Reduction in Blood Pressure with a Sodium-Reduced, Potassium- and Magnesium-Enriched Mineral Salt in Subjects with Mild Essential Hypertension

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A parallel controlled clinical trial was carried out to investigate the effect on blood pressure (BP) of replacing normal salt with mineral salt in seasonings. After a 2-wk run-in period, 21 subjects (10 men and 11 women; age, 66.0 ± 7.6 yr) were given mineral salt in seasonings instead of normal salt [mineral salt (MS) group], while 20 subjects (10 men and 10 women; age, 65.9 ± 7.4 yr) continued to receive normal salt in seasonings [regular salt (RS) group] for the next 5 wk in the experimental (E) period. In the MS group, systolic (S) and diastolic (D) BP decreased significantly from $134.7 \pm 17.2/77.2 \pm 9.7$ at baseline (week 0) to $127.3 \pm 12.0/73.5 \pm 8.9$ mmHg at the end of the E period (week 5), and the reductions in both SBP and DBP were larger in hypertensive subjects than in normotensive subjects in the MS group. The serum sodium and chloride concentrations decreased significantly, while the serum potassium and HDL-cholesterol concentrations increased significantly at week 5. The 24-h urinary sodium excretion decreased, and the 24-h potassium and magnesium excretions increased significantly from week 0 to week 5 in the MS group. In contrast, SBP, DBP, serum chemistry, and urinary electrolyte excretion did not change significantly in the RS group. These findings suggest that the excessive salt content and insufficient potassium and magnesium content of the present Japanese diet could be easily and safely corrected by replacing seasonings prepared with regular salt with those prepared with mineral salt. (*Hypertens Res* 1998; 21: 235-243)

Key Words: dietary sodium, potassium supplement, magnesium supplement, mineral salt, blood pressure, hypertension

Numerous studies have suggested that sodium may play an important role in the development and maintenance of hypertension (1-9) with a few exceptions (10, 11). Although a reduction in sodium intake may lower blood pressure (BP), recent studies indicate that the antihypertensive effects of a low-sodium diet may be enhanced by simultaneous potassium supplementation (12). Lowering the sodium intake or increasing the potassium intake, or both, have been shown to exert a beneficial effect on high BP (13-15). There is also evidence that an increased intake of magnesium may favorably affect BP (16-20). Such evidence has thus led to recommendations by the Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure (21) to restrict the intake of salt to less than 6 g per d, while additional recommendations of the committee include maintaining an adequate dietary intake of potassium, magnesium, and calcium (22).

These observations thus indicate that a modest reduction in sodium intake combined with an increased intake of potassium and magnesium might

have therapeutic effects in essential hypertensive subjects. In particular, elderly hypertensive subjects tend to be salt sensitive and more responsive to sodium restriction than younger subjects (23). However, many subjects with hypertension find it difficult to give up the taste of regular salt and consequently are unable to sufficiently reduce their intake to have an effect on BP, even though sodium restriction is widely recognized as the best non-pharmacological approach to the prevention and treatment of hypertension (21, 22). Compliance with a low-salt diet is particularly difficult for elderly Japanese subjects because their diet is high in salt and includes salt-containing products such as soy sauce and miso.

A new reduced-sodium-content mineral salt containing potassium and magnesium, which was originally produced by Karppanen (24, 25), may aid in the prevention and management of hypertension while also offering consumers a tasty alternative to regular salt. To explore the antihypertensive effects of mineral salt, we performed a trial of mild dietary sodium reduction with mild potassium and magne-

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Table 1. Clinical Characteristics of the Subjects at Entry

	Regular Salt Group	Mineral Salt Group
Number of subjects	20	21
Sex (males/females)	10/10	10/11
Age (yr)	65.8±7.6	65.9±7.4
Height (cm)	157.6±9.3	156.6±8.3
Weight (kg)	57.8±7.8	56.0±7.3
Body mass index (kg/m ²)	23.3±2.3	22.9±2.7
Systolic blood pressure (mmHg)	133.2±18.9	136.9±16.6
Diastolic blood pressure (mmHg)	77.2±12.2	76.6±9.4
Pulse rate (beats/min)	70.1±10.5	71.7±10.4

sium supplementation in normotensive and hypertensive Japanese middle-aged and elderly subjects. An additional study including healthy subjects was also conducted to examine the effects on taste of mineral salt and regular salt in seasonings.

