RESEARCH
Original Research

Association between High Blood Pressure and Intakes of Sodium and Potassium among Korean Adults: Korean National Health and Nutrition Examination Survey, 2007-2012

Hye-Mi Noh, MD*; So-Young Park, MD, MS*; Haeng-Shin Lee, PhD; Hye-Young Oh, MD; Yu Jin Paek, MD, PhD; Hong Ji Song, MD, PhD, MPH; Kyung Hee Park, MD, PhD, MPH

ARTICLE INFORMATION

Article history:
Submitted 19 November 2014
Accepted 22 April 2015

Keywords:
Sodium
Potassium
Blood pressure
Hypertension

http://dx.doi.org/10.1016/j.jand.2015.04.021

*Hye-Mi Noh and So-Young Park request to be regarded as joint first authors.

ABSTRACT

Background The association between dietary sodium and potassium, the ratio of sodium to potassium, and blood pressure remains unclear.

Objective We evaluated the associations between blood pressure and dietary sodium and potassium intake in terms of the amount and ratio in Korean adults.

Design This cross-sectional study was based on data from the fourth and fifth Korean National Health and Nutrition Examination Survey, 2007-2012.

Participants/setting A total of 24,096 adults (aged ≥19 years) without history of antihypertensive medication use were selected. The 24-hour recall method was used for dietary assessment. We categorized the subjects into four groups using median intakes of sodium and potassium, and defined the low sodium/high potassium intake group as the reference group.

Main outcome measures High blood pressure (HBP) was defined as mean systolic or diastolic blood pressures of ≥140 or ≥90 mm Hg, respectively.

Statistical analyses performed Multivariate logistic regression was performed to estimate the odds ratio and 95% CI to investigate the association between the four groups of sodium and potassium intakes and HBP.

Results Sodium intake was positively associated with diastolic blood pressure, with an increase of 0.21 mm Hg per 1 mg/kcal increase in sodium ($P<0.001$). In contrast, potassium intake was negatively associated with systolic blood pressure, with a decrease of 1.01 mm Hg per 1 mg/kcal increase in potassium ($P<0.001$). After adjusting for confounders, the high sodium/low potassium (odds ratio 1.21, 95% CI 1.02 to 1.44) and low sodium/low potassium intake groups (odds ratio 1.19, 95% CI 1.01 to 1.40) were at higher risk of HBP than the reference group. The risk of HBP in the high sodium/high potassium group did not differ from that in the reference group.

Conclusions Low potassium intake was associated with an increased risk of hypertension. These results suggest that increasing potassium intake might be beneficial for hypertension control among populations with low-potassium diets.

J Acad Nutr Diet. 2015;■:■-■.

CARDIOVASCULAR DISEASES ARE THE LEADING cause of morbidity and mortality globally.[1] Hypertension is a major risk factor for cardiovascular diseases, including coronary heart disease, stroke, heart failure, and chronic kidney disease.[2] It affects one-fourth of adults worldwide, and the prevalence continues to increase in developing countries.[3]

The effect of dietary sodium intake on blood pressure (BP) has been well established.[4,5] Higher sodium intake is related to increased BP and higher prevalence of hypertension.[6] The BP-lowering effect of a low-salt diet has been demonstrated by a Cochrane systematic review and meta-analysis of randomized control trials.[7-9] Although recent epidemiologic studies and intervention trials have shown that potassium intake has a significant inverse relationship with BP, these results are inconsistent. A meta-analysis that included 22 randomized controlled trials and 11 cohort studies reported that increased potassium intake reduced systolic BP (SBP) and diastolic BP (DBP).[10] However, other population-based studies have found no association between dietary potassium intake and BP.[11,12] One possible explanation for these inconsistent results might be the differences in the amount of salt in the diet of each study. Potassium intake mitigates the BP response associated with a high-sodium diet.[10,13,14] Although the mechanism is unclear, potassium modulates the renin-angiotensin system that regulates BP. Reduced

potassium intake leads to renal sodium retention,[15] whereas the intake of potassium-rich food stimulates natriuresis and suppresses plasma renin activity.[16]

The prevalence of hypertension in South Korea is high (24.9%),[17] and the mean sodium intake in Korea (4.6 g/day) is 2.3 times higher than that (2 g/day) recommended by the World Health Organization (WHO). In contrast, the mean potassium intake (2.5 g/day) in Korea is lower than that (2.7 to 3.1 g/day) recommended by the WHO.[18,19] The ratio of sodium to potassium (NA:K) in Koreans may, therefore, be greater than that ($\leq$1) recommended by the WHO.[20] Considering the high sodium and low potassium intake in Korea, modifications of dietary patterns are a potential strategy for hypertension control. Previous Korean studies have demonstrated that dietary interventions that include both low-sodium and high-potassium diet reduced BP[21,22]; however, the effects on BP could not be separated by either low-sodium or high-potassium intake. Although a few population-based Korean studies have investigated the association between dietary sodium and potassium intakes and BP, they did not consider the interaction between sodium and potassium.

