Original Article

High consumption of salt-fermented vegetables and hypertension risk in adults: a 12-year follow-up study

Hong Ji Song MD, MPH, PhD[1], Seon-Joo Park PhD[2], Dae Ja Jang PhD[3], Dae Young Kwon PhD[4], Hae-Jeung Lee PhD[2]

[1]*Department of Family Medicine, Hallym University Sacred Heart Hospital, Anyang-si, Korea*
[2]*Department of Food & Nutrition, Gachon University, Seongnam-si, Korea*
[3]*Research Group of Food Value Creation, Korea Food Research Institute, Seongnam-si, Korea*
[4]*Division of Nutrition and Metabolism Research, Korea Food Research Institute, Seongnam-si, Korea*

Background and Objectives: The aim of this study was to investigate the causal relationship between high consumption of salt-fermented vegetables and hypertension risk in adults. **Methods and Study Design**: Data came from the Korean Genome and Epidemiology Study, an ongoing community-based cohort study that began in 2001. In the final analysis, a total of 5,932 participants (men=2,822, women=3,110) was included. Daily energy, nutrient, and major salt-fermented vegetables for Korean (kimchi) intakes were assessed using a semi-quantitative food frequency questionnaire. Relative risks and 95% CIs associated with kimchi intake by gender and body mass index (BMI) were estimated using the multivariate Cox proportional hazards regression model. **Results**: Out of the 5,932 participants, 1,798 (905 men, 893 women) developed hypertension during the 12-year follow-up period. A significant difference in baseline BMI was shown between the non-hypertension and hypertension groups. There was no significant difference with regard to the risk of developing hypertension across quintiles for total kimchi intake and quartile or quartiles for specific kimchi intake in multivariate models by gender and baseline BMI. The trend for increased risk of hypertension according to increasing quartile of watery kimchi intake was significant for obese men in the multivariate model ($p<0.05$). **Conclusion**: High consumption of salt-fermented vegetables was not shown to be associated with increased risk of hypertension. The trend for increased risk of hypertension according to increasing quartile of watery kimchi intake was significant only in obese men.

Key Words: salt, fermentation, vegetable, hypertension, cohort

INTRODUCTION

Hypertension is one of the most important risk factors for mortality and several morbidities, including cardiovascular disease, heart failure, stroke, and renal disease.[1,2] Despite efforts to lower blood pressure, hypertension remains the leading cause of disease and disability worldwide due to its prevalence and attributable risk for cardiovascular and renal diseases.[3] Even a small reduction in blood pressure can lead to reductions in morbidity and mortality at the population level.[4] Therefore, the American Heart, Lung, and Blood Institute and European Society of Hypertension recommend a diet based on a low intake of sodium and high intakes of fruits and vegetables for the prevention and management of hypertension.[1,4,5] Moreover, in Asian countries, low salt intake has been recommended for prevention and management of hypertension. However, salt intake remains high in Korean and Japanese has been still high, and one of the major sources of sodium was traditional food.[6-8] In Korea, the major salt fermented vegetable foods, kimchi, has been consumed since a long time ago. One of the beneficial effects of kimchi comes from the fermentation process by lactic acid bacteria (LAB), which leads to the eradication of pathogenic organisms and increases its health benefits and functionalities as a probiotic.[9-12] However, the average salt content of kimchi is 2.0-5.0%,[9] and a high salt intake is one of the major risk factors contributing to an increase in blood pressure.[13] Although kimchi is becoming more popular globally because of its health benefits and taste, recently concern about the risk of increasing blood pressure due to high salt intake accompanied with high consumption of kimchi has arisen.[14,15] However, there are still areas of uncertainty about the association between the quantity and type of kimchi consumption and the risk of increasing blood pressure.

Therefore, the aim of the present study was to investigate the direct causal relationship between the risk of hypertension and the quantity and type of kimchi consumption using data from a community-based cohort study in the Republic of Korea.

Corresponding Author: Dr Hae-Jeung Lee, Department of Food & Nutrition, Gachon University, 1342 Seongnam-daero, Sujeong-gu, Seongnam-si, Gyeonggi-do, Korea, 461-701.
Tel: 82-31-750-5968; Fax: 82-31-750-5974
Email: skysea1010@gmail.com; skysea@gachon.ac.kr
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MATERIALS AND METHODS

Study population and exclusion criteria

The Korean Genome and Epidemiology Study (KoGES) is an ongoing community-based cohort study that was initiated in 2001 with support from the Korean National Institute of Health. The study has been described in detail previously.[16,17] Briefly, the cohort initially included 10,038 participants aged 40-69 years. Baseline examinations were performed between 2001 and 2003, and follow-up examinations are conducted biennially. Partici-pants included residents of a rural area (Ansung) and an industrialized area (Ansan). The data was provided with bioresources from National Biobank of Korea, the Centers for Disease Control and Prevention, Republic of Ko-rea (4845-301, 4851-302 and -307).

