Use of Lightly Potassium-Enriched Soy Sauce at Home Reduced Urinary Sodium-to-Potassium Ratio

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RESEARCH

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ABSTRACT

A high sodium (Na) intake and low potassium (K) intake are factors affecting hypertension in Japan. Thirty-three residents took part in a randomized, controlled crossover trial. The purpose was to evaluate the effects of use of lightly potassium-enriched condiments (low Na/K condiments; 25% less Na and 20% higher K) on the urinary Na/K ratio, which is related to the dietary Na/K ratio. One week after the baseline measurements (run-in period), the participants were assigned to either a low Na/K condiments group or a standard condiments group for 2 weeks (experiment period 1). The conditions were then reversed for the next 2 weeks (experiment period 2). The participants were requested to use the given low Na/K or standard condiments during the designated periods at their home as usual instead of their own condiments. Casual urine measurements were taken over seven consecutive days in each run-in period during experiment periods 1 and 2. The average urinary Na/K ratios (mol/mol, mean±SD) in the low Na/K period were significantly lower than those in standard period by the paired t-test (3.28±1.56 vs. 3.96±1.98, P=0.001). The use of low Na/K condiments was effective in lowering the urinary Na/K ratio, which suggests blood pressure lowering effects.

Key Words: Hypertension; Sodium; Potassium; Intervention; Condiments.

Introduction

Stroke and dementia are the top two causes of the need for long-term care under the Japanese long-term care insurance system [1]. Elevated blood pressure is the major risk factor for stroke [2]. High blood pressure was the cause of 42.9% of the total cardiovascular disease deaths and 48.3% of stroke deaths in Japan [3]. Regarding cognitive decline, recent studies have suggested hypertension and other cardiovascular risk factors to be associated with onset

of vascular dementia and Alzheimer disease [4-5]. Prevention of hypertension is of concern to maintain social vitality in Japan, where more than two-thirds of the elderly aged over 70 is hypertensive [6].

Excess sodium (Na) intake and insufficient potassium (K) intake are both associated with blood pressure elevation [7-9], and their alteration through diet may be an effective strategy to prevent hypertension. According to a meta-analysis of studies using 24-hr urine samples in Japan, Na excretion in 24-hr urine has significantly decreased from 8500 mg/day (21.6 g/day of salt) in the 1950s to 4260 mg/day (10.8 g/day of salt) in the 2010s, whereas there was no significant decrease from 1978 to 2014 [10]. The average salt intake in Japan exceeds the recommended values by WHO (5 g/day) 11 and the Dietary Reference Intakes for Japanese 2015 (8 g/day) [12]. Japanese traditional high-salt condiments, such as soy sauce and miso, are the major sodium sources. According to a detailed dietary survey in Japan by the INTERMAP study, soy sauce and miso accounted for 17% and 7% of the total sodium intake, respectively [13]. Due to their high contribution, reduced sodium versions of these condiments with 40-50% lower sodium content are commercially available, but their taste acceptability may be not be satisfactory to consumers and their effects on salt intake reduction are unclear.

Previously, the use of potassium-enriched and sodium-reduced salt was reported to be associated with decreased CVD mortality in a long-term randomized trial in Taiwan [11]. An intervention study in Finland, in which participants used processed foods and salt with less sodium that were rich in magnesium and potassium, demonstrated a significant decrease in BP [14]. However, such studies in Japan are limited [15] and the results are inconclusive.

Potassium is contained in many foods, including vegetables and fruits, and can be used in reduced sodium condiments to increase the salty taste [16]. However, higher concentrations yield an acrid taste and may impair acceptability. Mildly potassium-enriched and reduced sodium (low Na/K) soy sauce and miso with sufficient taste acceptability for Japanese may be an effective method for reducing the dietary Na/K ratio without stress, which may help prevent hypertension; the most prevalent disease in elderly which accounts for the largest fraction of the healthcare expenditure in Japan [17]. They could have various uses; hypertensive people who find difficulties in reducing salt, normotensive people who want to prevent future elevation of BP, eating-out or food industries which are often receive criticism that they provide too salty foods.

We performed an intervention study in which participants used low Na/K soy sauce, miso, and other condiments at home, and examined the effects on the spot urinary Na/K ratio.

