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Original article

Consumption of kimchi, a salt fermented vegetable, is not associated with hypertension prevalence

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ABSTRACT

Background: The aim of this study was to investigate the association between hypertension and kimchi, a salt-fermented vegetable, intake.
Methods: This study was based on the data from the Korea National Health and Nutrition Examination Survey conducted in 2007, 2008, 2009, 2010, 2011, and 2012. In the final analysis, a total of 20,114 Korean adults (men = 7,815, women = 12,299) was included. Daily energy, nutrient, and kimchi intake were assessed using 24-hour dietary recall. The odds ratios for hypertension, according to groups of quintiles of kimchi consumption by gender, were assessed using logistic regression and multivariable models.
Results: Out of 20,114 participants, 11.3% were newly diagnosed as having hypertension. Although participants with higher consumption of kimchi were more likely to have an older age, higher blood pressure, and a higher BMI, as well as higher consumption of calories and sodium, there was no significant difference in the distribution of prevalence of hypertension across quintiles of kimchi consumption in men and women. In multivariate models by gender, higher consumption of kimchi was not associated with a higher prevalence of hypertension (odds ratio = 0.87; 95% confidence interval = 0.70 −1.08 for ≥216.5 g/day vs. <39.2 g/day; p for trend = 0.7532, in men; odds ratio = 1.04; 95% CI = 0.80 −1.34 for ≥145.1 g/day vs. < 19.5 g/day; p for trend = 0.2875, in women).
Conclusion: High consumption of kimchi was not associated with an increased prevalence of hypertension in humans. Our results suggested that high potassium intake due to high consumption of kimchi may have helped neutralize the effect of elevated sodium intake on blood pressure levels.

1. Introduction

Many types of fermented foods are prepared in Korea, including kimchi, which is one of the most famous foods made from fermented vegetables and is becoming popular globally. Kimchi has been consumed as a traditional Korean side dish for nearly 2000 years. There are more than 160 different types of kimchi, depending on vegetables, other food ingredients, preparation methods, and region, of which cabbage kimchi has been consumed most widely. Addition of other ingredients and fermentation byproducts of lactic acid bacteria promotes the fermentation process, eventually leading to eradication of putrefactive and pathogenic bacteria, and also increases the health benefits and functionalities of kimchi [1–4] Accordingly, kimchi can be considered a vegetable probiotic food that enhances health benefits in a similar manner to yogurt as a dairy probiotic food [1]. Kimchi is also an important source of vitamins, minerals, dietary fibers, and other nutrients with low calorie (18 kcal/100 g) and low fat (0.5 g/100 g) [5]. As kimchi has been one of world's famous fermented foods with many health benefits, the Korean government has set up the World Institute of Kimchi in order to systematically help other nations understand kimchi [6].

Although kimchi has become more popular globally because of its health benefits, functionalities, and taste, recently, a concern about high salt intake accompanied with high consumption of kimchi has arisen [7,8]. The average sodium intake of Koreans was reported to be more than 5,000 mg/day, which is one of the highest intake levels worldwide [8–10]. Since almost all Koreans consume kimchi as a side dish daily and as kimchi is a salt-fermented food, it

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can be one of the main contributors of sodium to Korean diet [8]. High salt intake is one of the major risk factors for hypertension [11]. Hypertension is a major public health concern in developed countries, as it is one of the leading risk factors for mortality, including stroke, heart, and renal diseases [12,13]. Even a small reduction in the mean blood pressure of a population can lead to a decrease in cardiovascular morbidity and mortality [14]. Therefore, for prevention and management of hypertension, the American Heart, Lung and Blood Institute recommends adherence to the DASH (Dietary Approaches to Stop Hypertension) diet—a diet based on low intake of sodium and fat, and high intake of fruits and vegetables [12,14]. The European Society of Hypertension also recommends a decrease in the intake of sodium and fat, and an increase in the consumption of vegetables and fruits to lower blood pressure levels [15]. According to the recommendations for prevention and treatment of hypertension, kimchi has both good and harmful effects because it is a salt-fermented vegetable.