Based on previous results, we hypothesized that there might be a differential effect of dietary potassium intake on BP according to the concurrent sodium intake. We evaluated the associations between BP and dietary sodium and potassium intakes in terms of the amount and ratio in Korean adults, using 2007 to 2012 data from the fourth and fifth Korean National Health and Nutrition Examination Surveys (KNHANES).

METHODS

Study Population

Our data source, KNHANES, is a cross-sectional nationwide survey representing the general Korean population. A stratified, multistage probability sampling design was used. It includes comprehensive information on health status, health behavior, and sociodemographic characteristics. Face-to-face interviews at the participants' homes were conducted by trained interviewers to gather information, including the nutrition survey. The details of the KNHANES have been previously described.[23] Of 50,405 KNHANES participants during 2007 to 2012 who completed the health interview and health examination surveys, 38,005 (aged $\geq$19 years) were included in our analysis. Subjects with a history of antihypertensive medication use (n=6,787), those who did not answer the question relating to their history of hypertension (n=176), those with missing sodium or potassium data (n=3,859), those with missing BP data (n=2,048), and those with missing covariate information (n=1,039) were sequentially excluded. Finally, 24,096 participants were selected as the study population (see the Figure).

The KNHANES survey was conducted in accordance with Ethical Principles for Medical Research Involving Human

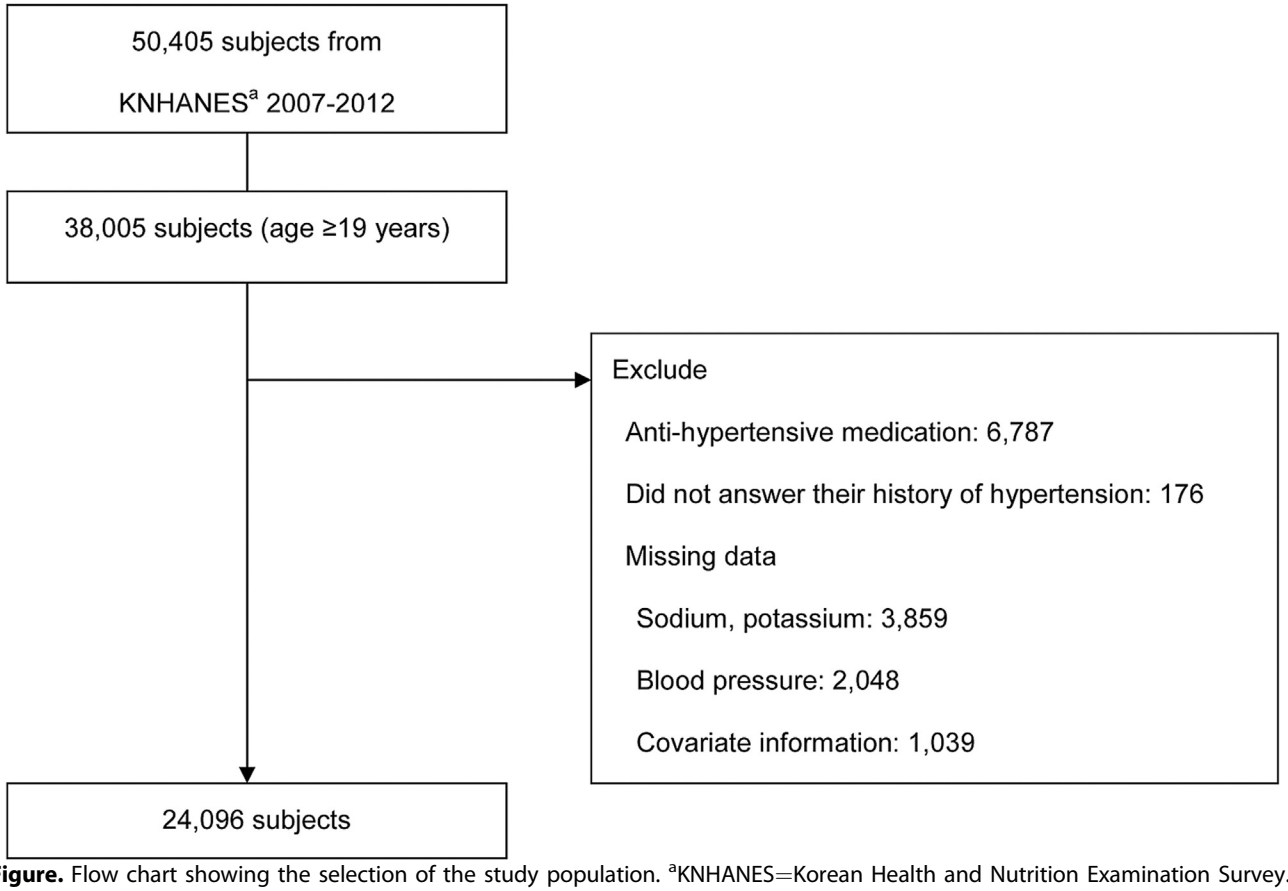

Figure. Flow chart showing the selection of the study population. [a]KNHANES=Korean Health and Nutrition Examination Survey.

Subjects. All the participants provided informed consent before participation in the study. Because the KNHANES survey data were publicly available (http://knhanes.cdc.go.kr/knhanes/), ethical approval was not required.

