Original Article

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Validity of five formulas in estimating 24-h urinary sodium via spot urine sampling in hypertensive patients living in Northeast China

Ni Qian[a], Yinong Jiang[a], Ying Wang[b], Peishi Yan[c], Fumei Yao[d], Min Sun[e], Xiaojie Liu[f], Ying Zhang[a], Yunpeng Cheng[a], Yan Lu[a], and Wei Song[a]

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Objective: The objective was to evaluate the accuracy of five formulas – the Kawasaki, Tanaka, INTERSALT, Mage, and Uechi methods – using spot urinary sampling for 24-h urinary sodium (U_{Na}) prediction in hypertensive patients living in northeast China.

Methods: There were 1154 hypertensive patients enrolled from multiple centers. Five different formulas were used to predict 24-h U_{Na} excretion via spot morning urinary samples. Actual U_{Na} excretion was measured from 24-h urine samples. The estimated value was compared with the actual value by examining biases, the intraclass correlation coefficients (ICC), and Bland–Altman plots.

Results: The average excretion of sodium was 2.97 ± 1.26 g/day. The formula-produced mean biases for actual U_{Na} were 0.31 g/day for INTERSALT, 0.80 g/day for Mage, 0.88 g/day for Tanaka, 1.14 g/day for Uechi, and 1.95 g/day for Kawasaki. The ICC was 0.511 for Kawasaki, 0.499 for INTERSALT, 0.468 for Tanaka, 0.402 for Mage, and 0.378 for Uechi. The least mean bias in the lower and moderate salt intake subgroups was 1.22 and 0.07 g/day, respectively, which was calculated using the Mage and INTERSALT methods. The least mean bias in the higher salt intake subgroup was 0.10 g/day for the Uechi method. The INTERSALT method was more efficiency at the individual level, with 17.4% of participants having relative differences within 10%, and 22.3% participants having absolute differences within 393 mg.

Conclusion: The INTERSALT method may exhibit a good performance in estimating 24-h urinary sodium level for the hypertensive population living in northeast China.

Keywords: 24-h urine, hypertension, sodium intake, spot urine, validation

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficients; PM, post meridiem; PURE, Prospective Urban Rural Epidemiology; SD, standard deviation; SMASH, Shandong-Ministry of Health Action on Salt and Hypertension; SMU, second morning voiding urine; U_{Cr}, urinary creatinine; U_K, urinary potassium; U_{Na}, urinary sodium

INTRODUCTION

High salt consumption, which is closely related to elevated blood pressure, is an important risk factor for cardiovascular diseases. In 2017, three million deaths and 70 million disabilities were attributed to high-salt intake globally, and it was also deemed one of the top three dietary risk factors [1]. A large prospective epidemiological cohort study showed that every 1 g/day of sodium intake corresponds to an increase of 2.86 mmHg in SBP [2]. High sodium consumption or preference for a salty diet was also considered to be associated with gastric cancer and renal disease [3]. Furthermore, evidence has shown that the risk of being overweight and obesity were also related to high-salt intake [3]. So, the WHO recommended a mean salt intake was 5 g/day for general population (equivalent to 2 g/day sodium) [4].

Salt consumption can be evaluated by several methods, including an assessment of urine and 24-h diet recall [5]. Twenty-four-hour urine collection is considered the gold standard method for assessing sodium intake, although it is expensive and relatively burdensome in large-scale population surveys. Numerous studies have used spot urine samples instead of 24-h urinary collection in order to estimate 24-h urinary sodium (U_{Na}) excretion using different formulas. These formulas include, among others, the Kawasaki method [6], Tanaka method [7], INTERSALT method [8,9], Mage method [10,11], and Uechi method [12]. They were developed

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[a]Department of Cardiology, First Affiliated Hospital of Dalian Medical University, Dalian, Liaoning, [b]Department of General Medicine, The First People's Hospital of Guiyang, Guiyang, [c]Department of Cardiology, The Center Hospital of Dalian, [d]Department of Cardiology, The 2nd Hospital of Dalian, [e]Department of Cardiology, The 3rd Hospital of Dalian and [f]Department of Cardiology, The Liaoyu Hospital of Dalian, Liaoning, China

Correspondence to Wei Song, Department of Cardiology, First Affiliated Hospital of Dalian Medical University, Dalian, Liaoning 116011, China. Tel: +86 18098875773; e-mail: songwei8124@163.com

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based on population and country, as salt consumption can vary greatly. However, the validity of these formulas in the hypertensive population living in northeast China has been uncertain. Therefore, the objective of the present study was to evaluate the accuracy of these five formulas in order to identify the optimal method for assessing the salt intake of the hypertensive population living in northeast China.

