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ARTICLE

Salt and potassium intake evaluated with spot urine and brief questionnaires in combination with blood pressure control status in hypertensive outpatients in a real-world setting

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Abstract

Reducing salt and increasing potassium intake are recommended lifestyle modifications for patients with hypertension. The estimated 24-h urinary salt excretion value from spot urine using Tanaka's formula and the salt check-sheet scores, questionnaire-based scores of salt intake, are practical indices of daily salt intake. However, few studies have evaluated salt intake with these methods in hypertensive outpatients. We examined salt and potassium intake with the spot urine method and the salt check-sheet scores of hypertensive outpatients in a multi-facility, real-world setting and examined whether the salt or potassium intake evaluated with these methods related to inadequate blood pressure control. Hypertensive outpatients from 12 medical facilities in the Okinawa prefecture were enrolled from November 2011 to April 2014 ($n = 1559$, mean age 63.9 years, 46% women). The mean blood pressure, urinary salt excretion value, urinary potassium excretion value, and total score on the salt check-sheet were 129/75 mmHg, 8.7 g/day, 1.6 g/day, and 10.4 points, respectively. The urinary salt excretion value and total score on the salt check-sheet but not urinary potassium excretion value were associated with inadequate blood pressure control (≥140/90 mmHg). Higher body mass index, estimated glomerular filtration rate, urinary potassium excretion value, total score on the salt check-sheet, and presence of inadequate blood pressure control were associated with high urinary salt excretion (≥10.2 g/day). In conclusion, hypertensive outpatients with high urinary salt excretion values estimated using Tanaka's formula or with high scores on the salt check sheet may be candidates for more intensive salt reduction guidance.

Keywords Hypertension · Sodium · Obesity

Introduction

Reducing salt intake and increasing potassium intake are recommended lifestyle modifications for patients with hypertension and lifestyle-related diseases. According to the Japanese National Health and Nutrition Survey 2018 [1], salt intake in the Japanese population has tended to decrease in the past decade; however, the changes in recent years have been small, and the intake is still high at 10.1 g/day. In the survey, vegetable consumption, which could result in an increase in potassium intake, changed little over the past decade, and the proportion of individuals achieving the tentative dietary goal for vegetable intake of 350 g/day was low at ~30%. For patients with hypertension, the dietary goal for daily salt intake in the 2019 Japanese Society of Hypertension Guideline for the Management of Hypertension is <6 g/day [2], and efforts have been made to achieve this goal.

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Daily salt and potassium intake are estimated by evaluations of dietary content or measurements of urinary sodium and potassium excretion values. Weighing the food ingested and 24-h urine collection are highly reliable methods to estimate daily salt and potassium intake; however, these methods are complicated and not always feasible for a large number of participants. Tanaka et al. [3] developed a formula to estimate the 24-h urinary sodium and potassium excretion values from a spot urine specimen collected at any time. This method was considered practical and suitable for general medical facilities to estimate individual daily salt intake by the Japanese Society of Hypertension [4], and the estimated salt intake has been used in daily clinical practice.

Okinawa prefecture is a subtropical island located in the southernmost part of Japan and has a population of 1.46 million. According to a national survey [5], Okinawa is the Japanese prefecture with the lowest salt intake but also has relatively low vegetable consumption. Although salt and potassium intake are important for blood pressure control, few studies have evaluated salt and potassium intake by Tanaka's spot urine method in hypertensive outpatients in a multi-facility setting. Furthermore, it is unclear whether the salt or potassium intake evaluated with this method actually relates to inadequate blood pressure control (≥140/90 mmHg). The same applies to salt check-sheet scores, a questionnaire-based score of salt intake. In addition, Okinawa used to be one of the prefectures known for longevity in Japan; however, the increase in mortality related to cardiovascular and other diseases in the younger generation has become a recent problem and suggests that changes in lifestyle may be associated with this increase [6]. Therefore, we evaluated the dietary habits of hypertensive outpatients through salt and potassium intake, which are related to hypertension and cardiovascular diseases, to resolve public health concerns in Okinawa. Our data provide important references for the estimated salt intake of hypertensive outpatients using Tanaka's spot urine method and salt check-sheet scores and suggest that promoting a reduction in salt intake and increased vegetable consumption remain important issues for hypertensive outpatients, especially in younger generations in Okinawa.