Data Collection

Dietary Assessment. The dietary intake of the participants was assessed by a 24-hour dietary recall. Actual food shapes and two-dimensional models of plates and bowls were used to help respondents to recall dietary information, including food content and recipes and amounts consumed during the past 24 hours. The recalls were conducted by trained dietitians. Quality control on interviews in the field was conducted through a survey by the Center for Nutrition Policy and Promotion at the Korea Health Industry Development Institute.[24] Previous studies have reported that sodium and potassium intakes based on a 24-hour recall are correlated with levels from a 24-hour urine collection.[25]

On the basis of these data, intakes of nutrients and electrolytes, including sodium and potassium, sodium (milligrams per 1,000 kcal), potassium (milligrams per 1,000 kcal), Na:K, total energy (kilocalories per day), and vitamin C (milligrams per day) were calculated using the National Standard Food Composition Table and the recipe database published and updated since 1970 by the Rural Development Administration.[26] Given that specified information regarding the contents of dietary supplements was not documented for all eligible participants, intakes of sodium and potassium via dietary supplement could not be considered in this study.

Sodium and potassium intakes were categorized into four groups using median intakes of sodium and potassium as references. The median sodium and potassium intakes were 2,302.9 and 1,507.8 mg/1,000 kcal, respectively. “Low” intake was defined as below the median value; “high” intake was defined as equal to the median value or higher. The four groups comprised combinations of sodium and potassium intakes, and were as follows: low sodium/low potassium intake, low sodium/high potassium intake, high sodium/low potassium intake, and high sodium/high potassium intake.

Measurement of BP. The primary outcomes of interest were mean BP and hypertension status. Trained and quality-controlled examiners manually measured BP with a mercury sphygmomanometer (Baumanometer; Baum). BP was measured in the sitting position after a 5-minute rest period. The subjects were asked to refrain from smoking for 30 minutes before the measurement. Three measurements were obtained with a 30-second interval. The average of the second and third BPs was used as the mean SBP or DBP. We used the Eighth Joint National Committee criteria to define hypertension.[27] Participants were classified as having high BP (HBP) if they were found to have a mean SBP $\geq$140 mm Hg or a mean DBP $\geq$90 mm Hg.

Assessment of Other Variables. Information on demographic and socioeconomic characteristics of the subjects was obtained. The demographic variables were age, sex, education level (elementary school education or lower, middle school education, high school education, and college education or higher), and monthly household income. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. The smoking status was classified according to three categories as follows: never smoker, ex-smoker, and current smoker. Alcohol intake was categorized as follows: high-risk drinking was defined as seven or more standard drinks per drinking day and 2 or more days of drinking per week for men, and five or more standard drinks per drinking day and 2 or more days of drinking per week for women.[28] A standard drink of alcohol was defined as any drink that contains 12 g pure alcohol (based on 4.5 vol% in beer, 12 vol% in wine, 6 vol% in Korean traditional *makgeolli*, 20 vol% in Korean *soju*, and 40 vol% in whiskey).[29] The physical activity of the participants was classified as adequate exercise if they reported >150 minutes of moderate-intensity and/or 60 minutes of vigorous-intensity activity per week.[30] Self-reported history of diseases (eg, hypertension, dyslipidemia, stroke, coronary heart disease, and diabetes mellitus) was considered as a covariate.

Statistical Analysis

Considering the complex sampling design of the KNHANES, the weighted mean and standard error (SE) or proportion (%) and SE of the general characteristics according to BP group were calculated. The prevalence of individuals with normal BP and HBP and the dietary characteristics of the four sodium and potassium intake groups (low sodium/low potassium, low sodium/high potassium, high sodium/low potassium, and high sodium/high potassium) were described as weighted means and SE. Linear regression or the Pearson χ^2 test was used to investigate the associations between the variables, as appropriate.

The association between intakes of sodium (milligrams per kilocalorie) and potassium (milligrams per kilocalorie), Na:K (per unit), and SBP and DBP were assessed using multivariate linear regression. Adjusted beta coefficient and *P* value were estimated. Sodium and potassium intakes were adjusted for in the same model, and Na:K model was not adjusted for sodium or potassium intakes.

The multivariate logistic regression was performed to estimate the adjusted odds ratio (OR) and 95% CI to investigate the association between the four groups of sodium and potassium intakes and HBP. Because high sodium and low potassium intakes are associated with increased BP, the low sodium/high potassium intake group was used as the reference, and the OR of hypertension in each group was calculated.

Given that the use of anti-hypertensive drugs will influence BP, participants who were taking anti-hypertensive medications were excluded from the analysis. In addition, participants with a history of hypertension who reported no current medication use were adjusted for in the final model.

In the linear and logistic regression analyses, we first adjusted for age and sex only. In the fully adjusted model, covariates included age and sex, plus monthly household income, BMI, smoking status, high-risk drinking, level of physical activity, history of diseases (ie, hypertension, dyslipidemia, stroke, coronary heart disease, and diabetes mellitus), and total energy intake.

All the tests were two-sided, with significance levels at a $P<0.05$. All the analyses were performed using SAS (version 9.3, 2013, SAS Institute Inc).