METHODS

Study design and participants

This was a prospective multicenter clinical study registered at www.Chictr.org.cn as ChiCTR1800019727. There were 1154 hypertensive hospitalized patients enrolled from April 2017 to November 2019 at the five following clinic centers: 1st Affiliated Hospital of Dalian Medical University, the Center Hospital of Dalian, 2nd Hospital of Dalian, 3rd Hospital of Dalian, and the Liaoyu Hospital of Dalian. The inclusion criteria for the participants included: age between 18 and 80 years and estimated glomerular filtration rate (eGFR) at least 60 ml/min per 1.73 m^2. Individuals with the following conditions were excluded: recent use of diuretic; severe chronic kidney disease and liver dysfunction; women who were menstruating, pregnant, or breastfeeding; secondary hypertension, including disease of the adrenal gland (e.g. primary aldosteronism, hypercortisolism, or pheochromocytoma), renal hypertension, some endocrine disease (e.g. hyperthyroidism, or hypothyroidism), Liddle syndrome, obstructive sleep apnea hypoventilation syndrome, and drug-induced hypertension (e.g. contraceptive or glucocorticoid); morning voiding urine sample and 24-h urine sample not within 1 day. Basic patient information, including age, sex, height, and weight, were collected. This study was approved by the Ethics Review Committee. The objectives and process of the clinical trial were discussed with each participants all of whom provided their consent to this study.

Urine collection and measurement

The participants were asked to collect a 24-h urine sample, starting from their first urine after waking up and ending before their first urine the following morning. A morning voiding urine sample (clean midstream urine) after the collection of 24-h urine was regarded as a spot urine specimen. Spot urine collection started immediately after the 24-h urine collection was completed, as spot urine and 24-h urine collection must occur within the same 24-h period. A disposable capped plastic bottle with labels (5 ml) and a plastic drum (8–10 l) were provided to collect the spot urine and 24-h samples according to standard procedures. When the collection of the 24-h urine was completed, the study staff was asked to confirm the total urine volume, and the participants were asked to confirm the missed volume. The urine collections were discarded if the 24-h urine specimens had a total capacity less than 250 ml, or if the patient missed two or more spot urine voids during the 24-h urine collection period.

The capacity of the 24-h urine, the U_{Na} and urinary potassium (U_K) concentrations of the 24-h urine and the morning voiding urine sample were measured. Both the 24-h urine sample and spot urine were tested within 2 h after collection at the central laboratory. The urine sample was frozen at −20 °C if the specimen could not be analyzed the day of urine collection. The U_{Na} and U_K concentrations from the 24-h urine and morning voiding urine sample were tested using specific ion electrode methods using the HITACHI 7600-020 auto-biochemistry clinical analyzer (Hitachi, Tokyo, Japan), and urinary creatinine (U_{Cr}) was tested using the sarcosine oxidase method.

Actual U_{Na} excretion was calculated from the 24-h urine sample according to the total 24-h urine volume and the average ion concentrations of 24-h urine. The ion concentration of the morning voiding urine was used to calculate the estimated excretion of the 24-h U_{Na} via the five formulas: Kawasaki, Tanaka, INTERSALT, Mage, and Uechi (Table 1). The participants were divided into three subgroups based on actual U_{Na} excretion: the lower salt intake subgroup ($U_{Na} \leq$ 2.36 g/day, salt ≤ 6.00 g/day), moderate salt intake subgroup (2.36 < $U_{Na} \leq$ 4.72 g/day, 6.00 < salt ≤ 12.00 g/day), and higher salt intake subgroup (4.72 g/day < U_{Na}, 12.00 g/day < salt) according to an expert recommendation on salt intake and blood pressure management in Chinese patients with hypertension [13]. The performance of the five formulas was compared across sex and salt intake subgroups.