Methods

Participants

Residents aged 40 years and older in a rural town in Iwate Prefecture located in north-eastern Japan who participated in an annual specific health check-up in 2016 spring were invited to enroll. We held an explanatory meeting before the enrollment and explained that participants would be asked to use potassium-enriched condiments for home cooking, and that they were unable to enroll if any of their family members required potassium restriction because of medical reasons.

Study procedure

The study procedures are shown in Figure 1. Two weeks prior to the beginning of the experimental periods, the study was explained to the participants by trained investigators. After confirming that no family member required potassium restriction, written informed consent was received from each participant. Participants were grouped into two groups by lottery; group A used low Na/K condiments in experiment period 1 (two weeks) and standard condiments in experiment period 2 (two weeks), whereas group B used standard condiments in experiment period 1 and low Na/K condiments in experiment period 2. The assignment was opened to the participants at the beginning of experiment period 1. The trial was conducted from November to December 2016. The ethics committee

of the Research Institute of Strategy for Prevention approved the study protocol.

Study condiments

Low Na/K and standard condiments were used. The NaCl content was 20 to 30% lower than that in the standard condiments, and the reduced content was replaced with K salt (K gluconate or KCl). Both standard and low Na/K soy sauce, miso, table salt, and mentsuyu (mixed seasoning made from soy sauce, sake, and bonito broth used for Japanese noodles, tempura sauce, and seasoning of dishes) were given. The Na and K content, and Na/K ratio are presented in Table 1.

Participants brought their own condiments from home in order to make sure they only used the study condiments. Participants were requested to use the study condiments as usual, and were told that they did not have to restrict eating out or manufactured foods, and they were allowed to use other condiments, such as dressings, Worcester sauce, etc., throughout the study period. At the end of experimental periods 1 and 2, they returned the remaining study condiments, which were measured to calculate the amount used.

Questionnaire

Two weeks prior to the beginning of the experimental period, a questionnaire was conducted by trained investigators. Participants were considered to have a history hypertension if they responded “yes” to the question “have you ever been told that you have hypertension at a medical institution or health checkup?” The use of antihypertensive agents was investigated. Participants were asked if they were following a reduced salt diet. The number of household members was asked to estimate the amount of condiments to be provided. A short dietary propensity questionnaire (SDPQ) [18] was conducted, in which the frequency of food consumption for the previous two weeks was evaluated. Another SDPQ was performed at the end of experimental periods 1 and 2, and participants were asked if they used the test condiments for foods they had at home as usual.

Measurement

Blood pressure was measured in duplicate using standard automated sphygmomanometers (OMRON HEM-7251G) on the right arm of seated participants after 5 minutes of rest. The mean of two blood pressure measurements was used for analysis. Height and weight without shoes were measured. The body mass index (kg/m^2) was calculated as weight (kg) divided by height (m) squared.

Spot urine

Participants were requested to take first morning spot urine samples on seven consecutive days prior to the beginning of experimental period 1, and during the latter half of experimental periods 1 and 2 (Figure 1). The spot urine samples were kept at home and then brought to the study office at the beginning of experimental periods 1 and 2, and at the end of experimental period 2. The urine samples were placed in a freezer (-40°C) soon after they were brought to the study office. After all study procedures were finished, all samples were measured in one batch. Urinary Na (mEq/L) and K (mEq/L) were measured by the electrode method. Urinary creatinine (mg/dL) was measured by the enzymatic method.

Statistical analysis

For each set of the seven spot urine samples, the average Na (mEq/L), K (mEq/L), and creatinine (mg/dL) density was calculated. The average urinary Na/K ratio (mEq/mEq) was calculated as the average Na (mEq/L) divided by the average K (mEq/L) for each period. The average estimated 24-hr urinary Na excretion (E24Na, mmol/24 hr) and estimated 24-hr urinary K excretion (E24K, mmol/24 hr) were calculated using the average Na (mEq/L), K (mEq/L), and creatinine (mg/dL) by Kawasaki’s formula [19]. The amount of condiments used per person per day during the experimental periods were calculated as the amount used within experimental period 1 or 2 divided by number of family members and 14 days.