From the 10,038 baseline participants, we excluded subjects using the following criteria: a) lack of nutrient data (n=326), b) unrealistic reported daily total energy intake (<500 kcal or >6,000 kcal; n=52),[18,19] and c) lack of blood pressure data (n=14). We also excluded subjects diagnosed with hypertension or on antihypertensive medication (n=1,136), those with systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg at baseline examination (n=1,869), and subjects who did not attend the follow-up examination (n=709). The remaining 5,932 participants (2,822 men, 3,110 women) were eligible for analysis (Figure 1).

The written informed consent was obtained from all participants. The study protocol was approved by the Human Subjects Review Committee of Eulji University.

Measurements

All participants completed a comprehensive health examination and interview. The health examination included evaluation of anthropometric indices and collection of specimens for assessment. Participants also completed interviewer-administered questionnaires to collect data on demographic (e.g., age, sex, income, education, residential area) and lifestyle (e.g., smoking, alcohol consumption, exercise) characteristics, medical history, and medication use. The baseline examination question about menopausal status ("Have you menstruated in the last 12 months?") was inadequate; hence, we used a follow-up question ("When did you reach menopause?") and judged baseline menopause status by inference.

Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared; these variables were measured to the nearest 0.1 kg and 0.1 cm, respectively. After participants had fasted for at least 8 hours, venous blood samples were collected and assayed to determine plasma glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride concentrations. The low-density lipoprotein (LDL) cholesterol was calculated by using the Friedwald equation (LDL cholesterol = total cholesterol – HDL cholesterol – triglycerides/5).

Blood pressure was measured by trained technicians using mercury sphygmomanometers (Baumanometer Standby; W. A. Baum Co. Inc, New York, USA). The values of SBP and DBP were defined as the average of the left and right arm readings obtained in a seated position after a minimum of 5 minutes of rest. Incident hypertension was defined as the first occurrence of SBP ≥140 mmHg or DBP ≥90 mmHg at any follow-up examination, or treatment with anti-hypertensive medication.

Dietary assessment

Usual dietary intake was assessed using a 103-item semi-quantitative food frequency questionnaire (SQFFQ) developed for the KoGES. The development of the SQFFQ has been described in detail previously.[17,20] Briefly, based on dietary intake data from the 1998 Korea National Health and Nutrition Examination Survey, the frequency of serving intake was classified into nine categories, 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, twice a day, and ≥3 times a day. The portion size of each food item was classified as small, medium, or large. For seasonally available food items, participants were instructed to indicate the time period during which they ate each item using the following four categories: 3, 6, 9, and 12 months. Nutrient intakes were calculated for each participant using the recommended

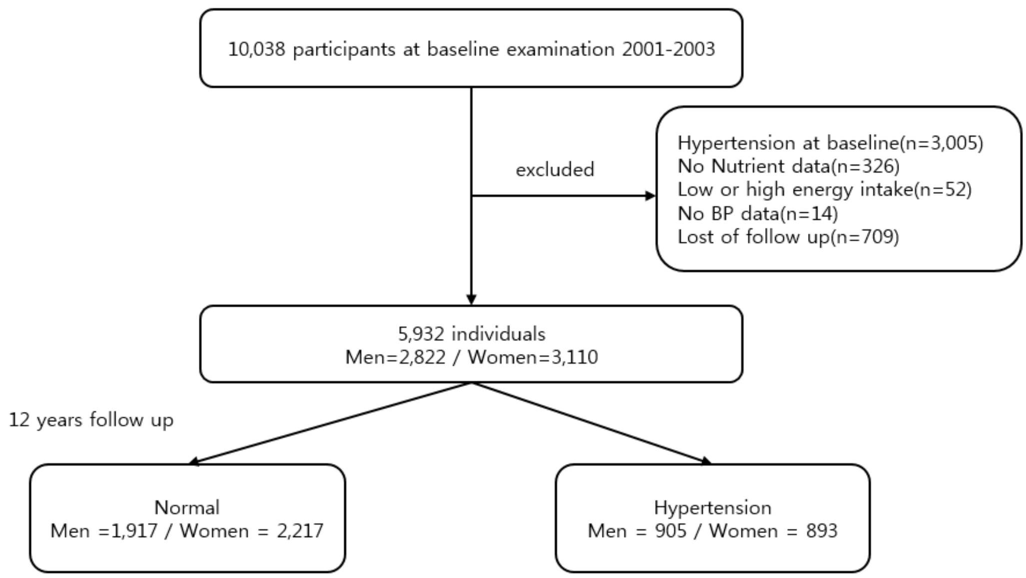

Figure 1. Diagram of the study population selected for analysis.

