



# Estimated 24-Hour Urine Sodium Excretion Is Correlated with Blood Pressure in Korean Population: 2009-2011 Korean National Health and Nutritional Examination Survey

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No large-scale studies have investigated the association between salt intake and hypertension in Korean population. To investigate the relationship of blood pressure to salt consumption, we analyzed data from 19,476 participants in the 2009-2011 Korean National Health and Nutritional Examination Survey (KNHANES). Urinary sodium excretion over 24-hr (24HUNa) was estimated from spot urine tests using Tanaka's equation. The study subjects were stratified into hypertensive and normotensive groups. Hypertensive participants ( $n = 6,552$ , 33.6%) had higher estimated 24HUNa,  $150.4 \pm 38.8$  mEq/day, than normotensive participants,  $140.5 \pm 34.6$  mEq/day ( $P < 0.001$ ). The association between 24HUNa and blood pressure outcomes was not affected by adjustment for other risk factors for hypertension (odds ratio 0.001; 95% confidence interval 0.001-0.003;  $P < 0.001$ ). Increases in 24HUNa of 100 mEq/day were associated with a  $6.1 \pm 0.3/2.9 \pm 0.2$  mmHg increase in systolic/diastolic blood pressure in all participants. This effect was stronger in hypertensive participants (increase of  $8.1 \pm 0.5/3.4 \pm 0.3$  mmHg per 100 mEq/day) and smaller in normotensive participants ( $2.9 \pm 0.3/1.3 \pm 0.2$  mmHg). These results support recommendations for low salt intake in Korean population to prevent and control adverse blood pressure levels.

**Key Words:** Hypertension, Blood Pressure, Sodium

## INTRODUCTION

As the population ages, the prevalence of hypertension is increasing (1). Hypertension is a major risk factor for cardiovascular disease. A large body of evidence indicates that high sodium intake is related with high blood pressure (2, 3). Numerous studies have reported that primary hypertension and age-associated increases in blood pressure were nearly absent (less than 1%) in populations with very low consumption of sodium chloride, defined as less than 50 mEq/day. High blood pressure has been identified mainly in populations with high consumption of sodium chloride (more than 100 mEq/day) (4). The introduction of salt to the diet of isolated populations is consistently associated with an increased prevalence of hypertension (5, 6). The rate of hypertension is approximately 25% to 40% in adults in industrialized countries (4). These data suggest that hypertension is closely related to salt intake, and many studies have shown adverse effects of excessive sodium intake on blood pressure (7-10).

The Korean diet is high in salt, especially in the form of soup and stew. During the period from 2010 to 2011, Koreans consumed 4,878-4,791 mg of sodium on average (11), which is 2.4-fold higher than the WHO's recommended daily intake of 2,000

mg. Excessive consumption of salt increases the likelihood of high blood pressure, which has a significant impact on public health.

Among methods for estimating salt intake, 24-hr urine collection is regarded as the most reliable because most dietary sodium is excreted into the urine in healthy individuals (12). However, it is difficult and impractical to collect complete 24-hr urine for all participants in large-scale epidemiological surveys such as the Korean National Health and Nutrition Examination Survey (KNHANES). In the present study, we used the Tanaka's equation to estimate 24-hr urine sodium excretion (24HUNa) from measurements of sodium (Na) and creatinine (Cr) in spot urine samples (13). Though the KNHANES contains important epidemiologic information on the prevalence of hypertension in Korea since 1998, the relationship between salt intake and blood pressure in this population has not yet been investigated.

Therefore, a population-based study of the relationship between 24HUNa and blood pressure could contribute to the development of a comprehensive public health strategy to lower the incidence of hypertension. In the present study, we analyzed population-based data from a nationwide cross-sectional health survey to determine the association of 24HUNa with hypertension.

## MATERIALS AND METHODS

### Participants

The data analyzed in this study were obtained from the 2009-2011 KNHANES, which included a population-based random sampling of 42,347 individuals in households across 600 national districts. The survey was conducted with a rolling sampling design in order to select a representative nationwide sample of the non-institutionalized Korean population. A total of 22,871 subjects were excluded from this study because they were aged < 18 yr (n = 10,215), or did not have urinary Na and Cr (n = 12,629) or blood pressure (n = 15) data available.

After the above exclusion criteria were applied, 19,476 individuals aged 18 yr or older were included in this investigation. Because the analyzed survey data are publicly available, ethical approval was not required for this study.

