25 (2.00–2.99)	3.5 (3.00–4.99)	6.13 (5.00–18.00)	
Obese*						
Cases/participants (n)	1865/5081	2516/7303	2062/5816	4539/12675	2291/5881	
Multivariate-adjusted model†‡	Ref. (1.000)	0.875 (0.808–0.947)	0.893 (0.817–0.978)	0.919 (0.834–1.014)	1.014 (0.880–1.169)	0.0981
Abdominal obesity§						
Cases/participants (n)	1263/5081	1766/7303	1453/5816	3235/12675	1647/5881	
Multivariate-adjusted model¶	Ref. (1.000)	0.922 (0.845–1.006)	0.941 (0.853–1.039)	0.929 (0.836–1.033)	0.980 (0.841–1.143)	0.6977
Baechu kimchi consumption	**<1 serving/day**	**1–2 serving/day**	**2–3 servings/day**	**≥3 servings/day**	**p for trend**	
Median (range), serving/day	0.50 (0.00–0.79)	1.00 (1.00–1.50)	2.00 (2.00–2.00)	3.00 (3.00–4.50)		
Obese						
Cases/participants (n)	2899/7868	2921/8497	1854/5127	5599/15264		
Multivariate-adjusted model**	Ref. (1.000)	0.866 (0.809–0.927)	0.907 (0.836–0.984)	0.904 (0.832–0.982)	0.3901	
Abdominal obesity						
Cases/participants (n)	1953/7868	2083/8497	1352/5127	3976/15264		
Multivariate-adjusted model††	Ref. (1.000)	0.919 (0.853–0.990)	1.003 (0.918–1.096)	0.903 (0.825–0.989)	0.1730	
Kkakdugi consumption	**non**	**<median**	**≥median**	**p for trend**		
Median (range), serving/week	0.00 (0.00–0.00)	0.75 (0.12–2.75)	7.00 (3.50–31.50)			
Obese						
Cases/participants (n)	1329/3707	5653/16333	6291/16716			
Multivariate-adjusted model‡‡	Ref. (1.000)	0.908 (0.842–0.979)	0.982 (0.908–1.062)	0.0244		
Abdominal obesity						
Cases/participants (n)	994/3707	3980/16333	4390/16716			
Multivariate-adjusted model§§	Ref. (1.000)	0.888 (0.819–0.964)	0.915 (0.840–0.996)	0.9498		

Baechu kimchi is made of cabbage, and kkakdugi is made of radish.
N = 78 970. Range: median (min-max).
*Obesity defined as normal (18.5 kg/m²<BMI<25 kg/m²) and obese (≥25 kg/m²), and reference group of obesity is 18.5 kg/m²<BMI<25 kg/m².
†Multivariate-adjusted model: adjusted for age (continuous), income level (<1 million won, 1–1.99 million won, 2–2.99 million won and ≥3 million won), education level (below middle school, high school or above college), marital status (married or others), alcohol consumption (non-drinker or current drinker), smoking status (never, past or current smoker), physical activity (active or inactive), energy intake (continuous), energy-adjusted sodium intake (continuous), energy-adjusted potassium intake (continuous), energy-adjusted fibre intake (continuous), cooked rice, pickled radish and jangajji consumption (continuous) and other kimchi consumption (except for total kimchi analysis). One serving of baechu kimchi and kkakdugi is 50 g. Median of kkakdugi consumption is 3.5 servings/week.
‡R-square: 0.0120
§Abdominal obesity: WC ≥90 cm in men.
¶R-square: 0.0066.
**R-square: 0.0093.
††R-square: 0.0067.
‡‡R-square: 0.0092.
§§R-square: 0.0066.
BMI, body mass index; Ref, reference.

Table 3 ORs (95% CI) for the association between obesity and total kimchi, baechu kimchi and kkakdugi consumption in women

	Kimchi consumption					
Total kimchi consumption	**<1 serving/day**	**1–2 serving/day**	**2–3 servings/day**	**3–5 servings/day**	**≥5 servings/day**	**p for trend**
Median (range), serving/day	0.50 (0.00–0.99)	1.35 (1.00–1.99)	2.18 (2.00–2.98)	3.37 (3.00–4.99)	6.12 (5.00–18.00)	
Obese*						
Cases/participants (n)	3192/14 376	4215/18 421	2877/12 314	6434/24 671	2765/9188	
Multivariate-adjusted model†‡	Ref. (1.000)	0.991 (0.937–1.049)	1.007 (0.942–1.077)	1.029 (0.957–1.106)	1.098 (0.985–1.224)	0.0409
Abdominal obesity§						
Cases/participants (n)	2270/14 376	3007/18 421	1998/12 314	4736/24 671	2008/9188	
Multivariate-adjusted model¶	Ref. (1.000)	0.985 (0.924–1.050)	0.967 (0.897–1.043)	1.014 (0.936–1.099)	1.033 (0.914–1.166)	0.4003
Baechu kimchi consumption	**<1 serving/day**	**1–2 serving/day**	**2–3 servings/day**	**≥3 servings/day**	**p for trend**	
Median (range), serving/day	0.50 (0.00–0.79)	1.00 (1.00–1.50)	2.00 (2.00–2.00)	3.00 (3.00–4.50)		
Obese						
Cases/participants (n)	4555/19 961	4999/21 031	2367/10 257	7562/27 721		
Multivariate-adjusted model**	Ref. (1.000)	0.955 (0.909–1.003)	0.921 (0.865–0.981)	0.951 (0.893–1.013)	0.2240	
Abdominal obesity						
Cases/participants (n)	3244/19 961	3524/21 031	1691/10 257	5560/27 721		
Multivariate-adjusted model††	Ref. (1.000)	0.940 (0.889–0.994)	0.948 (0.883–1.019)	0.966 (0.900–1.036)	0.8459	
Kkakdugi consumption	**non**	**<median**	**≥median**	**p for trend**		
Median (range), serving/week	0.00 (0.00–0.00)	0.58 (0.12–1.50)	7.00 (1.75–31.50)			
Obese						
Cases/participants (n)	3671/14 104	7585/33 365	8227/31 501			
Multivariate-adjusted model‡‡	Ref. (1.000)	0.895 (0.855–0.938)	0.966 (0.919–1.014)	0.0602		
Abdominal obesity						
Cases/participants (n)	2811/14 104	5393/33 365	5815/31 501			
Multivariate-adjusted model§§	Ref. (1.000)	0.854 (0.811–0.900)	0.889 (0.842–0.939)	0.3905		

