ORIGINAL ARTICLE

Estimated urinary salt excretion by a self-monitoring device is applicable to education of salt restriction

Kenichiro Yasutake¹, Noriko Horita², Yusuke Murata³, Susumu Koyama³, Munechika Enjoji³
and Takuya Tsuchihashi⁴

The objective was to investigate the validity of a self-monitoring device that estimates 24-h urinary salt excretion from overnight urine samples as a tool for education regarding salt restriction. Twenty healthy volunteers consumed test meals for 14 days, with salt content as follows: 10 g (days 1–5); 5 g (days 6–8, 12 and 14); and 13 g (days 9–11 and 13). On days 2–15, urinary salt excretion was estimated from overnight urine samples by a self-monitoring device. Twenty-four-hour urine samples were collected on days 5 and 8 to measure salt excretion directly. Blood pressure was measured in the morning and during sleep on days 1–15. Estimated urinary salt excretion measured by the device showed a correlation with salt intake, and the ratio of estimated urinary salt excretion to salt intake was 0.84 ± 0.10 (days 2–6), 1.27 ± 0.28 (days 7–9), 0.70 ± 0.11 (days 10–12), 1.37 ± 0.22 (day 13), 0.68 ± 0.13 (day 14) and 1.33 ± 0.19 (day 15). The correlation between estimated urinary salt excretion measured by a device and directly measured 24-h urinary salt excretion was significant ($r = 0.65$, $P < 0.05$) during the period of 10 g salt intake, but not during 5 g salt intake. Blood pressure in the morning was not influenced by the change in salt intake, but systolic pressure during sleep showed a significant increase or decrease according to the levels of salt intake. In conclusion, a self-monitoring device, which can estimate 24-h urinary salt excretion from overnight urine samples, is considered to be a practical tool for education regarding salt restriction, although a similar future investigation is needed in older and/or hypertensive subjects.

Hypertension Research (2015) 38, 143–148; doi:10.1038/hr.2014.155; published online 23 October 2014

Keywords: blood pressure; salt intake; salt restriction; self-monitoring device

INTRODUCTION

Excess dietary salt intake is one of the main causes of hypertension onset and progression.^{1–6} Therefore, salt consumption restriction is the most important lifestyle modification for controlling the incidence of hypertension in many countries. However, daily eating habits make it difficult to continue salt restriction for an extended period.⁷ Prolonged restriction is difficult because salt included in foods and meals is not visible, and therefore salt consumption is not easily discernable. Practically, actual salt intake is often inconsistent with predicted intake.⁸

In many studies on salt restriction, daily salt consumption is usually assessed by inquiry and nutrition surveys. However, the accuracy of these methods relies on the honesty and memory of the subjects, as well as the skill of the investigators.⁹ In some medical institutes, salt intake is evaluated by measuring excreted salt in collected 24-h urine samples,^{6,10,11} but repeated evaluation is difficult using this method because of the burden on subjects. Another way to assess salt intake is by using spot urine or the second-morning urine, which is easier for

subjects.^{12–15} However, measuring creatinine and sodium is difficult to do on one's own. The Working Group for Dietary Salt Reduction of the Japanese Society of Hypertension recommends the use of a self-monitoring device for estimating 24-h urinary salt excretion from overnight urine samples, because subjects can simply use the device at home and can promptly obtain the estimated levels of daily salt intake.^{16,17} We have reported the possibility that using a self-monitoring device leads to the reduction of urinary salt excretion and seems to be an effective tool for the motivation of dietary salt restriction.¹⁸

Recently, we investigated the validity of a self-monitoring device by examining the relationship between salt intake and overnight urinary salt excretion.¹⁹ Consequently, estimated 24-h urinary salt excretions from overnight urine samples were roughly governed by salt intake during the previous day and followed the change in salt intake. However, whether estimated urinary salt excretion by a self-monitoring device is consistent with directly measured values from collected 24-h urine samples has not been examined. To address this

¹Department of Nutritional Sciences, Faculty of Nutritional Sciences, Nakamura Gakuen University, Fukuoka, Japan; ²Department of Health and Nutrition Sciences, Faculty of Health and Nutrition Sciences, Nishikyushu University, Saga, Japan; ³Health Care Center, Fukuoka University, Fukuoka, Japan and ⁴Hypertension Center, Steel Memorial Yawata Hospital, Kitakyushu, Japan

Correspondence: Dr K Yasutake, Department of Nutritional Sciences, Faculty of Nutritional Sciences, Nakamura Gakuen University, 5-7-1 Befu, Jonan-ku, Fukuoka 814-0198, Japan.