### Laboratory parameters

Blood and urine samples were collected after a 12-hr overnight fast; they were properly processed, immediately refrigerated, and transported in cold storage to the central laboratories (Seoul Medical Science Institute, Seoul, Korea and Seegene Medical Foundation, Seoul, Korea) within 24-hr. Serum and urine laboratory values were measured using the ADVIA 1650 system (Bayer Health Care, Tarrytown, NY) and Hitachi 7600 DDP (Hitachi High-Technologies, Tokyo, Japan). The serum Cr concentration was measured using the kinetic Jaffe method, and the inter-assay coefficient of variation was less than 5%. Because the serum Cr assay was not calibrated to be traceable to an isotope dilution mass spectrometry (IDMS), estimated glomerular filtration rate (eGFR) was calculated using the original Modification of Diet in Renal Disease (MDRD) equation as follows:  $eGFR = 186.3 \times (\text{serum Cr})^{-1.154} \times (\text{age})^{-0.203} \times 0.742$  (if female) (14). Urine protein was measured using a dipstick in a spot urine sample.

Measurement of urinary sodium excretion over 24-hr is considered the best method for assessing sodium intake in population surveys. However, 24-hr urine collection is cumbersome and not possible in all patients. In this study, we estimated 24HUNa using the Cockcroft-Gault, Korea and Tanaka equations as follows. Although we present the results of all these three equations, we used the values from Tanaka's equation to assess association with hypertension, as this method of estimation has been validated (13, 15).

Cockcroft-Gault (CG) equation (16);

$$24\text{-hr urine Cr (mg)} = [28 - (0.2 \times \text{age (yr)})] \times \text{weight (kg)},$$

(if women,  $\times 0.85$ )

$$24\text{HUNa (mEq/L)} = 33.409 \times \text{XNA}^{0.347}$$

Tanaka equation (13);

$$24\text{-hr urine Cr (mg)} = -2.04 \times \text{age (yr)} + 14.89 \times \text{body weight (kg)} \\ + 16.14 \times \text{height (cm)} - 2244.45.$$

$$24\text{HUNa (mEq/L)} = 21.98 \times \text{XNA}^{0.392}$$

KOREA equation (HS Koo, co-author, provided this equation);

$$24\text{-hr urine Cr (mg)} = -7.428 \times \text{age (yr)} + 15.631 \times \text{body weight (kg)} \\ + 10.372 \times \text{height (cm)} - 1234.78$$

$$24\text{HUNa (mEq/L)} = 28.985 \times \text{XNA}^{0.346}$$

$$*\text{XNA} = [\text{spot urine Na (mEq/L)} / (10 \times \text{spot urine Cr (mg/dL)})] \\ \times \text{estimated 24-hr urine Cr}$$

### Demographic and clinical characteristics

Demographic characteristics included age, gender, body mass index (BMI,  $\text{kg}/\text{m}^2$ ), waist circumference (cm), smoking state (non-or ex-smoker/current smoker), alcohol intake (never drinking/less than once per month/more than once per month) and comorbidities such as diabetes mellitus (DM), ischemic heart disease (IHD), cerebrovascular accident (CVA), and chronic kidney disease (CKD). Individuals were classified as hypertensive if they met at least one of the following three criteria: physician diagnosis of hypertension, self-report of antihypertensive drug intake, and systolic blood pressure (SBP)  $\geq 140$  mmHg or diastolic blood pressure (DBP)  $\geq 90$  mmHg. Blood pressure was measured manually twice at 30-sec intervals after a minimum of 5 min of rest in a seated position; mean values were used to identify hypertensive participants.

Subjects were classified as having DM if their fasting plasma glucose was  $\geq 126$  mg/dL or they reported actively using an oral hypoglycemic agent or insulin on the health survey. Information regarding IHD and CVA was acquired from self-reported history. Ischemic heart disease included angina pectoris and myocardial infarction. Chronic kidney disease was defined as  $eGFR\text{-MDRD} < 60$  mL/min/1.73  $\text{m}^2$ . Proteinuria was assayed by dipstick and categorized as either negative or positive ( $\geq$  trace).

Information on health-related behaviors such as smoking status and alcohol intake was obtained from the health questionnaire. Current smokers included those adults who reported that they had smoked at least 100 cigarettes in their lifetime, and non-smokers included respondents who had smoked fewer than 100 cigarettes in their lifetime and did not smoke at the time of the survey. Current drinker refers to those who had taken alcohol more than once per month.

### Statistical analyses

Data are presented as frequencies and percentages for categorical variables or means with standard deviations for continuous variables. Analyses involving participants' age used either integral values or categorical stratification as  $\leq 50$  or  $> 50$  yr old. Demographic and laboratory factors were compared using the analysis of variance (ANOVA) method for continuous variables

and chi-square test for categorical variables.