Baechu kimchi is made of cabbage, and kkakdugi is made of radish.
*Obesity defined as normal (18.5 kg/m²<BMI<25 kg/m²) and obese (≥25 kg/m²), and reference group of obesity is 18.5 kg/m²<BMI<25 kg/m².
†Multivariate-adjusted model: Adjusted for age (continuous), income level (<1 million won, 1–1.99 million won, 2–2.99 million won and ≥3 million won), education level (below middle school, high school or above college), marital status (married or others), alcohol consumption (non-drinker or current drinker), smoking status (never, past or current smoker), physical activity (active or inactive), menopausal status (pre- or post-), energy intake (continuous), energy-adjusted sodium intake (continuous), energy-adjusted potassium intake (continuous), energy-adjusted fibre intake (continuous), cooked rice, pickled radish and jangajji consumption (continuous) and other kimchi consumption (except for total kimchi analysis). One serving of baechu kimchi and kkakdugi is 50 g. Median of kkakdugi consumption is 1.5 servings/week.
‡R-square: 0.0358.
§Abdominal obesity: WC ≥85 cm in women.
¶R-square: 0.0401.
**R-square: 0.0266.
††R-square: 0.0401.
‡‡R-square: 0.0269.
§§R-square: 0.0405.
BMI, body mass index; Range, median (min-max); Ref., reference.

group showed more physical inactiveness. An imbalanced energy balance associated with matched energy intake and expenditure could increase the prevalence of obesity.[46] Rice and kimchi pattern is a common dietary pattern in Korean adults, and in a previous study, the white rice and kimchi pattern was positively associated with obesity.[47] Previous results can support the reason for the J-shaped results in our study, but further research is needed.

Increased sodium intake from kimchi consumption might also be one of the concerns of increased risk of obesity. Kimchi is the major food contributing to sodium intake because it is fermented by salt. Findings from the 1998–2018 KNHANES reported that the mean total sodium intake was 3477.2 mg/day, and the sodium intake from kimchi was 14.0% (487.3 mg/day) of total sodium intake in 2017.[48] Kimchi only contributes to a small proportion of the total sodium intake of the Korean diet although our results present that higher kimchi consumption is associated with higher sodium intake.[49] Moreover, the main vegetables of kimchi, such as cabbage and radish, are dietary sources of potassium, and individuals who consume higher amounts of sodium might benefit from increasing potassium intakes to counteract the effect of sodium.[50 51]

This study has some strengths. It included a considerably large number of Korean adults to investigate the association between kimchi and obesity, and the participants who had a history of some disease were excluded. This could show a more precise relationship between kimchi consumption and obesity. Moreover, the validated SQ-FFQ was used for estimating dietary intake. In addition, to evaluate the independent relationship between kimchi consumption and obesity, we adjusted for confounding variables such as age, BMI, income, education, marital status, alcohol consumption, smoking, physical activity, and nutritional and food intake as influential factors.

However, several limitations of this study should be considered. First, the cross-sectional design of this study limited our ability to make a causal inference. Thus, a longitudinal study is necessary to better understand the impact of kimchi on obesity. Furthermore, this finding cannot be generalised due to the study's focus on Korean participants. Second, although BMI is the most widely used measure of obesity, it might have limitations as an obesity measure. Third, Koreans consume kimchi in various ways, such as raw, soup, stew and stir-fry. Because food frequency questionnaire (FFQ) usually is composed of highly consumed food items, FFQ may make it difficult to quantify the portion size of kimchi consumption. All kimchi intake per person may not be reflected because all the dishes or foods including kimchi are not listed in the FFQ. Finally, although the results showed that the association between kimchi consumption and obesity was independent of several confounding variables, other potential factors might have existed.

CONCLUSIONS

This large cross-sectional study described the association between kimchi consumption and obesity. In conclusion, total kimchi consumption of 1–3 servings/day was shown to be reversely associated with obesity in men. Regarding the type of kimchi, baechu kimchi was associated with a lower prevalence of obesity in men, and kkakdugi was associated with a lower prevalence of abdominal obesity in both men and women. However, since all results showed a 'J-shaped' association, excessive consumption suggests the potential for an increase in obesity prevalence. As kimchi is one of the major sources of sodium intake, a moderate amount of kimchi should be recommended for the health benefits of its other components. In addition, further investigation and prospective studies are needed to confirm the relationship between kimchi consumption and obesity.

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Patient consent for publication Consent obtained directly from patient(s)

Ethics approval The HEXA study protocol was approved by the Ethics Committee of Korean Health and institutional review boards of all participating hospitals (IRB number E-1503-103-657). Participants gave informed consent to participate in the study before taking part.

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