E-mail: yasutake@nakamura-u.ac.jp

Received 14 May 2014; revised 31 July 2014; accepted 3 September 2014; published online 23 October 2014

question, we first assessed the consistency between estimated values from overnight urine using a self-monitoring device and actual values from collected 24-h urine in healthy volunteers, and then reviewed the practicality of a self-monitoring device as an education tool for dietary salt restriction. Moreover, we computed the correlation between salt intake and blood pressure in the subjects.

METHODS

Subjects

Twenty healthy volunteers in their twenties were prospectively enrolled in the Faculty of Health and Social Welfare Sciences, Nishikyushu University (Table 1). This study was conducted over 15 consecutive days between the first week of October and the fourth week of November 2013. In the case of female volunteers, non-menstrual days were selected. The exclusion criteria included subjects with physical, psychological and social difficulties; those undergoing medical treatment; or those with chronic diseases such as chronic kidney disease. The study protocol was confirmed by the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Ethics Committee of

Nishikyushu University. The subjects were given oral and written explanations of the purpose and outline of this study, and written informed consent was obtained according to their discretion.

Intervention schedule

The intervention schedule of this study is shown in Figure 1. All subjects consumed test meals containing varying amounts of salt (sodium chloride; NaCl) but consistent energy/nutritional content from days 1–14. Twenty-four-hour urinary salt excretion was estimated from 8-h overnight urine samples on days 2–15 using a self-monitoring device. On days 5 and 8, 24-h urine samples were collected, and the actual values of 24-h urinary salt excretion were measured simultaneously. Blood pressure was measured upon rising and during sleep from days 1 to 15. During the study period, subjects were only allowed to consume test meals, tap water and barley tea. In addition, traveling and physical exercise were prohibited.

Test meals

The salt content of the test meals was adjusted to 10 g (days 1–5), 5 g (days 6–8, 12 and 14) and 13 g (days 9–11 and 13). Mealtimes for breakfast, lunch and supper were limited within 0600–0900, 1100–1400 and 1800–2200 hours, respectively. According to the mean intake levels of the Japanese population, the potassium content of the test meals was adjusted to ~2200 mg.²⁰ The test meals were prepared using foodstuffs from the same manufacturers and place of origin. It was explained to the subjects that leftovers, including their weights, had to be recorded. The levels of sodium and potassium in the test meals were verified using the atomic absorption method (Saga Environmental Science Inspection Association, Saga, Japan). The salt content (g) was calculated using the following formula: sodium (mg) $\times$ 2.54/1000. Other nutrient values of the test meals were calculated according to the Standard Food Composition Table of Japan (Table 2).

Self-monitoring device

A self-monitoring device (KME-03, Kohno ME laboratory, Kanagawa, Japan) was used in this study. The device is capable of estimating 24-h salt excretion from collected 8-h overnight urine samples. Therefore, subjects were asked to urinate 8 h before a prearranged time of waking up. Urination during the sleeping period was collected in a dedicated cup. The measurement principle is as follows: the volume sensor consists of 50 small resistant chips, and the conductivity sensor consists of two gold-plated nickel metal plates. These sensors measure urine volume, urinary concentration of chloride and temperature. These values are then integrated, and NaCl concentration is estimated by the original algorithm. The NaCl concentration was adjusted by a correlation formula so that it was between the value obtained with the ion electrode method and the value for the conductivity method, because measurement of concentration by conductivity is affected by other electrolytes such as potassium. The self-monitoring device estimated 24-h salt excretion from overnight urine samples using the following formula: $Y = 5.76X + 0.53$ g per day, where Y is the estimated 24-h urinary salt excretion and X is the sodium content of the overnight urine samples.¹⁶

Table 1 Characteristics of participants

Number	20
Sex (male/female)	9/11
Age (years)	22.3 $\pm$ 1.0
Height (cm)	163.9 $\pm$ 6.7
Weight (kg)	60.4 $\pm$ 10.4
Body mass index (kg m ⁻²)	22.5 $\pm$ 3.4

Values are the means $\pm$ s.d.

Intake of the test meals	↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑
Overnight urine collection and measurement of salt excretion	↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑
Twenty-four-hour urine collection	↑ ↑
Blood pressure measurement (morning/night-time)	↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑ ↑

Figure 1 Schema of the intervention schedule.