dietary allowances of the 7th edition of the Food Composition Tables for Koreans of the Korean Nutrition Society.

Using the following four types of kimchi, participants were divided into quartiles or quintiles of intake: (1) baechukimchi (Korean traditional cabbage kimchi), (2) watery kimchi (kimchi with water), (3) total kimchi [baechukimchi, watery kimchi, kkakdugi (sliced radish kimchi), and other kimchis], and (4) total kimchi minus watery kimchi.

Statistical analysis

Baseline characteristics of the KoGES participants were calculated using means for continuous variables and frequency/percentages for categorical variables. The difference between groups was tested using the *t* test for continuous variables and chi-square test for categorical variables.

Relative risks (RRs) and 95% confidence intervals (CIs) associated with kimchi intake were estimated using the multivariate Cox proportional hazards regression model. The model controlled for the following categorical variables: area of residence (Ansung, Ansan), sex (male, female), income (<1,500,000 Won/month, ≥1,500,000 Won/month), education (elementary school, middle school, high school, college and over), drinking (non-/ex-drinker, current drinker), smoking (non-/ex-smoker, current smoker), exercise (no exercise, <2.5 hr/week, 2.5-6.5 hr/week, >6.5 hr/week), and menopausal status (yes, no). The significance level that was considered for variables to be included in the multivariate model was $p<0.05$. We additionally adjusted for the variables of life style including smoking, alcohol consumption, and exercise because they have been reported to correlate with hypertension.[13]

We also conducted additional analyses according to obesity (BMI <25 kg/m^2 vs BMI ≥25 kg/m^2) and gender.[21]

To assess whether there was any linear association between kimchi intake and hypertension, tests for linear trends were performed by treating the median value of each kimchi intake category as a continuous variable. All analyses were performed using the SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC, USA).

RESULTS

Of the 5,932 participants, 1,798 (905 of 2,822 men, 893 of 3,110 women) were newly diagnosed with hypertension during the 12-year follow-up period (Figure 1). The mean duration of follow up was 7.1 years. The cumulative incidence of hypertension during the 12-year follow-up period was 30.3%.

Table 1 shows the baseline characteristics of participants. The mean age and baseline BMI of the hypertension group were higher than those of the non-hypertension group. No significant difference between the non-hypertension and hypertension groups was observed in terms of energy, sodium, potassium, and fruit intakes in men or women. Among men, vegetable intake was higher in the hypertension group than in the non-hypertension group. There was no significant difference between the non-hypertension and hypertension groups in the prevalence of smoking and alcohol consumption in men or women. The hypertension group had lower income and education levels. The proportion of women engaging in high-intensity exercise was higher in the non-hypertension group than in the hypertension group. Moreover, the total and watery kimchi intakes were higher in the hypertension group than in the non-hypertension group in men and women.

There were no significant differences in the risk of developing hypertension across quintiles of total kimchi intake or quartiles of specific kimchi intake in multivariate models by gender (Table 2).

The risk of hypertension incidence according to kimchi intake by gender and baseline BMI can be found in Tables 3 and 4. There were no significant differences in the risk of hypertension across quintiles of total kimchi intake or quartiles of specific kimchi intake in multivariate analyses according to sex and BMI. However, the risk of hypertension development in the fourth quartile of watery kimchi intake increased to 1.36 in obese men (Table 3). Although the confidence intervals of hazard ratios were not significant, a significantly increased trend according to watery kimchi intake was observed in the multivariate model for obese men ($p<0.05$). In obese women, the trend of increased risk of hypertension was significant in age-adjusted analyses, but not in the multivariate model (Table 4).