Statistical analysis

Continuous variables were described as mean ± standard deviation (SD), whereas categorical variables were

TABLE 1. Five methods to estimate 24-h urinary sodium excretion

Equation name	Equation to predict 24-h urinary Na excretion(mg/d)
Kawasaki	$23 \times 16{\cdot}3 \times \{[\text{spot Na (mmol/l)/spot Cr (mg/dl)} \times 10] \times \text{PreCr (mg/day)}\}^{0.5}$
Men	$\text{PreCr (mg/day)} = [15.12 \times \text{weight (kg)}] + [7.39 \times \text{height (cm)}] + [-12.63 \times \text{age (years)}] - 79.9$
Women	$\text{PreCr (mg/day)} = [8.58 \times \text{weight (kg)}] + [5.09 \times \text{height (cm)}] + [-4.72 \times \text{age (years)}] - 74.95$
Tanaka	$23 \times 21.98 \times \{[\text{spot Na (mmol/l)/spot Cr (mg/dl)} \times 10] \times \text{PreCr (mg/day)}\}^{0.392}$
	$\text{PreCr (mg/day)} = [-2.04 \times \text{age (years)}] + [14.89 \times \text{weight (kg)}] + [16.14 \times \text{height (cm)}] - 2244.45$
Intersalt	
Men	$23 \times \{23.51 + [0.45 \times \text{spot Na (mmol/l)}] - [3.09 \times \text{spot Cr (mmol/l)}] + [4.16 \times \text{BMI (kg/m}^2\text{)}] + [0.22 \times \text{age (years)}]\}$
Women	$23 \times \{3.74 + [0.33 \times \text{spot Na (mmol/l)}] - [2.44 \times \text{spot Cr (mmol/l)}] + [2.42 \times \text{BMI (kg/m}^2\text{)}] + [2.34 \times \text{age (years)}] - [0.03 \times \text{age}^2\text{ (years)}]\}$
Mage	$23 \times [\text{spot Na (mmol/l)/spot Cr (mg/dl)} \times 10] \times \text{PreCr (mg/day)}$
Men	$\text{PreCr (mg/day)} = 0.00179 \times [140 - \text{age (years)}] \times [\text{weight (kg)}^{1.5} \times \text{height (cm)}^{0.5}] \times [1 + 0.18 \times A \times [1.366 - 0.0159 \times \text{BMI (kg/m}^2\text{)}]$
Women	$\text{PreCr (mg/day)} = 0.00163 \times [140 - \text{age (years)}] \times [\text{weight (kg)}^{1.5} \times \text{height (cm)}^{0.5}] \times [1 + 0.18 \times A \times [1.429 - 0.0198 \times \text{BMI (kg/m}^2\text{)}]$
Uechi	$23 \times [\text{spot Na (mmol/l)/spot Cr (mmol/l)}] \times \text{PreCr (mmol/day)}$
Men	$\text{PreCr (mmol/day)} = 2.78 + [0.139 \times \text{age (years)}] - [0.002 \times \text{age}^2\text{ (years)}] + [0.127 \times \text{weight (kg)}] + [0.157 \times \text{height (cm)}] - 2.78$
Women	$\text{PreCr (mmol/day)} = [0.139 \times \text{age (years)}] - [0.002 \times \text{age}^2\text{ (years)}] + [0.127 \times \text{weight (kg)}] + [0.157 \times \text{height (cm)}] - 2.78$

PreCr, predicted 24-h urinary creatinine excretion, where A is African American or black race = 1, other race = 0. The molecule weight of Na is 23 mg/mmol.

TABLE 2. Characteristics of participants[a]