Subjects and Methods

Subjects

More than 50 of approximately 200 clinically healthy middle-aged and elderly male and female volunteers with ordinary life styles in a certain community responded to a questionnaire that stated in detail the objectives and clinical relevance of the study. Individuals were excluded from the study if they planned to travel during the study period, frequently dined away from home, or had a high risk of noncompliance with the protocol. Finally, 41 subjects were enrolled; written informed consent was obtained from all subjects. These subjects were randomly assigned to receive either mineral salt (MS group) or regular salt (RS group). Both groups were similar with respect to age, sex, body size, and blood pressure during the run-in period. Four subjects in each group who were receiving anti-hypertensive drugs (β -blockers, calcium-channel blockers, or both) were requested not to change the dose or administration schedule during the study, including the run-in period. Although no special limitations were placed on daily activities, the subjects were instructed to refrain from taking day trips and from eating away from home. If they had to dine out, they were requested to take with them lunch boxes prepared using the mineral salt seasoning whenever possible. The protocol was approved by the Ethics Committee of the Japan Nutrition Society before starting the study.

Table 1 shows the baseline clinical characteristics of the subjects enrolled in the study. There was no significant difference in any variable between the two groups. Each group included both normotensive (NT: SBP < 140 mmHg and DBP < 90 mmHg) and hypertensive subjects (HT: SBP $\geq$ 140 mmHg, DBP $\geq$ 90 mmHg, or both). There were no significant differences in variables other than BP values between the NT and HT subjects in either the RS or MS group.

Methods

Protocol

The subjects were strictly instructed to avoid changing their ordinary diet during the 7-wk study period. After a 2-wk run-in period, the MS group consumed food containing mineral salt instead of the three seasonings of salt, soy sauce, and miso for the next 5 wk, designated as the experimental (E) period. Body weight and BP were measured, and the subjects were instructed again not to alter their life styles 2 wk after starting the E period. Good compliance was maintained throughout the study.

BP and pulse rate were measured three times consecutively with an automatic sphygmomanometer BP-203 (Nippon Colin Co., Ltd., Komaki, Japan) (26) every 2 min at about 8:00 AM on the first and the last days of the run-in period (week 0), and 2 wk (week 2) and 5 wk after starting the E period (week 5), after the subjects had urinated and sat down quietly for at least 10 min. The average of the three measurements was used for analysis.

After measuring BP, blood samples were collected in the early morning after the subjects had fasted for 12 h and rested for 30 min in the supine position on the last day of each period. The serum and plasma were separated by centrifugation and stored at -40°C until assay. Urine was collected for 24 h on the last day of each period. The urinary concentrations of sodium, potassium, magnesium, calcium, and creatinine (Cr) and urine volume were measured and the 24-h excretions were calculated. The completeness of the 24-h urine collection was evaluated on the basis of the creatinine value predicted using our maneuver as described elsewhere (27).

After the run-in period, the subjects in the RS group continued to eat their normal diet containing the same seasonings for the next 5 wk. The subjects were requested to continue their usual activities without modification, similar to the subjects in the MS group. Furthermore, we regularly contacted all subjects by telephone to ensure that their life styles were not changed. Blood samples and 24-h urine were collected twice, similar to the MS group.

