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Original article

Contribution of food groups to sodium and potassium intakes by their ratio in Korean adults

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Summary. *Background/Aims:* Koreans have relatively high sodium intakes, and a higher sodium-to-potassium (Na/K) ratio is associated with increased mortality resulting from cardiovascular diseases. The purpose of this study was to analyze the dietary patterns and food groups that contribute to sodium and potassium intakes according to dietary Na/K ratio in Koreans. *Methods:* A 24-hour dietary recall was collected twice from 640 healthy adults (aged 19-69 years) in four Korean provinces. The subjects were divided into groups of Na/K<1 and Na/K≥1, and their dietary pattern focused on sodium and potassium intakes and Na/K ratio of major food groups were analyzed and compared. *Results:* The average Na/K ratio of the subjects was 1.5; the highest ratio was in the twenties. Daily sodium and potassium intakes were significantly high in the Na/K≥1 group and the Na/K<1 group, respectively. Sodium intake from grains, meat, fish, and seasonings of the Na/K≥1 group and potassium intake from potatoes, beans, nuts, and fruits of the Na/K<1 group were significantly higher than the counterpart groups. Food groups with the lowest Na/K (0.1) were fruits, cooked rice, and beans, and a Na/K ratio greater than 10.0 included seasonings and salted seafood. The Na/K<1 group consumed more fruits and potatoes and the Na/K≥1 group consumed more grains, beverages, meats, and seasonings. *Conclusions:* Dietary Na/K ratio of Koreans was significantly higher than Korean or WHO guidelines. Recommendation of reducing sodium intake from grains, meats, and seasonings and increasing potassium intake from fruits, potatoes, and beans may be suggested for lowering the Na/K ratio.

Key words: sodium, potassium, Na/K ratio, food group, 24-hour dietary recall

Introduction

Excessive sodium intake can induce hypertension, stroke, cardiovascular diseases (CVD), and renal diseases, and can also accelerate osteoporosis (1-5). Therefore, to improve public health, sodium intake should be reduced. The Ministry of Health and Welfare in Korea launched Health Plan 2020 in an attempt to reduce 15% of the population's sodium intake to less than 2000 mg/day (6). Additionally, the Ministry of Food and Drug Safety implemented a similar sodium reduction project with the goal of decreasing sodium intake by 20% (3900 mg/day) by 2017. When the goal was achieved by 2014, a second goal was set of reducing sodium intake to 3500 mg/day by 2020.

In the last ten years, the average Korean daily sodium intake was 5256.6 mg in 2005, 4831.1 mg in 2010, 4583.1 mg in 2012, and 3889.9 mg in 2014 (7).

Sodium intake has continuously decreased since 2010 when national initiatives actively promoted sodium reduction. However, the average daily sodium intake of Koreans is still twice the recommended value of the World Health Organization (8). Approximately 80% of the population ingests more than 2000 mg of sodium per day (7).

Appropriate potassium intake along with sodium reduction aids in the excretion of excess sodium (9, 10), promotes bone health by suppressing urine excretion of calcium as a result of excessive sodium intake, and helps prevent hypertension and stroke (11-13). Despite the health benefits of appropriate potassium intake, potassium is the second least ingested nutrient in Korea after calcium. The Korea National Health and Nutrition Examination Survey (KNHANES) reported that the average daily potassium intake level was 2773.2 mg in 2005, 2843.0 mg in 2008, 2998.5 mg in 2010, 2918.0 mg in 2012, and 2983.3 mg in 2014. All levels were lower than 3500 mg, the recommended intake (RI) for adults (14), and the percentage of people who did not meet the RI was about 80%, suggesting a high rate of insufficient potassium intake.

In addition, the sodium-to-potassium (Na/K) ratio can affect the risk of hypertension (15). Cook et al. (16) reported that the Na/K in urine is correlated to blood pressure and serves as a strong predictive risk factor for CVD prediction in comparison to simple sodium or potassium levels. The INTERSALT study, an international study of electrolyte excretion and blood pressure, also reported that the urinary Na/K ratio in female is associated with increased mortality rates resulting from cerebrovascular diseases (17). Therefore, researches are needed to investigate the dietary Na/K ratio and suggest adequate intake level.

