


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

Hyein Jung,^{1,2} Ye-Rang Yun,³ Sung Wook Hong,³ Sangah Shin ¹

To cite: Jung H, Yun Y-R, Hong SW, *et al.* Association between kimchi consumption and obesity based on BMI and abdominal obesity in Korean adults: a cross-sectional analysis of the Health Examinees study. *BMJ Open* 2024;**14**:e076650. doi:10.1136/bmjopen-2023-076650

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2023-076650>).

Received 13 June 2023
Accepted 22 November 2023



© Author(s) (or their employer(s)) 2024. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

¹Department of Food and Nutrition, Chung Ang University, Anseong, South Korea

²Division of Cancer Prevention, National Cancer Center, Goyang, South Korea

³Technology Innovation Research Division, World Institute of Kimchi, Gwangju, South Korea

Correspondence to
Professor Sangah Shin;
ivory8320@cau.ac.kr and
Dr Sung Wook Hong;
swhong@wikim.re.kr

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/m², 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) \geq 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.

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

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.

(BMI) ≥ 30 kg/m², and for the Asian population, the classification of obesity is BMI ≥ 25 kg/m².⁴ 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 weight²⁰ and improved fasting blood glucose and total cholesterol level²¹ 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

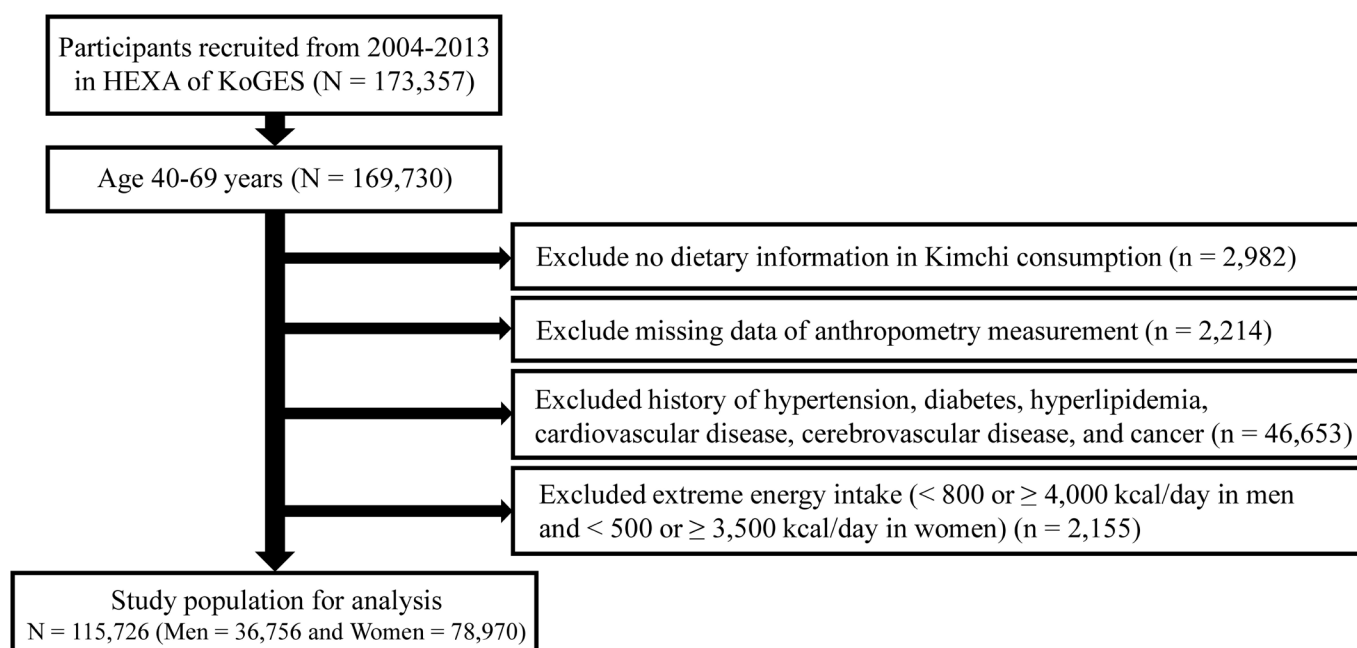


Figure 1 Flow chart of the study population. HEXA, Health Examinees.