There were no significant differences in baseline characteristics between group A (start with low Na/K condiments) and group B (start with standard condiments)

(data not shown), and we pooled data from group A and B collected from the periods using the same condiments, and used them to examine difference between periods using low Na/K condiments and standard condiments. The paired t-test was used to compare the urinary Na/K ratio, E24Na, and E24K between the low Na/K period and the standard period. The results of the SDPQ and amount of condiments used were also compared between the periods. To compare results among participants with a higher or lower Na/K ratio at baseline, participants were grouped into tertiles according to the urinary Na/K ratio in the run-in period. Analysis of variance was used to compare the urinary results among the tertiles. We used the analysis of covariance to compare the estimated mean of differences (low N/K period minus standard period) among the tertiles adjusted for sex, age, use of antihypertensive agents, reduced salt diet, and body weight. Linearity was evaluated with regression analyses, with the run-in period Na/K tertiles analyzed as a continuous variable.

Analyses were performed using SPSS for Windows 23.00 (IBM Corporation, Chicago, Illinois, USA). The significance level was set at 0.05, and was two-tailed.

Results

A total of 33 participants (8 men and 25 women) were enrolled. All participants completed all study procedures. Their baseline characteristics are presented in Table 2. They had a mean age of 64.6 years, 14 (42.4%) had a history of hypertension, and 28 participants (84.8%) answered that they were following a reduced salt diet in the questionnaire. On average, they had one bowl of miso-soup per day and did not eat out often. The average spot urinary Na/K ratio in the run-in period was 3.81 mol/mol.

The average spot urinary data, amount of condiments used, results of the SDPQ, blood pressure during standard condiment period and low Na/K condiment period, and the differences between the periods are shown in Table 3. The average spot urinary Na/K ratio (mol/mol) was significantly lower in the low Na/K period than in the standard period (3.28 vs. 3.96, P=0.001). There was no significant difference in E24Na between the periods. E24K (mmol/24hr) was significantly higher in the low Na/K period than in the standard period (50.1 vs. 46.9, P=0.010). There was no significant difference in the systolic or diastolic blood pressure. Food intake as evaluated by SDPQ was similar. More soy sauce (g/person/day) was used in the low Na/K period than in the standard period (6.7 vs. 4.8, P<0.001), but there were no significant differences for the other condiments.

The characteristics of tertiles of participants according to urinary Na/K ratio in the run-in period are presented in Table 4. The average Na/K ratio at baseline was 2.13 for the low tertile and 5.92 for the high tertile. A significantly higher E24Na and lower E24K were observed in the high tertile. The tertiles had similar characteristics i.e., age, body mass index, and blood pressure; however, fewer participants using antihypertensive agents were included in the middle tertile (9.1%, P=0.064).

The amounts of condiments used and spot urine data during the standard and low Na/K periods for tertiles are shown in Table 5. In each tertile, urinary results in the standard period were similar to those in the run-in period. The mean decrease in the urinary Na/K ratio (mol/mol) in the low Na/K period was significantly larger than that in the standard period in the high tertile. The average difference (95% confidence interval [CI]) was -0.28 (-0.62 to 0.07) for the low tertile and -1.29 (-2.19 to -0.38) for the high tertile (P for trend=0.018). The results were similar for the adjusted means of the difference; -0.29 (-0.89 to 0.31) for the low tertile and -1.36 (-1.94 to -0.78) for the high tertile (P for trend=0.008). There was no significant difference in E24Na for all tertiles, but the adjusted difference in E24K (mmol/24 hr) was significant and positive for the high tertile (5.30 with 95% CI 1.2 to 6.0), but not for the low tertile (1.79 with 95%CI -2.4 to 6.0) (P for trend=0.213).

Discussion

We conducted an intervention study in which participants used standard or low Na/K condiments for two weeks each at home. Their urinary Na/K ratio was significantly reduced while using the low Na/K condiments compared with that during the period in which they used

standard condiments. The estimated 24-hr urinary potassium excretion significantly increased, which may help to prevent hypertension. A previous cohort study in Japan reported an increased mortality risk from total CVD and stroke for participants with a higher dietary Na/K ratio [20]. Our results suggest that this method may improve the dietary Na/K ratio and prevent hypertension in Japan.

A higher Na intake and lower K intake in Japan compared with Western countries have been repeatedly reported [8, 21-22]. Although the average Na intake in Japan has decreased with advances in food processing and preservation, there has been no notable decline and the intake remains above the recommended values by WHO10 and related authorities in Japan [12, 23-24]. Moreover, salt reduction by persons following a reduced salt diet was found to be low, 17.9 mmol/day (1.1 g/day in salt) in Japan, in a study using 24-hr urine samples [25]. Thus, population approaches for salt reduction are needed. On the other hand, the average potassium intake in Japan was 2219 mg/day in 2016 according to the National Survey on Health and Nutrition Japan [26], which is far below the recommended value (3510 mg/day) set by WHO to prevent hypertension and CVDs [27]. Although fruit and vegetables are major sources of potassium, the average total intake of fruit and vegetables decreased from 432 g/day in 1975 to 344 g/day in 2016 [26]. During this period, eating out and use of ready-made dishes became more common due to the economic growth [28], and the participation of women in the workforce increased [29]. These changes may be partially responsible for the high salt intake and insufficient potassium intake due to decreased fruit and vegetable consumption at home [26].