DISCUSSION

The traditional Korean diet of rice and kimchi together with a variety of foods, has previously been reported to be associated with a lower risk of elevated blood pressure.[22,23] However, a high salt intake is one of the major risk factors for hypertension[13,24] and the average sodium intake of Koreans has been shown to be more than 5,000 mg/day.[15,25,26] As almost all Koreans have kimchi daily with meals and it accounts for 19.6% of their sodium intake, kimchi is one of the main sources of sodium for Koreans.[15] To reduce salt consumption, the reduction of kimchi intake has been recommended. However, the present study showed no relationship between high consumption of kimchi and the incidence of hypertension in Korean adults. Kimchi may have both beneficial and harmful effects on blood pressure because of its positive effects as a vegetable and its probiotic properties, and the negative effect as containing relatively high amount of salt. In addition to being an important source of vitamins, minerals, dietary fiber, and other nutrients, and being a low-energy (18 kcal/100 g) and low-fat (0.5 g/100 g) food,[27] kimchi is a source of probiotics, has antioxidative activity, and improves metabolic profiles.[9,10,28-30] Its function as a probiotic may prevent increases in blood pressure despite its high sodium content, as probiotics have been reported to have a beneficial effect on blood pressure.[31] Interestingly, in our study, the trend for increased risk of hypertension according to quartile of watery kimchi intake was significant only in obese men. The various types of kimchi are generally categorized into two types, ordinary and watery kimchi, based on whether brine was added during the fermentation process.[27,32] Therefore, the microbial ecology and metabolites of fermentation differ between ordinary and watery kimchi.[32,33] Watery kimchi has fewer probiotic components than do other types of kimchi. Thus, the beneficial effects of kimchi on blood

Table 1. Baseline characteristics of participants

Variables	Men			Women		
	No hypertension (n=1,917)	Hypertension† (n=905)	*p* value	No hypertension (n=2,217)	Hypertension† (n=893)	*p* value
Continuous variables, mean±SE						
Age (year)	50.2±0.2	52.0±0.3	<0.0001	49.1±0.2	54.1±0.3	<0.0001
Follow up years	8.0±0.1	4.9±0.1	<0.0001	8.2±0.1	5.0±0.1	<0.0001
Systolic blood pressure (mmHg)	111±0.2	120±0.3	<0.0001	109±0.2	120±0.4	<0.0001
Diastolic blood pressure (mmHg)	75.2±0.2	80.1±0.2	<0.0001	72.0±0.2	78.0±0.2	<0.0001
Body Mass Index (kg/m^2)	23.7±0.1	24.4±0.1	<0.0001	24.2±0.1	25.0±0.1	<0.0001
Fasting glucose (mg/dL)	88.4±0.5	89.5±0.9	0.250	82.9±0.4	84.2±0.6	0.048
Total cholesterol (mg/dL)	191±0.8	189±1.2	0.336	186±0.7	190±1.1	0.017
HDL-cholesterol (mg/dL)	43.7±0.2	43.0±0.3	0.084	46.6±0.2	45.0±0.3	<0.0001
LDL-cholesterol (mg/dL)	116±0.7	113±1.1	0.023	114±0.6	115±1.0	0.238
Triglycerides (mg/dL)	165±2.6	177±3.6	0.009	132±1.5	150±2.9	<0.0001
Energy (kcal/day)	2,016±13.5	2,047±22.0	0.214	1,916±14.3	1,920±22.3	0.886
Potassium (mg/day)	2,532±24.1	2,580±38.1	0.269	2,601±26.5	2,579±41.8	0.644
Sodium (mg/day)	3,325±37.3	3,439±56.4	0.088	3,035±33.1	3,101±53.8	0.283
Vegetables (g/d)‡	120±2.6	130±4.2	0.038	144±3.0	144±4.8	0.898
Baechukimchi (g/d)	114±1.3	113±1.9	0.594	103±1.2	101±1.8	0.463
Radish kimchi (g/d)	45.4±1.2	47.4±1.8	0.368	34.6±1.0	37.4±1.7	0.149
Watery kimchi (g/d)	37.8±1.7	46.4±2.6	0.006	35.1±1.5	45.8±2.6	0.000
Other kimchi (g/d)	9.9±0.5	13.0±0.9	0.005	8.3±0.5	8.6±0.8	0.722
Total kimchi (g/d)	207±3.3	219±5.2	0.042	181±2.9	193±4.8	0.028
Total kimchi-watery kimchi (g/d)	169±2.3	173±3.4	0.343	146±2.0	147±3.1	0.669
Fruits (g/d)	218±6.0	234±9.1	0.124	309±7.9	332±13.7	0.128
Area, n (%)						
Ansung	727 (60.7)	470 (39.3)	<0.0001	939 (63.2)	547 (36.8)	<0.0001
Ansan	1,190 (73.2)	435 (26.8)		1,278 (78.7)	346 (21.3)	
Smoking, n (%)						
Non/Ex-smoker	660 (67.2)	322 (32.8)	0.568	48 (66.7)	24 (33.3)	0.363
Current smoker	1,254 (68.3)	583 (31.7)		2,142 (71.6)	851 (28.4)	
Drinking, n (%)						
Non/Ex-drinker	584 (69.9)	252 (30.1)	0.161	1,567 (70.6)	652 (29.4)	0.167
Current drinker	1,329 (67.2)	650 (32.8)		639 (73.1)	235 (26.9)	
Income, n (%)						
<1,500,000 Won/month	689 (62.1)	421 (37.9)	<0.0001	1,002 (64.3)	557 (35.7)	<0.0001
≥1,500,000 Won/month	1,215 (71.7)	479 (28.3)		1,172 (79.0)	311 (21.0)	