Therefore, there are still areas of uncertainty about the association between excess consumption of kimchi and an increased risk of hypertension. The aim of the present study was to investigate any direct, independent relationship between the prevalence of hypertension and consumption of kimchi, using data from the Korea National Health and Nutrition Examination Survey (KNHANES), a nationally representative survey conducted in the Republic of Korea.

2. Materials and methods

This study was based on the data from 2007, 2008, 2009, 2010, 2011, and 2012 KNHANES, which were the fourth and fifth KNHANES, provided by the Korea Centers for Disease Control and Prevention (KCDC). From the fourth round, KNHANES was conducted throughout the year to reduce any seasonal bias on diet. The sample for KNHANES was selected using a stratified, multistage, cluster-sampling design with proportional allocations based on the National Census Registry. The 2007, 2008, 2009, 2010, 2011, and 2012 KNHANES database comprised data of 4,594, 9,744, 10,533, 8,958, 8,518, and 8,058 individuals, respectively, out of a total of 550,405 participants. Individuals who participated in the nutritional survey were considered (n = 45,031). Among them, those aged 19–64 years were included (n = 25,323). We excluded participants using the following exclusion criteria: (1) pregnant women (n = 204); (2) individuals with no blood pressure data (n = 1,738); (3) individuals reporting unrealistic daily total energy intakes (<500 kcal or >6,000 kcal) (n = 188), as per other studies with similar study designs [16,17].

Additionally, we excluded those who were diagnosed with or were receiving treatment for hypertension (n = 3,079) at the time of the survey, in order to reduce any causal relationship. As a result, 20,114 individuals were included in the final analysis (men = 7,815 and women = 12,299).

The study was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects, as defined by the Helsinki Declaration. All study participants provided written informed consent for the survey. Moreover, de-identified data were used in the study.

2.1. Measurements

KNHANES included well-established questions to determine the demographic and socioeconomic characteristics of the participants. Questions on age, gender, education level, income, physical activity, smoking habits, and alcohol consumption were incorporated. Daily energy and nutrient intakes were assessed using 1-day 24-hour recall. Height and weight of participants were measured, with participants wearing light clothing and no shoes. The body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters squared). Moreover, well-trained observers manually measured blood pressure using a mercury sphygmomanometer (Baumanometer; Baum, Copiague, NY, USA). Hypertension was defined as having a systolic pressure of 140 mmHg (or higher) or a diastolic pressure of 90 mmHg (or higher) following the standard established by the KCDC.

Kimchi intake was calculated from the 24-hour recall data. A total of 7,815 men and 12,299 women were categorized into separate quintiles. As per education levels, participants were categorized into four groups: those who finished elementary school, middle school graduates, high school graduates, and college graduates or those with higher degrees. According to income, participants were categorized into the following quartiles: lowest, low, high, and highest (as defined by the KCDC). Based on alcohol consumption habits, they were categorized into four groups: non-drinkers, those drinking less than once a month, those drinking once a month (less than heavy drinker), and heavy drinkers. A “heavy drinker” was defined as someone consuming alcohol twice or more per week and having at least seven drinks per occasion (for men) or five drinks per occasion (for women). As per the smoking status, the participants were categorized as nonsmoker, ever-smoker, and current smoker (2 groups: <1 pack per day and ≥1 pack per day) groups. Based on physical activity, participants were categorized into four groups: no exercise with irregular walking, regular walking, regular moderate-level activity and regular vigorous-level activity. Menopausal status in women participants was categorized as either “yes “or “no”.

2.2. Statistical analyses

Means and standard errors of continuous variables were calculated according to quintile groups by gender. Proportions of each covariate in categorical variables were calculated for each group. The difference between groups was tested using a generalized linear model for continuous variables and chi-square test for categorical variables. The odds ratios (ORs) for hypertension according to quintile of kimchi intake were assessed using logistic regression after adjusting for age by gender. The multivariate model was additionally adjusted for BMI, fasting glucose, triglycerides, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, energy and sodium intakes, smoking, alcohol consumption, physical activity, education, income, receiving education for hypertension, survey year (for men and women), menopause (for women only), chronic disease status (those diagnosed with or taking medication(s) for the management of diabetes, stroke, myocardial infarction, angina pectoris, chronic renal failure, and cancers vs. those not), and potassium intake. For the missing data of covariates such as smoking (9.72%), alcohol consumption (1.85%), physical activity (1.95%), educational level (1.62%), income (1.53%), and blood index (2.68%; glucose, triglyceride, and cholesterol levels), we created a missing variable in the multivariate models. Tests for linear trends across categories were conducted by treating the median of each category as a continuous variable. All analyses were performed using SAS statistical software (version 9.2; SAS Institute Inc., Cary, NC, USA).