Table 2 Nutrient content of the test meals

Day	Calculated values				Analytical values		
	Energy (kcal)	Protein (g)	Fat (g)	Carbohydrate (g)	Potassium (mg)	Sodium (mg)	Salt (g)
1–5	1765	69.2	36.9	274.8	1920	3917	9.9
6–8	1717	62.1	34.4	274.9	1988	2365	5.2
9–11	1767	63.4	39.5	275.0	2237	4777	13.0
12	1717	62.1	34.4	274.9	1988	2365	5.2
13	1767	63.4	39.5	275.0	2237	4777	13.0
14	1717	62.1	34.4	274.9	1988	2365	5.2

Twenty-four-hour urine collection

Twenty-four-hour urine was collected on day 5, the last day of 10 g salt intake, and day 8, the third day of 5 g salt intake. Samples were prepared as 1/50 volume of total urine (24-h) by the proportional sampling method.²¹ Twenty-four-hour urine collection was considered to be successful when the difference between the predicted and actual values of 24-h urinary creatinine excretion was within 30%;^{10,11} unsuccessful samples were excluded from the analysis. Urinary creatinine, sodium and potassium values were determined by SRL Corporation (Fukuoka, Japan).

Blood pressure

Blood pressure was measured from the upper arm using an oscillometric device (HEM-7080IT, Omron, Kyoto, Japan) from days 1 to 15. Participants were asked to sit quietly for a few minutes before measuring. Blood pressure at rising was measured twice every morning after urination. During sleep, participants wore a cuff that automatically measured blood pressure three times each at 0200, 0300 and 0400 hours by setting a time switch. The mean pressure of each time was used for analysis.

Statistical analysis

Data analysis was performed using JMP version 10.0 software (SAS Institute, Cary, NC, USA). All data are presented as the mean $\pm$ s.d. The differences between two groups were analyzed using a paired *t*-test. Sensitivity and specificity of the self-monitoring device for estimating 24-h urinary salt excretion from overnight urine samples were assessed by logistic regression analysis and a receiver-operating characteristic curve. Correlations were

evaluated using a Pearson product-moment correlation coefficient. Values of $P < 0.05$ were considered to be statistically significant.

RESULTS

Each participant adhered to the experimental schedule and consumed the total amount of test meals during the study. The salt contents of the test meals per day were 9.9 g (days 1–5), 5.2 g (days 6–8, 12 and 14) and 13.0 g (days 9–11 and 13). The potassium content was within 1920–2237 mg (Table 2). The association between salt intake and estimated 24-h urinary salt excretion from overnight urine samples was analyzed (Figure 2), and the results suggest that the estimated urinary salt excretion measured by a self-monitoring device followed the salt intake of the previous day. The estimated 24-h urinary salt excretion was 8.29 ± 0.98 g (days 2–6), 6.63 ± 1.44 g (days 7–9), 9.16 ± 1.39 g (days 10–12), 7.11 ± 1.13 g (day 13), 8.81 ± 1.63 g (day 14) and 6.93 ± 0.98 g (day 15). The ratio of the urinary salt excretion to the salt intake of the previous day (U/S ratio) was 0.84 ± 0.10 (days 2–6), 1.27 ± 0.28 (days 7–9), 0.70 ± 0.11 (days 10–12), 1.37 ± 0.22 (day 13), 0.68 ± 0.13 (day 14) and 1.33 ± 0.19 (day 15).

On days 5 (the last day of 10 g salt intake) and 8 (the third day of 5 g salt intake), urinary salt excretion directly measured from 24-h urine samples was 8.6 ± 1.2 g (successful urine collection; $n = 10$) and 4.4 ± 1.3 g (successful urine collection; $n = 12$), respectively. During the period of 10 g salt intake, a significant positive correlation was found ($r = 0.65$, $P < 0.05$) between 24-h urinary salt excretion estimated from overnight urine samples (mean value of days 2–6) and that measured from 24-h urine samples (day 5) (Figure 3a). However, during the period of 5 g salt intake ($r = 0.41$), estimates from overnight urine samples (mean value of days 7–9) were not correlated with measured 24-h urine samples (day 8) (Figure 3b).