	All	Men	Women
Sample size [*n* (%)]	1154 (100)	623 (54)	531 (46)
Age (years)	55.6 ± 14.19	52.60 ± 14.21	59.43 ± 13.28
Height (cm)	168.54 ± 8.70	174.75 ± 5.96	161.25 ± 4.94
Weight (kg)	75.06 ± 14.12	82.15 ± 12.61	66.74 ± 10.90
BMI (kg/m^2)	26.28 ± 26.28	26.83 ± 3.31	25.64 ± 3.82
eGFR (ml/min per 1.73 m^2)	114.77 ± 25.81	111.74 ± 23.51	118.31 ± 27.89
24-h Urine sample			
Sodium concentration (mmol/l)	91.46 ± 41.92	100.32 ± 43.35	81.06 ± 37.63
Urine volume (ml)	1576.00 ± 695.88	1551.61 ± 699.25	1604.61 ± 691.47
Spot urine			
Spot urine creatinine (mmol/l)	9.82 ± 4.92	11.28 ± 5.00	8.12 ± 4.23
Spot urine sodium (mmol/l)	121.94 ± 16.74	125.43 ± 49.29	117.84 ± 45.82
Blood pressure			
SBP_{24H} (mmHg)	140.38 ± 15.92	143.89 ± 16.77	136.27 ± 13.80
Diastolic BP_{24H} (mmHg)	86.16 ± 12.67	89.95 ± 12.97	81.71 ± 10.74
Mean BP_{24H} (mmHg)	104.43 ± 12.83	107.36 ± 13.58	100.98 ± 10.94

SBP_{24H}, DBP_{24H}, mean BP_{24H} indicate average of SBP, DBP, and MBP values over 24 h.
[a]Values are means ± SDs unless otherwise stated.

described as proportions (%). The estimated value was evaluated by examining biases and Bland–Altman plots between the five methods. The intraclass correlation coefficient (ICC) was used to evaluate the association between actual U_{Na} excretion and estimated U_{Na} excretion. The correlation between the averages and differences of the estimated and measured 24-h U_{Na} excretion were evaluated by Pearson correlation coefficients. Furthermore, the relative difference and absolute differences were analyzed at the individual level, where the relative difference was calculated as [(estimated − measured)/measured × 100] and the absolute differences was calculated as [absolute of (estimated − measured)]. $P = 0.05$ or less was considered significant for the statistical analysis. All statistical tests were conducted using IBM SPSS software, version 23.0.

RESULTS

There were more men (54%) than women in the study group, and the average age was 55.6 ± 14.19 years. The mean sodium concentration of the 24-h urine was 91.46 ± 41.92 mmol/l, whereas the male participants had an average of 100.32 ± 43.35 mmol/l, which was higher than that of the female participants (81.06 ± 37.63 mmol/l). Similarly, the mean sodium concentration of the spot urine in the whole population was 121.94 ± 16.74 mmol/l, whereas the average sodium concentration of the spot urine sodium in the male population (125.43 ± 49.29 mmol/l) was higher than that in the female population (117.84 ± 45.82 mmol/l) (Table 2).

The average excretion of U_{Na} was 2.97 ± 1.26 g/day, which was equivalent to 7.54 ± 3.20 g/day of salt intake. The mean actual U_{Na} excretion of the male participants was 3.20 ± 1.23 g/day (salt 8.13 ± 3.12 g/day), which was higher than that of the female participants (sodium 2.70 ± 1.24 g/day, salt 6.86 ± 3.15 g/day) (Table 3). The least bias of the estimated U_{Na} was 0.31 g/day (95% CI: −2.16 to 2.78 g/day) for the INTERSALT, whereas the largest bias was 1.95 g/day (95% CI: −1.17 to 5.07 g/day) for the Kawasaki. The other formulas' biases for actual U_{Na} were 0.80 g/day for the Mage (95% CI: −4.17 to 5.77 g/day), 0.88 g/day for the Tanaka (95% CI: −1.68 to 3.43 g/day) and 1.14 g/day for the Uechi (95% CI: −3.98 to 6.26 g/day). All five formulas overestimated the U_{Na} excretion when compared with the measured 24-h U_{Na}. The ICC was 0.511 for the Kawasaki, 0.499 for the INTERSALT, 0.468 for the Tanaka, 0.402 for the Mage, 0.378 for the Uechi ($P < 0.05$), which showed that the estimated 24-h U_{Na} excretion values moderately correlated with the measured values (Table 3). The mean differences between the estimated and measured 24-h U_{Na} excretions for the five formulas exhibited large variations in the Bland–Altman plots (Fig. 1). There was no significant difference in the number of patients beyond the 95% confidence interval (CI). So, the accuracy of the INTERSALT method was found to be the best method among the five formulas.