All data are presented as mean±standard error or percentage of participants. *p* values were calculated using the χ^2 test for categorical variables and the *t* test for continuous variables.
†Hypertension prevalence was defined according to systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medication at the follow-up examination.
‡Vegetables did not include kimchi or other salt-fermented vegetables.
§Participants diagnosed with diseases such as diabetes, myocardial infarction, thyroid disease, congestive heart failure, coronary artery disease, dyslipidemia, peripheral vascular diseases, kidney disease, hepatitis, and cancer.

Table 1. Baseline characteristics of participants (cont.)

Variables	Men			Women		
	No hypertension (n=1,917)	Hypertension† (n=905)	*p* value	No hypertension (n=2,217)	Hypertension† (n=893)	*p* value
Education, n (%)						
Elementary school	300 (59.1)	208 (40.9)	<0.0001	703 (61.1)	448 (38.9)	<0.0001
Middle school	367 (61.7)	228 (38.3)		572 (73.7)	204 (26.3)	
High school	753 (70.2)	319 (29.8)		742 (79.4)	192 (20.6)	
College or higher degree	491 (77.0)	147 (23.0)		187 (81.3)	43 (18.7)	
Exercise n (%)						
No exercise	1,341 (67.9)	635 (32.1)	0.340	1,593 (70.4)	671 (29.6)	0.021
≤2.5 hr/week	222 (64.9)	120 (35.1)		171 (67.9)	81 (32.1)	
2.5< ≤6.5hr/week	186 (68.6)	85 (31.4)		232 (77.1)	69 (22.9)	
>6.5 hr/week	168 (72.1)	65 (27.9)		221 (75.4)	72 (24.6)	
Chronic disease status§ n (%)						
Yes	1,581 (67.9)	746 (32.1)	0.978	1,813 (71.4)	725 (28.6)	0.701
No	336 (67.9)	159 (32.1)		404 (70.6)	168 (29.4)	
Menopause n (%)						
Yes				853 (61.4)	537 (38.6)	<0.0001
No				1,038 (78.7)	281 (21.3)	

All data are presented as mean ± standard error or percentage of participants. *p* values were calculated using the χ^2 test for categorical variables and the *t* test for continuous variables.
†Hypertension prevalence was defined according to systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medication at the follow-up examination.
‡Vegetables did not include kimchi or other salt-fermented vegetables.
§Participants diagnosed with diseases such as diabetes, myocardial infarction, thyroid disease, congestive heart failure, coronary artery disease, dyslipidemia, peripheral vascular diseases, kidney disease, hepatitis, and cancer.

Table 2. Risk of hypertension† according to kimchi intake by gender in a 12-year follow-up cohort study.