Univariate logistic regression analysis was performed to assess the relationship between hypertension and clinical or demographic data. Variables that were significantly associated in the univariate analysis or that were of considerable theoretical relevance were entered into the multivariate logistic regression analysis using the backward conditional elimination method. Co-linear variables were excluded from multivariate analyses.

Multiple regression analysis was performed to compute the increase in systolic and diastolic blood pressure associated with a 100 mEq increase in 24HUNa. This analysis was adjusted for age groups, gender, BMI, diagnosis of CKD and DM, history of IHD and CVA, smoking state, alcohol consumption, waist circumference, total cholesterol, and proteinuria. All analyses were conducted using the SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA), and  $P < 0.05$  was considered to indicate statistical significance.

## RESULTS

### Characteristics of the study populations

The participants were stratified by the diagnosis of hypertension (HTN); HTN group or normal blood pressure (NBP) group. The demographic characteristics of each group are shown in Table 1. The mean age in the HTN group was a  $59.8 \pm 13.7$  yr, which was much older than that of the NBP group,  $44.4 \pm 15.4$  yr. In the HTN group, 51% were male, whereas the NBP group was 57% female.

Subjects with hypertension were older, predominantly males, and more likely to have comorbidities, including DM, IHD, CVA and CKD. Subjects in the HTN group had significantly higher BMI ( $P < 0.001$ ), waist circumference ( $P < 0.001$ ), total cholesterol ( $P < 0.001$ ), and serum Cr ( $P < 0.001$ ), and were more likely to have proteinuria ( $P < 0.001$ ). Further, hypertensive subjects had lower eGFR-MDRD ( $P < 0.001$ ) than those in the NBP group. Subjects with hypertension showed lower rates of smoking and alcohol consumption, which may imply decreased general health.

### Prevalence of hypertension

A total of 6,552 (33.6%) participants had hypertension. The prevalence of hypertension increased with age; more than half of people aged 60-75 yr and two out of three persons older than 75 were hypertensive (Fig. 1). In subjects up to 60 yr of age, hypertension was more prevalent in men. Between ages 61 and 70, hypertension affected men and women at similar rates; in older subjects, a much higher percentage of women than men had high blood pressure.

### Blood pressure in relation to urinary sodium excretion

Mean systolic and diastolic blood pressure in the HTN group

**Table 1.** Demographic characteristics of participants with or without hypertension

Characteristics	NBP group (n = 12,924)	HTN group (n = 6,552)	P
Age all (yr)	44.4 ± 15.4	59.8 ± 13.7	< 0.001
≤ 50	8,564 (66.3)	1,556 (23.7)	
> 50	4,360 (33.7)	4,996 (76.3)	< 0.001
Male, N (%)	5,555 (43)	3,339 (51)	
Female, N (%)	7,369 (57)	3,213 (49)	< 0.001
Body mass index (kg/m <sup>2</sup> )	23.1 ± 3.2	24.8 ± 3.4	< 0.001
Systolic blood pressure (mmHg)	111.9 ± 11.5	136.4 ± 16.2	< 0.001
Diastolic blood pressure (mmHg)	73.3 ± 8.1	84.3 ± 11.4	< 0.001
Waist circumference (cm)	79.1 ± 9.6	85.6 ± 9.3	< 0.001
Alcohol intake (current drinker), N (%)	7,037 (54.4)	3,260 (49.8)	< 0.001
Current smoking, N (%)	2,926 (23.3)	1,303 (20.0)	< 0.001
Comorbidities, N (%)			
Diabetes mellitus	775 (6.0)	1,342 (20.5)	< 0.001
Ischemic heart disease	186 (1.5)	299 (4.6)	< 0.001
Cerebrovascular accident	92 (0.7)	296 (4.5)	< 0.001
Chronic kidney disease	98 (0.8)	376 (5.7)	< 0.001
Total cholesterol (mg/dL)	186.4 ± 35.4	193.5 ± 37.9	< 0.001
Serum Cr (mg/dL)	0.81 ± 0.17	0.87 ± 0.27	< 0.001
eGFR-MDRD (ml/min/1.73m <sup>2</sup> )	98.1 ± 17.9	88.4 ± 18.6	< 0.001
Urine protein, N (%)			
Negative	11,805 (91.3)	5,794 (88.4)	
≥ trace	1,119 (8.7)	758 (11.6)	< 0.001
24HUNa <sub>CG</sub> (mEq/day)	164.6 ± 35.5	169.8 ± 38.9	< 0.001
24HUNa <sub>Korea</sub> (mEq/day)	164.7 ± 34.8	171.9 ± 38.6	< 0.001
24HUNa <sub>Tanaka</sub> (mEq/day)	140.5 ± 34.6	150.4 ± 38.8	< 0.001