Table 1. Comparison of selected characteristics between the high blood pressure and normal blood pressure groups (Korean National Health and Nutrition Examination Survey, 2007-2012)

Characteristic	High blood pressure (n=2,812)	Normal blood pressure (n=21,284)	*P* value
	←—*estimated mean±SE*[a]—→		
Age (y)	49.9±0.37	40.8±0.16	<0.001
Body mass index	25.0±0.09	23.2±0.03	<0.001
Dietary intake			
Total energy (kcal)	2,150.8±24.92	2,034.4±9.44	<0.001
Vitamin C (mg)	108.2±2.27	109.8±1.07	0.496
Sodium (mg/1,000 kcal)	2,585.4±30.43	2,562.8±11.93	0.473
Potassium (mg/1,000 kcal)	1,511.9±13.18	1,575.0±6.18	<0.001
Sodium to potassium ratio	1.8±0.02	1.7±0.01	<0.001
Income ($\times 10^4$, Korean won)	367.0±19.45	402.3±10.38	0.078
	←—*estimated percent (SE)*—→		
Male	66.9 (0.99)	48.1 (0.39)	<0.001
Education			
Elementary school	26.2 (1.02)	12.1 (0.33)	<0.001
Middle school	12.5 (0.76)	8.8 (0.24)	
High school	35.9 (1.25)	43.4 (0.52)	
University	25.5 (1.16)	35.6 (0.57)	
Smoking status			
Never smoker	41.3 (1.08)	54.8 (0.43)	<0.001
Ex-smoker	15.6 (0.96)	10.0 (0.28)	
Current smoker	43.0 (1.19)	35.2 (0.45)	
Alcohol[b]			
High-risk drinking	24.6 (1.13)	12.5 (0.33)	<0.001
Physical activity[c]			
Adequate exercise	10.0 (0.68)	11.0 (0.30)	0.148
History of diseases[d]			
Hypertension	15.2 (0.84)	1.6 (0.10)	<0.001
Dyslipidemia	6.8 (0.56)	4.5 (0.16)	<0.001
Stroke	1.2 (0.20)	0.6 (0.05)	<0.001
Coronary heart disease	1.3 (0.26)	1.2 (0.08)	0.629
Diabetes mellitus	5.3 (0.48)	3.6 (0.14)	<0.001

[a]SE=standard error.
[b]High-risk drinking was defined as seven or more standard drinks per drinking day and 2 or more days of drinking per week for men, and five or more standard drinks per drinking day and 2 or more days of drinking per week for women. A standard drink of alcohol was defined as any drink that contains 12 g pure alcohol.
[c]The physical activity of the participants was classified as adequate exercise if they reported performing >150 minutes of moderate- and/or 60 minutes of vigorous-intensity activity per week.
[d]History of diseases was self-reported.

RESULTS

The general characteristics of the HBP and normal BP groups are presented in Table 1. The mean dietary sodium and potassium intakes for the study population were 2,565±11 mg/1,000 kcal and 1,568±6 mg/1,000 kcal, respectively. Na:K was 1.73±0.01. Compared with the normal BP group, the HBP group had significantly lower potassium intake and a higher Na:K. With respect to anthropometric measurement and lifestyle-related questionnaires, the HBP group was older, had higher BMI, and was of lower socioeconomic status relative to the normal BP group. The HBP group tended to have a higher prevalence of history of hypertension, dyslipidemia, stroke, and diabetes.

The results of the linear regression analysis that examined the relationship between sodium and potassium intakes as well as their ratio and BP are shown in Table 2. After adjusting for potential confounders, DBP was significantly increased by 0.21 mm Hg for every milligram per kilocalorie increase in sodium and 0.36 mm Hg for every unit increase in Na:K, whereas potassium intake did not show a significant association. In both models, potassium intake and Na:K were significantly associated with SBP, whereas sodium intake was not.

The BP, HBP, and dietary characteristics for the categorized groups using median intakes of sodium and potassium are described in Table 3. The prevalence of HBP differed among

Table 2. Association between sodium and potassium intakes and their ratio and blood pressure among Korean adults (Korean National Health and Nutrition Examination Survey, 2007-2012)

Intake	Systolic Blood Pressure		Diastolic Blood Pressure	
	β coefficient	*P* value	*β* coefficient	*P* value
Sodium (mg/kcal)				
Adjusted for age and sex only	−.01	0.857	.24	<0.001
Fully adjusted model[a]	.04	0.626	.21	<0.001
Potassium (mg/kcal)				
Adjusted for age and sex only	−.93	<0.001	−.06	0.629
Fully adjusted model[a]	−1.01	<0.001	−.21	0.092
Sodium to potassium ratio				
Adjusted for age and sex only	.58	<0.001	.48	<0.001
Fully adjusted model[a]	.43	<0.001	.36	<0.001

[a]Adjusted for age, sex, household income, body mass index, smoking status, high-risk drinking, physical activity, history of diseases (ie, hypertension, dyslipidemia, stroke, coronary heart disease, and diabetes mellitus), and total energy. Sodium and potassium intakes were adjusted for in the same model, and the sodium to potassium ratio model did not adjust for sodium and potassium intakes. High-risk drinking was defined as seven or more standard drinks per drinking day and 2 or more days of drinking per week for men, and five or more standard drinks per drinking day and 2 or more days of drinking per week for women.