Methods

Participants

The present study was conducted in accordance with the standards of the Ethics Committee of the University of the Ryukyus (approval # 331, # 564). Hypertensive outpatients ≥20 years old from 12 medical facilities in Okinawa prefecture were recruited from November 2011 to April 2014, and 1559 patients gave written informed consent and participated in the present study. We defined hypertensive outpatients as those patients whose attending physicians listed hypertension as a diagnosis in their medical record. The 12 medical facilities and their number of participants were as follows: University of the Ryukyus Hospital ($n = 740$), Shuri Jokamachi Clinic ($n = 230$), Tomishiro Central Hospital ($n = 124$), Hata Medical Clinic ($n = 112$), Nishizaki Hospital ($n = 80$), Yonabaru Central Hospital ($n = 68$), Mihara Clinic ($n = 66$), Tokuyama Clinic ($n = 61$), Tomori Internal Medicine and Cardiology Clinic ($n = 59$), Imai Internal Medicine Clinic ($n = 8$), Matsuoka Clinic ($n = 6$), and Okinawa Red Cross Hospital ($n = 5$). The participants' blood pressure was measured twice by an attending physician or a trained nurse while the participants were sitting. We also asked the participants to respond to questionnaires related to food intake at the same visit. We collected the clinical and laboratory data of the participants on the day when informed consent was obtained or within 3 months of that visit. We also collected information on medical diagnoses of diabetes, dyslipidemia, and cardiovascular complications by reviewing the patient's medical records.

Estimation of 24-h urinary salt and potassium excretion values

To evaluate the daily salt and potassium intake of the hypertensive outpatients, we examined the concentrations of sodium, potassium, and creatinine in their spot urine samples and calculated the estimated 24-h urinary salt and potassium excretion values using Tanaka's formula [3] as follows:

- Estimated 24-h urinary sodium excretion value (mEq/day) = 21.98 × [spot urine sodium concentration (mEq/L) ÷ spot urine creatinine concentration (mg/dL) ÷ 10 × 24-h creatinine predicted value]$^{0.392}$.
- Estimated 24-h urinary potassium excretion value (mEq/day) = 7.59 × [spot urine potassium concentration (mEq/L) ÷ spot urine creatinine concentration (mg/dL) ÷ 10 × 24-h creatinine predicted value (mg/day)]$^{0.431}$.
- Estimated 24-h urinary creatinine excretion value (mg/day) = body weight (kg) × 14.89 + height (cm) × 16.14 − age × 2.04 − 2244.45.

We further converted the urinary sodium and potassium excretion values (mEq/day) obtained from the above formulas into urinary salt excretion (g/day) and urinary potassium excretion (g/day) with the following equation:

- Estimated 24-h urinary salt excretion value (g/day) = Estimated 24-h urinary sodium excretion value (mEq/day) × 0.0585.

- Estimated 24-h urinary potassium excretion value (g/day) = Estimated 24-h urinary potassium excretion value (mEq/day) × 0.0391.
- We calculated the urinary sodium-to-potassium ratio as follows:
- Urinary sodium-to-potassium ratio = spot urine sodium concentration (mEq/L) ÷ spot urine potassium concentration (mEq/L).

The estimated glomerular filtration rate (eGFR) was calculated using the following Japanese formula adopted by the Japanese Society of Nephrology:

- eGFR (mL/min/1.73 m^2) = 194 × serum creatinine $(mg/dL)^{-1.094}$ × $Age^{-0.287}$ (× 0.739 if female).

Questionnaires

The salt check sheet is a scoring sheet that consists of 13 questions that normally take 3–5 min to answer [7]. The first seven questions are related to salty food preferences, and the remaining six questions are related to eating behaviors associated with high salt intake. Each question is scored up to three points, with higher points suggesting higher salt intake based on a brief self-administered diet history questionnaire (BDHQ) [8, 9] and 24-h urinary salt excretion value in hypertensive outpatients in Fukuoka prefecture [7, 10]. With the permission of Dr. Takuya Tsuchihashi, a supervisor of the salt check sheet, we added the following salty foods, which have relatively high consumption rates in Okinawa prefecture, to the sheet: bacon and pork luncheon meat in the processed food category, and *Okinawa soba* in the noodle category. We also performed a questionnaire survey on awareness of the need for a reduction in salt intake, vegetable consumption, and subjective symptoms.

The original form of the salt check sheet appeared in reference [7] (Yasutake K et al. *Hypertens Res* 2016). The salt check sheet is provided in the online supplementary information.

Statistical analysis

Values are expressed as the mean ± SD. Student's *t* test, Wilcoxon signed-rank test, and the χ^2 test were used for comparisons of discrete variables. We used multivariable logistic regression analysis to estimate the odds ratio (95% confidence interval) of the determinants of inadequate blood pressure control (≥140/90 mmHg) and high salt intake (estimated 24-h urinary salt excretion value ≥10.2 g/day) by using JMP Pro 15 (SAS Institute Inc., Cary, NC, USA). A p value < 0.05 was considered statistically significant.