Using the data from the patients from whom 24-h urine was successfully collected on days 5 and 8, we assessed whether the self-monitoring device was capable of measuring salt intake that is < 6 g per day, which is recommended in the guidelines from the Japanese Society of Hypertension. In logistic regression analysis, a significant correlation was shown between the objective variable (urinary salt excretion directly measured from 24-h urine samples: $\geq$ or < 6 g) and the explanatory variable (urinary salt excretion estimated by a self-monitoring device: mean values of days 2–6 and days 7–9) ($P < 0.05$, odds ratio 0.46). From the analysis with the receiver-operating characteristic curve, selected cutoff points of 24-h urinary salt excretion estimated by the self-monitoring method for predicting

Figure 2 Association between salt intake and estimated salt excretion from overnight urine samples.

Figure 3 Correlation between estimated salt excretion from overnight urine samples and measured salt excretion from 24-h urine samples on days 5 (a) and 8 (b). NS, not significant.

urinary salt excretion ≥ 6 g per day in 24-h urine samples were 6.3 g (sensitivity 1.00, specificity 0.45) and 7.3 g (sensitivity 0.82, specificity 0.45) (Figure 4). The area under the curve was 0.74.

Mean blood pressure in the morning was almost constant regardless of salt intake levels: $109.3 \pm 10.6/67.4 \pm 8.3$ mm Hg (days 2–6); $108.5 \pm 11.1/68.0 \pm 8.9$ mm Hg (days 7–9); and $108.9 \pm 10.7/66.2 \pm 10.4$ mm Hg (days 10–12). Mean systolic blood pressure during sleep changed according to salt intake levels, although the differences were not statistically significant: $103.1 \pm 12.5/58.9 \pm 7.8$ mm Hg (days 2–6); $99.2 \pm 10.6/57.1 \pm 8.4$ mm Hg (days 7–9); and $101.3 \pm 9.3/57.7 \pm 7.3$ mm Hg (days 10–12).

Figure 4 Receiver-operating curve: sensitivity and specificity of 24-h salt excretion from overnight urine samples successfully collected on days 5 and 8.

Next, the association between salt intake and blood pressure was analyzed using the method described by Obarzanek *et al.*⁴ (Table 3). Mean blood pressure in the morning was almost constant in both systolic and diastolic phases, regardless of salt-intake levels (10, 5 and 13 g). In contrast, larger changes were shown in systolic blood pressure during sleep. In response to decreased salt intake (10 to 5 g), mean systolic pressure significantly decreased by 4.5 ± 7.5 mm Hg. In response to increased salt intake (5–13 g), mean systolic pressure significantly increased by 2.4 ± 6.4 mm Hg. A similar trend was shown in diastolic pressure, although the differences were not statistically significant.

DISCUSSION

In this study evaluating the success of a self-monitoring device in estimating urinary salt excretion and in promoting salt restriction, we measured the consistency between estimated 24-h urinary salt excretion and both salt intake and actual 24-h excretion. Moreover, we measured the correlation between blood pressure and salt intake. First, estimated urinary salt excretion from overnight urine samples showed a trend of correlating with salt intake of the previous day. The findings on the last 3 days are especially important. Specifically, when the salt content of the test meals was altered day by day (5 g on day 12, 13 g on day 13 and 5 g on day 14), estimated 24-h urinary salt excretion was synchronized with the increase or decrease in salt intake (Figure 2). These relationships are consistent with the results from our previous study,¹⁹ which verifies the coherence of the data from a self-monitoring device.

The mean U/S ratio was 0.84 during the period of 10 g salt intake. Holbrook *et al.*²² reported that nearly 90% of salt intake was excreted into urine, meaning that our result within the period of 10 g salt intake is reasonable and reliable. Conversely, the mean U/S ratios during the periods of 5 g and 13 g salt intake were overestimated (1.27) and underestimated (0.70), respectively. These results are consistent with another observation that the correlation between estimated urinary salt excretion from overnight urine samples and directly measured

Table 3 Association between the movement of blood pressure and changes in salt intake

Quintiles	Morning SBP (mm Hg)		Night-time SBP (mm Hg)	
	10 g → 5 g	5 g → 13 g	10 g → 5 g	5 g → 13 g
Maximum (largest increase)	5.6	9.8	9.1	17.4
75th	3.0	2.8	1.5	7.3
50th	1.2	0.5	−4.0	2.0
25th	−3.8	−3.0	−8.9	−1.1
Minimum (largest decrease)	−12.2	−7.3	−21.1	−9.5
Mean ± s.d.	−0.8 ± 5.2	0.5 ± 4.4	−4.5 ± 7.5*	2.4 ± 6.4*