In the present analysis, participants in the high urinary Na/K tertile at baseline consumed more high-Na condiments than those in the low Na/K tertile. Individuals with a higher urinary Na/K ratio who are at higher risk of hypertension may prefer the salty taste and it may therefore be more difficult for them to reduce their salt intake by themselves. In the present study, the condiments used at home were changed, but they tasted similar. At the end of experimental periods 1 and 2, all participants answered that they used both the standard and low Na/K condiments in a satisfactory manner, and found no burden in using the condiments on the questionnaires (data not shown). The participants with a high urinary Na/K ratio at baseline had a greater decrease in the urinary Na/K ratio. The use of low Na/K condiments may be beneficial for those who prefer the salty taste and require support for reducing their sodium intake.

We asked participants to use the test condiments at home, and placed no restrictions on eating out or the use of manufactured foods. The average amount of the test soy sauce used was 4.8 g/person/day during the standard period and 6.7 g/person/day during the low Na/K period, demonstrating that the participants had not restricted their use of condiments. According to a previous population study in Japan, the average amount of consumed soy sauce, including that in restaurant dishes and manufactured foods, was 13.8 g/day. Japanese pickles and salted fish are also important Na sources, with the average salt intake being 1.4 g/day and 1.0 g/day from Japanese pickles and salted fish, respectively [30]; these are usually bought. If low Na/K condiments are used at restaurants and in manufactured foods, improvement in the dietary Na/K ratio will be more significant throughout the population.

In the present analysis, average difference in urinary Na/K ratio (mol/mol) associated with use of low Na/K condiments at home was -0.68 and -1.29 for total participants and those in the highest Na/K tertile, respectively. The differences may correspond to expected decrease of 1.5mmHg and 2.8mmHg in SBP according to a previous meta-analysis study presenting significant effect of reduced urinary Na/K [31]. Participants did not declare any difficulty in using the condiments, thus they would be facilitated in various situations such as home cooking, restaurants, and processed foods.

There are some limitations in this study. To accurately provide the designated condiments to each participant, the study was not blinded, and participants and research investigators knew the type of condiments used during the experimental periods. Thus, there is a possibility that participants altered their food consumption based on

the condiments given. Most of the participants reported that they were following a reduced salt diet and the possibility of a selection bias cannot be excluded. The amounts of test condiments used per person were calculated as the total amount used divided by the number of household members, and we did not separate the amounts consumed by the participant and the other family members. Thus, the amount used may have been affected by the family members.

Conclusions

We noted a significant decrease in the urinary Na/K ratio when participants used low Na/K condiments at home. Further studies with a larger sample size are necessary to examine the effects on blood pressure. This study suggested that low Na/K condiments can improve blood pressure by reducing the dietary Na/K ratio in populations with an excess salt intake and insufficient potassium intake such as in Japan and other Asian countries.

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Conflicts of Interest

Authors declare no conflicts of interest.