Table 1 Demographic and clinical characteristics of the hypertensive outpatients

	All	Men	Women
Number	1559	843	716
Age (years old)	63.9 ± 12.8	63.6 ± 12.9	64.2 ± 12.8
≥75 years old (%)	22	20	24
BMI (kg/m^2)	25.8 ± 4.2	25.8 ± 4.0	25.7 ± 4.4
Systolic BP (mmHg)	129 ± 16	129 ± 15	130 ± 16
Diastolic BP (mmHg)	75 ± 11	75 ± 11	75 ± 10
CKD[a] (%)	37	40	35*
DM (%)	32	36	26**
Dyslipidemia (%)	77	77	76
Ischemic heart disease (%)	19	25	13**
Cerebrovascular disease (%)	11	13	9**
Current smoker (%)	10	14	5**
Habitual drinking[b] (%)	22	36	7**
Antihypertensive drug use (%)	94	94	94
Calcium channel blockers (%)	57	57	58
ACEIs (%)	15	17	12**
ARBs (%)	60	61	60
Aldosterone blockers (%)	10	13	8**
Direct renin inhibitors (%)	2	3	2
Diuretics (%)	21	22	20
β blockers (%)	25	32	18**
α blockers (%)	7	8	5*
Number of antihypertensive types	2.0 ± 1.2	2.1 ± 1.2	1.8 ± 1.0**
Urinary salt excretion (g/day)	8.7 ± 2.5	8.9 ± 2.6	8.5 ± 2.3*
Urinary potassium excretion (g/day)	1.6 ± 0.4	1.7 ± 0.4	1.6 ± 0.4
Urinary sodium-to-potassium ratio	2.87 ± 1.92	2.98 ± 2.13	2.73 ± 1.77*
Total score on salt check sheet (points)	10.4 ± 4.4	11.2 ± 4.4	9.5 ± 4.2**

Data are expressed as the mean ± SD. *$p < 0.05$, **$p < 0.01$ (vs. men)

BMI body mass index, *BP* blood pressure, *CKD* chronic kidney disease, *DM* diabetes mellitus, *ACEIs* angiotensin-converting enzyme inhibitors, *ARBs* angiotensin II receptor blockers

[a]CKD was defined as estimated glomerular filtration rate (eGFR) <60 mL/min/1.73 m^2

[b]Habitual drinking was defined as drinking alcohol every day

Results

Demographic and clinical characteristics of the participants

The demographic and clinical characteristics of the hypertensive outpatients are summarized in Table 1. The overall mean age was 63.9 years, 46% were women, 22% were ≥75 years old, and the mean body mass index (BMI) was 25.8 kg/m^2. The mean blood pressure value was 129/75 mmHg. Blood pressure was measured twice with a pressure column sphygmomanometer with the auscultation method, and the second measurement value was adopted; 6 facilities ($n = 374$, 24%) used an automatic rolling-type sphygmomanometer, and seven facilities ($n = 454$, 29%) measured blood pressure only once. Chronic kidney disease (CKD) was present in 37% of the participants, and 94% were taking antihypertensive medication, with a mean of 2.0 drug types. The male participants had higher incidences of CKD, diabetes, cardiovascular complications, smoking, and alcohol consumption, used a higher number of antihypertensive drug types, and had higher total salt check-sheet scores than the female participants.

Distributions of estimated urinary salt and potassium excretion values

For all participants, the mean urinary salt and potassium excretion values were 8.7 ± 2.5 and 1.6 ± 0.4 g/day, respectively (Table 1). Figure 1A shows the estimated 24-h urinary salt excretion distribution according to sex. In men, the estimated 24-h urinary salt excretion value ranged from a minimum of 3.4 g/day to a maximum of 20.0 g/day (mean 8.9 ± 2.6 g/day). In women, the estimated 24-h urinary salt excretion value ranged from 3.0 to 19.2 g/day (mean 8.5 ± 2.3 g/day). The urinary salt excretion value was significantly higher in men than in women ($p < 0.05$). The overall proportion of patients who achieved salt intake <6 g/day, which was recommended in the 2019 Japanese Society of Hypertension Guidelines for the Management of Hypertension [2], was 12.7% (12.1% in men and 13.4% in women). Figure 1B shows the distributions of the estimated 24-h urinary potassium excretion values according to sex. In men, the estimated 24-h urinary potassium excretion value ranged from 0.5 to 4.3 g/day (mean 1.7 ± 0.4 g/day). In women, the estimated 24-h urinary potassium excretion value ranged from 0.6 to 3.4 g/day (mean 1.6 ± 0.4 g/day). The estimated 24-h urinary potassium excretion values were similar for men and women. The potassium intake recommended by the Japanese Ministry of Health, Labour and Welfare for the prevention of lifestyle-related diseases [11] is 3.0 g/day for men and 2.6 g/day for women in adults <75 years old and 2.8 g/day for men and 2.4 g/day for women in adults ≥75 years old. In 1059 patients with an eGFR ≥45 mL/min/1.73 m^2 who did not need to restrict potassium intake, the proportion who achieved the recommended intake was 1.1% (0.4% for men and 2.1% for women). The mean urinary sodium-to-potassium ratio was 2.87 ± 1.98 overall and was significantly higher in men than in women (2.98 ± 2.13 vs. 2.73 ± 1.77, $p < 0.05$).