Quintiles	Morning DBP (mm Hg)		Night-time DBP (mm Hg)	
	10 g → 5 g	5 g → 13 g	10 g → 5 g	5 g → 13 g
Maximum (largest increase)	6.7	5.3	7.5	12.1
75th	3.1	−0.4	1.1	4.9
50th	1.3	−2.1	−3.0	1.2
25th	−2.0	−3.8	−5.6	−2.1
Minimum (largest decrease)	−10.5	−11.0	−9.6	−13.9
Mean ± s.d.	−0.6 ± 4.1	−1.9 ± 3.7	−2.2 ± 4.7	0.7 ± 6.6

Abbreviations: DBP, diastolic blood pressure; SBP, systolic blood pressure. Values are the means ± s.d. * $P < 0.05$.

excretion from 24-h urine samples was significant during the period of 10 g salt intake, but not 5 g salt intake (Figure 3). These findings are consistent with other studies reporting that in a measurement using a self-monitoring device, estimated 24-h urinary salt excretion from overnight urine samples was overestimated in the subjects with low levels of salt intake.^{16,23} This consistency indicates that overestimation of salt excretion under conditions of low salt intake may be an internal property of a self-monitoring device. Underestimation during the period of 13 g salt intake may also be the result of the deterioration of the accuracy of measurement by the device. Ohta *et al.*²³ also reported that salt excretion estimated by a self-monitoring device tended to be overestimated compared with that measured from 24-h urine samples in patients with low salt excretion. However, further examination is needed because we did not conduct a 24-h urine collection during the period of 13 g salt intake.

As described above, if subjects consume average intakes of salt (11.6 g in males and 9.6 g in females in Japan by National Health and Nutrition Survey 2012), the estimated values from overnight urine samples are reliable and a self-monitoring device is a sufficiently practical tool for educating about salt restriction. Conversely, practical use of the device is questionable in subjects with higher or lower levels of salt intake. Moreover, potassium overload leads to overestimation of salt excretion regardless of salt restriction, because a self-monitoring device directly measures chloride values but not NaCl *per se*. However, in these subjects, the general fluctuations of daily salt intake can be roughly estimated,¹⁸ and the device may be available as a tool for promoting the continuation of daily salt restriction.

In the analysis of the association between salt excretion measured from 24-h urine samples and that estimated by a self-monitoring device, we found that patients who cannot achieve a salt intake <6 g per day may be selected by cutoff points of 6.3 and 7.3 g estimated by a self-monitoring device. We recommend 6.3 g as a cutoff point for the prevention of hypertension because of the higher sensitivity of the device. Although the specificity was not sufficient, the self-monitoring device has sufficient functionality for screening salt intake because the sensitivity is excellent.

Mean systolic blood pressure changed significantly with change in salt intake within the sleeping period, but not in the morning (Table 3). It has been shown that salt restriction leads to decreasing blood pressure.²⁴ In this study, all subjects were young and healthy, and low salt (5 g per day) and high salt (13 g per day) periods were very short (3 days). Nevertheless, mean blood pressure during sleep showed a sharp reaction, with a significant decrease in the period of 5 g salt per day and a significant increase in the period of 13 g salt per day. It has been reported that in patients with salt-sensitive hypertension, salt restriction induces larger pressure reductions in the night compared with the daytime.²⁵ Disorders of night blood pressure, such as non-dipper and riser, exacerbate vital prognosis.²⁶ Our results suggest the possibility that blood pressure during the night sharply reacts to changes in salt intake. Therefore, a self-monitoring device for estimating urinary salt excretion, which can promptly evaluate daily salt consumption, is a convincing tool for observing salt restriction.

There were several limitations to this study: (1) although the correlation was examined between 24-h urinary salt excretion estimated from overnight urine samples and that measured from 24-h urine samples, only 10 (day 5) and 12 (day 8) subjects could successfully collect 24-h urine samples. (2) The correlation described above was not examined in urine samples prepared during a high-salt (13 g per day) period. (3) The accuracy of the self-monitoring device was assessed only in the range of 5–13 g salt intake. To validate the capability of the device, we need to examine the accuracy of estimated

urinary salt excretion in a wider range because salt consumption changes daily.²⁷ (4) Mealtime was allowed from 0600 to 2200 hours in this study. It is known that salt consumption after 2200 hours especially increases overnight urinary salt excretion,²⁸ and this situation may be unsuitable for using the device. (5) In this study, heavy burdens, such as exactly controlled salt intake (test meals), urine collection at night, 24-h urine collection and measuring blood pressure in the morning and during sleep, were imposed on the subjects. Therefore, a large-scale study may be difficult to undertake. (6) Young and healthy volunteers were enrolled in this study, but we may find different results in older subjects or in patients with hypertension.