However, studies on the dietary Na/K ratio are still insufficient in Korea. The KNHANES investigated sodium and potassium intakes separately, but analysis of their ratio was not conducted. While the survey investigated the sodium and potassium content in each food group and the annual trends in source foods and food groups with high contribution rates, no study has been conducted that investigates the dietary patterns of the Na/K ratio. To solve both problems, high sodium intake and low potassium intake, at the same time, it is necessary to evaluate the dietary Na/K ratio and to suggest effective dietary strategies for simultaneously lowering sodium intake and increasing potassium intake. Therefore, the purpose of this study was to investigate the dietary patterns and food groups that contribute to sodium and potassium intakes according to dietary Na/K ratio in Korean adults with typical common diet.

Materials and Methods

Subjects

Between August and December 2014, 640 healthy adults (320 males, 320 females) were recruited through city halls, health centers, university home pages, and senior welfare facilities in the following four provinces of Korea: Seoul, Chungcheong, Gyeongsang, and Jeolla. Individuals were excluded if they were taking medicine, pregnant or lactating, on dietary control, or diagnosed with hypertension, heart failure, diabetes, renal diseases or cancer. A total of 160 subjects were recruited from each region, and 64 males and 64 females were recruited from each of the following age groups: 19-29 years, 30-39 years, 40-49 years, 50-59 years, and 60-69 years. WHO recommended that the general population consume a sufficient amount of potassium to maintain the molar ratio of Na/K of 1:1 (8). The recommended Na/K ratio in Korea is 0.57 (i.e., 2000 mg sodium per day and 3500 mg potassium per day) as a weight ratio (14). However, most people do not meet this recommended level because they consume too much sodium and not enough potassium. The average Korean Na/K ratio was 1.3 (i.e., 3889.9 mg sodium per day and 2983.3 mg potassium per day) in 2014 (7). Yang et al. (18) reported a beneficial protective effect of usual Na/K<1 on CVD and all-cause mortality. Therefore, the subjects of this study were divided into two groups (<1 and ≥1) depending on the dietary Na/K ratio. The study protocol was approved by the Institutional Review Board of Kyungpook National University (KNU 2014-0053), and all subjects provided their written informed consent to participate in the study.

Analysis of sodium and potassium intakes

A 24-hour dietary recall survey was conducted twice for meals on ordinary days, excluding weekends

and holidays, and the survey was carried out by trained dieticians following the method of the Food Intake Survey in the KNHANES. To ensure efficient dietary recall, subjects directly documented meal information on a provided record sheet. Subjects were pre-trained to take a picture of each meal, and the recall survey was conducted through direct interviews. To increase the accuracy of survey intake reporting, Food Photos for Quantity Estimation: Korean Genome and Epidemiology Study (19) were used in conjunction with comparative measuring tools, such as food models and rulers.

The results of the food intake survey were analyzed using a nutritional assessment program, CAN-Pro 4.0 (Computer Aided Nutritional Analysis Program version 4.0, Korea Nutrition Society, 2010). The main database of the CAN-Pro 4.0 is based on the National Standard Food Composition Table (20, 21). For processed foods and foods not registered in CAN-Pro 4.0, calculations were performed by adding the nutrient contents based on the nutrition facts of the corresponding food.

Analysis of Na/K ratio

Based on the classification standards of the KNHANES and the National Standard Food Composition Table for each food, this study classified a total of 16 food groups: grains, potatoes, sugars, beans, nuts and seeds, vegetables, mushrooms, fruits, meats, eggs, fish and shellfish, seaweeds, milk, oils and fat, beverages, and seasonings. This study also classified a total of 31 food groups for detailed evaluation of sodium and potassium sources. The sodium and potassium intake and their ratio of the listed food or detailed food groups were calculated.

Statistical analysis

All data of this study were statistically analyzed with the SAS 9.3 program (Version 9.3 SAS Institute, Cary, NC, USA). A *t*-test for continuous variables and chi-square test for categorical variables were used to assess differences between the Na/K groups, and ANOVA and Duncan's multiple-range tests were used to assess differences among age groups. The level of significance of all analyses was set to $p<0.05$.

Results

General characteristics

Table 1 shows the general characteristics of the subjects according to Na/K ratio. Na/K<1 subjects had lower proportion of men, higher age and lower height and weight compared with Na/K≥1 subjects ($p<0.05$). The average Na/K ratio of the subjects was 1.5; the highest ratio was in the twenties (Figure 1).