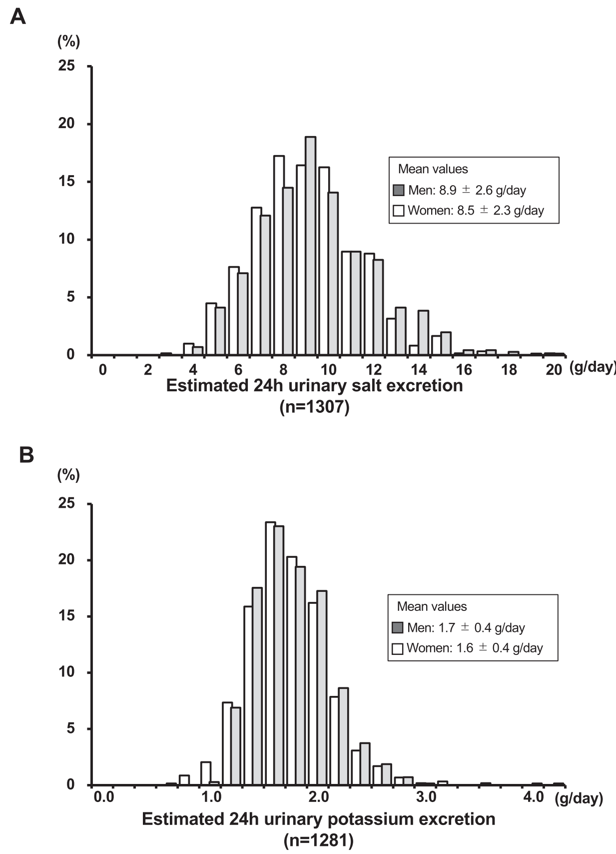

Fig. 1 Distributions of the estimated 24-h urinary salt (**A**) and potassium (**B**) excretion values according to sex. **A** Each bar in the graph represents a percentage of patients for every 1 g/day of the estimated 24- urinary salt excretion in men (shaded bar) and women (open bar). **B** Each bar in the graph represents a percentage of patients for every 0.2 g/day of the estimated 24-h urinary potassium excretion

Factors associated with inadequate blood pressure control

To examine whether urinary salt or potassium excretion values were associated with inadequate blood pressure control in hypertensive outpatients, we performed a multivariable logistic regression analysis. Table 2 shows the factors that were associated with inadequate blood pressure control. We defined inadequate blood pressure control as a blood pressure ≥ 140/90 mmHg. Higher BMI, higher urinary salt excretion value, and fewer types of antihypertensive drugs were significantly associated with inadequate blood pressure control, but age, sex, eGFR, and urinary potassium excretion value were not associated with inadequate blood pressure control. To examine whether the total score on the salt check sheet was associated with inadequate blood pressure control in hypertensive outpatients, we performed a different set of analyses with variables including the total score on the salt check sheet instead of urinary salt or potassium excretion values. Higher BMI and the total score on the salt check sheet were significantly associated with inadequate blood pressure control,

Table 2 Factors associated with inadequate blood pressure control in hypertensive outpatients according to a multivariable logistic regression model

Variables	Odds ratio	95% CI	*p* value	Odds ratio	95% CI	*p* value
Age (years old)	1.01	1.00–1.02	ns	1.01	1.00–1.02	ns
Men (vs. women)	0.96	0.74–1.25	ns	0.81	0.62–1.06	ns
BMI (kg/m^2)	1.04	1.01–1.08	<0.01	1.04	1.01–1.07	<0.05
eGFR (mL/min/1.73 m^2)	1.00	0.99–1.01	ns	1.00	1.00–1.01	ns
Urinary salt excretion (g/day)	1.07	1.00–1.14	<0.05			
Urinary K excretion (g/day)	1.21	0.78–1.86	ns			
Number of antihypertensive drug types	0.84	0.75–0.96	<0.01	0.92	0.81–1.04	ns
Total score on salt check sheet				1.06	1.02–1.09	<0.01

Inadequate blood pressure control was defined as ≥140/90 mmHg

CI confidence interval, *ns* not significant, *BMI* body mass index, *eGFR* estimated glomerular filtration rate, *K* potassium

Table 3 Factors associated with high urinary salt excretion in hypertensive outpatients according to a multivariable logistic regression model