References

1. Naruse T, Sakai M, Matsumoto H, Nagata S, Diseases that precede disability among latter-stage elderly individuals in Japan. Biosci Trends, 2015. 9: p. 270-274.
2. NIPPON DATA Research Goup. Impact of elevated blood pressure on mortality from all causes, cardiovascular diseases, heart disease and stroke among Japanese: 14 year follow-up of randomly selected population from Japanese -- Nippon data 80. J Hum Hypertens, 2003. 17: p. 851-857.
3. Takashima N, Ohkubo T, Miura K, Okamura T, Murakami Y, Fujiyoshi A, et al; Long-term risk of BP values above normal for cardiovascular mortality: a 24-year observation of Japanese aged 30 to 92 years. J Hypertens, 2012. 30: p. 2299-2306.
4. Pendlebury ST, Rothwell PM, Prevalence, incidence, and factors associated with pre-stroke and post-stroke dementia: a systematic review and meta-analysis. Lancet Neurol, 2009. 8: p.1006-1018.
5. de Bruijn RF, Ikram MA, Cardiovascular risk factors and future risk of Alzheimer's disease. BMC Med, 2014. 12: p. 130.
6. National Institutes of Biomedical Innovation Health and Nutrition. The National Health and Nutrition Survey Japan, 2012 (in Japanese). Tokyo: Daiichi Shuppan, 2016.
7. Cutler JA, Follmann D, Allender PS, Randomized trials of sodium reduction: an overview. Am J Clin Nutr, 1997. 65: p. 643S-651S.
8. INTERSALT Cooperative Research Group. INTERSALT: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. Intersalt Cooperative Research Group. BMJ, 1988. 297: p. 319-328.
9. D'Elia L, Barba G, Cappuccio FP, Strazzullo P. Potassium intake, stroke, and cardiovascular disease a meta-analysis of prospective studies. J Am Coll Cardiol, 2011. 57: p.1210-1219.
10. Uechi K, Sugimoto M, Kobayashi S, Sasaki S, Urine 24-Hour Sodium Excretion Decreased between 1953 and 2014 in Japan, but Estimated Intake Still Exceeds the WHO Recommendation. J Nutr, 2017. 147: p. 390-397.
11. Chang HY, Hu YW, Yue CS, Wen YW, Yeh WT, Hsu LS, et al; Effect of potassium-enriched salt on cardiovascular mortality and medical expenses of elderly men. Am J Clin Nutr, 2006. 83: p. 1289-1296.
12. Overview of Dietary Reference Intakes for Japanese Ministry of Health, Labour and Welfare (2015). 2015.
13. Okuda N, Okayama A, Miura K, Yoshita K, Saito S, Nakagawa H, et al; Food sources of dietary sodium in the Japanese adult population: the international study of macro-/micronutrients and blood pressure (INTERMAP). Eur J Nutr, 2017. 56: p. 1269-1280.

14. Sarkkinen ES, Kastarinen MJ, Niskanen TH, Karjalainen PH, Venalainen TM, Udani JK, et al; Feasibility and antihypertensive effect of replacing regular salt with mineral salt -rich in magnesium and potassium- in subjects with mildly elevated blood pressure. Nutr J, 2011. 10: p. 88.
15. Nakamura M, Kubo N, Aoki N, Reduction in salt intake with low sodium soy sauce and miso (soybean paste) in Japanese diet: randomized, placebo-controlled, double-blind cross-over study (in Japanese). JJCDP, 2002. 37: p. 12-18.
16. Maleki A, Soltanian AR, Zeraati F, Sheikh V, Poorolajal J, The flavor and acceptability of six different potassium-enriched (sodium reduced) iodized salts: a single-blind, randomized, crossover design. Clin Hypertens, 2016. 22: p. 18.
17. Nakamura K, Impact of cardiovascular risk factors on medical expenditure: evidence from epidemiological studies analysing data on health checkups and medical insurance. J Epidemiol, 2014. 24(6): p. 437-43.
18. Okuda N, Itai K, Okayama A, Usefulness of a short dietary propensity questionnaire in Japan. J Atheroscler Thromb, 2018. 25(5): p. 430-438.
19. Kawasaki T, Itoh K, Uezono K, Sasaki H, A simple method for estimating 24 h urinary sodium and potassium excretion from second morning voiding urine specimen in adults. Clin Exp Pharmacol Physiol, 1993. 20: p. 7-14.
20. Okayama A, Okuda N, Miura K, Okamura T, Hayakawa T, Akasaka H, et al; Dietary sodium-to-potassium ratio as a risk factor for stroke, cardiovascular disease and all-cause mortality in Japan: the NIPPON DATA80 cohort study. BMJ, 2016. 6: p. e011632.
21. Zhou BF, Stamler J, Dennis B, Moag-Stahlberg A, Okuda N, Robertson C, et al; Nutrient intakes of middle-aged men and women in China, Japan, United Kingdom, and United States in the late 1990s: the INTERMAP study. J Hum Hypertens, 2003. 17: p. 623-630.
22. Brown IJ, Tzoulaki I, Candeias V, Elliott P, Salt intakes around the world: implications for public health. Int J Epidemiol, 2009. 38: p. 791-813.
23. Nishi N, Okuda N, National Health and Nutrition Survey in target setting of Health Japan 21 (2nd edition) (in Japanese). J Natl Inst Public Health, 2012. 61: p. 399-408.
24. Japan Society of Hypertension. Guidelines for the Management of Hypertension 2014. Tokyo: Life Science Publishing, 2014.
25. Okuda N, Stamler J, Brown IJ, Ueshima H, Miura K, Okayama A, et al; Individual efforts to reduce salt intake in China, Japan, UK, USA: what did people achieve? The INTERMAP Population Study. J Hypertens, 2014. 32: p. 2385-2392.
26. National Health and Nutrition Survey Japan (2016), Ministry of Health, Labour and Welfare (in Japanese). 2017.
27. WHO. Guideline: Potassium intake for adults and children. 2012.
28. Hotta M, Recent trend of deli food market (in Japanese). Journal of Cookery Science of Japan 2007. 40: p. 104-108.
29. Cooke FL, Women's participation in employment in Asia: a comparative analysis of China, India, Japan and South Korea. The international journal of human resource management, 2010. 21: p. 2249-2270.
30. Okuda N, Itai K, Okayama A, Usefulness of a Short Dietary Propensity Questionnaire in Japan. J Atheroscler Thromb 2018, 25: p. 430-438.
31. Binia A, Jaeger J, Hu Y, Singh A, Zimmermann D, Daily potassium intake and sodium-to-potassium ratio in the reduction of blood pressure: a meta-analysis of randomized controlled trials. J Hypertens, 2015. 33: p. 1509-1520.