Data are expressed as the mean ± standard deviation or a percentage. eGFR calculated using the modified MDRD formula. NBP, normal blood pressure; HTN, hypertension; Cr, creatinine; eGFR, estimated glomerular filtration rate; MDRD, modification of diet in renal disease; 24HUNa<sub>CG</sub>, estimated 24-hr urine sodium<sub>Cockcroft-Gault</sub> equation; 24HUNa<sub>Korea</sub>, estimated 24-hr urine sodium<sub>Korea</sub> equation; 24HUNa<sub>Tanaka</sub>, estimated 24-hr urine sodium<sub>Tanaka</sub> equation.

were  $136.4 \pm 16.2$  and  $84.3 \pm 11.4$  mmHg; both values were higher than those in the NBP group ( $111.9 \pm 11.5$  and  $73.3 \pm 8.1$  mmHg) ( $P < 0.001$ ) (Table 1). Participants with hypertension had higher 24HUNa than normotensive individuals. The mean 24HUNa was  $150.4 \pm 38.8$  mEq/day in the HTN group and  $140.5 \pm 34.6$  mEq/day in the NBP group ( $P < 0.001$ ) (Fig. 2). The correlation of blood pressure with 24HUNa was illustrated in Fig. 3. To describe the correlation in detail, we plotted the systolic and diastolic blood pressure vs. 24HUNa stratified by gender and age group. Participants in the HTN group had a tendency towards higher 24HUNa for most age ranges; differences in 24HUNa between the HTN and NBP groups were significant in women aged 36-55 yr and in men aged less than 50 yr. Based on this information, subjects were divided into two age categories, ≤ 50 and > 50 yr old.

### Correlates of hypertension

A logistic regression model was built to identify factors significantly associated with hypertension. For this model, certain continuous values were transformed into categorical values, as previously described. As few subjects had urinary protein levels

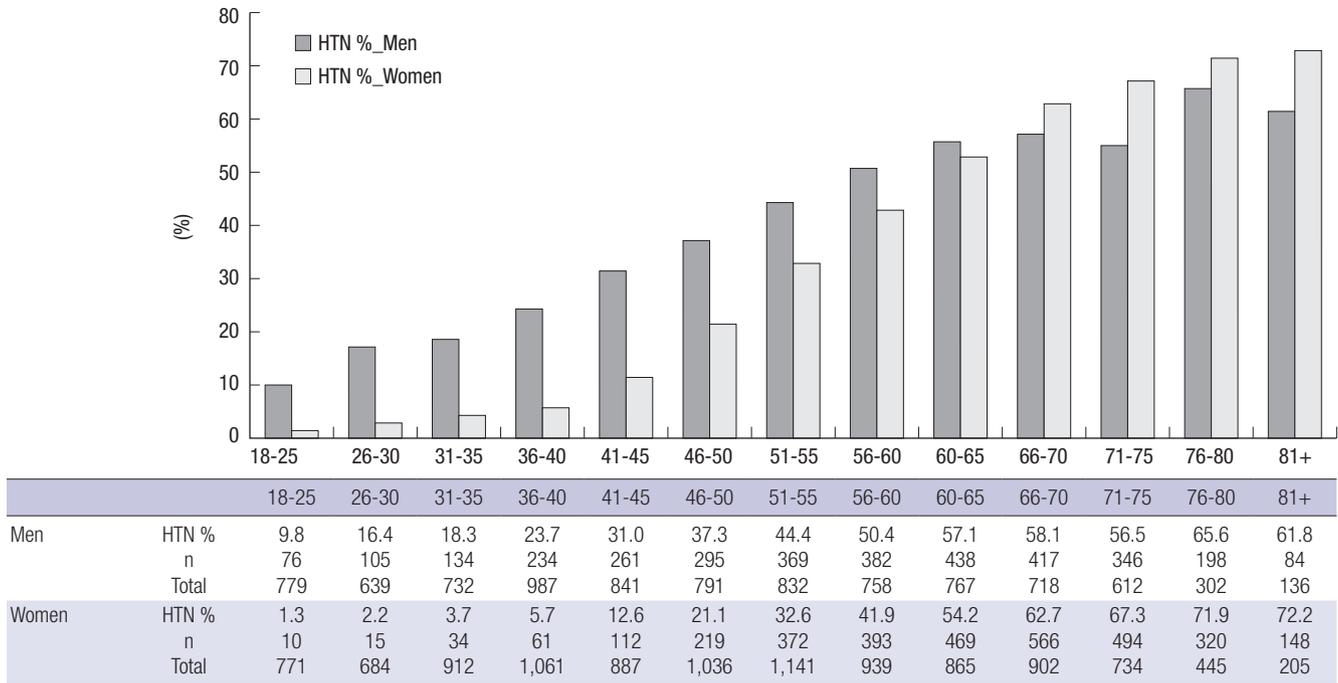


Fig. 1. Prevalence of hypertension among men and women; KNHANES, 2009-2011.