3. Results

Out of 20,114 participants, 11.3% were newly diagnosed with hypertension. Baseline characteristics according to quintiles of kimchi consumption by gender are shown in Table 1. There was no significant difference in the distribution of prevalence of hypertension across quintiles of kimchi consumption in men and women.

Table 1
Characteristics of Study Population.

Variables	Men						Women					
	Q1	Q2	Q3	Q4	Q5	*p*	Q1	Q2	Q3	Q4	Q5	*p*
Number of participants	1,561	1,565	1,518	1,664	1,507		2,466	2,453	2,460	2,460	2,460	
Prevalence of hypertension (%)	16.3	17.4	19.0	18.9	18.3	0.2384	6.0	7.3	7.5	7.8	7.1	0.1702
Age (y)	40.1 ± 0.3	41.7 ± 0.3	42.8 ± 0.3	42.3 ± 0.3	44.2 ± 0.3	<0.0001	39.8 ± 0.3	41.7 ± 0.2	41.4 ± 0.2	42.1 ± 0.2	43.3 ± 0.2	<0.0001
Systolic blood pressure (mmHg)	117.2 ± 0.3	117.8 ± 0.3	117.9 ± 0.4	118.2 ± 0.3	119.1 ± 0.4	0.0049	109.8 ± 0.3	110.2 ± 0.3	110.5 ± 0.3	110.5 ± 0.3	111.3 ± 0.3	0.0107
Diastolic blood pressure (mmHg)	78.5 ± 0.3	79.2 ± 0.3	79.4 ± 0.3	79.6 ± 0.3	79.7 ± 0.3	0.0082	72.1 ± 0.2	72.4 ± 0.2	72.6 ± 0.2	72.7 ± 0.2	73.2 ± 0.2	0.0021
Body mass index (kg/m^2)	23.8 ± 0.1	23.9 ± 0.1	23.9 ± 0.1	24 ± 0.1	24.3 ± 0.1	0.0001	22.6 ± 0.1	22.8 ± 0.1	22.7 ± 0.1	22.9 ± 0.1	23.2 ± 0.1	<0.0001
Fasting glucose (mg/dL)	96.8 ± 0.6	97.3 ± 0.5	97.3 ± 0.5	96.4 ± 0.4	98.1 ± 0.6	0.2731	92.2 ± 0.4	91.8 ± 0.3	93 ± 0.4	92.4 ± 0.3	94.1 ± 0.4	<0.0001
Triglyceride (mg/dL)	146 ± 2.8	146.5 ± 2.8	155.1 ± 3.2	155.5 ± 2.9	169.8 ± 4	<0.0001	100.2 ± 1.6	100.4 ± 1.2	101.2 ± 1.3	102.4 ± 1.3	108.6 ± 1.6	<0.0001
LDL cholesterol (mg/dL)	111.6 ± 0.6	111.6 ± 0.7	114 ± 0.7	112.4 ± 0.7	111.1 ± 0.6	0.0165	111.7 ± 0.5	112.4 ± 0.5	111.6 ± 0.5	112.5 ± 0.5	113.2 ± 0.5	0.1491
HDL cholesterol (mg/dL)	47.1 ± 0.2	47.0 ± 0.2	47.1 ± 0.2	46.6 ± 0.2	46.8 ± 0.2	0.3070	50.8 ± 0.2	50.7 ± 0.2	50.6 ± 0.2	50.6 ± 0.2	50.4 ± 0.2	0.6369
Energy (kcal/d)	2,297.5 ± 22.8	2,333.6 ± 21.5	2,378.4 ± 21.9	2,415.6 ± 20.9	2,600.6 ± 23.4	<0.0001	1,632.1 ± 13.5	1,654.2 ± 12.8	1,690.3 ± 12.2	1,751.1 ± 12.6	1,884.6 ± 12.9	<0.0001
Sodium (mg/d)	4,673.3 ± 76.0	5,091.8 ± 66.0	5,756.1 ± 73.0	6,451.4 ± 67.6	8,688.6 ± 99.3	<0.0001	3,307 ± 50.4	3,493 ± 46.3	3,923.9 ± 42.9	4,574.5 ± 51	6,435.6 ± 70.5	<0.0001