In conclusion, 24-h urinary salt excretion estimated by a self-monitoring device was correlated with daily salt intake and directly measured salt excretion from 24-h urine samples. Changes in salt intake were significantly associated with those in blood pressure during the night. Our results suggest the practicality of a self-monitoring device, which can estimate daily salt consumption promptly, as a convenient tool for education regarding salt restriction.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We would like to thank the kind volunteers in the Department of Health and Nutrition Sciences, Faculty of Health and Social Welfare Sciences, Nishikyushu University, for their enrollment in this study. This work was supported by JSPS KAKENHI Grant Number 25750067.

- 1 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**: 319–328.
- 2 Antonios TF, MacGregor GA. Salt intake: potential deleterious effects excluding blood pressure. *J Hum Hypertens* 1995; **9**: 511–515.
- 3 Espeland MA, Whelton PK, Kostis JB, Bahnson JL, Ettinger WH, Cutler JA, Appel LJ, Kumanyika S, Farmer D, Elam J, Wilson AC, Applegate WB. Predictors and mediators of successful long-term withdrawal from antihypertensive medications. TONE Cooperative Research Group. Trial of Nonpharmacologic Interventions in the Elderly. *Arch Fam Med* 1999; **8**: 228–236.
- 4 Obarzanek E, Proschan MA, Vollmer WM, Moore TJ, Sacks FM, Appel LJ, Svetkey LP, Most-Windhauser MM, Cutler JA. Individual blood pressure responses to changes in salt intake: results from the DASH-Sodium trial. *Hypertension* 2003; **42**: 459–467.
- 5 du Calair G, Ribstein J, Mimran A. Dietary sodium and target organ damage in essential hypertension. *Am J Hypertens* 2002; **15**: 222–229.
- 6 Ohta Y, Tsuchihashi T, Kiyohara K, Oniki H. High salt intake promotes a decline in renal function in hypertensive patients: a 10-year observational study. *Hypertens Res* 2013; **36**: 172–176.
- 7 Neaton JD, Grimm Jr. RH, Prineas RJ, Stamler J, Grandits GA, Elmer PJ, Cutler JA, Flack JM, Schoenberger JA, McDonald R, Lewis CE, Liebson PR, Raines J, Joffrion I, Allen RE, Jones L, Parker D, De Worth JK, Anzelone E, Gunn D, George A, Montgomery J, Neri GS, Betz E, Mascitti B, Plank E, Peterson B, Remijas T, Washington W, Turner I, Stefanie L, Aye P, Madnek-Oxman S, Jones H, Mascioli SR, Heel NV, Bjerk C, Galle F, Laqua P, Miller M, Bell LM, Robinson ME, Thorson C, Townsend R, Caggiula A, Dianzumba S, Ciak C, Link M, Hall B, Monske M, Theobald TM, Berry M, Coyne T, Bunker CA, Kramer K, DuChene AG, Holland LA, Tze S, Sjolund S, Launer CA, Lagus J, Miller CM, Svendsen KH, Leon A, Laing B, McDonald M, Surbey D, Wiche MK, Kuiper K, Remington R, Coates TJ, Devereux R, Gifford RW Jr, Langford H, McCullough L, Tyroler HA. Treatment of Mild Hypertension Study. Final results. Treatment of Mild Hypertension Study Research Group. *JAMA* 1993; **270**: 713–724.
- 8 Ohta Y, Tsuchihashi T, Fujii K, Matsumura K, Ohya Y, Uezono K, Abe I, Iida M. Improvement of blood pressure control in a hypertension clinic: a 10-year follow-up study. *J Hum Hypertens* 2004; **18**: 273–278.
- 9 Forster JL, Jeffery RW, VanNatta M, Pirie P. Hypertension prevention trial: do 24-h food records capture usual eating behavior in a dietary change study? *Am J Clin Nutr* 1990; **51**: 253–257.
- 10 Ohta Y, Tsuchihashi T, Ueno M, Kajioaka T, Onaka U, Tominaga M, Eto K. Relationship between the awareness of salt restriction and the actual salt intake in hypertensive patients. *Hypertens Res* 2004; **27**: 243–246.