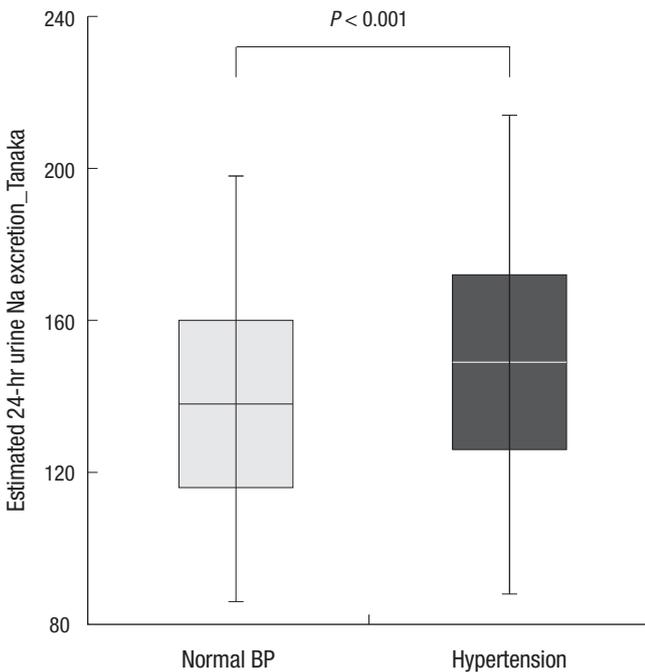


Fig. 2. Participants with hypertension had higher estimated 24-hr urinary sodium excretion than normotensive participants. The midline of the boxes represents the median and the lower and upper margins represent the 25th and 75th percentiles, respectively. The lower and upper ends represent the minimum and maximum values, respectively.

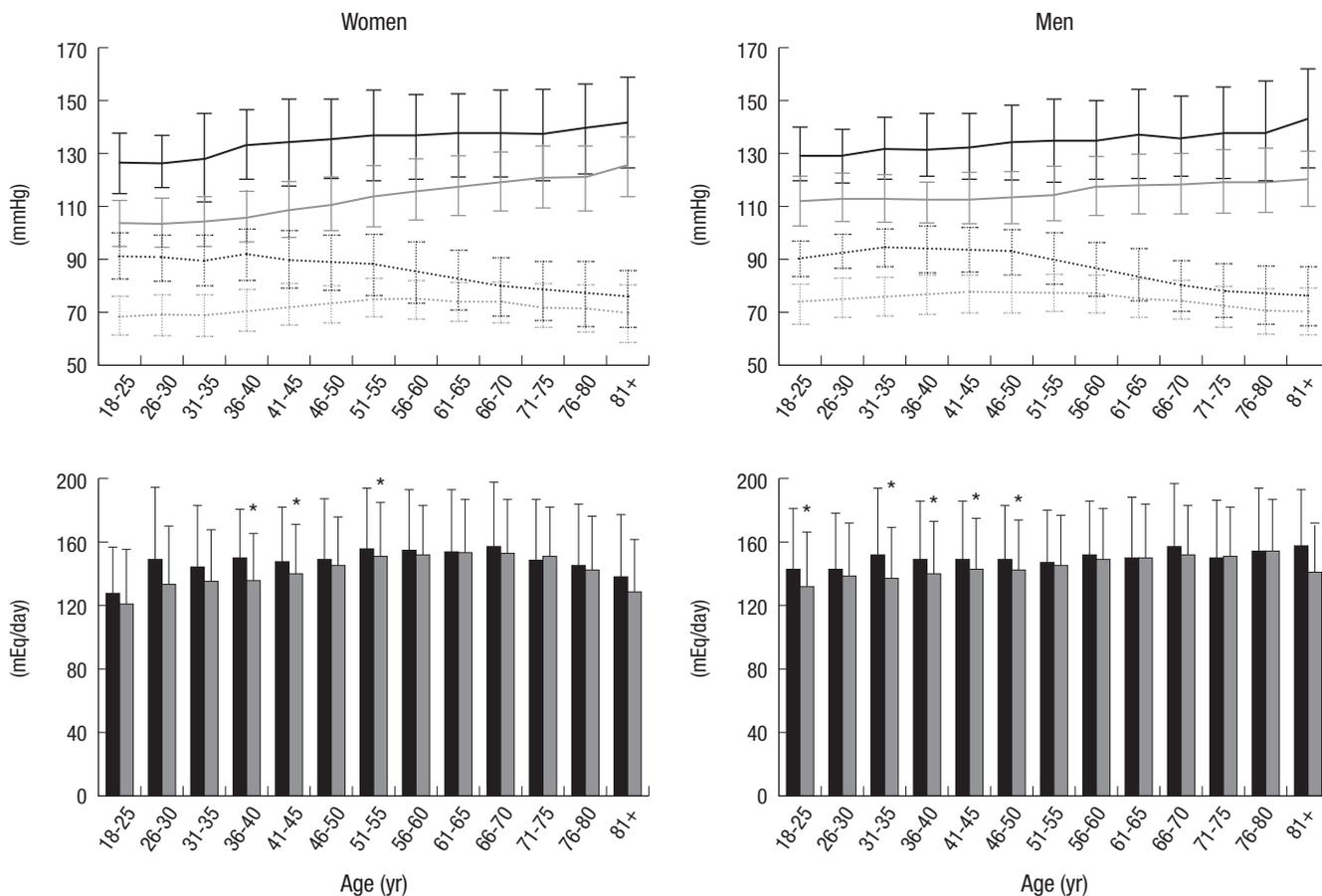
the multivariate analysis. All three estimates of 24HUNa were significantly associated with hypertension risk in the univariate analysis.