PEER REVIEW

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Tables

Table 1. Na and K content in test condiments.

	Na (mg/100 g)	K (mg/100 g)	Na/K (mol/mol)
Soy sauce			
Standard[a]	5449	434	21.3
Low Na/K (K gluconate used)[b]	4040	1738	4
Miso			
Standard[c]	4481	257	29.6
Low Na/K (K gluconate used)[d]	3644	1760	3.5
Mentsuyu			
Standard[d]	3567	470	12.9
Low Na/K (K gluconate used)[d]	2833	987	4.9
Salt			
Standard[e]	36337	402	154
Low Na/K (K gluconate used)[f]	29035	11210	4.4

[a]Tokusen Soy-Sauce, Asanuma Soy Sauce Shop Co., Ltd.

[b]Iwate Kenmin, Asanuma Soy Sauce Shop Co., Ltd.

[c]Takeya Special Miso, Takeya Miso Co., Ltd

[d]Prototype for this study

[e]Setouchi no Shio, AEON Co., Ltd.

[f]Herushio Light, Japan Low-Salt Promotion Consortium

Table 2. Characteristics of participants (n=33).

	Mean	**(SD)**
Women, n (%)	25	75.8
Age (year)	64.6	10.5
First group, n (%)	18	54.5
Number of household members	3.1	1.9
History of hypertension, n (%)	14	42.4
Use of antihypertensive agents, n (%)	12	36.4
Following salt reduction diet, n (%)	28	84.8
Body weight (kg)	54.2	9
Body mass index (kg/m2)	22.9	2.3
Systolic blood pressure (mmHg)	126.4	16.9
Diastolic blood pressure (mmHg)	78.3	12
Food intake (obtained from SDPQ)		
Rice (g/week)	1616	879
Noodles with soup (ramen, udon, etc.) (bowls/week)	1.8	1.6
Miso soup (bowls/week)	6.9	3.7
Discretionary soy sauce (times/week)	2.8	3.2
Japanese pickles (times/week)	7.2	8.2
Vegetables (times/week)	14.7	6.5
Fruit (times/week)	5.7	2.8
Eating out (times/week)	1.1	1.7
Spot urine data in the run-in period		
Na/K（mol/mol)	3.81	1.85
E24Na (mmol/24 hr)	208	45.9
E24K (mmol/24 hr)	49.3	8.9

SDPQ, short dietary propensity questionnaire29; E24Na, estimated 24-hr urinary sodium excretion; E24K, estimated 24-hr urinary potassium excretion

Table 3. Averages for spot urine samples, blood pressure, food intake, and condiments used during the standard condiment period and low Na/K condiment period (n=33).