Variables	Odds ratio	95% CI	*p* value
Age (years old)	1.00	0.99–1.01	ns
Men (vs. women)	1.06	0.76–1.47	ns
BMI (kg/m^2)	1.06	1.02–1.09	<0.01
BP ≥ 140/90 mmHg	1.46	1.05–2.02	<0.05
eGFR (every 10 mL/min/1.73 m^2)	1.15	1.07–1.25	<0.01
Urinary K excretion (every 0.1 g/day)	1.19	1.14–1.24	<0.01
Habitual drinking	1.25	0.87–1.79	ns
Diuretics	1.00	0.66–1.52	ns
Number of antihypertensive drug types	1.16	0.99–1.35	ns
Total score on salt check sheet	1.07	1.03–1.11	<0.01

High urinary salt excretion was ≥10.2 g/day

CI confidence interval, *ns* not significant, *BMI* body mass index, *BP* blood pressure, *eGFR* estimated glomerular filtration rate, *K* potassium

but age, sex, and number of antihypertensive drug types were not associated with inadequate blood pressure control.

Blood pressure values and control status according to urinary salt excretion

We investigated the blood pressure control status in hypertensive outpatients according to urinary salt excretion. The first, second (median), and third quartiles of urinary salt excretion for all participants were 7.0, 8.5, and 10.2 g/day, respectively. We divided the hypertensive outpatients into two groups according to the third quartile of urinary salt excretion: low-to-regular urinary salt excretion (<10.2 g/day; $n = 981$) and high urinary salt excretion (≥10.2 g/day, $n = 326$). The mean urinary salt excretion value of patients with low-to-regular urinary salt excretion was 7.6 ± 1.6 g/day and that of patients with high urinary salt excretion was 12.0 ± 1.6 g/day. The mean blood pressure was 128/74 mmHg in patients with low-to-regular urinary salt excretion and 132/77 mmHg in patients with high urinary salt excretion. Patients with high urinary salt excretion had significantly higher systolic and diastolic pressures than patients with low-to-regular urinary salt excretion. The percentage of patients with inadequate blood pressure control (≥140/90 mmHg) was significantly higher in patients with high urinary salt excretion than in patients with low-to-regular urinary salt excretion (31% vs. 23%, respectively). Patients with high salt check-sheet scores (≥14 points, $n = 310$) had a significantly higher diastolic pressure than patients with low-to-regular salt check-sheet scores (<14 points; $n = 1\ 099$). The percentage of patients with inadequate blood pressure control was significantly higher in patients with high salt check-sheet scores than in patients with low-to-regular salt check-sheet scores (35% vs. 24%, respectively).

Factors associated with high urinary salt excretion

To examine the factors associated with high urinary salt excretion in hypertensive outpatients, we performed a multivariable logistic regression analysis. Table 3 shows the factors associated with high urinary salt excretion. Higher BMI, eGFR, urinary potassium excretion, total score on salt check sheet, and the presence of inadequate blood pressure control were significantly associated with high urinary salt excretion. Age, sex, habitual drinking, use of diuretics, and number of antihypertensive drug types were not associated with high urinary salt excretion.

Questionnaire-based survey of salty food preferences, eating behavior, and awareness of the need for a reduction in salt intake and vegetable consumption

To examine preferences for salty foods and eating behaviors related to high salt intake, we used the salt check-sheet to

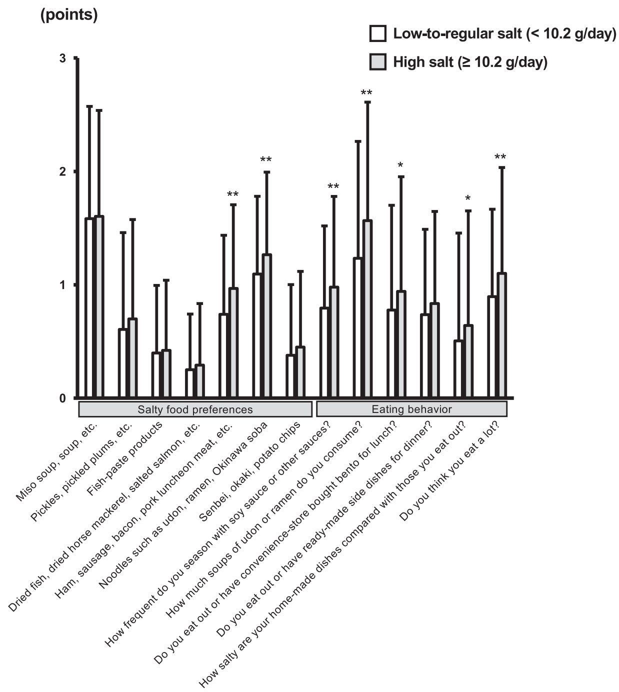

Fig. 2 The point scores for each question on the salt check-sheet according to the participants' urinary salt excretion values. Data are expressed as the mean ± SD. *$p < 0.05$, **$p < 0.01$ (vs. patients with low-to-regular urinary salt excretion)