Daily sodium and potassium intakes

Sodium and potassium intakes in the two groups of the Na/K ratio are shown in Table 2. Daily energy intake was significantly lower in the Na/K<1 group than in the Na/K≥1 group (1813.5 kcal vs. 1972.3 kcal, $p<0.01$). Daily total intake or intake per 1000 kcal of the Na/K<1 group was significantly lower than in the Na/K≥1 group for sodium and was higher for potassium ($p<0.001$). The proportion of the subjects who consumed >2000 mg sodium in the Na/K<1 group was significantly lower than that in the Na/K≥1 group (74.8% vs. 95.5%, $p<0.001$). The proportion of subjects who ingested <3500 mg potassium was significantly lower in the Na/K<1 group than in the Na/K≥1 group (64.9% vs. 84.1%, $p<0.001$).

Sodium and potassium intakes from food groups

Table 3 shows daily sodium and potassium intakes from each food group between the subjects according to the Na/K ratio. Sodium intake from grains, meat, fish, and seasonings showed a significant difference between the Na/K groups and was higher in the Na/K≥1 group. Potassium intake from potatoes, beans, nuts, and fruits was significantly higher in the Na/K<1 group, while potassium intake from meat and seasonings was higher in the Na/K≥1 group. Table 4 summarizes the Na/K ratio of detailed food groups. The food groups with the lowest Na/K ratio (0.1) were fruits, cooked rice, and beans/nuts/seeds; seasonings and salted seafood were the food groups with a Na/K ratio greater than 10.0.

Comparison of food intakes between the Na/K groups

Daily intake of each food group between the Na/K groups is shown in Figure 2. Fruits and potatoes intakes of the Na/K<1 group was significantly higher

Table 1. General characteristics of the subjects according to dietary Na/K ratio

	Na/K<1	Na/K≥1	p value
All subjects	n=111	n=529	
Men, %	32.4	53.7	<0.001
Age, y	50.9±12.3[1)]	42.2±14.5	<0.001
Height, cm	162.3±8.5	165.9±8.3	<0.001
Weight, kg	61.6±10.5	64.5±11.6	0.015
BMI, kg/m^2	23.3±2.9	23.3±3.1	0.910
Waist circumference, cm	81.5±9.5	81.4±9.4	0.907
Hip circumference, cm	95.7±6.6	96.5±5.9	0.214
WHR	0.85±0.06	0.84±0.07	0.242
Men	n=36	n=284	
Age, y	52.2±12.9	42.6±14.2	<0.001
Height, cm	171.3±5.9	171.5±5.8	0.881
Weight, kg	71.1±8.9	71.5±9.7	0.845
BMI, kg/m^2	24.3±2.8	24.3±3.0	0.934
Waist circumference, cm	87.7±9.4	85.8±8.0	0.182
Hip circumference, cm	99.1±7.2	98.3±5.8	0.441
WHR	0.88±0.05	0.87±0.05	0.248
Women	n=75	n=245	
Age, y	50.2±12.0	41.7±14.8	<0.001
Height, cm	158.0±5.7	159.4±5.7	0.059
Weight, kg	57.0±7.8	56.4±7.8	0.562
BMI, kg/m^2	22.8±2.9	22.2±2.9	0.104
Waist circumference, cm	78.5±8.0	76.3±8.3	0.040
Hip circumference, cm	94.0±5.6	94.3±5.3	0.674
WHR	0.83±0.06	0.81±0.06	0.001

[1)] *Mean±standard deviation*

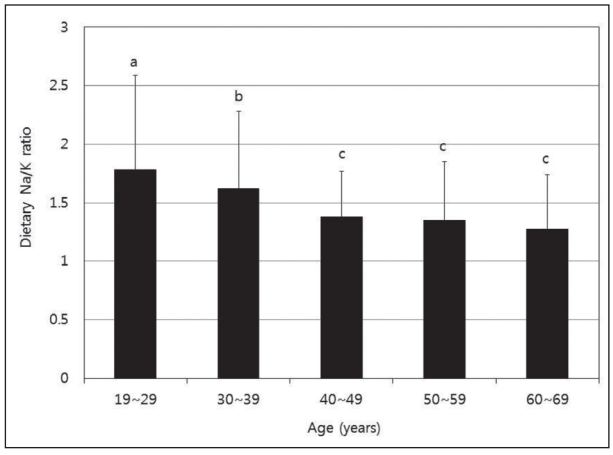

Figure 1. Dietary Na/K ratio of the subjects according to age groups (each group: n=128). Different letters indicate significant difference among age groups by Duncan's multiple range test at p<0.05. Different letters (a, b, c) over the graph indicate significantly difference among age groups at p<0.05 by Duncan's multiple-range test

than the Na/K≥1 group. However, the Na/K≥1 group significantly and highly consumed grains, beverages, meats, and seasonings compared to the Na/K<1 group (p<0.001).