Determination of electrolyte content of seasonings

The contents of sodium, potassium, and magnesium in 100 g of three different seasonings, (table salt, soy sauce, and miso) prepared with regular salt and

Table 2. Comparison of Electrolyte Contents of 100 g of Table Salt, Soy Sauce, and Miso Prepared with Regular Salt or Mineral Salt

Electrolytes		Sodium	Potassium	Magnesium
Table salt	Regular salt	39,000	130	21
	Mineral salt	22,900	10,110	1,240
	Ratio	0.59	77.8	59.1
Soy sauce	Regular salt	5,400	310	69
	Mineral salt	4,250	1,230	160
	Ratio	0.79	3.97	2.32
Miso	Regular salt	4,280	215	46
	Mineral salt	2,850	1,640	175
	Ratio	0.67	7.63	3.80

Unit: mg/100 g, Ratio: Ratio of electrolyte content of regular salt to that of mineral salt.

mineral salt were measured at our laboratory. Table 2 shows the electrolyte content of 100 g of regular salt and mineral salt and the electrolyte content of 100 g of soy sauce and miso prepared with regular salt and mineral salt. The sodium content of the mineral salt used during the E period was 59% that of the salt used during the run-in period, and the potassium and magnesium contents of the mineral salt were 78 times and 59 times higher than those of regular salt, respectively. Although the sodium content of the mineral salt soy sauce used during the E period was 79% that of the soy sauce used during the run-in period, the potassium and magnesium contents of the former were, respectively, 4 times and 2.3 times those of the latter. In addition, the sodium content of the mineral salt miso during the E period was 67% that of the miso used during the run-in period, whereas the potassium and magnesium contents of the former were 7.6 times and 3.8 times higher than those of the latter.

The blind sensory taste study

Twenty-four healthy subjects (10 men and 14 women) 20 to 75 yr of age who had normal life styles participated in the taste test. The test foods were presented randomly to avoid bias. The subjects were asked to consume both a miso soup and a clear soup made with soy sauce on different occasions and to evaluate the saltiness, palatability, and savoriness of each.

The control food was a clear soup containing Kikkoman soy sauce® and commercially sold salt, while the test food was a clear soup containing the same amounts of mineral salt soy sauce and mineral salt as control. Blind sensory tests were conducted using four different clear soups: regular salt [A] and mineral salt [B] with 0.8% salinity, and regular salt [C] and mineral salt [D] with 1.0% salinity. Sensory tests for the miso soups were conducted with a soup containing Marukome miso®, made with regular salt, and a soup containing the same amount of 'mineral salt miso'.

In both sensory taste tests, the total scores were obtained by the rank method and were tested with Kendall's coefficient of concordance. As concordance was confirmed, the mean scores were compared by the rank method. The lower score repre-

sented better saltiness, palatability, or savoriness.

In the blind sensory taste test with four kinds of clear soups, A (regular salt: 0.8%), B (mineral salt: 0.8%), C (regular salt: 1.0%), and D (mineral salt: 1.0%), total scores were obtained by the rank method and were tested with Kendall's coefficient of concordance. As concordance was confirmed, the mean scores were compared by the rank method. The best score was 1 point and the worst 4. The lower scores for salty taste, palatability, and savoriness thus represented better or the more preferred quality.

Salty taste was weakest for soup B and strongest for soup C. There was no difference between soup A and soup B or D. As for palatability and savoriness, clear soup A was best. There were no differences in palatability between soup A and D, and no difference in savoriness among the four soups (Table 3).

Blind sensory taste tests were conducted with miso soups prepared with equivalent amounts of miso (10%) containing either regular salt or mineral salt. As shown in Table 3, a significant difference was found only in salty taste; soup E was felt to be more salty than the other soups. There were no differences in palatability or savoriness between miso soups E and F.

There were no significant differences in saltiness, palatability, and savoriness of either the clear soups or miso soups between subjects younger than 60 yr of age and those 60 yr of age or older.