- 11 Ohta Y, Tsuchihashi T, Onaka U, Miyata E. Long-term compliance of salt restriction and blood pressure control status in hypertensive outpatients. *Clin Exp Hypertens* 2010; **32**: 234–238.
- 12 Tanaka T, Okamura T, Miura K, Kadowaki T, Ueshima H, Nakagawa H, Hashimoto T. A simple method to estimate populational 24-h urinary sodium and potassium excretion using a casual urine specimen. *J Hum Hypertens* 2002; **16**: 97–103.
- 13 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**: 7–14.
- 14 Hirota S, Sadanaga T, Mitamura H, Fukuda K. Long-term compliance with salt restriction assessed using the spot urine method in Japanese cardiology outpatients. *Hypertens Res* 2013; **36**: 1096–1099.
- 15 Hirota S, Sadanaga T, Mitamura H, Fukuda K. Spot urine-guided salt reduction is effective in Japanese cardiology outpatients. *Hypertens Res* 2012; **35**: 1069–1071.
- 16 Yamasue K, Tochikubo O, Kono E, Maeda H. Self-monitoring of home blood pressure with estimation of daily salt intake using a new electrical device. *J Hum Hypertens* 2006; **20**: 593–598.
- 17 Kawano Y, Tsuchihashi T, Matsuura H, Ando K, Fujita T, Ueshima H. Report of the Working Group for Dietary Salt Reduction of the Japanese Society of Hypertension: (2) Assessment of salt intake in the management of hypertension. *Hypertens Res* 2007; **30**: 887–893.
- 18 Yasutake K, Sawano K, Yamaguchi S, Sakai H, Amadera H, Tsuchihashi T. Self-monitoring urinary salt excretion in adults: a novel education program for restricting dietary salt intake. *Exp Ther Med* 2011; **2**: 615–618.
- 19 Yasutake K, Sawano K, Shono N, Tsuchihashi T. Validation of a self-monitoring device for estimating 24-hour urinary salt excretion. *Asia Pac J Clin Nutr* 2013; **22**: 25–31.
- 20 US Department of Health and Human Services National health and nutrition examination survey 2013. <http://www.mhlw.go.jp/stf/houdou/0000032074.html>.
- 21 Tochikubo O, Uneda S, Kaneko Y. Simple portable device for sampling a whole day's urine and its application to hypertensive outpatients. *Hypertension* 1983; **5**: 270–274.
- 22 Holbrook JT, Patterson KY, Bodner JE, Douglas LW, Veillon C, Kelsay JL, Mertz W, Smith Jr. JC. Sodium and potassium intake and balance in adults consuming self-selected diets. *Am J Clin Nutr* 1984; **40**: 786–793.
- 23 Ohta Y, Tsuchihashi T, Miyata E, Onaka U. Usefulness of self-monitoring of urinary salt excretion in hypertensive patients. *Clin Exp Hypertens* 2009; **31**: 690–697.
- 24 He FJ, MacGregor GA. Effect of modest salt reduction on blood pressure: a meta-analysis of randomized trials. Implications for public health. *J Hum Hypertens* 2002; **16**: 761–770.
- 25 Uzu T, Ishikawa K, Fujii T, Nakamura S, Inenaga T, Kimura G. Sodium restriction shifts circadian rhythm of blood pressure from nondipper to dipper in essential hypertension. *Circulation* 1997; **96**: 1859–1862.
- 26 Ben-Dov IZ, Kark JD, Ben-Ishay D, Mekler J, Ben-Arie L, Bursztyn M. Predictors of all-cause mortality in clinical ambulatory monitoring: unique aspects of blood pressure during sleep. *Hypertension* 2007; **49**: 1235–1241.
- 27 Okubo H, Sasaki S, Hirota N, Notsu A, Todoriki H, Miura A, Fukui M, Date C. The influence of age and body mass index on relative accuracy of energy intake among Japanese adults. *Public Health Nutr* 2006; **9**: 651–657.
- 28 Yamori Y, Kihara M, Fujikawa J, Soh Y, Nara Y, Ohtaka M, Horie R, Tsunematsu T, Note S, Kukase M. Dietary risk factors of stroke and hypertension in Japan – Part 2: Validity of urinalysis for dietary salt and protein intakes under a field condition. *Jpn Circ J* 1982; **46**: 939–943.