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 ($\text{BMI} < 18.5 \text{ kg}/\text{m}^2$), normal ($18.5 \text{ kg}/\text{m}^2 \leq \text{BMI} < 25.0 \text{ kg}/\text{m}^2$) and obese ($\text{BMI} \geq 25 \text{ kg}/\text{m}^2$). 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 ($\text{BMI} < 18.5 \text{ kg}/\text{m}^2$), normal ($18.5 \text{ kg}/\text{m}^2 \leq \text{BMI} < 25.0 \text{ kg}/\text{m}^2$) and obese ($25.0 \text{ kg}/\text{m}^2 \leq \text{BMI}$). 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 $18.5 \text{ kg}/\text{m}^2 \leq \text{BMI} < 25.0 \text{ kg}/\text{m}^2$. 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 ($\text{BMI} \geq 25 \text{ kg}/\text{m}^2$) 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 |
| N | 5081 (13.8) | 5816 (15.8) | 5881 (16.0) | |
| Age, years | 52.4±8.1 | 51.3±8.1 | 51.5±8.2 | <0.0001 |
| Age | | | | |
| 40s | 1969 (38.8) | 2620 (45.1) | 2644 (45.0) | <0.0001 |
| 50s | 1976 (38.9) | 2098 (36.1) | 2053 (34.9) | |
| 60s | 1136 (22.4) | 1098 (18.9) | 1184 (20.1) | |
| BMI*, kg/m ² † | 24.1±2.7 | 24.1±2.7 | 24.4±2.7 | <0.0001 |
| Obesity | | | | |
| Underweight | 76 (1.5) | 89 (1.5) | 74 (1.3) | <0.0001 |
| Normal | 3140 (61.8) | 3665 (63.0) | 3516 (59.8) | |
| Obese | 1865 (36.7) | 2062 (35.5) | 2291 (39.0) | |
| Abdominal obesity† | 1263 (24.9) | 1453 (25.0) | 1647 (28.0) | <0.0001 |
| Anthropometric measurements | | | | |
| Height, cm | 168.8±5.7 | 169.1±5.7 | 169.1±5.8 | <0.0001 |
| Weight, kg | 68.7±9.0 | 69.0±9.1 | 69.8±9.2 | <0.0001 |
| Waist circumference, cm | 84.7±7.3 | 84.9±7.4 | 85.4±7.4 | <0.0001 |
| Monthly income level | | | | |
| <1 million won | 297 (6.9) | 274 (5.4) | 351 (7.2) | <0.0001 |
| 1–1.99 million won | 833 (19.3) | 789 (15.6) | 850 (17.4) | |
| 2–2.99 million won | 1049 (24.2) | 1163 (23.0) | 1250 (25.6) | |
| ≥3 million won | 2149 (49.7) | 2821 (55.9) | 2432 (49.8) | |
| Education level | | | | |
| Below middle school | 1087 (21.7) | 1047 (18.3) | 1365 (23.6) | <0.0001 |
| High school | 2070 (41.3) | 2283 (39.9) | 2400 (41.5) | |
| Above college | 1861 (37.1) | 2397 (41.9) | 2017 (34.9) | |
| Marital status | | | | |
| Married | 4613 (91.2) | 5363 (92.6) | 5494 (93.8) | <0.0001 |
| Others | 443 (8.8) | 427 (7.4) | 363 (6.2) | |
| Alcohol consumption | | | | |
| <1 serving/day | 14376 (18.2) | 12314 (15.6) | 9188 (11.6) | |
| 2–3 servings/day | 50.8±7.4 | 50.4±7.3 | 51.0±7.5 | <0.0001 |
| ≥5 servings/day | 6698 (46.6) | 5918 (48.1) | 4168 (45.4) | <0.0001 |
| 2060 (14.3) | 1563 (12.7) | 1421 (15.5) | | |
| 23.1±2.8 | 23.2±2.8 | 23.8±2.9 | <0.0001 | |
| 402 (2.8) | 290 (2.4) | 169 (1.8) | <0.0001 | |
| 10782 (75.0) | 9147 (74.3) | 6254 (68.1) | | |
| 3192 (22.2) | 2877 (23.4) | 2765 (30.1) | | |
| 2270 (15.8) | 1998 (16.2) | 2008 (21.9) | <0.0001 | |
| 156.8±5.3 | 156.9±5.2 | 156.5±5.3 | <0.0001 | |
| 56.9±7.3 | 57.2±7.3 | 58.2±7.7 | <0.0001 | |
| 76.8±7.8 | 77.2±7.7 | 78.5±8.0 | <0.0001 | |
| 1416 (11.9) | 904 (8.7) | 852 (12.1) | <0.0001 | |
| 2423 (20.3) | 1958 (18.9) | 1448 (20.5) | | |
| 2614 (21.9) | 2345 (22.6) | 1701 (24.1) | | |
| 5463 (45.9) | 5170 (49.8) | 3057 (43.3) | | |
| 4905 (34.5) | 3698 (30.5) | 3412 (37.9) | <0.0001 | |
| 6281 (44.2) | 5547 (45.7) | 4068 (45.2) | | |
| 3018 (21.3) | 2892 (23.8) | 1521 (16.9) | | |
| 12066 (84.5) | 10683 (87.1) | 7989 (87.4) | <0.0001 | |
| 2222 (15.6) | 1576 (12.9) | 1148 (12.6) | | |