Potassium (mg/d)	3,120.9 ± 39.6	3,254.1 ± 36.5	3,422.6 ± 37.1	3,670.5 ± 38.0	4,319.8 ± 41.8	<0.0001	2,530.0 ± 29.1	2,598.5 ± 26.3	2,732.8 ± 26.7	2,920.6 ± 27.3	3,488.3 ± 32.1	<0.0001
Smoking (%)												
Nonsmoker	28.7	26.3	23.5	22.5	22.1	0.0003	89.8	92.0	91.2	91.7	91.4	0.2267
Ever smoker	18.2	19.3	21.0	23.6	23.4		3.9	3.1	4.0	3.2	3.9	
Current smoker, <1 pack per day	26.7	29.7	27.4	27.2	26.8		5.4	4.5	4.3	4.5	4.0	
Current smoker, ≥1 pack per day	26.5	24.7	28.1	26.8	27.7		0.9	0.5	0.5	0.6	0.8	
Alcohol intake habit (%)												
Nondrinker	3.5	3.7	4.0	3.1	4.2	0.2975	10.3	12.5	12.0	14.6	14.0	<0.0001
Less than once a month	20.5	20.5	18.1	19.3	18.8		42.9	42.5	43.2	40.9	43.9	
Once a month—less than heavy drinker	55.0	54.1	55.7	52.8	53.4		41.4	40.8	40.5	38.6	37.2	
Heavy drinker[†]	21.0	21.8	22.2	24.8	23.7		5.4	4.2	4.3	5.9	4.9.0	
Physical activity (%)												
No regular exercise with irregular walking	43.9	47.3	46.8	46.4	41.9	0.1045	10.3	12.5	12.0	14.6	14.0	0.0007
Regular walking	30.1	27.0	26.3	27.4	30.2		42.9	42.5	43.2	40.9	43.9	
Regular, moderate-level activity	6.4	6.5	7.3	7.6	7.2		41.4	40.8	40.5	38.6	37.2	
Regular, vigorous-level activity	19.6	19.2	19.6	18.6	20.7		5.4	4.2	4.3	5.9	4.9	
Education (%)												
Elementary school	9.1	8.3	8.5	7.6	12.3	<0.0001	51.9	49.5	51.1	49.5	47.5	0.0007
Middle school	8.1	9.1	10.6	10.1	12.8		27.9	29.1	29.6	28.7	27.4	
High school	27.9	28.7	32.9	32.9	34.2		6.4	7.6	6.7	7.2	9.3	
College or higher degree	54.9	53.9	48.0	49.4	40.7		13.7	13.7	12.7	14.5	15.8	
Income (%)												
1st (lowest)	24.1	22.2	24.7	23.6	25.5	0.3629	12.7	13.8	13.0	14.1	16.5	0.0059
2nd	24.7	25.7	25.3	25.9	27.4		8.8	10.1	9.1	11.1	12.6	
3rd	24.5	26.5	25.4	25.7	23.0		32.2	33.8	36.6	36.5	38.0	
4th (highest)	26.7	25.5	24.5	24.8	24.1		46.2	42.4	41.3	38.4	33.0	
Receiving education for hypertension (%)	3.2	3.2	3.1	2.9	3.8	0.0002	3.9	3.5	2.2	2.4	2.4	<0.0001
Chronic disease[‡] status (%)	7.8	6.4	7.4	6.3	7.2	0.3921	6.3	5.9	5.8	5.2	6.1	0.5712
Survey year (%)												
2007	6.8	8.9	8.4	9.4	9.2	<0.0001	6.5	7.8	8.4	9.4	10.1	<0.0001
2008	16.4	19.6	18.9	20.0	19.2		16.0	19.0	19.0	21.0	22.0	
2009	21.9	19.7	21.5	22.4	24.4		19.3	20.7	20.3	21.5	23.4	
2010	17.4	17.8	17.4	18.5	16.7		18.5	16.8	18.2	18.4	16.7	
2011	17.9	16.4	18.2	17.0	18.5		18.3	18.0	17.6	16.4	16.2	
2012	19.6	17.6	15.6	12.7	12.0		21.5	17.9	16.4	13.3	11.6	