Table 3. Comparison of the selected characteristics between the combinations of sodium and potassium intakes[a] among Korean adults (Korean National Health and Nutrition Examination Survey, 2007-2012)

Characteristic	Low sodium/high potassium (n=4,516)	High sodium/high potassium (n=7,532)	Low sodium/low potassium (n=7,532)	High sodium/low potassium (n=4,516)	*P* value
	←——— *estimated mean±SE*[b] ———→				
Systolic blood pressure (mm Hg)	113.0±0.30	113.7±0.22	114.2±0.24	114.8±0.31	<0.001
Diastolic blood pressure (mm Hg)	73.9±0.21	75.0±0.17	74.6±0.17	75.8±0.22	<0.001
Dietary intake					
Total energy (kcal)	1,930.5±17.90	1,887.1±11.82	2,207.1±17.04	2,127.5±17.81	<0.001
Vitamin C (mg)	158.1±3.06	138.3±1.64	76.3±1.05	79.4±1.09	<0.001
Sodium (mg/1,000 kcal)	1,690.3±8.51	3,666.9±20.46	1,624.0±6.52	3,176.5±17.30	<0.001
Potassium (mg/1,000 kcal)	1,981.5±10.78	2,017.4±9.53	1,133.5±3.76	1,248.1±3.60	<0.001
Sodium-to-potassium ratio	0.9±0.01	1.9±0.01	1.5±0.01	2.6±0.02	<0.001
	←——— *estimated percent (SE)* ———→				
High blood pressure (%)	9.5 (0.53)	10.3 (0.46)	11.8 (0.49)	12.4 (0.61)	<0.001

[a]The low category is defined as below the median (sodium: 2,302.9 mg/1,000 kcal and potassium: 1,507.9 mg/1,000 kcal).
[b]SE=standard error.

the four groups. Mean SBP and DBP were higher in the high sodium/low potassium intake group. Likewise, the prevalence of HBP was high in the high sodium/low potassium intake group. With regard to dietary intake, mean vitamin C intake was higher in the low sodium/high potassium intake group.

Table 4 presents associations between HBP and the combinations of sodium and potassium intakes. In comparison with the subjects in the low sodium/high potassium intake group (reference group), the subjects in the low sodium/low potassium group and high sodium/low potassium group were more likely to have HBP. After adjustment for age, sex, BMI, monthly household income, smoking status, high-risk drinking, physical activity, history of cardiometabolic diseases, and total energy intake, the subjects in the high sodium/low potassium intake group (OR 1.21, 95% CI 1.02 to 1.44) and low sodium/low potassium intake group (OR 1.19, 95% CI 1.01 to 1.40) were at higher risk of HBP compared with the reference group. The risk of HBP in the high sodium/high potassium intake group did not differ from that in the reference group.

DISCUSSION

In this large, nationally representative study of Korean adults, we found that dietary sodium intake and Na:K were positively associated with BP, whereas dietary potassium intake was inversely related to BP.

To date, several studies, including meta-analyses and systematic reviews, have shown the link between a higher sodium intake and the risk of hypertension.[4,9] Dietary trials of reduced salt intake have indicated a BP-lowering effect among hypertensive subjects, and an additive effect among normotensive subjects.[7,31,32] Contrary to our results, two previous studies using data from KNHANES III did not demonstrate any associations between sodium intake and BP among Korean adults.[18,33] The differing results might be caused by different characteristics of the subjects in terms of age or medical history and the confounders used in the multiple regression model. Park and colleagues[33] included only relatively young adults (aged 19 to 49 years) compared with our study subjects (aged ≥19 years). Because the salt sensitivity of BP has been known to increase with increasing age,[34,35] the relationship between sodium intake and BP might not be so prominent at a younger age. In addition, they did not adjust for energy intake and history of cardiovascular diseases. Those who are already diagnosed with cardiovascular diseases might try to reduce

Table 4. Odds ratio (OR) of sodium or potassium intake and high blood pressure among Korean adults (Korean National Health and Nutrition Examination Survey, 2007-2012)

	Adjusted for Age and Sex Only		Fully Adjusted Model[a]	
Sodium or potassium status[b]	**OR**	**95% CI**	**OR**	**95% CI**
Low sodium/high potassium	1.00		1.00	
High sodium/high potassium	1.03	0.87-1.21	0.99	0.84-1.18
Low sodium/low potassium	1.25	1.07-1.46	1.19	1.01-1.40
High sodium/low potassium	1.29	1.10-1.52	1.21	1.02-1.44

[a]Adjusted for age, sex, household income, body mass index, smoking status, high-risk drinking, physical activity, history of diseases (hypertension, dyslipidemia, stroke, coronary heart disease, and diabetes mellitus), and total energy. High-risk drinking was defined as seven or more standard drinks per drinking day and 2 or more days of drinking per week for men, and five or more standard drinks per drinking day and 2 or more days of drinking per week for women.
[b]The low category is defined as below the median (sodium: 2,302.9 mg/1,000 kcal and potassium: 1,507.9 mg/1,000 kcal).

their sodium intake, which could attenuate the association between sodium intake and BP.