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 | <1 serving/day | 2-3 servings/day | ≥5 servings/day | |
| Non-drinker | 1302 (25.7) | 1260 (21.7) | 1247 (21.3) | 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) | 13714 (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) | 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 ≥90cm 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), *aekejeot* (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.

¶††-square: 0.0066.

**††-square: 0.0093.

†††-square: 0.0067.

††††-square: 0.0092.

§§††-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) | 3192/14376 | 4215/18421 | 2877/12314 | 6434/24671 | 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) | 2270/14376 | 3007/18421 | 1998/12314 | 4736/24671 | 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 | | | | | | |
| Median (range), serving/day | <1 serving/day 0.50 (0.00-0.79) | 1-2 serving/day 1.00 (1.00-1.50) | 2-3 servings/day 2.00 (2.00-2.00) | ≥3 servings/day 3.00 (3.00-4.50) | | p for trend |
| Obese | | | | | | |
| Cases/participants (n) | 4555/19961 | 4999/21031 | 2367/10257 | 7562/27721 | | |
| 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) | 3244/19961 | 3524/21031 | 1691/10257 | 5560/27721 | | |
| 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 | | | | | | |
| Median (range), serving/week | non 0.00 (0.00-0.00) | <median 0.58 (0.12-1.50) | ≥median 7.00 (1.75-31.50) | | | p for trend |
| Obese | | | | | | |
| Cases/participants (n) | 3671/14104 | 7585/33365 | 8227/31501 | | | |
| 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) | 2811/14104 | 5393/33365 | 5815/31501 | | | |
| 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.

Acknowledgements This study used data from the HEXA study, which was supported by the National Genome Research Institute, Korea Centers for Disease Control and Prevention. This research was supported by grants from the World Institute of Kimchi (KE2201-1) funded by the Ministry of Science and ICT, Republic of Korea.

Contributors Guarantor, conceptualisation, project administration: SS. Data curation, funding acquisition: SS, SWH. Formal analysis, writing—original draft: HJ. Methodology: SS, HJ. Visualisation: HJ, Y-RY. Writing—review and editing: SS, SWH, HJ.

Funding This research was supported by grants from the World Institute of Kimchi (KE2201-1) funded by the Ministry of Science and ICT, Republic of Korea.

Competing interests HJ and SS have no conflicts of interest to declare for this study. Y-RY and SWH are members of the staff at the World Institute of Kimchi.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

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.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. The data that support the findings of this study are available from Korea National Institute of Health. In addition, we did not have any special access to this data that other researchers would not have. Data are available (<https://biobank.nih.gov/cmm/main/mainPage.do>) with the permission of Korea National Institute of Health.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iD