Laboratory and Statistical Methods

The concentrations of sodium and potassium in serum and urine were measured by flame photometry (Hitachi 775, Hitachi Co., Ltd., Hitachi, Japan), and the concentration of Cr in serum and urine was measured by the picric acid method (Olympus AU-5000, Olympus Optical Co., Ltd., Tokyo, Japan). Serum chemistry was analyzed with autoanalyzers (Olympus AU-5000 and AUA-8000, Olympus Optical Co., Ltd., Tokyo, Japan). Serum and urinary magnesium and calcium concentrations were measured by atomic absorption spectrophotometry (Shimadzu AA660, Shimadzu Co., Ltd., Tokyo, Japan). LDL-cholesterol was calculated by the formula of

Table 3. Mean Scores by the Rank Method in a Blind Sensory Test to Evaluate Salty Taste, Palatability, and Savoriness

	Salty taste	Palatability	Savoriness
A. Clear soup with regular salt (0.8%) ^{a)}	2.44±0.83	2.00±1.00	2.36±1.05
B. Clear soup with mineral salt (0.8%) ^{b)}	1.83±1.24	2.87±1.10**	2.59±1.18
C. Clear soup with regular salt (1.0%) ^{a)}	3.15±1.14*	2.70±1.15*	2.64±1.14
D. Clear soup with mineral salt (1.0%) ^{b)}	2.58±0.88	2.43±1.16	2.41±1.14
E. Miso soup with regular salt ^{c)}	1.92±0.27	1.48±0.51	1.38±0.50
F. Miso soup with mineral salt ^{d)}	1.08±0.27 ^{††}	1.52±0.51	1.62±0.50

* $p<0.01$, ** $p<0.01$ (vs. A); ^{††} $p<0.01$ (vs. E).

^{a)}: 0.8% or 1.0% salinity prepared with Kikkoman soy sauce and commercially available salt, ^{b)}: 0.8% or 1.0% salinity prepared with mineral salt soy sauce and mineral salt, ^{c)}: Miso soup prepared with Marukome miso using commercially available salt, ^{d)}: Miso soup prepared with the same amount of miso containing mineral salt.

Fig. 1. Changes in systolic and diastolic blood pressure (BP) and pulse rate from baseline (week 0:) to after receiving regular salt (n=20) and mineral salt (n=21) in seasonings and certain processed foods for 5 wk (week 5:) . Values are means±SD, ** $p<0.01$, *** $p<0.001$ (vs. week 0)

Friedewald *et al.* (28). The plasma renin activity (PRA), plasma aldosterone concentration (PAC), and urinary aldosterone excretion (AER) were determined by a radioimmunoassay. The tests were conducted simultaneously for each subject's serum and urine samples.

All results are expressed as means±standard deviations (SD). Any differences between the run-in and E period were evaluated by Student's paired *t*-test for variables showing an approximately normal distribution. Nonparametric analyses using the Mann Whitney *U*-test were performed for data not normally distributed. A value of $p<0.05$ was considered to indicate statistical significance.

Results

Changes in the SBP, DBP, and pulse rate from

baseline (week 0) to after receiving the mineral salt in seasonings and selected processed foods for 5 wk (week 5) are shown in Fig. 1. In the MS group, both SBP and DBP decreased significantly from 134.7±17.2 mmHg at week 0 to 125.8±15.9 at week 2 and 127.3±12.0 at week 5 and from 77.2±9.7 mmHg to 72.9±9.6 and 73.5±8.9, respectively. Pulse rate also decreased significantly from 71.0±10.8 beats/min at week 0 to 70.5±9.7 at week 2 and 67.5±11.1 at week 5 in the MS group. In contrast, there were no significant changes in SBP, DBP, or pulse rate in the RS group (Fig. 1). The reductions in both SBP and DBP were larger in the 10 HT subjects (from 149.1±10.9 mmHg to 136.8±9.6 and 133.7±8.3 for SBP and from 85.6±5.9 mmHg to 80.9±5.2 and 79.3±6.8 for DBP) than in the 11 NT subjects (from 121.7±6.0 mmHg to 115.7±13.8 and 121.5±12.2 for SBP and from

69.5 ± 4.3 mmHg to 65.6 ± 6.0 and 68.3 ± 7.3 for DBP) in the MS group (Fig. 2).