Table 2 displays the results of multivariate analysis for hypertension. Age, gender, other co-morbidities (e.g., CKD, DM, IHD and CVA), health-related behaviors (smoking, alcohol consumption), BMI, waist circumference, total cholesterol, and proteinuria were significantly associated with hypertension.

In the multivariate analysis, estimated 24HUNa was an independent risk factor predicting hypertension (odds ratio [OR], 0.001; 95% confidence interval [CI], 0.001-0.003;  $P < 0.001$ ) after adjustment for age, gender, other co-morbidities, health-related behaviors, BMI, waist circumference, and total cholesterol and proteinuria, all of which are well-known strong risk factors for hypertension.

After adjustment for covariates the increase in blood pressure corresponding to a 100 mEq increase in daily Na excretion was 6.1 mmHg (95% CI, 5.47-6.76;  $P < 0.001$ ) for SBP and 2.9 mmHg (95% CI, 2.45-3.29;  $P < 0.001$ ) for DBP in all patients (Table 3). When this analysis was restricted to hypertensive subjects, the effect of salt intake on blood pressure was more pronounced. The increase in blood pressure associated with a 100 mEq increase in urinary Na excretion was 8.1 mmHg (95% CI, 7.06-9.11;  $P < 0.001$ ) for systolic and 3.4 mmHg (95% CI, 2.74-4.06;  $P < 0.001$ ) for diastolic blood pressure. In persons with normal blood pressure, systolic and diastolic blood pressure changed 2.9 (95% CI, 2.34-3.44;  $P < 0.001$ ) mmHg and 1.3 (95% CI, 0.88-1.69;  $P < 0.001$ ) mmHg, respectively, for each 100

greater than 2+, urinary protein was divided into negative and more than trace. In the univariate analysis, there was no variable without significance and all covariates were included in



**Fig. 3.** Upper panels, mean systolic (solid lines) and diastolic (dotted lines) blood pressure of HTN group (black line) and NBP group (gray line) in relation to the age group by gender. Vertical lines denote the standard deviation of the mean; lower panels, mean 24-hr urine Na excretion (calculated by the Tanaka equation) of HTN group (black bar) and NBP group (gray bar) in relation to the age group by gender among the KNHANES 2009-2011. Error bars represent the standard deviation of the mean; \*Denotes  $P < 0.05$ .