Sangah Shin <http://orcid.org/0000-0003-0094-1014>

REFERENCES

- 1 Sheu N, Lin Y-C, Chen C-J. Mechanisms, pathophysiology, and management of obesity. *N Engl J Med* 2017;376:1490.
- 2 Wadden TA, Tronieri JS, Butryn ML. Lifestyle modification approaches for the treatment of obesity in adults. *Am Psychol* 2020;75:235–51.
- 3 Solmi M, Ioannidis JPA, Carvalho AF. Environmental risk factors and interventions for obesity. *Eur J Clin Invest* 2019;49:e13080.
- 4 Weir CB, Jan A. BMI classification Percentile and cut off points. StatPearls. Treasure Island (FL): StatPearls Publishing Copyright © 2022, StatPearls Publishing LLC, 2022.
- 5 Yang YS, Han B-D, Han K, et al. Obesity fact sheet in Korea, 2021: trends in obesity prevalence and obesity-related Comorbidity incidence stratified by age from 2009 to 2019. *J Obes Metab Syndr* 2022;31:169–77.
- 6 Yun H-R, Kim H, Park JT, et al. Obesity, metabolic abnormality, and progression of CKD. *Am J Kidney Dis* 2018;72:400–10.
- 7 Aras M, Tchang BG, Pape J. Obesity and diabetes. *Nurs Clin North Am* 2021;56:527–41.
- 8 Powell-Wiley TM, Poirier P, Burke LE, et al. Obesity and cardiovascular disease: A scientific statement from the American heart Association. *Circulation* 2021;143:e984–1010.
- 9 Blüher M. Obesity: global epidemiology and pathogenesis. *Nat Rev Endocrinol* 2019;15:288–98.
- 10 Song HJ, Hwang J, Pi S, et al. The impact of obesity and overweight on medical expenditures and disease incidence in Korea from 2002 to 2013. *PLoS ONE* 2018;13:e0197057.
- 11 Lee SH, Whon TW, Roh SW, et al. Unraveling microbial fermentation features in Kimchi: from classical to meta-Omics approaches. *Appl Microbiol Biotechnol* 2020;104:7731–44.
- 12 Park WJ, Kong SJ, Park JH. Kimchi Bacteriophages of lactic acid bacteria: population, characteristics, and their role in watery Kimchi. *Food Sci Biotechnol* 2021;30:949–57.
- 13 Korus A, Bernas E, Korus J. Health-promoting constituents and selected quality parameters of different types of Kimchi: fermented plant products. *Int J Food Sci* 2021;2021:9925344.
- 14 Jeong Y, Kim ES, Lee J, et al. Trends in sodium intake and major contributing food groups and dishes in Korea: the Korea national health and nutrition examination survey 2013–2017. *Nutr Res Pract* 2021;15:382–95.
- 15 Ministry of Health and KCfDCaP Welfare. Korea National Health Statistics Plus, Current states of diet in Korea 2021, Available: https://knhanes.kdca.go.kr/knhanes/sub04/sub04_04_02.do [Accessed 18 Aug 2022].
- 16 Lanaspá MA, Kuwabara M, Andres-Hernando A, et al. High salt intake causes Leptin resistance and obesity in mice by stimulating endogenous fructose production and metabolism. *Proc Natl Acad Sci U S A* 2018;115:3138–43.
- 17 Ma Y, He FJ, MacGregor GA. High salt intake: independent risk factor for obesity. *Hypertension* 2015;66:843–9.
- 18 Moosavian SP, Haghighatdoost F, Surkan PJ, et al. Salt and obesity: a systematic review and meta-analysis of observational studies. *Int J Food Sci Nutr* 2017;68:265–77.
- 19 Rust P, Ekmekcioglu C. Impact of salt intake on the pathogenesis and treatment of hypertension. *Adv Exp Med Biol* 2017;956:61–84.
- 20 Kim EK, An S-Y, Lee M-S, et al. Fermented Kimchi reduces body weight and improves metabolic parameters in overweight and obese patients. *Nutr Res* 2011;31:436–43.
- 21 Choi IH, Noh JS, Han J-S, et al. Kimchi, a fermented vegetable, improves serum lipid profiles in healthy young adults: randomized clinical trial. *J Med Food* 2013;16:223–9.
- 22 Song HJ, Park S-J, Jang DJ, et al. High consumption of salt-fermented vegetables and hypertension risk in adults: a 12-year follow-up study. *Asia Pac J Clin Nutr* 2017;26:698–707.
- 23 Lee S-J, Jeon H-S, Yoo J-Y, et al. Some important metabolites produced by lactic acid bacteria originated from Kimchi. *Foods* 2021;10:2148.
- 24 Patra JK, Das G, Paramithiotis S, et al. Kimchi and other widely consumed traditional fermented foods of Korea: A review. *Front Microbiol* 2016;7:1493.
- 25 Park JE, Oh SH, Cha YS. Lactobacillus brevis OPK-3 isolated from Kimchi inhibits Adipogenesis and exerts anti-inflammation in 3T3-L1 Adipocyte. *J Sci Food Agric* 2014;94:2514–20.
- 26 Park S, Ji Y, Jung H-Y, et al. Lactobacillus Plantarum Hac01 regulates gut Microbiota and Adipose tissue accumulation in a diet-induced obesity murine model. *Appl Microbiol Biotechnol* 2017;101:1605–14.