Discussion

In this study, the dietary pattern and contributing food groups of sodium and potassium according to Na/K levels of Korean adults were analyzed. As main results, sodium intake from grains, meat, fish, and seasonings of the Na/K≥1 group and potassium intake from potatoes, beans, nuts, and fruits of the Na/K<1 group were significantly higher than the counterpart groups. Also, the Na/K<1 group consumed more fruits and potatoes and the Na/K≥1 group consumed more grains, beverages, meats, and seasonings.

Table 2. Daily intakes of Na and K of the subjects according to dietary Na/K ratio

	Na/K<1 (n=111)	Na/K≥1 (n=529)	p value
Energy, kcal/d	1813.5±456.4[1)]	1972.3±543.5	0.002
Na			
mg/d	2673.3±1026.3	3982.5±1508.3	<0.001
mg/1000 kcal·d	1464.6±399.4	2056.4±665.9	<0.001
>2000 mg/d, %	74.8	95.5	<0.001
K			
mg/d	3320.0±1320.7	2615.1±891.5	<0.001
mg/1000 kcal·d	1812.2±483.8	1356.5±389.7	<0.001
<3500 mg/d, %	64.9	84.1	<0.001
Na/K	0.8±0.1	1.6±0.6	<0.001

[1)]Mean±standard deviation

Table 3. Daily intakes of Na and K from food groups of the subjects according to dietary Na/K ratio

Food groups	Na		K	
	Na/K<1 (n=111)	Na/K≥1 (n=529)	Na/K<1 (n=111)	Na/K≥1 (n=529)
Grains	267.3±297.5[1)]	572.9±651.3***[2)]	341.1±209.7	333.9±165.4
Potatoes	8.1±20.4	11.1±40.3	443.1±544.1	178.5±266.2***
Sugars	1.1±3.4	1.7±7.1	2.4±15.0	3.0±13.2
Beans	19.8±56.6	16.4±58.1	169.9±261.7	85.4±123.6**
Nuts and seeds	6.0±12.9	4.9±15.7	58.7±104.6	33.7±69.5*
Vegetables	342.9±242.1	375.2±333.3	800.2±414.9	723.3±409.3
Mushrooms	0.4±0.7	0.4±0.8	30.5±56.3	28.4±57.6
Fruits	19.3±19.1	28.5±171.3	462.4±501.0	200.0±229.9***
Meats	89.0±145.0	187.4±270.4***	134.5±135.0	216.2±201.0***
Eggs	38.8±37.3	46.3±56.9	41.0±38.1	47.1±45.7
Fish and shellfish	225.9±213.9	363.1±351.9***	200.2±253.2	225.6±200.8
Seaweeds	84.7±188.2	91.4±207.0	146.0±289.7	128.1±242.0
Milk	52.4±73.7	53.0±77.0	119.5±161.8	96.7±149.6
Oils and fat	2.3±9.0	1.1±6.0	2.0±11.0	0.4±2.5
Beverages	19.3±44.4	24.4±49.7	210.2±661.5	113.6±215.2
Seasonings	1496.0±700.5	2204.8±1107.6***	158.5±108.6	208.3±187.2***
Total	2673.3±1026.3	3982.5±1508.3***	3320.0±1320.7	2615.1±891.5***

[1)]Mean±standard deviation.
*[2)]Significantly different between two groups of Na/K by unpaired t-test. *p<0.05, **p<0.01, ***p<0.001*

Na/K groups of this study were classified on the basis of previous study that Na/K<1 is associated with a lower risk of mortality resulting from CVD and various diseases (21). Recently, the sodium intake of Koreans by KNHANES was 3889.9 mg/d, exceeding the recommendation of 2000 mg, and the potassium intake was 2983.3 mg/d, which was below the 3500 mg recommendation level. As a result, the dietary Na/K ratio highly exceeded the recommendation of <0.57 (i.e., 2000 mg/d and 3500 mg/d) as well as <1. In a study using NHANES data, it was reported that only <0.015% of the population met the recommenda-