perform a questionnaire-based survey of the participants. Figure 2 summarizes the point scores of each question on the salt check sheet according to the participants' urinary salt excretion values. The scores for the frequency of eating ham, sausage, bacon, or pork luncheon meet and noodles such as *udon*, *ramen*, and *Okinawa soba* as their preferred salty foods were significantly higher for patients with high urinary salt excretion than for patients with low-to-regular urinary salt excretion. The following eating behaviors were associated with significantly higher scores in patients with high urinary salt excretion than in patients with low-to-regular urinary salt excretion: frequency of seasoning with sauces, the amount of *udon* or *ramen* soups consumed, the frequency of eating out or buying convenience store *bento* for lunch, habit of cooking homemade dishes with a saltier taste, and eating a larger volume of food. Table 4 shows the estimated 24-h urinary salt and potassium excretion values in relation to awareness of the need for a reduction in salt intake and vegetable consumption in the questionnaire responses. The estimated 24-h urinary salt excretion values were significantly lower in the patients who answered that they cared about reducing salt intake and that they were actually trying to reduce their dietary salt intake than in patients who responded negatively. Patients who ate vegetables every day had significantly higher estimated 24-h urinary potassium excretion values and significantly lower 24-h urinary salt excretion values than patients who did not.

Discussion

We demonstrated that the mean estimated 24-h urinary salt excretion value was 8.7 g/day, the mean estimated 24-h urinary potassium excretion value was 1.6 g/day, and the mean total score on the salt check sheet was 10.4 points in hypertensive outpatients in a real-world setting in Okinawa, Japan. The urinary salt excretion value and total salt check-sheet score but not urinary potassium excretion value were associated with inadequate blood pressure control (≥140/90 mmHg). Higher BMI, eGFR, urinary potassium excretion value, total salt check-sheet score, and presence of inadequate blood pressure control were significantly associated with high urinary salt excretion values (≥10.2 g/day). Higher scores on questions on the salt check sheet, such as the frequency of eating ham, bacon, and noodles, and some questions related to eating behaviors, were significantly associated with high urinary salt excretion. These results suggested that correcting high salt intake remains an important issue for hypertensive outpatients in a real-world setting in Okinawa and that hypertensive outpatients with high urinary salt excretion estimated using Tanaka's formula or with high scores on the salt check sheet may be candidates for more intensive salt reduction guidance.

According to the 2016 Japanese National Health and Nutrition Survey [5], the national average salt and vegetable intake values of men and women were 10.8 and 9.2 g/day and 284 and 270 g/day, respectively. In the survey, the salt intake levels of men and women in Okinawa prefecture were the lowest in Japan at 9.1 and 8.0 g/day, respectively. Vegetable consumption, which could result in an increase in potassium intake, was below the national average for both men and women in Okinawa (273 and 268 g/day, respectively). Therefore, Okinawa prefecture has low salt intake but also low potassium intake. However, these estimations of salt and vegetable intake were derived from estimates based on dietary content. Miyagawa et al. [12] reported the urinary sodium and potassium excretion values of participants ($n = 2560$) in the NIPPON DATA2010, a nationwide survey of the general Japanese population. In that report, the 24-h estimated urinary salt and potassium excretion values were calculated with Tanaka's formula [3], and the urinary salt and potassium excretion values of the men and women were 10.3 and 10.1 g/day and 1.7 and 1.6 g/day, respectively. The hypertensive outpatients in the present study had lower urinary salt excretion values but similar urinary potassium excretion values compared to the representative Japanese population. Iseki et al. [13] used Kawasaki's formula [14] to report the estimated 24-h urinary salt and potassium excretion values of health screening subjects ($n = 2\ 411$) in Okinawa prefecture, of whom 24% had hypertension. In that study, the urine samples of the participants who received a health evaluation in the Okinawa

Table 4 Estimated 24-h urinary salt and potassium excretions according to responses on the questionnaire related to awareness of need for salt reduction and vegetable eating

Questions		Answered "Yes"	Answered "No"	p value
Do you care about reducing the amount of salt in your diet?	Number	1072 (84%)	207 (16%)	
	U-salt (g/day)	8.7 ± 2.5	9.1 ± 2.4	<0.05
	U-K (g/day)	1.6 ± 0.4	1.6 ± 0.3	ns
Do you actually try to reduce salt in your regular diet?	number	1008 (79%)	269 (21%)	
	U-salt (g/day)	8.6 ± 2.4	9.1 ± 2.6	<0.01
	U-K (g/day)	1.6 ± 0.4	1.7 ± 0.4	ns
Do you eat vegetables every day?	number	923 (74%)	318 (26%)	
	U-salt (g/day)	8.6 ± 2.4	9.0 ± 2.6	<0.05
	U-K (g/day)	1.7 ± 0.4	1.6 ± 0.3	<0.01