TABLE 3. Differences of five methods to estimate 24-h urinary sodium excretion (g/day)

	24-h urinary sodium excretion			Mean difference				ICC[c] (all)
	All[a]	Men[a]	Women[a]	All[a]	95% CI (all)[b]	Men[a]	Women[a]	
Measured	2.97 ± 1.26	3.20 ± 1.23	2.70 ± 1.24	–	–	–	–	–
Kawasaki	4.92 ± 1.51	5.17 ± 1.56	4.62 ± 1.39	1.95 ± 1.59	−1.17 to 5.07	1.97 ± 1.67	1.92 ± 1.50	0.511
Tanaka	3.85 ± 0.93	3.86 ± 0.93	3.84 ± 0.93	0.88 ± 1.30	−1.68 to 3.43	0.66 ± 1.31	1.14 ± 1.24	0.468
INTERSALT	3.28 ± 0.89	3.87 ± 0.68	2.59 ± 0.56	0.31 ± 1.26	−2.16 to 2.78	0.67 ± 1.23	−0.11 ± 1.16	0.499
Mage	3.77 ± 2.65	4.12 ± 2.88	3.35 ± 2.29	0.80 ± 2.54	−4.17 to 5.77	0.92 ± 2.80	0.65 ± 2.18	0.402
Uechi	4.11 ± 2.71	4.43 ± 2.96	3.73 ± 2.33	1.14 ± 2.61	−3.98 to 6.26	1.23 ± 2.92	1.03 ± 2.20	0.378

[a]Means ± SDs.
[b]95% confidence interval.
[c]Intraclass correlation coefficient.