Body weight did not change at all in either the MS (56.0 ± 7.3 kg at week 0 vs. 56.0 ± 7.3 kg at

week 5) or RS group (57.8 ± 7.9 kg vs. 57.9 ± 8.2 kg) during the E period.

The 24-h urinary electrolyte excretion on the last day of each period are shown according to NT and HT subjects in each group in Table 4. The 24-h urinary sodium excretion in both NT and HT subjects in the MS group slightly but insignificantly decreased from week 0 to week 5. When NT and HT subjects were combined, the reduction in the 24-h urinary sodium excretion was statistically significant between week 0 and week 5. The 24-h urinary potassium and magnesium excretion increased significantly from 51.5 mEq and 9.9 mg at week 0 to 69.0 mEq and 11.6 mg at week 5 in the MS group. A significant increase in urinary potassium excretion was observed in both NT and HT subjects, while urinary magnesium excretion increased significantly only in HT subjects. The 24-h urinary calcium and Cr excretion did not change. Urinary electrolyte excretion changed slightly but not significantly in both NT and HT subjects in the RS group.

Serum electrolytes and lipids were measured at week 0 and week 5 (Table 5). The serum sodium and chloride concentrations decreased and the serum potassium and HDL-cholesterol concentrations increased significantly after 5 wk of mineral salt consumption. When the data were analyzed according to NT and HT subjects in each group, however, there was no significant change in serum sodium or chloride concentration in NT subjects or in serum HDL-cholesterol concentration in either HT or NT subjects. LDL-cholesterol concentration and atherosclerosis index (total cholesterol/HDL-cholesterol) did not change after mineral salt inges-

Fig. 2. Changes in systolic (SBP) and diastolic blood pressure (DBP) from baseline (week 0:) to after receiving mineral salt in seasonings and certain processed foods for 2 wk (week 2:) and 5 wk (week 5:) in normotensive and hypertensive subjects. Values are means ± SD, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (vs. week 0).

Table 4. Urinary Excretion of Sodium, Potassium, Magnesium, Calcium, and Creatinine in Normotensive and Hypertensive Subjects at Baseline (Week 0) and After Receiving Either Regular Salt or Mineral Salt in Seasonings for 5 Weeks (Week 5)

Regular Salt Group						
	All Subjects (n=20, 10M/10F)		Normotensives (n=12, 7M/5F)		Hypertensives (n=8, 3M/5F)	
	Week 0	Week 5	Week 0	Week 5	Week 0	Week 5
Urine Na (mEq/d)	171 ± 47	182 ± 50	174 ± 57	177 ± 44	174 ± 50	185 ± 50
Urine K (mEq/d)	56.9 ± 17.3	61.5 ± 18.2	53.8 ± 15.5	60.2 ± 18.3	55.0 ± 21.4	62.7 ± 21.2
Urine Mg (mg/d)	11.6 ± 6.1	11.6 ± 6.8	11.4 ± 6.6	11.7 ± 5.9	11.9 ± 5.8	11.4 ± 8.4
Urine Ca (mg/d)	10.1 ± 4.0	10.4 ± 4.4	9.4 ± 3.3	10.0 ± 4.1	10.9 ± 4.9	10.9 ± 5.2
Urine volume (ml/d)	1,560 ± 673	1,600 ± 570	1,477 ± 543	1,510 ± 385	1,696 ± 855	1,738 ± 784
Urine Cr (mg/d)	965 ± 252	966 ± 257	1,023 ± 289	1,023 ± 297	878 ± 161	881 ± 161
Mineral Salt Group						
	All Subjects (n=21, 10M/11F)		Normotensives (n=11, 6M/5F)		Hypertensives (n=10, 4M/6F)	
	Week 0	Week 5	Week 0	Week 5	Week 0	Week 5
Urine Na (mEq/d)	192 ± 61	173 ± 56*	174 ± 63	158 ± 61	211 ± 55	189 ± 49
Urine K (mEq/d)	51.5 ± 12.6	69.0 ± 19.1***	51.7 ± 14.3	63.9 ± 23.2*	52.3 ± 10.7	72.4 ± 10.1***
Urine Mg (mg/d)	9.9 ± 2.8	11.6 ± 4.4**	9.5 ± 2.7	11.2 ± 5.1	10.3 ± 3.1	12.0 ± 3.8*
Urine Ca (mg/d)	9.2 ± 4.1	9.2 ± 3.7	11.2 ± 5.1	13.4 ± 6.1	8.7 ± 5.3	7.5 ± 4.0
Urine volume (ml/d)	1,600 ± 453	1,550 ± 453	1,515 ± 389	1,528 ± 506	1,704 ± 527	1,586 ± 407
Urine Cr (mg/d)	908 ± 226	949 ± 248	891 ± 242	946 ± 232	927 ± 217	945 ± 274