Urinary salt and potassium excretions are expressed as the mean ± SD

U-salt urinary salt excretion, *U-K* urinary potassium excretion, *ns* not significant

General Health Maintenance Association from 1997 to 1998 were analyzed, and the urinary salt and potassium excretion values of the men and women were 11.6 and 10.3 g/day and 2.1 and 2.0 g/day, respectively. We used Kawasaki's formula to convert the urinary salt and potassium excretion values in the present study to 11.7 and 10.7 g/day and 2.1 and 2.0 g/day in men and women, respectively. Although the hypertensive outpatients in the present study were older and had a higher BMI than the health screening subjects in Okinawa prefecture, the urinary salt excretion values were similar or slightly higher and the urinary potassium excretion values were similar to those of the health screening subjects. Ito et al. [15] used Tanaka's formula [3] to report the estimated urinary salt and potassium excretion values of children attending public elementary school in Okinawa prefecture and their mothers. The estimated urinary salt and potassium excretion values of the mothers were 7.7 and 1.2 g/day, respectively, and both excretion values were lower than those of the hypertensive outpatients in the present study. Taken together, although the urinary salt excretion values of the hypertensive outpatients in the present study were lower than those of the general Japanese population, they were not lower than those of health screening subjects and the mothers of elementary school children in Okinawa prefecture. The urinary potassium excretion values of the hypertensive outpatients in the present study were similar to those of the general Japanese population and screening subjects in Okinawa prefecture. Because the recommended salt intake level is lower in hypertensive patients than in the general population, correcting high salt intake remains an important issue for hypertensive outpatients in a real-world setting in Okinawa prefecture.

Higher levels of salt intake are reported to be associated with higher blood pressure [16, 17] and increased risks of death and major cardiovascular events [18, 19]. In the present study, higher BMI, eGFR, urinary potassium excretion value, and total points on the salt check sheet were significantly associated with high urinary salt excretion (≥10.2 g/day). In the Japanese National Health and Nutrition Survey 2016 [5], the national average obesity rates of men and women were 31.3% and 20.6%, respectively, with BMIs of 23.8 and 22.6 kg/m^2, respectively; the BMIs of men and women who were general residents in Okinawa prefecture (24.1 and 23.8 kg/m^2, respectively) were higher the national averages. In our hypertensive outpatients, the obesity rates and the BMIs of men and women (46.1% and 47.9% and 25.8 and 25.7 kg/m^2, respectively) were much higher than the national averages, and the BMIs were higher than those of general residents in Okinawa. Because eating large meals is related to both high salt intake and potassium intake, the high obesity rate in the present study may reflect overeating by hypertensive outpatients in Okinawa. In the present study, the eGFR and urinary potassium excretion values of hypertensive outpatients were positively associated with high urinary salt excretion. Although a decrease in renal function may relate to a decrease in urinary sodium and potassium excretion, this may result from hypertensive outpatients with reduced renal function refraining from the consumption of potassium-rich food in addition to reducing salt intake. In the present study, a higher total score on the salt check sheet, a BDHQ [9]-based scoring sheet of salt intake, was significantly associated with high urinary salt excretion. Sakata et al. [8] found a significant correlation between the BDHQ and 24-h urinary salt excretion. In the present study, there was a weak but significant correlation between the total score on the salt check sheet and the estimated urinary salt excretion values ($r = 0.2$, $p < 0.01$). Because salt intake varies greatly from individual to individual, brief questionnaires on salt intake, such as the salt check sheet, may be an effective method to help identify individual patients' salty food preferences and eating behaviors related to high salt intake and may lead to providing patients with specific instructions to restrict salt intake. Furthermore, patient awareness of their salt intake level through feedback from their urinary salt excretion level was reported to lower urinary salt excretion [20, 21]. Although estimated 24-h urinary salt excretion values with spot urine and brief questionnaires on salt intake may be less reliable methods [4, 10], both methods are practical and could be performed in an outpatient clinic at the same visit [22]. The combination of feedback on the patient's urinary salt excretion level with brief questionnaires on salt intake may help patients and attending physicians find personalized ways to reduce salt intake.