Category	Range (g/day)	Median intake (g/day)	Total no.	No. of cases	Multivariate-adjusted HR	Multivariate-adjusted 95% CI	p value	p value for trend§
Men								
Baechukimchi								0.976
Q1	<75	25.0	536	178	1.00			
Q2	75–<150	75.0	819	249	0.88	0.71–1.10	0.260	
Q3	150–<225	150	1,247	416	1.01	0.78–1.30	0.970	
Q4	≥225	225	220	62	0.84	0.55–1.27	0.399	
Watery kimchi								0.728
Q1	<1.5	0.0	790	234	1.00			
Q2	1.5–<10	4.0	644	197	1.01	0.83–1.23	0.927	
Q3	10–<47.5	20.4	657	208	1.07	0.88–1.31	0.498	
Q4	≥47.5	95.0	731	266	1.05	0.84–1.32	0.672	
Total kimchi								0.994
Q1	<97.5	64.5	562	178	1.00			
Q2	97.5–<157	128	567	182	1.05	0.84–1.32	0.659	
Q3	156.5–<202	175	567	161	0.88	0.69–1.13	0.308	
Q4	202–<303	247	560	183	1.05	0.80–1.37	0.741	
Q5	≥303	384	566	201	0.99	0.69–1.41	0.943	
Total kimchi - watery kimchi								0.824
Q1	<82.4	54.2	560	179	1.00			
Q2	82.4–<150	105	640	200	1.00	0.80–1.25	0.982	
Q3	150–<171	161	473	151	1.09	0.85–1.41	0.503	
Q4	171–<250	200	568	173	0.95	0.72–1.25	0.699	
Q5	≥250	303	581	202	1.05	0.74–1.49	0.801	
Women								
Baechukimchi								0.793
Q1	<75	25.0	718	196	1.00			
Q2	75–<100	75.0	814	260	0.90	0.73–1.12	0.361	
Q3	100–<150	100	239	56	0.99	0.71–1.39	0.969	
Q4	≥150	150	1,339	381	0.95	0.74–1.22	0.674	
Watery kimchi								0.349
Q1	<1.58	0.0	1,028	271	1.00			
Q2	1.58–<4.75	3.2	583	158	0.97	0.78–1.21	0.813	
Q3	4.75–<47.5	11.9	744	203	0.85	0.69–1.04	0.114	
Q4	≥47.5	143	755	261	0.85	0.68–1.08	0.187	
Total kimchi								0.219
Q1	<78.7	52.1	622	165	1.00			
Q2	78.7–< 136	100	622	170	1.00	0.79–1.27	0.993	
Q3	136–<175	155	613	179	1.09	0.85–1.41	0.493	
Q4	175–<275	211	633	170	0.89	0.68–1.18	0.415	
Q5	≥275	348	620	209	0.83	0.58–1.20	0.318	
Total kimchi–watery kimchi								0.997
Q1	<75	37.5	554	146	1.00			
Q2	75–<104	80.4	685	198	0.95	0.74–1.21	0.660	
Q3	104–<154	150	613	192	1.03	0.79–1.34	0.854	
Q4	154–<206	170	638	176	1.03	0.77–1.38	0.860	
Q5	≥206	300	620	181	0.97	0.67–1.41	0.884	

Q: quartile or quintile; HR: hazard ratio; CI: confidence interval.
†Hypertension prevalence was defined according to systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medication at the follow-up examination.
‡Multivariate models were adjusted for age, education, income, alcohol consumption, smoking, exercise, chronic disease status, menopause (women), body mass index, fasting glucose, HDL-C, LDL-C, triglycerides, energy intake, potassium intake, sodium intake, vegetable intake, fruit intake, and other kimchi intake (except for total kimchi analysis).
§Tests for linear trends across categories were conducted by treating the median of each category as a continuous variable.

pressure may have been lessened with watery kimchi intake in obese men, which supports the hypothesis that the underlying preventive effects of kimchi on hypertension are due to its actions as a probiotic.[31] Another potential underlying mechanism of kimchi in preventing hypertension due to high sodium intake is its potassium content. Blood pressure was found to be elevated in rats consuming high-sodium kimchi, but not in those consuming low-sodium kimchi.[14] Sodium and potassium levels were similar in the two groups, and elevated serum aldosterone levels decreased in the low-sodium kimchi group, which suggests the involvement of the rennin-angiotensin-aldosterone system (RAAS) to regulate blood pressure. However, in human epidemiological studies, daily sodium intake was not correlated with the risk of hypertension after adjusting for confounding factors.[25] Moreover, high intakes of sodium and potassium were not associated with increased blood pressure.[34] Therefore, the pathogenesis of primary hypertension in humans could result from the combined effects of sodium excess and potassium deficiency, rather than the occurrence of either disturbance independently.[34-36] High intake of vegetables, which are