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (vs. Week 0)

Table 5. Serum Chemistry in Normotensive and Hypertensive Subjects at Baseline (Week 0) and After Receiving Either Regular Salt or Mineral Salt in Seasonings for 5 Weeks (Week 5)

Regular Salt Group

	All Subjects (<i>n</i> =20, 10M/10F)		Normotensives (<i>n</i> =12, 7M/5F)		Hypertensives (<i>n</i> =8, 3M/5F)	
	Week 0	Week 5	Week 0	Week 5	Week 0	Week 5
Sodium (mEq/l)	141.2±1.4	141.0±1.3	140.8±1.4	140.7±1.6	141.8±1.2	141.4±0.5
Potassium (mEq/l)	4.44±0.37	4.46±0.34	4.4±0.4	4.5±0.3	4.4±0.4	4.4±0.4
Chloride (mEq/l)	101.8±2.4	102.5±2.3	102.2±2.6	103.2±1.9	101.3±2.3	101.5±2.5
Magnesium (mg/dl)	2.34±0.15	2.33±0.16	2.3±0.1	2.4±0.2	2.3±0.2	2.3±0.1
Total cholesterol (mg/dl)	227.5±40.2	227.6±29.3	212.1±17.2	221.4±24.2	250.6±53.8	236.8±35.2
HDL-cholest. (mg/dl)	54.7±14.6	54.4±13.9	51.2±12.4	50.3±12.3	60.0±16.6	60.5±14.7
Triglyceride (mg/dl)	130.9±75.4	137.0±90.1	135.4±93.1	144.0±105.3	116.4±47.4	137.4±63.7

Mineral Salt Group

	All Subjects (<i>n</i> =21, 10M/11F)		Normotensives (<i>n</i> =11, 6M/5F)		Hypertensives (<i>n</i> =10, 4M/6F)	
	Week 0	Week 5	Week 0	Week 5	Week 0	Week 5
Sodium (mEq/l)	140.9±1.4	139.6±1.8**	140.8±1.4	140.1±1.5	140.9±1.5	139.1±2.0**
Potassium (mEq/l)	4.33±0.39	4.71±0.34***	4.28±0.48	4.64±0.38*	4.39±0.25	4.80±0.27***
Chloride (mEq/l)	103.4±2.1	102.5±2.3**	103.8±1.8	103.3±2.2	102.9±2.4	101.7±2.2*
Magnesium (mg/dl)	2.30±0.13	2.31±0.13	2.31±0.09	2.31±0.13	2.29±0.18	2.31±0.13
Total cholesterol (mg/dl)	208.9±29.8	211.0±29.8	208.6±29.0	207.8±29.9	209.2±32.3	214.4±31.0
HDL-cholest. (mg/dl)	63.7±18.4	65.6±17.9**	65.9±17.3	68.4±16.9	61.2±20.2	63.1±19.4
Triglyceride (mg/dl)	107.3±55.1	93.3±41.4	95.2±47.3	92.6±50.3	120.6±62.2	100.4±41.7

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (vs. Week 0)

tion in either NT or HT subjects in the MS group.