	Standard		**Low Na/K**		**Difference (Low Na/K - standard)**		***P*[α]**
	M	**SD**	**M**	**SD**	**M**	**SD**	
Spot urine data							
Na/K(mol/mol)	3.96	1.98	3.28	1.56	-0.68	0.18	0.001
E24Na (mmol/24 hr)	202	38	199	42	-3	4	0.451
E24K (mmol/24 hr)	46.9	6.6	50.1	8.7	3.3	1.2	0.010
Body weight (kg)	54.5	8.9	54.4	9	-0.1	0.6	0.294

BMI(kg/m^2)	22.4	2.9	22.4	2.9	-0.1	0.2	0.237
SBP(mmHg)	127.3	17.5	125.4	18.2	-2.0	2.1	0.365
DBP(mmHg)	79.7	11.2	78.5	12.4	-1.2	1	0.261
Food intake (obtained from SDPQ)							
Rice (g/week)	1316	1039	1566	869	250	863	0.106
Noodles (bowls/ week)	1.7	1.5	1.5	1.6	-0.2	1.8	0.606
Miso soup (bowls/ week)	5.9	3.2	6.5	3.2	0.5	3.6	0.388
Discretionary use of soy sauce (times/ week)	2.4	2.8	2.1	2.5	-0.3	2.5	0.539
Japanese pickles (times/ week)	5.3	4.5	5.6	7.6	0.3	7.5	0.835
Vegetables (times/ week)	12.4	6.2	12.1	6.6	-0.2	8.1	0.873
Fruit (times/ week)	5.7	2.9	5.7	3	0	3.1	0.978
Eating out (times/ week)	1.3	1.5	1.3	1.3	0	1.4	0.904
Amount of condiments used (g/person/day)							
Soy sauce	4.8	4.1	6.7	4.2	1.9	0.5	<0.001
Miso	8.4	4.6	8.8	4.3	0.4	0.5	0.37
Salt	1	2	1.5	1.6	0.5	0.4	0.265
Mentsuyu	10	8.7	11	9.6	0.9	0.9	0.276

M, Mean; BMI, Body mass index; SBP, Systolic blood pressure; DBP, Diastolic blood pressure

SDPQ, short dietary propensity questionnaire29; E24Na, estimated 24-hr urinary sodium excretion; E24K, estimated 24-hr urinary potassium excretion

[a]P-values by paired-t tests.

Table 4. Characteristics of tertiles of participants according to the urinary Na/K ratio in the run-in period (n=33).

	T[a]1 (n=11)		T2 (n=11)		T3 (n=11)		P[b]	Trend *P*
	M	SD	M	SD	M	SD		
Spot urine data								
Na/K ratio (mol/mol)	2.13	0.6	3.38	0.3	5.92	1.5	<0.001	<0.001
E24Na (mmol/24 hr)	181	34	194	32	249	41	<0.001	<0.001
E24K (mmol/24 hr)	55.9	10	46.3	6.7	45.6	5.5	0.006	0.017
Women, n (%)	8	73	9	82	8	73	1	
Age (year)	65.6	11	63.7	12	64.5	8.5	0.916	0.796
Assigned to group A, n (%)	3	27	7	64	8	73	0.146	
History of HTN, n (%)	6	55	4	36	4	36	0.609	
Use of antihypertensive agents, n (%)	6	55	1	9.1	5	46	0.064	
Following reduced salt diet, n (%)	10	91	10	91	8	73	0.39	
Body weight (kg)	53.8	9.5	52.3	8.5	56.6	9.2	0.534	0.47
BMI (kg/m^2)	22.4	2.7	21.7	2.3	22.9	3.9	0.638	0.684
SBP (mmHg)	129	19	121	19	130	11	0.424	0.912
DBP (mmHg)	78.9	13	75.3	11	80.7	12	0.576	0.722

M, Mean; BMI, Body mass index; SBP, Systolic blood pressure; DBP, Diastolic blood pressure

E24Na, estimated 24-hr urinary sodium excretion; E24K, estimated 24-hr urinary potassium excretion; HTN, Hypertension

[a]P-values by analysis of variance for continuous variables and chi-squared tests for categorical variables.

Table 5. Amount of condiments used and spot urine data during the intervention period for tertiles according to the spot urine Na/K ratio.