HDL, high-density lipoprotein; LDL, low-density lipoprotein; Q, quintile.

*All data represent mean ± standard error or number (%) of participants.

† Heavy drinkers were those who consumed alcohol twice or more per week and had at least seven drinks per occasion (for men) or five drinks per occasion (for women).

‡ Those who were diagnosed to have or taking medicine for diseases such as diabetes, stroke, myocardial infarction, angina pectoris, chronic renal failure, and cancers.

Kimchi consumption in men was 145.5 g/day and 137.2 g/day for hypertension and nonhypertension groups, respectively (data not shown). Interestingly, kimchi consumption in women was 92.9 g/day for both hypertension and nonhypertension groups (data not shown).

In men, participants with higher consumption of kimchi were more likely to have an older age, a higher blood pressure level, and a higher BMI, as well as higher consumption of calories, sodium, and potassium. Furthermore, men with higher kimchi consumption appeared to have higher education than those with lower kimchi consumption. Participants with high and low kimchi consumption did not appear to differ with regard to income, alcohol intake habits, chronic disease status, fasting glucose, and high-density lipoprotein cholesterol levels. In women, participants with higher consumption of kimchi were more likely to have an older age, higher blood pressure level, and higher BMI, as well as higher intake of calories and sodium. Smoking habit and chronic disease status were not different across quintiles. Participants with higher consumption of kimchi appeared to differ with regard to alcohol intake, physical activity, income level, hypertension education, and survey year (Table 1).

Table 2 presents the odds ratio of hypertension according to quintiles of kimchi consumption in men and women. Higher kimchi consumption was not associated with a higher prevalence of hypertension in multivariate models by gender [OR = 0.87; 95% confidence interval (CI) = 0.70–1.08 for ≥216.5 g/day vs. <39.2 g/day; p for trend = 0.7532, in men; OR = 1.04; 95% CI = 0.80–1.34 for ≥145.1 g/day vs. <19.5 g/day; p for trend = 0.2875, in women].

4. Discussion

The present study documents that there was no association between kimchi consumption and the prevalence of hypertension. Previous research has reported the beneficial effects of kimchi, including it being a source of probiotics and its antioxidative activity, immune regulation, chemopreventive effects, and ability to improve metabolic profiles [1,2,18–20]. Due to these health benefits, kimchi has been one of most famous fermented foods worldwide, and industrial production of high-quality, standardized kimchi has been considered [3,6].

However, concerns about the possibility of kimchi contributing to an increased risk of hypertension have risen because of high salt intake as a result of high kimchi consumption [7,8]. In animal studies, blood pressure was elevated by consumption of high-sodium-containing kimchi but was not influenced by supplementing with low-sodium kimchi [7]. In this study, levels of serum biochemical parameters, including sodium and potassium, were not different among the groups and the elevations in serum levels of aldosterone decreased in the low-sodium kimchi group, which meant that the renin–angiotensin–aldosterone system might have been involved in the mechanism of blood pressure change accompanied by kimchi consumption. However, in epidemiologic studies, sodium intake itself, accompanied by a daily diet, did not appear to have a relationship with the risk for hypertension after adjusting for confounding factors [9]. When people have an increased intake of potassium, high intake of sodium is not associated with higher blood pressure [21]. Recent human trials have probed the joint effects of sodium and potassium on hypertension and its cardiovascular sequelae [22,23]. In the present study, although the group of participants with the highest consumption of kimchi also had the highest sodium intake, the risk of hypertension was not different between the groups. With the increased intake of kimchi, potassium intake was increased too in this study. The results of recent human studies reported that the pathogenesis of primary hypertension was the interaction of sodium excess and potassium deficiency in the body, rather than either of the disturbances alone [21–23]. As vegetables are a major source for potassium, increased consumption of vegetables reduced the risk for developing hypertension [24–26]. Kimchi is not only a source of sodium, but also a major source of potassium in the typical Korean diet. Therefore, our results suggest that high potassium intake from high consumption of kimchi can help neutralize the effect of elevated sodium intake on blood pressure levels.