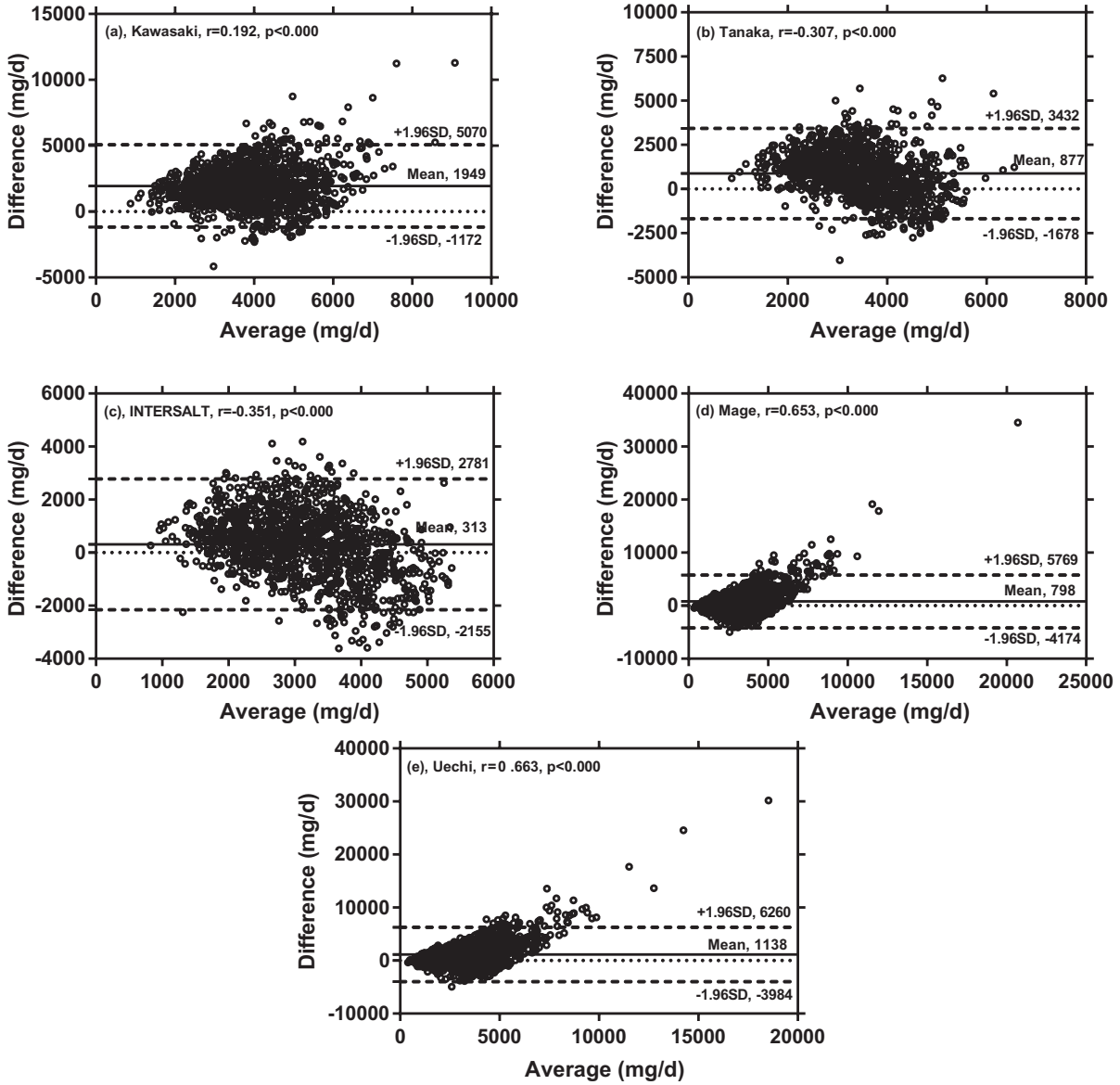

FIGURE 1 Bland–Altman plots showing the mean differences between the measured and estimated 24-h urinary sodium excretions for the Kawasaki (a), Tanaka (b), INTERSALT (c), Mage (d), and Uechi (e) methods. The long solid line represents the mean bias. The short dotted lines represents the level of zero. The two long dotted lines represent the upper/lower limits of agreement (±1.96 SD of mean). Pearson correlation coefficients (*r*) were calculated between the means and differences of the estimated and measured 24-h sodium excretions.

Furthermore, the validity of the five formulas was compared in male and female subgroups. Only the estimated 24-h U_{Na} excretion calculated by the INTERSALT equation underestimated the U_{Na} excretion compared with the actual U_{Na} excretion in the female subgroup. Meanwhile, the estimated 24-h U_{Na} excretion calculated by the five equations overestimated the U_{Na} excretion among the male population. The mean biases between the actual and estimated U_{Na} excretions were lower in the female subgroup than in the male subgroup, with the exception of the Tanaka method. The least bias for the estimated U_{Na} of the male subgroup was 0.66 g/day (salt 1.68 g/day) for the Tanaka, whereas the highest bias was 1.97 g/day (salt 5.0 g/day) for the Kawasaki. Other formulas producing biases in the male population included 0.67 g/day for the INTERSALT (salt 1.70 g/day), 0.92 g/day for the Mage (salt 2.34 g/day), and 1.23 g/day for the Uechi (salt 3.12 g/day). Similarly, the least bias for the estimated U_{Na} of the female subgroup was −0.11 g/day (salt −0.28 g/day) for the INTERSALT, whereas the highest bias was 1.92 g/day (salt 4.88 g/day) for the Kawasaki (Table 3). So, the INTERSALT method was suitable for both the male and female populations in our research.

Participants were divided into three subgroups according to salt intake. The least mean biases in the lower salt intake subgroup and the moderate salt intake subgroup were 1.22 and 0.07 g/day, respectively, and were calculated by the Mage and INTERSALT methods. The least mean bias in the higher salt intake subgroup was 0.10 g/day for the Uechi method (Table 4).

At the individual level, the proportions of the absolute differences in 24-h U_{Na} excretions below 393 mg (1 g salt)

TABLE 4. Mean biases (g/d) of five methods compared with measured urine sodium across subgroups[a]

	No. of participants	Kawasaki	Tanaka	INTERSALT	Mage	Uechi
Low-salt intake ($U_{Na} \leq 2.36$ g/day)	408	2.69 ± 1.44	1.87 ± 0.94	1.27 ± 0.90	1.22 ± 2.11	1.6 ± 2.40
Medium-salt intake ($2.36 < U_{Na} \leq 4.72$ g/day)	622	1.78 ± 1.41	0.60 ± 0.98	0.07 ± 0.92	0.72 ± 2.67	1.04 ± 2.60
High-salt intake (4.72 g/day $< U_{Na}$)	124	0.37 ± 1.57	-0.99 ± 0.98	-1.62 ± 0.89	-0.19 ± 2.84	0.10 ± 0.30