	T*1 (n=11)		T2 (n=11)		T3 (n=11)		*P*[a]	Trend *P*
	M	SD	M	SD	M	SD		
Amount of condiments used								
Standard condiments								
Soy sauce (g/day)	3.6	2.6	3.9	2.8	7	5.7	0.098	0.051
Miso (g/day)	7.6	5.2	7.3	4	10.2	4.4	0.274	0.184
Salt (g/day)	1.3	2.3	1.1	2.5	0.8	0.9	0.813	0.518
Mentsuyu (g/day)	9.9	8.3	9.3	10.7	10.8	7.6	0.93	0.822
Low Na/K condiments								
Soy sauce (g/day)	5.4	3.8	7.1	4	7.6	4.8	0.462	0.234
Miso (g/day)	7.4	3.1	7.3	3.9	11.8	4.6	0.016	0.014
Salt (g/day)	1.2	0.9	1	1.3	2.3	2.1	0.101	0.083
Mentsuyu (g/day)	10	8.2	10.4	11.6	12.5	9.4	0.808	0.536
Results from spot urine samples								
Standard period								
Na/K ratio (mol/mol)	2.67	0.9	3.15	1	6.05	1.85	<0.001	<0.001
E24Na (mmol/24 hr)	180.9	32.1	187.6	32.8	236.7	19.8	<0.001	<0.001
E24K (mmol/24 hr)	49.9	6.7	47.4	6.3	43.7	6	0.087	0.027
Low Na/K period								
Na/K ratio (mol/mol)	2.39	0.74	2.69	0.55	4.76	1.81	<0.001	<0.001
E24Na (mmol/24 hr)	174.1	40.5	188.4	30.6	233.2	32.4	0.001	<0.001
E24K (mmol/24 hr)	50.5	9.9	51.1	7.1	49.2	9.6	0.873	0.722
Difference (low Na/K - standard)								
Na/K ratio (mol/mol)	-0.28	0.51	-0.46	0.78	-1.29	1.35	0.042	0.018
(95%CI)	(-0.62, 0.07)		(-0.99, 0.06)		(-2.19, -0.38)			
E24Na (mmol/24 hr)	-6.8	26	0.8	9.7	-3.5	31.7	0.768	0.754
(95%CI)	(-24.2, 10.7)		(-5.7, 7.3)		(-24.8, 17.8)			
E24K (mmol/24 hr)	0.7	7.5	3.7	4.7	5.5	7.8	0.262	0.103
(95%CI)	(-4.4, 5.7)		(0.6, 6.8)		(0.2, 10.7)			
Adjusted difference (low Na/K - standard) (SE)								
Na/K ratio (mol/mol)	-0.28	0.29	-0.37	0.29	-1.39	0.28	0.022	0.013
(95%CI)	(-0.87, 0.32)		(-0.96, 0.23)		(-1.97, -0.81)			
E24Na (mmol/24 hr)	-0.3	7.7	-3.5	7.8	-6.3	7.8	0.883	0.552
(95%CI)	(-15.7, 16.4)		(-19.5 12.5)		(-21.3, 9.6)			
E24K (mmol/24 hr)	1.9	2.1	2.7	2	5.2	2	0.467	0.213
(95%CI)	(-2.3, 6.2)		(-1.5, 6.9)		(1.1, 9.4)			

M, Mean; E24Na, estimated 24-hr urinary sodium excretion; E24K, estimated 24-hr urinary potassium excretion

[a]P-values by analysis of variance or analysis of covariance for comparison of adjusted differences with adjustment for age, sex, use of antihypertensive agents, reduced salt diet, and body weight.

Figure

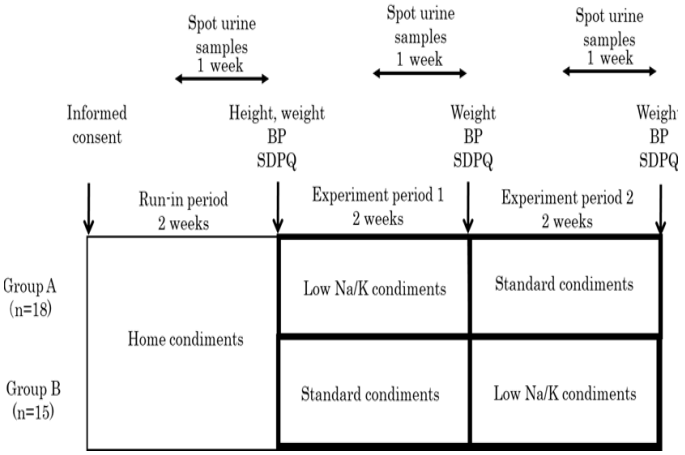

Figure 1. Design of the study.

SDPQ, short dietary propensity questionnaire; BP, blood pressure