**Table 2.** Multivariate logistic regression analysis for hypertension

Parameters	Adjusted OR (95% CI)	P
Age		
≤ 50	Reference	
> 50	1.599 (1.519~1.679)	< 0.001
Gender		
Female	Reference	
Male	0.386 (0.298~0.475)	< 0.001
Chronic kidney disease		
Yes	1.181 (0.933~1.428)	< 0.001
Diabetes mellitus		
Yes	0.625 (0.517~0.734)	< 0.001
Ischemic heart disease		
Yes	0.227 (0.019~0.434)	0.032
Cerebrovascular accidents		
Yes	1.020 (0.759~1.282)	< 0.001
Alcohol intake		
Never drinking	Reference	
Ex-drinker < 1 drink/month	-0.366 (-0.474~-0.258)	< 0.001
Current drinker ≥ 1 drink/month	-0.211 (-0.320~-0.102)	< 0.001
Smoking		
Never-/ex-smoker	Reference	
Current smoker	-0.120 (-0.21~-0.025)	0.013
Body mass index	0.106 (0.085~0.127)	< 0.001
Waist circumference	0.020 (0.012~0.028)	< 0.001
Total cholesterol	0.001 (0.001~0.002)	0.003
Proteinuria		
Urine protein ≥ trace	0.246 (0.121~0.371)	< 0.001
24HUNa CG (mEq/day)	0.001 (0.000~0.002)	0.042
24HUNa_Korea (mEq/day)	0.002 (0.001~0.003)	< 0.001
24HUNa_Tanaka (mEq/day)	0.002 (0.001~0.003)	< 0.001

Values shown are OR (95% CI). The multivariate logistic regression analysis model was derived using the backward conditional method. OR, odds ratio; CI, confidence interval; 24HUNa CG, estimated 24-hr urine sodium\_Cockcroft-Gault equation; 24HUNa\_Korea, estimated 24-hr urine sodium\_Korea equation; 24HUNa\_Tanaka, estimated 24-hr urine sodium\_Tanaka equation.

**Table 3.** Regression coefficients ( $\beta$ ) with standard errors (SE) for estimates of increases in systolic and diastolic blood pressure corresponding to 100 mEq increases in 24-hr urinary sodium excretion\*

24-hr urine Na		All participants		NBP group		HTN group	
		SBP	DBP	SBP	DBP	SBP	DBP
24HUNa_CG (mEq/day)	$\beta \pm SE$ 95% CI	5.5 $\pm$ 0.3 (4.87-6.15)	2.9 $\pm$ 0.2 (2.45-3.28)	2.6 $\pm$ 0.3 (2.03-3.10)	1.1 $\pm$ 0.2 (0.72-1.51)	8.6 $\pm$ 0.5 (7.52-9.62)	4.2 $\pm$ 0.3 (3.51-4.83)
24HUNa_Korea (mEq/day)	$\beta \pm SE$ 95% CI	6.1 $\pm$ 0.3 (5.49-6.76)	2.8 $\pm$ 0.2 (2.39-3.21)	2.8 $\pm$ 0.3 (2.30-3.37)	1.2 $\pm$ 0.2 (0.75-1.54)	8.7 $\pm$ 0.5 (7.65-9.72)	3.6 $\pm$ 0.3 (2.89-4.21)
24HUNa_Tanaka (mEq/day)	$\beta \pm SE$ 95% CI	6.1 $\pm$ 0.3 (5.47-6.76)	2.9 $\pm$ 0.2 (2.45-3.29)	2.9 $\pm$ 0.3 (2.34-3.44)	1.3 $\pm$ 0.2 (0.88-1.69)	8.1 $\pm$ 0.5 (7.06-9.11)	3.4 $\pm$ 0.3 (2.74-4.06)

\*Multiple adjusted for age, sex, body mass index, chronic kidney disease, diabetes mellitus, ischemic heart disease, cerebrovascular accidents, smoking, alcohol drink, waist circumference, total cholesterol, and proteinuria. NBP, normal blood pressure; HTN, hypertension; SBP, systolic blood pressure; DBP, diastolic blood pressure; 24HUNa\_CG, estimated 24-hr urine sodium\_Cockcroft-Gault equation; 24HUNa\_Korea, estimated 24-hr urine sodium\_Korea equation; 24HUNa\_Tanaka, estimated 24-hr urine sodium\_Tanaka equation.

mEq/day increase in daily sodium excretion.

## DISCUSSION

In this cross-sectional study, our analysis of the KNHANES data from 2009 to 2011 showed that 24HUNa is independently associated with hypertension after adjusting for age, gender, BMI, diagnosis of CKD and DM, history of IHD and CVA, smoking, alcohol consumption, waist circumference, total cholesterol, and proteinuria. There was a significant difference in 24HUNa between NBP and HTN group, particularly in the young and middle-aged populations. The prevalence of hypertension in this population (aged 18 yr and older) was 33.6%. Overall, the prevalence of hypertension was higher in older individuals, which is consistent with reports from other countries (17).