- 27 Lim S, Moon JH, Shin CM, et al. Effect of Lactobacillus Sakei, a Probiotic derived from Kimchi, on body fat in Koreans with obesity: A randomized controlled study. *Endocrinol Metab (Seoul)* 2020;35:425–34.
- 28 Health Examinees Study G. The health Examinees (HEXA) study: rationale, study design and baseline characteristics. *Asian Pacific Journal of Cancer Prevention* 2015;16:1591–7.
- 29 Kim Y, Han B-G, KoGES group. Cohort profile: the Korean genome and epidemiology study (Koges) consortium. *Int J Epidemiol* 2017;46:1350.
- 30 Ahn Y, Kwon E, Shim JE, et al. Validation and reproducibility of food frequency questionnaire for Korean genome epidemiologic study. *Eur J Clin Nutr* 2007;61:1435–41.
- 31 Rural Development Administration NloAS. 9th revision, Korean food composition table 2016. Available: <http://koreanfood.rda.go.kr/eng/ftcFoodSrcEng/engMain> [Accessed 22 Aug 2022].
- 32 Seo MH, Lee W-Y, Kim SS, et al. Korean society for the study of obesity guideline for the management of obesity in Korea. *JOMES* 2019;28:40–5.
- 33 Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* 1997;65(4 Suppl):1220S–1228S;
- 34 Tan L-J, Yun Y-R, Hong SW, et al. Effect of Kimchi intake on body weight of general community dwellers: a prospective cohort study. *Food Funct* 2023;14:2162–71.
- 35 Song E, Ang L, Lee HW, et al. Effects of Kimchi on human health: a Scoping review of randomized controlled trials. *J Ethn Food* 2023;10.
- 36 Michael DR, Davies TS, Jack AA, et al. Daily supplementation with the Lab4P Probiotic consortium induces significant weight loss in overweight adults. *Sci Rep* 2021;11:5.
- 37 Rahayu ES, Mariyatun M, Putri Manurung NE, et al. Effect of Probiotic Lactobacillus Plantarum Dad-13 powder consumption on the gut Microbiota and intestinal health of overweight adults. *World J Gastroenterol* 2021;27:107–28.
- 38 Sudha MR, Ahire JJ, Jayanthi N, et al. Effect of multi-strain Probiotic (Ub0316) in weight management in overweight/obese adults: a 12-week double blind, randomised, placebo-controlled study. *Benef Microbes* 2019;10:855–66.
- 39 Lee J, Jang J-Y, Kwon M-S, et al. Mixture of two Lactobacillus Plantarum strains modulates the gut Microbiota structure and regulatory T cell response in diet-induced obese mice. *Mol Nutr Food Res* 2018;62:e1800329.
- 40 Cui M, Kim H-Y, Lee KH, et al. Antiobesity effects of Kimchi in diet-induced obese mice. *Journal of Ethnic Foods* 2015;2:137–44.
- 41 Lee K-H, Song J-L, Park E-S, et al. Anti-obesity effects of starter fermented Kimchi on 3T3-L1 Adipocytes. *Prev Nutr Food Sci* 2015;20:298–302.
- 42 Lu M, Cao Y, Xiao J, et al. Molecular mechanisms of the anti-obesity effect of bioactive ingredients in common spices: a review. *Food Funct* 2018;9:4569–81.
- 43 Imaizumi VM, Laurindo LF, Manzan B, et al. Garlic: A systematic review of the effects on cardiovascular diseases. *Crit Rev Food Sci Nutr* 2023;63:6797–819.
- 44 Cordeiro GS, Santos LS, Vieira GP, et al. Antioxidant, anti-inflammatory and anti-obesity effects of onion and its by-products in high-fat Fed rodents: a systematic review. *Braz J Biol* 2023;83:S1519–69842023000100433.
- 45 Seo SH, Fang F, Kang I. Ginger (Zingiber Officinale) attenuates obesity and Adipose tissue remodeling in high-fat diet-Fed C57Bl/6 mice. *Int J Environ Res Public Health* 2021;18:631.
- 46 Hill JO, Wyatt HR, Peters JC. Energy balance and obesity. *Circulation* 2012;126:126–32.
- 47 Kim J, Jo I, Joung H. A rice-based traditional dietary pattern is associated with obesity in Korean adults. *J Acad Nutr Diet* 2012;112:246–53.
- 48 Kweon S, Park JY, Park M, et al. Trends in food and nutrient intake over 20 years: findings from the 1998–2018 Korea national health and nutrition examination survey. *Epidemiol Health* 2021;43:e2021027.
- 49 Kim SY, Freeland-Graves JH, Kim HJ. Nineteen-year trends in fermented food consumption and sodium intake from fermented Foods for Korean adults from 1998 to 2016. *Public Health Nutr* 2020;23:515–24.
- 50 McLean RM, Wang NX. Potaciam. *Adv Food Nutr Res* 2021;96:89–121.
- 51 Mitsopoulou AV, Magriplis E, Michas G, et al. Micronutrient dietary intakes and their food sources in adults: the Hellenic national nutrition and health survey (HNNHS). *J Hum Nutr Diet* 2021;34:616–28.