There were several limitations in the present study. Our study had a cross-sectional design, from which causal relationships cannot be confirmed. To minimize this limitation, we excluded the participants who were diagnosed with hypertension or were receiving treatment for it. A randomized controlled trial design could have provided stronger evidence for the causal relationship. Considering the feasibility of randomized controlled trials for diet intervention for humans in a large nationwide sample, an epidemiologic study with 24-hour recalls can serve as one of the most cost-effective and feasible replacements for a randomized controlled trial, as the reliability of questionnaire-derived dietary

Table 2
ORs (95% CI) of Risk of Hypertension* According to Kimchi Intake in Korean Adults.

Quintile	Total number	Range of total kimchi intake (g/d)	Median of total kimchi intake (g/d)	No. of cases	Age-adjusted ORs (95% CI)	Multivariate-adjusted ORs† (95% CI)
Men						
Q1	1,561	<39.2	18.0	254	Reference	Reference
Q2	1,565	39.2–<85.5	71.5	273	1.10 (0.87–1.26)	1.04 (0.85–1.27)
Q3	1,518	85.5–<144.0	108.0	289	1.14 (0.94–1.37)	1.07 (0.88–1.31)
Q4	1,664	144.0–<216.5	173.8	314	1.14 (0.95–1.37)	1.08 (0.89–1.32)
Q5	1,507	≥216.5	293.9	275	1.04 (0.86–1.26)	0.87 (0.70–1.08)
p value for trend‡					0.3759	0.7532
Women						
Q 1	2,466	<19.5	1.5	149	Reference	Reference
Q2	2,453	19.5–<49.8	36.0	178	1.11 (0.88–1.40)	1.12 (0.88–1.42)
Q3	2,460	49.8–< 89.1	72.0	184	1.20 (0.95–1.51)	1.22 (0.96–1.54)
Q4	2,460	89.1–<145.1	109.5	191	1.21 (0.96–1.52)	1.21 (0.96–1.54)
Q5	2,460	≥145.1	214.1	175	1.04 (0.82–1.31)	1.04 (0.80–1.34)
p value for trend‡					0.2667	0.2875

CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; LDL, low-density lipoprotein cholesterol; ORs, odds ratios; Q, quintile.

* Hypertension was defined as having a systolic pressure of 140 mmHg (or higher) or a diastolic pressure of 90 mmHg (or higher).

† Multivariate-adjusted models were adjusted for age, body mass index, fasting glucose, triglycerides, LDL-C, HDL-C, energy, sodium intake, smoking, alcohol consumption, physical activity, education, income, receiving education for hypertension, survey year (for men and women), chronic diseases status, potassium intake, and menopause (for women only).

‡ Tests for linear trends across categories were conducted by treating the median of each category as a continuous variable.

information and the stability of dietary intake habits of adults with over time can provide valid and reliable data [27]. The other limitation was that daily intakes of energy, nutrient, and kimchi were estimated using one 24-hour dietary recall. Ideally, in biomedical studies, at least three 24-hour recalls, one on an off day and two on working days, would provide valid and reliable data to estimate the intake of individuals. However, realistically, this could not be easily applied to a large nationwide sample.

Even though longitudinal studies and randomizedcontrolled trials are needed to confirm the relationship between kimchi consumption and hypertension risk, the present study revealed high consumption of kimchi was not associated with an increased prevalence of hypertension in humans. Our results suggested that high potassium intake from high consumption of kimchi might have neutralized the effect of elevated sodium intake on blood pressure levels. To confirm this association, well-designed randomized controlled trials are warranted.

Conflicts of interest

The authors have no conflicts of interest.

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