High salt consumption is an important contributor to high blood pressure and cardiovascular diseases (CVD) (18). Modifiable factors such as diet, smoking, and physical inactivity are reported to be responsible for ~80% of CVD (18). WHO has recommended consumption of less than 5 g/day of salt to prevent CVD (19). However, most populations consume much higher levels of salt (20). It has been estimated that decreasing dietary salt from the current intake of 9-12 g/day to the WHO recommended level would lower the prevalence of blood pressure and cardiovascular disease. The Dietary Approaches to Stop Hypertension (DASH) study showed that reducing sodium intake from high to intermediate and from intermediate to low levels caused stepwise decreases in blood pressure over 30 consecutive days (8). Recently, a long-term follow-up study of the effects of the UK nationwide salt reduction program in 2003 to 2004 was published; the program led to a 15% reduction in population salt intake by 2011 (21). During the same period there was a significant decrease in blood pressure of  $3.0 \pm 0.33/1.4 \pm 0.20$  mm Hg and a 42% decrease in mortality from stroke ( $P < 0.001$ ) and IHD by 40% ( $P < 0.001$ ).

Our results indicated that blood pressure significantly increases with age (Fig. 1) and that 24HUNa is higher in hypertensive individuals than in those with normal blood pressure in

all age groups in both men and women (Fig. 3). Differences in estimated 24-hr urine sodium excretion between hypertensive and normotensive subjects were significant in the young and middle-aged populations. The proportion of elderly subjects (> 65 yr old) in our population was 5.9% ( $n = 758$ ) among normotensives and 23.3% ( $n = 1,528$ ) among hypertensives. Although estimated 24HUNa did not differ significantly in these subjects, SBP and DBP of hypertensive persons were significantly higher than those of normotensive persons. Notably, SBP in women older than 70 yr old continued to increase despite decreasing 24HUNa. Whereas many studies have addressed the association between sodium intake and hypertension, studies specifically addressing this association in elderly populations could not be identified. Older individuals were not enrolled in many previous studies investigating the relationship between blood pressure and salt intake. In the International Study of Salt and Blood Pressure (INTERSALT) study, men and women aged 20-59 yr were selected from 32 countries (10). The average age of the participants in the DASH study was  $47-49 \pm 10$  yr (8). In the analysis of Healthy Survey for England the salt intake, as measured by 24-hr urinary sodium, was assessed in participants aged 19-64 yr (21). Therefore, the evidence for the positive correlation between salt intake and blood pressure in older populations is sparse. It is well known that high salt intake is associated with high blood pressure among all ages from infancy (22, 23) to middle age. Overall, all of these findings suggest the importance of moderating sodium intake beginning in the early life and may imply that reducing sodium intake at old age does not alter the effects of high salt consumption earlier in life.

After adjustment for covariates, we calculated the increase in blood pressure corresponding to a 100 mEq/day increase in daily sodium excretion, which revealed that increased salt intake has stronger effects on blood pressure in hypertensive than in normotensive subjects (Table 3). Several meta-analyses of randomized clinical trials have consistently shown the same results (24). One such meta-analysis concluded that reducing sodium intake by 100 mEq per day decreases systolic blood pressure by an average of 8.0 mmHg and diastolic blood pressure by

an average of 5.0 mmHg in hypertensive subjects, whereas it affects each measure by only 4.0 mmHg and 2.0 mmHg in normotensive subjects (25).

We acknowledge several limitations of this cross-sectional study. First, the salt intake was assessed by estimating 24HUNa from a spot urine test. Collecting 24-hr urine was not feasible in this large-scale survey. As the renal excretion rate of Na is not constant throughout each 24-hr period, this limits the accuracy of our estimation of sodium intake. Second, we did not consider the effects of other dietary components on blood pressure. Blood pressure response to salt intake can be modified by dietary potassium (24). Low dietary intake of potassium potentiates the effects of increased salt intake on blood pressure. Finally, although the diuretic use, especially loop diuretics, can be a bias in estimating sodium excretion from a spot urine sample, the information of diuretic use was not contained in this survey. For this concern, Mann et al. (26) reported that the accuracy of predicting 24-hr sodium excretion from a spot urine sample did not differ between patients taking a diuretic or thiazide diuretic and those not taking any diuretic.

In summary, hypertensive subjects had higher estimated 24HUNa than normotensive subjects, which likely reflects higher salt intake. Increased urinary sodium excretion was firmly associated with increased blood pressure, and this effect was not attenuated by other strong contributors to hypertension in a multivariate analysis. Each 24-hr urinary sodium excretion increase of 100 mEq/day was associated with greater increases in SBP and DBP in the hypertensive group than in the normotensive group.

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## DISCLOSURE

The authors have no conflicts of interest to disclose.

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