Table 4. Dietary Na/K ratio from detailed food groups of the subjects

Food groups	Na (mg/d)	K (mg/d)	Na/K
Fruits	10.1±15.3[1)]	205.4±305.1	0.1±0.1
Cooked rice	13.7±23.3	215.0±162.1	0.1±0.1
Beans, nuts and seeds	3.7±15.1	34.5±75.6	0.1±0.3
Grains and potatoes	9.0±79.1	131.7±328.7	0.3±1.2
Alcoholic beverages	4.6±13.1	16.3±39.7	0.3±0.3
Vegetables and seaweeds	39.9±176.4	77.6±157.8	0.4±1.0
Beverages and tea	44.4±85.4	175.9±367.2	0.5±1.3
Others	6.5±47.4	17.1±131.9	0.6±1.4
Milk and dairy products	40.2±62.2	88.2±147.3	1.0±2.3
Fats and oils	0.3±3.5	0.3±4.6	1.0±0.4
Meat, fish and eggs	15.2±56.0	23.4±105.9	1.0±1.6
One-dish meals	207.9±456.4	144.1±206.4	1.5±1.1
Kimchi	253.1±282.8	155.1±139.8	1.6±1.2
Stews	253.4±363.2	152.3±215.6	1.8±0.9
Roasted foods	183.9±574.6	112.3±209.8	1.9±2.6
Seasoned vegetables	314.4±372.5	192.6±236.5	2.0±2.6
Stir-fried foods	411.0±431.4	219.2±237.1	2.2±1.5
Pan-fried foods	97.0±187.1	49.7±93.5	2.2±2.7
Sugars	8.4±46.0	4.1±18.3	2.3±4.1
Soups	481.5±499.3	239.8± 257.3	2.3±1.6
Fried foods	125.2±248.0	74.9±150.6	2.4±2.2
Steamed foods	137.0±267.0	65.8±147.3	2.9±2.0
Meat and fish products	45.1±128.6	15.7±41.6	3.1±2.0
Bread and snacks	182.5±287.3	69.5±114.8	3.3±11.9
Braised foods	158.9±252.0	64.8±108.8	3.3±1.8
Porridge	28.8±113.1	27.4±122.6	3.6±6.8
Noodles	431.4±676.4	116.8±164.3	3.9±3.1
Rice cake	44.0±118.5	14.0±43.6	5.1±3.0
Pickled and salted foods	98.9±301.6	17.2±38.6	8.0±5.9
Seasonings	71.6±169.9	11.0±24.9	12.6±46.2
Salted seafoods	33.5±122.9	5.9±30.5	14.6±13.1

[1)] *Mean±standard deviation*

tion of Na/K<0.83 (22). Baily et al. (23) also reported that about a quarter of US adults meet the Na/K<1. In the present study, sodium intake of the subjects was 3755.4 mg/d and the potassium intake was 2737.3 mg/d thus, the average Na/K ratio was 1.5. About 17% of the subjects were Na/K<1, similar to previous study (23). These results show the necessity of research to suggest both dietary guidance and a strategy to lower Na/K intake.

Dietary Na/K ratio decreased with age, and subjects in their 20s had the most undesirable level. This finding is believed to be attributed to the trend of individuals in their twenties having a high consumption rate of processed foods such as noodles and bread/snacks, which have high sodium and low potassium contents (24). Further, this age group showed a lower intake of vegetables and fruits, which have high potassium content. The subjects with Na/K<1 had a

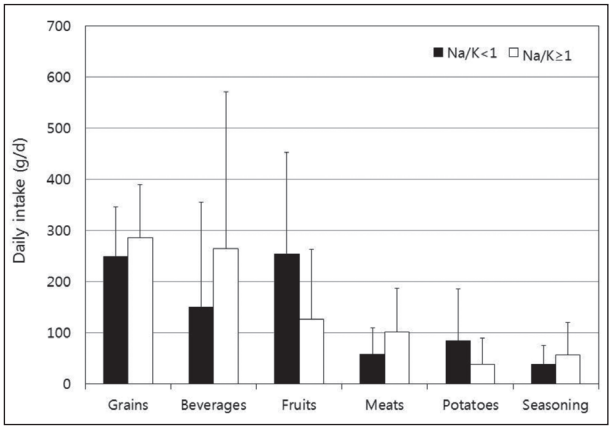

Figure 2. Daily food intakes of the subjects according to dietary Na/K ratio (Na/K<1: n=111; Na/K≥1: n=529). Six food groups in the figure show significant difference between two groups of Na/K<1 and Na/K≥1 by unpaired Student's *t*-test at p<0.001