Table 3. Risk of hypertension† according to kimchi intake and BMI in men

Category	Range (g/day)	Median intake (g/day)	Total no.	No. of cases	Multivariate-adjusted HR	95% CI)	*p* value	*p* value for trend§
BMI <25 kg/m^2								
Baechukimchi								0.792
Q1	<75	25.0	351	94	1.00			
Q2	75–<150	75.0	565	157	1.01	0.76–1.34	0.966	
Q3	150–<225	150	795	241	1.10	0.79–1.53	0.575	
Q4	≥225	225	135	34	0.91	0.52–1.56	0.722	
Watery kimchi								0.578
Q1	<1.58	0.0	491	124	1.00			
Q2	1.58–<10.1	3.2	419	117	1.02	0.78–1.32	0.908	
Q3	10.1–<47.5	20.4	425	119	1.04	0.80–1.36	0.775	
Q4	≥47.5	95.0	511	166	0.94	0.71–1.26	0.694	
Total kimchi								0.601
Q1	<97.5	65.5	369	102	1.00			
Q2	97.5–< 155	125	367	110	1.12	0.84–1.50	0.435	
Q3	155–<204	175	372	91	0.84	0.61–1.15	0.267	
Q4	204–<304	248	369	96	0.90	0.64–1.26	0.523	
Q5	≥304	385	369	127	0.94	0.60–1.45	0.766	
Total kimchi - watery kimchi								0.913
Q1	<81.1	55.4	366	100	1.00			
Q2	81.1–<150	101	337	92	1.08	0.79–1.46	0.632	
Q3	150–<167	155	406	120	1.17	0.86–1.59	0.311	
Q4	167–< 250	200	362	92	0.88	0.62–1.26	0.496	
Q5	≥250	302	375	122	1.09	0.70–1.70	0.697	
BMI ≥25 kg/m^2								
Baechukimchi								0.910
Q1	<75	25.0	185	84	1.00			
Q2	75–<150	75.0	254	92	0.73	0.51–1.03	0.075	
Q3	150–<225	150	452	175	0.94	0.62–1.41	0.757	
Q4	≥225	225	85	28	0.82	0.43–1.57	0.547	
Watery kimchi								0.037
Q1	<1.58	0.0	299	110	1.00			
Q2	1.58–<7.91	3.2	154	55	0.97	0.68–1.38	0.867	
Q3	7.91–<23.8	10.2	268	96	1.00	0.75–1.35	0.980	
Q4	≥23.8	95.0	255	118	1.36	0.97–1.91	0.079	
Total kimchi								0.604
Q1	<97.6	61.9	196	77	1.00			
Q2	97.6–< 160	135	195	72	1.00	0.69–1.44	0.983	
Q3	160–<200	175	195	64	0.93	0.62–1.38	0.715	
Q4	200–<301	244	198	96	1.52	0.97–2.36	0.065	
Q5	≥301	385	192	70	1.05	0.56–1.97	0.886	
Total kimchi–watery kimchi								0.540
Q1	<85.7	51.7	193	79	1.00			
Q2	85.7–<150	111	201	79	0.97	0.67–1.38	0.846	
Q3	150–<175	161	182	64	0.97	0.64–1.47	0.898	
Q4	175–< 252	202	207	82	1.16	0.73–1.83	0.526	
Q5	≥252	304	193	75	1.16	0.64–2.11	0.619	

Q: quartile or quintile; HR: hazard ratio; CI: confidence interval.
†Hypertension prevalence was defined according to systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medication at the follow-up examination.
‡Multivariate models were adjusted for age, education, income, alcohol consumption, smoking, exercise, chronic disease status, body mass index, fasting glucose, HDL-C, LDL-C, triglycerides, energy intake, potassium intake, sodium intake, vegetable intake, fruit intake, and other kimchi intake (except for total kimchi analysis).
§Tests for linear trends across categories were conducted by treating the median of each category as a continuous variable.

important sources of potassium, reduced the risk of hypertension development.[37-39] Thus, our results suggest that elevated potassium intake from kimchi blunts the effect of high sodium on blood pressure in individuals with high kimchi intake. Our result from cohort study confirms the null association between kimchi intake and hypertension similar to our study using cross-sectional data.[40]

This study is not without limitations. First, it is of cohort design, preventing any conclusions about causal relationships; a randomized controlled trial would provide the best evidence for causal relationships. However, considering the infeasibility of randomized controlled trials involving dietary interventions in large nationwide populations, epidemiological studies with cohort designs provide a useful indication of plausible causality. Another limitation was that, although kimchi intake was estimated using a validated FFQ, intake may have been underestimated compared with data obtained from a 24-hour recall, as kimchi intake was calculated from a limited list of food items. Lastly, while determining involvement of the