[a]Values are means±SDs, U_{Na}: 24-h urinary sodium excretion

were 7.6% for the Kawasaki, 18.1% for the Tanaka, 22.3% for the INTERSALT, 19.7% for the Mage, and 18.5% for the Uechi; meanwhile, the proportions above 1573 mg (4 g salt) were 59.9, 31.9, 23.0, 35.8, and 39.2%, respectively (Fig. 2a). The proportions of the relative differences within ±10% for the five formulas were 7.6, 16.9, 17.4, 12.3, and 13.2, respectively; the proportions of relative differences beyond ±40% were 69.5, 45.6, 36.6, 49.7, and 51.5%, respectively (Fig. 2b). Overall, the INTERSALT formula may provide the least amount of bias for mean U_{Na} excretion at both the population and individual levels.

DISCUSSION

The results of our study show that all five formulas overestimated the 24-h U_{Na} excretion. The INTERSALT formula was the closest to the actual U_{Na} excretion, and the Kawasaki method exhibited the largest bias.

Our conclusion was differed from previous studies, which demonstrated that the Kawasaki method shows the least bias – whereas the INTERSALT method shows the highest bias – in both the general and hypertensive Chinese populations [14–17]. For example, the Prospective Urban Rural Epidemiology (PURE) study demonstrated that the Kawasaki method performed well. However, there were only 120 hypertensive participants in their study group, whereas our study contained 1154 hypertensive participants. And, the average salt intake was extremely high (16.1 g/day) in the PURE study when compared with our study (7.54 g/day) [14]. Moreover, a salt-reduction program, which contained 141 Chinese community residents, demonstrated that the Kawasaki method exhibited better validity than INTERSALT method. Similarly, the average salt intake was extremely high (12.9 g/day) in their study when compared with our study [15]. Furthermore, we divided our study group into subgroups according to salt intake. In the higher salt intake subgroup, our data showed that the Kawasaki method was better than the INTERSALT method but the least bias was calculated by the Uechi method.

The spot urinary specimens being collected at different time points may affect the performance of the formulas. The morning voiding urine specimen was chosen as spot urine in our study as Kawasaki method used the morning voiding urine specimen. A Chinese population study found that the mean biases of 24-h U_{Na} excretion with the Kawasaki formula were 0.05 and 1.94 g/day when using second morning voiding urine (SMU) and post meridiem (PM) specimens, respectively, which suggested that the validity of the Kawasaki method was greatly influenced by the spot urine specimens collected at different times of the day [17]. Another research found that the Tanaka and Mage methods exhibited the least mean differences for estimating 24-h U_{Na} excretion using overnight specimens, and there was no obvious difference between using the morning, afternoon, evening, and overnight samples when the INTERSALT equation was used [18]. Therefore, we excluded the influence of urine at different time spots on the accuracy of Kawasaki method in our study.

The large mean differences in predicting 24-h U_{Na} excretion with the Kawasaki method in our study might be because of two primary reasons. First, the Kawasaki method was developed based on data from the Japanese population, whereas our data came from a northeast Chinese population. Secondly, the Kawasaki method was developed from data of clinically healthy, free-living individuals who had high-salt intake (12.2 g/day), whereas our study recruited hypertensive hospitalized patients who had relatively low-salt intake (7.54 g/d) [6]. As a consequence, the accuracy of the formulas may be not consistent among different populations as they were developed according to