Changes in PRA and AER were compared between week 0 and week 5. In the MS group, PRA did not change significantly (from 0.43 ± 0.32 to 0.60 ± 0.51 ng/ml/h), whereas both PAC and AER increased significantly during the E period from 7.6 ± 2.9 to 10.4 ± 5.4 ng/dl ($p < 0.01$) and from 12.2 ± 5.6 to 15.8 ± 10.0 μ g/d ($p < 0.05$), respectively. However, no significant changes in these variables were found in the RS group.

Discussion

The Japanese diet is high in salt and salt-containing seasonings such as soy sauce and miso. A survey on National Nutrition in Japan (1995) revealed that the average daily intake of salt (NaCl) was 13.2 g. The use of seasonings prepared with the mineral salt, a novel potassium-, magnesium-, and *l*-lysine-enriched salt alternative, can reduce salt intake by 21% (29). The additional use of certain processed foods made with mineral salt is thus expected to further reduce salt intake.

In some previous investigations, a modest reduction in sodium intake combined with increased intake of potassium, magnesium, or both was reported to have an antihypertensive effect in patients with essential hypertension (18, 24) or hypertensive Type II diabetes mellitus (30). We therefore studied the effects of using either regular salt or mineral salt in seasonings and certain processed foods in middle-aged and elderly subjects with normotension and mild hypertension over a 5-wk period. We found

that both SBP and DBP fell significantly in the MS group as compared with baseline in the HT subjects. The 24-h urinary sodium excretion decreased and potassium and magnesium excretion increased significantly, accompanied by increases in plasma and urinary aldosterone concentrations but no change in plasma renin activity in the HT subjects. These findings suggest that a reduced sodium intake combined with an increased intake of potassium and magnesium, as evidenced by the changes in serum and urine variables, helps to lower blood pressure in Japanese patients with essential hypertension. Although a high sodium intake is thought to contribute to hypertension, elevated blood pressure does not develop in all individuals exposed to a high-salt diet. Approximately one third to 40% of hypertensive patients are estimated to be salt-sensitive (2, 3, 31). Most investigators agree that sodium intake can be decreased without harm and that this will help lower blood pressure. There is also increasing evidence that a low intake of potassium (9) and magnesium (32) may contribute to BP elevation.

The mechanism responsible for the reduction in blood pressure in our study is poorly understood. Modest sodium restriction alone has been shown to lower blood pressure in hypertensive subjects in several previous studies (33–37). In the present study, urinary sodium excretion decreased significantly after 5 wk of receiving mineral salt in the MS group. Other previous studies (12–18), including ours (19, 20), have consistently demonstrated an antihypertensive effect of dietary potassium and magnesium supplementation in patients with essen-

tial hypertension. Moreover, epidemiologic evidence also supports an inverse relation between potassium intake and BP. In a meta-analysis of 33 clinical trials involving 1,560 hypertensive and 1,005 normotensive subjects, oral potassium supplementation was shown to significantly lower both SBP and DBP (12).

In a previous study, we found a significant negative correlation between the percent change in urinary norepinephrine (NE) excretion from week 0 to week 2 or week 4 and the corresponding changes in urinary magnesium excretion. There was also a positive correlation between the percent change in urinary NE excretion from week 0 to week 4 and that in DBP (19, 20). These results suggest that oral magnesium supplementation might lower BP by decreasing adrenergic activity, which may be involved in the urinary excretion of NE. These findings also suggest that a natriuretic phenomenon may occur through the activation of prostaglandin- I_2 (PGI $_2$) after magnesium supplementation (38), although PGI $_2$ was not measured in the present study. The vasodilatory activity of magnesium is related to impairment of calcium permeability of the cellular membrane, calcium binding, and translocation in vascular smooth muscle cells (39). Urinary magnesium excretion increased only in HT subjects during the MS period, but there was no change in free Mg $^{++}$, which is considered to lower BP through its vasodilatory activity. In agreement with the findings of previous studies, the urinary potassium and magnesium excretions increased significantly at week 5 in HT subjects in the MS group in the present study, indicating that mild dietary potassium and magnesium supplementation combined with mild sodium reduction may contribute to decreases in both SBP and DBP in patients with essential hypertension.