We also demonstrated the positive relationship between Na:K and BP among Korean adults. Our findings are consistent with those of previous population-based studies undertaken in the United States and China using dietary recall data.[36,37] In the US study, the magnitudes of the increases in SBP and DBP (2.1 and 1.2 mm Hg, respectively) per unit change in Na:K were higher than those in our results (0.43 and 0.36 mm Hg, respectively).[36] In our study, only the low sodium/high potassium intake group achieved the goal set by the WHO for Na:K ($\leq$1).[20]

In addition, we assessed the differential effects of potassium on incident hypertension according to the concurrent sodium intake. In our study, the highest odds for HBP was found in the high sodium/low potassium group compared with the reference group (ie, low sodium/high potassium), and the low sodium/low potassium group showed a similar risk for HBP despite the relatively low sodium intake.

Contrary to the inconsistent results on the relationship between potassium intake and BP from recent meta-analyses, our study showed an inverse correlation between usual dietary potassium intake and BP. Several possible mechanisms might explain how potassium intake is associated with decreased BP. First, potassium intake directly affects vasomotor tone by modulating vascular sensitivity to catecholamines.[38] Second, high sodium intake increases endothelium-dependent nitric oxide and transforming growth factor-β,[39] which contributes to arterial stiffness by promoting hypertrophy of vascular smooth muscle.[40] Increased dietary potassium intake inhibits dose-dependently salt-induced endothelial production of transforming growth factor-β.[41]

Previous studies found that dietary potassium is more effective in reducing BP when sodium intake is high.[10,14] Because the usual sodium intake of Koreans is high,[18] even the low-sodium group in our study consumed considerable amounts of sodium, higher than the WHO recommendation (ie, 2 g/day).[19] Therefore, low intake of potassium might lead to an increased risk of hypertension among the both low- and high-sodium groups. Recent meta-analyses of the effect of dietary potassium intake on cardiovascular risk factors showed that the benefit of potassium intake on BP was observed when sodium intake was $>$2 g/day.[10] It has been reported that the sodium intake of most adult populations around the world is above 2 g/day.[42] Therefore, our results can be extended to most populations in most countries.

Our results showed that the risk of hypertension in the high sodium/high potassium group did not differ from the reference group, despite the high sodium intake. This suggests that potassium could be a key regulator of BP, and that increasing potassium intake may have a preventive effect on hypertension among most Korean adults. In addition, we found that vitamin C intakes in the high-potassium groups were twice that of the low-potassium group. This suggests that major sources of dietary potassium in our population are fruits and vegetables that contain high amounts of vitamin C.[43] Randomized controlled trials have shown that fruit and vegetable consumption is significantly associated with lower SBP and DBP.[44,45] In contrast, the effects of vitamin C on BP are unclear. A systematic review of cross-sectional studies reported an inverse association between vitamin C intake and BP,[46] whereas clinical trials show inconsistent results.[47,48]

Our study has several strengths. First, we used data from a large nationally representative sample and usual dietary intakes of sodium and potassium, which could warrant generalizability. Second, we adjusted for a wide range of confounding factors compared with previous Korean studies, and also performed sensitivity analyses. The results of our study still remained significant.

Despite these strengths, there are limitations to this study. First, this study had a cross-sectional design, which does not allow for causality. Second, we were not able to collect urine samples and analyze 24-hour urinary sodium and potassium excretion samples. Although previous studies reported that sodium and potassium intakes from 24-hour recall were correlated with levels from 24-hour urine collection, recent studies suggested that dietary self-reports could underestimate sodium intake and overestimate potassium intake. These possible measurement errors might have attenuated the associations between dietary intake of sodium and potassium and BP.[49,50]

CONCLUSIONS

In this study of Korean adults, sodium intake and Na:K were positively associated with BP, whereas potassium intake was negatively associated with BP. Regardless of the level of sodium intake, low potassium intake was associated with increased risk of hypertension. The results suggest that a higher dietary potassium intake might be preventative against hypertension in the majority of the Korean population, in which a high-sodium and low-potassium diet is the norm. These results support evidence indicating that modifications of dietary patterns could play a significant role in hypertension control.