lower number of males than subjects with Na/K≥1. This shows that men have a higher Na/K intake than women. This observation is believed to be attributed to the notion that females tend to ingest more fruit and grains/potatoes, which have low sodium and high potassium contents. Nagata et al. (25) reported a 2.4-fold increased risk of death from stroke associated with high sodium intake in men but, in women, the association of sodium intake with stroke mortality was weaker. Considering sodium and potassium intakes related to health (25, 26), nutritional education of appropriate sodium and potassium intake is needed, especially in males and individuals in their twenties.

In this study, sodium intake from grains, meat, fish, and seasonings was higher in Na/K≥1 subjects than in Na/K<1 subjects. These results may be related to the eating patterns of Koreans. The major foods contributing to sodium intake in Korea are liquids in soups and stews, fermented foods such as kimchi and salted fish, and noodles such as ramen (7, 27). This study also found that sodium intake from soups was the highest followed by noodles, seasoned vegetables, stews, and kimchi. Ogawa et al. (28) reported that miso soup and Japanese pickles were the top contributors of sodium intake among 197 common Japanese dishes. Na/K≥1 subjects may have a high intake of grains and potatoes because of their high intake of liquid and kimchi. Some evidence exists that sodium intake is related to energy intake and obesity risk (29, 30). This study also showed similar result that daily energy and sodium intake were higher in the Na/K≥1 group.

The main sources of potassium are unprocessed grains, vegetables and fruits, especially tomato, cucumber, zucchini, eggplant and root vegetables such as sweet potato and potato (7, 27). The present study also found that potassium intake from potatoes, beans, nuts, and fruits was higher in Na/K<1 subjects. In the complex aspect of sodium and potassium intakes, Na/K<1 subjects had a low intake of sodium from grains, meat, fish, and seasonings and a high intake of potassium from potatoes, beans, and fruits.

Reports indicate that blood pressure increases as the Na/K ratio increases (31), and the intake of potassium is appropriate when the molar Na/K ratio is close to 1.0 (8). In the present study, food groups with a Na/K ratio less than 1.0 were fruits, beans, grains and potatoes, vegetables and seaweeds, beverages and tea. Rhee (32) reported that foods with a Na/K ratio less than 1.0 were mushrooms, fruit, potatoes, beans, tea, and seaweeds; foods with a Na/K ratio greater than 1.0 were seasonings and spices, fish and shellfish, sugar, and cereal. These findings are similar to the results of the present study. As a geographical and cultural comparison, Meneton et al. (33) examined food intake patterns of adults and children in France, reporting the foods with the highest Na/K ratio to be cheese, pork, pastry and sugar products, cereal, bread, soup, and fast food, and the foods with the lowest Na/K ratio to be fruits, vegetables, and dairy products.

Na/K≥1 subjects consumed more grains, beverages, meats, and seasonings and less fruits and potatoes compared to Na/K≥1 subjects. These results were similar to the sodium and potassium intake patterns from the food group. As expected, Na/K≥1 subjects consumed more sodium sources and less main sources of potassium. However, grains and beverages intakes were high in Na/K≥1 subjects despite their low Na/K ratio, most likely because of the high sodium intake resulting from the high intake of main dishes and beverages. Considering the results of this study, for lower Na/K intake, a nutritional guide is needed to choose more foods with low Na/K ratio such as fruits, beans, potatoes, vegetables and seaweeds.

This study has several limitations. First, food intake status was surveyed using the 24-hour recall

method, which reflects only short-term food intake levels of individuals. Thus, it is difficult to examine ordinary intake levels. Second, the nutrient database used in this study lacks nutrient data on processed foods, fusion foods, and international foods. Therefore, the sodium and potassium content database of processed foods and other foods needs to be established in advance for accurate examination of the sodium and potassium intake status. Nevertheless, this study differs from previous studies that evaluated sodium or potassium intakes separately. Additionally, the strength of this study is the present results can be effectively applied to dietary guidance that recommends lowering Na/K intake by analyzing sodium and potassium intakes in various food groups and the dietary pattern that focuses on the Na/K ratio.

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