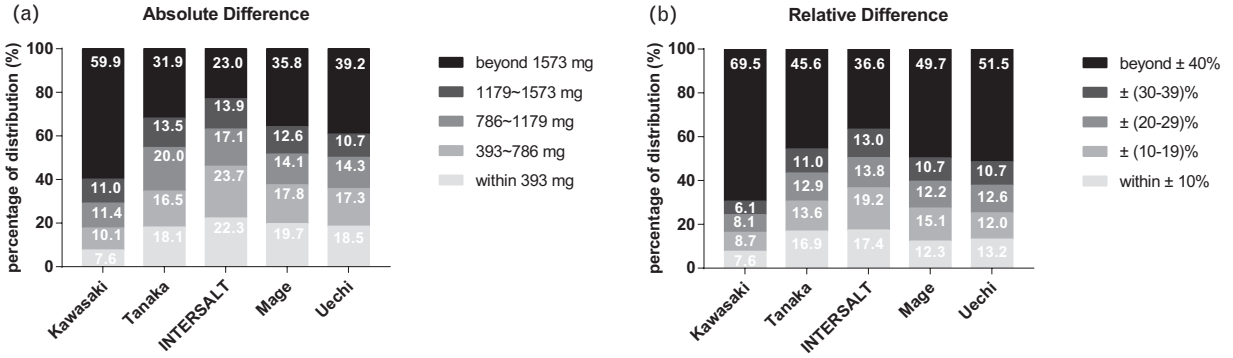

FIGURE 2 (a) Absolute difference distributions of measured and estimated 24-h urinary sodium excretions, absolute difference of urinary sodium excretions within 393, 393–786, 786–1179,1179–1573, and beyond 1573 mg were equivalent to the absolute difference of salt intake within 1, 1–2, 2–3, 3–4, and beyond 4 mg. (b) Relative difference distributions of measured and estimated 24-h urinary sodium excretions.

local concentrations of U_{Na} and U_{Cr} in the spot urine as well as gender, age, stature, weight, and BMI parameters.

Furthermore, the Kawasaki method was created by a series of hypotheses, the first of which states that the value of actual 24-h U_{Cr} excretion and predicted 24-h U_{Cr} excretion are approximately equal and the second of which states that the ratio of U_{Na} to U_{Cr} in 24-h urine is directly proportional to the ratio of U_{Na} to U_{Cr} in spot urine [6]. Conversely, the INTERSALT formula was directly created by regression models instead of a number of hypotheses [6,8,9].

There has also been data showing that the INTERSALT method performed well than Kawasaki method. In the Salt Substitute and Stroke Study contained a subgroup of 807 older hypertensive participants, it was found that the Kawasaki significantly overestimated 24-h U_{Na} excretion by 40.18 g/day (salt 102.06 g/day) and that the INTERSALT (U_{Na} mean bias: −0.07 g/day, salt 0.18 g/day) could be a more reliable option for predicting the level of salt intake in the hypertensive population [19]. The average 24-h U_{Na} excretions were approximately equal between the Salt Substitute and Stroke Study and our study (3.03 ± 1.52 vs. 2.97 ± 1.26 g/day), and all participants were hypertensive patients in both studies, which may help explain the consistency of the results [19]. In addition, the Shandong-Ministry of Health Action on Salt and Hypertension (SMASH) project study showed that the least bias of estimated U_{Na} was 0.06 g/day for the Tanaka method, the bias was 0.62 g/day for the INTERSALT method, whereas the largest bias was 1.35 g/day for the Kawasaki method. From this study, we conclude that INTERSALT method was also better than Kawasaki method in ordinary people as the SMASH project study recruited 1671 ordinary residents. But in ordinary people, Tanaka method performed better than other method, whereas in our study, we also found that Tanaka method was reliable in female hypertensive patients [20].

For relative differences within 10%, our results were lower than those in previously conducted studies in Chinese adults (Kawasaki: 7.6 vs. 25.5%; INTERSALT: 17.4 vs. 11.3%). Additionally, for relative differences beyond ±40%, our results were higher than in previous studies (Kawasaki: 69.5 vs. 31.2%; INTERSALT: 36.6 vs. 41.1%). Similar results were also acquired for the absolute difference distributions [15]. Large sample size and a comparatively large variation in 24-h U_{Na} excretion may be reasons to explain the lower performance of the absolute difference and relative difference distributions in our study population.

Kawasaki method may be suitable for high-salt intake population. But, salt intake has been significantly reduced in recent years with improvements in the healthy consciousness of patients globally. The validity of these formulas should to be reassessed or a more valid method should be developed.

The findings of our study are limited to patients with hypertension. Thus, the generalizability of these results to healthy populations remains unknown. Secondly, the data in our study was limited to one province of China. We did not have enough data to assess whether the five methods were suitable for other provinces in China.

In conclusion, a morning voiding urine sample may be a valid low-burden, low-cost alternative for the estimation of mean population salt intakes. Specifically, the INTERSALT method may exhibit a good performance in terms of mean 24-h sodium estimation for the hypertensive population living in northeast China.

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Conflicts of interest

There are no conflicts of interest.

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