Potassium reduces both systolic and diastolic blood pressures [23, 24]. In the PURE study, higher estimated urinary potassium excretion values were associated with lower risks of death and cardiovascular events [19]. In the present study, the urinary potassium excretion values were lower than those associated with the potassium intake recommended by the Japanese Ministry of Health, Labour and Welfare [11] or the World Health Organization [25]. Vegetables are a rich source of dietary potassium, and a positive correlation was found between urinary potassium excretion values and average daily vegetable intake [26]. To increase potassium intake, eating locally available vegetables may be a good option. Mano et al. [27] found that dietary interventions with Okinawan vegetables increased 24-h urinary potassium and magnesium excretion values as well as the number of endothelial progenitor cells in healthy young women. A weekly supply of 2.6 kg of Okinawan vegetables, which was based on the national recommendation for vegetable intake (350 g/day) from the Japanese Ministry of Health, Labour and Welfare, increased the 24-h urinary potassium excretion value from 1.6 to 2.5 g/day in the intervention group, whereas no significant change occurred in the control group (from 1.7 g/day to 1.6 g/day). Tuekpe et al. [26] also reported that dietary intervention with typical yellow–green Okinawan vegetables through home-parcel delivery increased the 24-h urinary potassium excretion values in healthy Japanese women. In the present study, the patients who ate vegetables every day had significantly higher urinary potassium excretion values and significantly lower urinary salt excretion values than patients who did not. These results suggested that an increase in the availability of Okinawan vegetables and frequent vegetable consumption may increase urinary potassium excretion. Promoting an increase in the consumption of vegetables, including locally available vegetables, to the government recommendation of 350 g/day may have benefits by increasing potassium intake as well as reducing salt intake.

In the present study, 53% of hypertensive outpatients were obese (BMI ≥ 25 kg/m^2), and they had significantly higher blood pressure and urinary salt and potassium excretion values than the patients with a BMI < 25 kg/m^2. This may suggest a problem with dietary habits in hypertensive outpatients in Okinawa. However, dietary habits related to a BMI ≥ 25 kg/m^2 might have different meanings in elderly hypertensive outpatients [6, 28]. In our elderly hypertensive outpatients (≥75 years old), 47% of patients had a BMI ≥ 25 kg/m^2, and the urinary salt and potassium excretion values were lower than those of patients <75 years old. For elderly hypertensive patients with a BMI ≥ 25 kg/m^2, there was no difference in the percentage of patients with inadequate blood pressure control or urinary salt excretion values compared to elderly patients with a BMI < 25 kg/m^2. However, the urinary potassium excretion value was significantly higher in elderly hypertensive patients with a BMI ≥ 25 kg/m^2 (1.7 g/day) than in elderly patients with a BMI < 25 kg/m^2 (1.5 g/day), and the value was similar to that of patients <75 years old (1.7 g/day). Furthermore, the percentage of patients who answered that they eat vegetables every day was significantly higher in elderly hypertensive patients (85%) than in patients <75 years old (72%). These results suggested that elderly hypertensive patients with a BMI ≥ 25 kg/m^2 might have different dietary habits, i.e., they prefer to choose low-salt but potassium-rich food. Therefore, we consider that the change in dietary habits, especially in our younger hypertensive patients with a BMI ≥ 25 kg/m^{2,} might be an ongoing problem in Okinawa.

There are several limitations to this study. First, the most important limitation of the present study is that Tanaka's formula was derived from an evaluation of the general population and has never been evaluated for accuracy against 24-h urine values in hypertensive patients. However, there are reports from Iwahori et al. [29–31] showing that the association between 24-h urine and spot urine values was consistent among sodium-to-potassium ratio and sodium and potassium concentration/excretion in both normotensive and hypertensive patients. Thus, it is reasonable to infer that applying Tanaka's formula in hypertensive patients may lead to relatively reliable estimates; however, further clarifications are awaited. Second, the participants may not have been representative of hypertensive outpatients in Okinawa. Third, because the urine samples were collected on only one occasion, the samples may not accurately reflect daily variations in salt excretion. Fourth, the use of drugs that may affect urine excretion, such as steroids and diuretics, was not excluded. Fifth, the questionnaires were based on self-assessments by the participants, and the answers may have some inaccuracies. Sixth, because ingested salt and potassium are not entirely excreted through urine, salt and potassium intake determined from urinary analysis as in the present study may be underestimated. Seventh, the blood pressure measurement methods were not consistent.

In summary, the estimated mean 24-h urinary salt and potassium excretion values and total score on the salt check sheet in hypertensive outpatients in Okinawa were 8.7, 1.6 g/day, and 10.4 points, respectively. Our results suggested that promoting a reduction in salt intake and increased vegetable consumption remain important issues for hypertensive outpatients, especially in younger generations in Okinawa. Hypertensive outpatients with high urinary salt excretion values estimated using Tanaka's formula or with high salt check-sheet scores may be candidates for more intensive salt reduction guidance.

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Compliance with ethical standards

Conflict of interest The authors declare no competing interests.

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