References

1. Kahn R, Robertson RM, Smith R, Eddy D. The impact of prevention on reducing the burden of cardiovascular disease. *Diabetes Care*. 2008;31(8):1686-1696.
2. MacMahon S, Peto R, Cutler J, et al. Blood pressure, stroke, and coronary heart disease. Part 1, prolonged differences in blood pressure: Prospective observational studies corrected for the regression dilution bias. *Lancet*. 1990;335(8692):765-774.
3. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: Analysis of worldwide data. *Lancet*. 2005;365(9455):217-223.
4. Meneton P, Jeunemaitre X, de Wardener HE, MacGregor GA. Links between dietary salt intake, renal salt handling, blood pressure, and cardiovascular diseases. *Physiol Rev*. 2005;85(2):679-715.
5. Safar ME, Temmar M, Kakou A, Lacolley P, Thornton SN. Sodium intake and vascular stiffness in hypertension. *Hypertension*. 2009;54(2):203-209.
6. The INTERSALT Co-operative Research Group. Sodium, potassium, body mass, alcohol and blood pressure: The INTERSALT Study. *J Hypertens Suppl*. 1988;6(4):S584-S586.
7. He FJ, Li J, Macgregor GA. Effect of longer-term modest salt reduction on blood pressure. *Cochrane Database Syst Rev*. 2013;4:CD004937.
8. Graudal NA, Hubeck-Graudal T, Jurgens G. Effects of low sodium diet versus high sodium diet on blood pressure, renin, aldosterone, catecholamines, cholesterol, and triglyceride. *Cochrane Database Syst Rev* 2011;(11):CD004022.
9. Strazzullo P, D'Elia L, Kandala NB, Cappuccio FP. Salt intake, stroke, and cardiovascular disease: Meta-analysis of prospective studies. *BMJ*. 2009;339:b4567.