A significant increase in the serum HDL-cholesterol concentration was observed at week 5 in the MS group. Only a few studies have evaluated the effects of oral potassium or magnesium supplementation on serum lipid metabolism in humans (19, 20, 40). In our previous study, serum total cholesterol and triglyceride concentrations decreased significantly after 10 d of potassium supplementation (19). These favorable effects may be due to a rise in lipoprotein-lipase activity *via* increased insulin secretion due to potassium supplementation (40). We also found a significant decrease in the serum LDL-cholesterol concentration and a significant increase in apo-AI during magnesium supplementation (20). Several studies have reported the effects of magnesium supplementation on serum lipid composition in humans (30, 41, 42). None of them, however, described the mechanism underlying the effects of magnesium supplementation on hyperlipidemia. We found that serum lecithin-cholesterol acyltransferase (LCAT) activity was increased significantly by magnesium supplementation (20), and to our knowledge no other reports have described a relation between the magnesium level and LCAT activity in humans. We previously reported that the percent change in HDL-cholesterol concentration and that in LCAT showed a significant positive correlation

on multiple regression analysis (20), suggesting that the increase in LCAT activity due to mild magnesium supplementation may have contributed to improved lipid metabolism in the MS group.

The sodium/potassium ratio is believed to be more important than the absolute amount of ingested salt. A high sodium and low potassium intake may contribute to BP elevation. Meta-analyses and clinical studies have shown that potassium and magnesium supplementation lowers BP and improves lipid metabolism (12, 20). In our precise balance study (28), we demonstrated that replacing ordinary seasonings with seasonings prepared with mineral salt containing a reduced level of sodium and high levels of potassium and magnesium mildly decreased the 24-h urinary sodium excretion (−21%) and substantially increased the 24-h urinary potassium (+55%) and magnesium excretion (+22%). The effects of this combination were larger than expected on the basis of previous estimates, and simultaneous modification of sodium, potassium, and magnesium intake may have a greater impact on BP than a change in one mineral alone for the nonpharmacological treatment of mild hypertension.

The blind sensory taste tests showed that the mineral salt used in these studies is as tasty, palatable, and savory as the seasonings used in Japan. It is commonly accepted that once salt intake has been reduced for a month or more, highly salted foods become distasteful. If salt alternatives are used not only instead of table salt, 'soy sauce' or 'miso', which are traditional Japanese seasonings, but also in processed foods, such as bread, which is one of the largest single sources of salt in the diet, then sodium intake may decrease by another 20% without a noticeable change in taste. In addition, everyone can also receive a sufficient intake of potassium and magnesium without any special effort. These new seasonings can easily be incorporated into the diet to aid in the management of hypertension and other cardiovascular-related conditions, such as ischemic heart disease and diabetes mellitus.

In conclusion, the Japanese diet, characterized by a high salt intake and an insufficient intake of potassium and magnesium, can thus be easily and safely modified by replacing currently used seasonings prepared with regular salt with those prepared with mineral salt. A reduction in sodium intake coupled with increased intake of potassium and magnesium is likely to contribute to the management of hypertension. A high salt intake may also have a role in bone demineralization (osteoporosis) (43), since there is evidence that the short-term increases in sodium intake can promote urinary calcium excretion and bone turnover. Therefore, the long-term benefits of a reduction in salt intake combined with increased intake of potassium and magnesium may be more important than previously predicted.

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