Table 4. Risk of hypertension† according to kimchi intake and BMI in women

Category	Range (g/day)	Median intake (g/d)	Total no.	No. of cases	Multivariate-adjusted‡ HR	Multivariate-adjusted‡ 95% CI	*p* value	*p* value for trend§
BMI <25 kg/m^2								
Baechukimchi								0.357
Q1	<75	25.0	468	113	1.00			
Q2	75–<100	75.0	503	138	0.77	0.57–1.03	0.077	
Q3	100–<150	100	138	25	0.79	0.48–1.30	0.348	
Q4	≥150	150	790	179	0.82	0.58–1.15	0.246	
Watery kimchi								0.729
Q1	<1.58	0.0	628	136	1.00			
Q2	1.58–<4.75	3.2	364	82	0.99	0.73–1.36	0.968	
Q3	4.75–<37.3	10.2	423	97	0.87	0.64–1.17	0.342	
Q4	≥37.3	95.0	484	140	0.90	0.65–1.27	0.558	
Total kimchi								0.166
Q1	<77.4	50.0	376	88	1.00			
Q2	77.4–< 126	94.2	385	89	0.91	0.65–1.27	0.588	
Q3	126–<171	154	378	95	1.02	0.72–1.44	0.930	
Q4	171–<267	208	380	81	0.77	0.52–1.13	0.178	
Q5	≥267	348	380	102	0.71	0.42–1.20	0.203	
Total kimchi–watery kimchi								0.681
Q1	<75	37.4	363	91	1.00			
Q2	75–<102	80.3	401	95	0.67	0.48–0.94	0.020	
Q3	102–<153	150	373	97	0.90	0.63–1.28	0.556	
Q4	153–< 202	165	388	85	0.77	0.52–1.15	0.199	
Q5	≥202	279	374	87	0.77	0.47–1.28	0.319	
BMI ≥25 kg/m^2								
Baechukimchi								0.585
Q1	<75	25.0	250	83	1.00			
Q2	75–<100	75.0	311	122	1.12	0.81–1.54	0.486	
Q3	100–<225	150	589	214	1.18	0.83–1.68	0.356	
Q4	≥225	225	61	19	0.95	0.49–1.87	0.888	
Watery kimchi								0.251
Q1	<1.58	0.0	400	135	1.00			
Q2	1.58–<4.75	3.2	219	76	0.91	0.66–1.25	0.554	
Q3	4.75–<47.5	10.2	298	101	0.87	0.65–1.15	0.322	
Q4	≥47.5	95.0	294	126	0.79	0.57–1.10	0.165	
Total kimchi								0.595
Q1	<81.0	55.9	242	79	1.00			
Q2	81.0–< 150	102	229	80	1.20	0.85–1.70	0.308	
Q3	150–<177	160	256	91	1.22	0.85–1.75	0.277	
Q4	177–<293	218	234	81	1.05	0.69–1.58	0.831	
Q5	≥293	345	250	107	0.95	0.57–1.59	0.847	
Total kimchi–watery kimchi								0.892
Q1	<75.8	50.0	241	76	1.00			
Q2	75.8–<123	87.5	243	90	1.30	0.92–1.84	0.135	
Q3	123–<156	150	243	93	1.17	0.80–1.70	0.421	
Q4	156–<225	175	242	89	1.30	0.86–1.98	0.214	
Q5	≥225	300	242	90	1.10	0.64–1.86	0.737	

Q: quartile or quintile; HR: hazard ratio; CI: confidence interval.

†Hypertension prevalence was defined according to systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of antihypertensive medication at the follow-up examination.

‡Multivariate models were adjusted for age, education, income, alcohol consumption, smoking, exercise, chronic disease status, menopause, body mass index, fasting glucose, HDL-C, LDL-C, triglycerides, energy intake, potassium intake, sodium intake, vegetable intake, fruit intake, and other kimchi intake (except for total kimchi analysis).

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

RAAS could explain the potential underlying mechanisms whereby kimchi intake affects blood pressure, serum aldosterone levels could not be estimated in our study.

Conclusions

A high consumption of salt-fermented vegetables was not associated with an increased risk of hypertension, despite the high sodium content of these foods. The trend for increased risk of hypertension according to increased quartile of watery kimchi intake was significant in a multivariate model for obese men. It is possible that probiotic effects of salt-fermented vegetables provide one an underlying mechanism for attenuation of the potential adverse effects of elevated sodium intake from kimchi on blood pressure.

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AUTHOR DISCLOSURES

The authors have no conflict of interest.

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