10. Aburto NJ, Hanson S, Gutierrez H, Hooper L, Elliott P, Cappuccio FP. Effect of increased potassium intake on cardiovascular risk factors and disease: Systematic review and meta-analyses. *BMJ*. 2013;346:f1378.
11. Sharma S, McFann K, Chonchol M, Kendrick J. Dietary sodium and potassium intake is not associated with elevated blood pressure in US adults with no prior history of hypertension. *J Clin Hypertens (Greenwich)*. 2014;16(6):418-423.
12. Kok FJ, Vandenbroucke JP, van der Heide-Wessel C, van der Heide RM. Dietary sodium, calcium, and potassium, and blood pressure. *Am J Epidemiol*. 1986;123(6):1043-1048.
13. Grimm RH Jr, Neaton JD, Elmer PJ, et al. The influence of oral potassium chloride on blood pressure in hypertensive men on a low-sodium diet. *N Engl J Med*. 1990;322(9):569-574.
14. Rodrigues SL, Baldo MP, Machado RC, Forechi L, MdCB Molina, Mill JG. High potassium intake blunts the effect of elevated sodium intake on blood pressure levels. *J Am Soc Hypertens*. 2014;8(4):232-238.
15. Krishna GG, Kapoor SC. Potassium depletion exacerbates essential hypertension. *Ann Intern Med*. 1991;115(2):77-83.
16. Brunner HR, Baer L, Sealey JE, Ledingham JG, Laragh JH. The influence of potassium administration and of potassium deprivation on plasma renin in normal and hypertensive subjects. *J Clin Invest*. 1970;49(11):2128-2138.
17. Han HR, Kim KB, Kang J, Jeong S, Kim EY, Kim MT. Knowledge, beliefs, and behaviors about hypertension control among middle-aged Korean Americans with hypertension. *J Community Health*. 2007;32(5):324-342.
18. Lee HS, Duffey KJ, Popkin BM. Sodium and potassium intake patterns and trends in South Korea. *J Hum Hypertens*. 2013;27(5):298-303.
19. *Review and Updating of Current WHO Recommendations on Salt/Sodium and Potassium Consumption*. Geneva, Switzerland: World Health Organization; 2011.
20. World Health Organization. Diet, nutrition and the prevention of chronic disease. http://whqlibdoc.who.int/trs/who_trs_916.pdf. Accessed April 30, 2014.
21. Kim EJ, Cho SW, Kang JY, Choi TI, Park YK. Effects of a 12-week lifestyle intervention on health outcome and serum adipokines in middle-aged Korean men with borderline high blood pressure. *J Am Coll Nutr*. 2012;31(5):352-360.
22. Kim H, Song HJ, Han HR, Kim KB, Kim MT. Translation and validation of the Dietary Approaches to Stop Hypertension for Koreans intervention: Culturally tailored dietary guidelines for Korean Americans with high blood pressure. *J Cardiovasc Nurs*. 2013;28(6):514-523.
23. Lim S, Shin H, Song JH, et al. Increasing prevalence of metabolic syndrome in Korea: The Korean National Health and Nutrition Examination Survey for 1998-2007. *Diabetes Care*. 2011;34(6):1323-1328.
24. Ministry of Health and Welfare, Korean Centers for Disease Control and Prevention, Korea Health Industry Development Institute. Guideline for Nutrition Survey of the Korea National Health and Nutrition Examination Survey. https://knhanes.cdc.go.kr/knhanes/index.do. Accessed June 1, 2015.
25. Kesteloot H, Joossens JV. The relationship between dietary intake and urinary excretion of sodium, potassium, calcium and magnesium: Belgian Interuniversity Research on Nutrition and Health. *J Hum Hypertens*. 1990;4(5):527-533.
26. National Rural Resources Development Institute. Rural Development Administration. Food Composition Table. 7th ed. 2006. http://koreanfood.rda.go.kr/kfi/fct/fctPdfDwn/view. Accessed June 1, 2015.
27. James PA, Oparil S, Carter BL, et al. 2014 evidence-based guideline for the management of high blood pressure in adults: Report from the panel members appointed to the Eighth Joint National Committee (JNC 8). *JAMA*. 2014;311(5):507-520.
28. Lee HK, Lee BH. The epidemiology of alcohol use disorders. *J Korea Diabet*. 2012;13(2):69.
29. The Korean Centers for Disease Control and Prevention. Health information service. http://www.cancer.go.kr/mbs/cancer/subview.jsp?id=cancer_010104040000. Accessed June 1, 2015.
30. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081-1093.
31. Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. *N Engl J Med*. 2001;344(1):3-10.
32. Campbell N, Correa-Rotter R, Neal B, Cappuccio FP. New evidence relating to the health impact of reducing salt intake. *Nutr Metab Cardiovasc Dis*. 2011;21(9):617-619.
33. Park J, Lee JS, Kim J. Relationship between dietary sodium, potassium, and calcium, anthropometric indexes, and blood pressure in young and middle aged Korean adults. *Nutr Res Pract*. 2010;4(2):155-162.
34. Khaw KT, Barrett-Connor E. Increasing sensitivity of blood pressure to dietary sodium and potassium with increasing age. A population study using casual urine specimens. *Am J Hypertens*. 1990;3(6 pt 1):505-511.
35. Weinberger MH, Fineberg NS. Sodium and volume sensitivity of blood pressure. Age and pressure change over time. *Hypertension*. 1991;18(1):67-71.
36. Zhang Z, Cogswell ME, Gillespie C, et al. Association between usual sodium and potassium intake and blood pressure and hypertension among U.S. adults: NHANES 2005-2010. *PLoS One*. 2013;8(10):e75289.
37. Du S, Neiman A, Batis C, et al. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. *Am J Clin Nutr*. 2014;99(2):334-343.
38. Barri YM, Wingo CS. The effects of potassium depletion and supplementation on blood pressure: A clinical review. *Am J Med Sci*. 1997;314(1):37-40.
39. Bech JN, Nielsen CB, Ivarsen P, Jensen KT, Pedersen EB. Dietary sodium affects systemic and renal hemodynamic response to NO inhibition in healthy humans. *Am J Physiol*. 1998;274(5 pt 2):F914-F923.
40. Owens GK, Geisterfer AA, Yang YW, Komoriya A. Transforming growth factor-beta-induced growth inhibition and cellular hypertrophy in cultured vascular smooth muscle cells. *J Cell Biol*. 1988;107(2):771-780.
41. Ying WZ, Aaron K, Wang PX, Sanders PW. Potassium inhibits dietary salt-induced transforming growth factor-beta production. *Hypertension*. 2009;54(5):1159-1163.
42. Brown IJ, Tzoulaki I, Candeias V, Elliott P. Salt intakes around the world: Implications for public health. *Int J Epidemiol*. 2009;38(3):791-813.
43. Loftfield E, Yi S, Curtis CJ, Bartley K, Kansagra SM. Potassium and fruit and vegetable intakes in relation to social determinants and access to produce in New York City. *Am J Clin Nutr*. 2013;98(5):1282-1288.
44. Karanja NM, Obarzanek E, Lin PH, et al. Descriptive characteristics of the dietary patterns used in the Dietary Approaches to Stop Hypertension Trial. DASH Collaborative Research Group. *J Am Diet Assoc*. 1999;99(8 suppl):S19-S27.
45. John JH, Ziebland S, Yudkin P, Roe LS, Neil HA. Effects of fruit and vegetable consumption on plasma antioxidant concentrations and blood pressure: A randomised controlled trial. *Lancet*. 2002;359(9322):1969-1974.
46. Ness AR, Chee D, Elliott P. Vitamin C and blood pressure—An overview. *J Hum Hypertens*. 1997;11(6):343-350.
47. Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM. Dietary approaches to prevent and treat hypertension: A scientific statement from the American Heart Association. *Hypertension*. 2006;47(2):296-308.
48. Kim MK, Sasaki S, Sasazuki S, Okubo S, Hayashi M, Tsugane S. Lack of long-term effect of vitamin C supplementation on blood pressure. *Hypertension*. 2002;40(6):797-803.
49. Espeland MA, Kumanyika S, Wilson AC, et al. Statistical issues in analyzing 24-hour dietary recall and 24-hour urine collection data for sodium and potassium intakes. *Am J Epidemiol*. 2001;153(10):996-1006.
50. Huang Y, Van Horn L, Tinker LF, et al. Measurement error corrected sodium and potassium intake estimation using 24-hour urinary excretion. *Hypertension*. 2014;63(2):238-244.

AUTHOR INFORMATION

H.-M. Noh and H.-Y. Oh are fellows, S.-Y. Park is a resident physician, Y. J. Paek and H. J. Song are professors, and K. H. Park is an associate professor, Department of Family Medicine, Hallym University Sacred Heart Hospital, Hallym University, Gyeonggi-do, Republic of Korea. H.-S. Lee is head researcher, Nutrition Policy and Promotion Team, Korea Health Industry Development Institute, Chungcheongbukdo, Republic of Korea.

Address correspondence to: Kyung Hee Park, MD, PhD, MPH, Department of Family Medicine, Hallym University Sacred Heart Hospital, Hallym University, Gyeonggi-do 431-796, Republic of Korea. E-mail: beloved920@gmail.com

STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT

None to report.