

# Validation of 4 Estimating Methods to Evaluate 24-hour Urinary Sodium Excretion for Young Adults in China by Different Seasons

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## Research

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# Abstract

**Background:** 24-hour urine sample collection is regarded as the gold standard for sodium intake evaluation, but the implementation can be difficult. To validate and evaluate the accuracy and feasibility of estimating sodium intake by four methods of Kawasaki, INTERSALT, Tanaka and Sun's equations.

**Methods:** 274 healthy volunteers aged 18-25y were enrolled in this study. 24-hour urine samples as well as timed (morning, afternoon, evening and overnight) urine samples were randomly collected. The sodium intake were estimated by 4 published equations—Kawasaki, INTERSALT Tanaka and Sun's. The consistencies between estimated sodium intake and real measured values of 24-hour urine sodium excretion were compared by Bland-Altman plots in each of the methods. Taking the variability of sodium excretion in different seasons into account, this study was conducted separately in summer (end of June 2017) and fall (end of November 2017).

**Results:** The 24-h urinary sodium analysis result indicated an average daily sodium intake of  $3043.0 \pm 1223.3$ mg in summer, and  $3563.7 \pm 1370.0$ mg in the fall. Compared with autumn, the average daily reduction in sodium was about 520.7 mg. From the group level, the mean bias (estimated value - measured value) of the INTERSALT method with morning specimens (-39.7 mg ) was the smallest in summer. The mean bias of Tanaka method for prediction of morning specimens (-149.8 mg ) was the smallest in autumn. For the individual level, the correlation between 24-hour urinary sodium excretion and Sun's methods was low, with a correlation coefficient of 0.406 in summer and 0.476 in the fall. Correlation coefficients between Kawasaki, INTERSALT, Tanaka methods and 24-hour urinary sodium excretion, respectively was in the range of 0.48-0.64. The correlation coefficient of Kawasaki method was the highest in summer (0.612) while that of Tanaka method with the afternoon specimens was the highest in the autumn (0.635).

**Conclusions:** Estimation of sodium intakes among young adults using the 4 methods have varying degrees of bias and volatility in different times and seasons.

## Introduction

With the development of the economy, the number of patients with cardiovascular disease (CVD) is growing rapidly. Hypertension is a major cause of cardiovascular disease, and high-sodium intake is closely related to hypertension [1, 2]. Evidence shows that moderate reduction in sodium consumption can reduce the incidence of cardiovascular disease and medical costs [3]. Studies have shown that high sodium diet is a risk factor for kidney disease, osteoporosis, and even gastric cancer [4, 5]. Therefore, reducing sodium intake has become an important measure to prevent and control non-communicable diseases worldwide [6].

The World Health Organization (WHO) recommends that adults consume less than 5 g of salt (or 2 g of sodium) per day [7]. The Chinese Nutrition Society recommends that the daily intake of salt in Chinese

adults should not exceed 6 g [8]. However, the average daily intake of salt in China is approximately 10.5 g/day/person [9], which is far more than the recommended value.

There are several methods for estimating salt intake, including dietary survey, 24-h urine collection and casual (spot) urine sodium measurements. The sodium intake is mainly excreted by the kidneys, so 24-h urine collection is considered as the gold standard for estimating salt or sodium intake [10–14]. This method is relatively accurate and reliable. However, it brings psychological burden to the participants and also has difficulties in ensuring the sample integrity. Therefore, there are certain limitations in practical applications. Dietary survey tends to underestimate the actual salt intake because of the emergence of more and more processed food and eating out of home. Indeed, the amount of salt added in a meal when eating out is unknown. People even don't know the amount of salt they added during cooking or at the table. Recently, some scholars have created the "One-Week Salt Estimation Method", which is easy to operate and useful in identifying the sources of salt in the diet [15]. However, this study still had an underestimation of salt intake. Furthermore, the method lasts for a whole week and is poorly compliant for most families, making it difficult to be promoted to the whole population as a method to estimate salt intake. Relatively, collecting a spot or casual urine specimen is convenient. In previous studies, some predictive equations were developed to estimate population mean and individual 24-h urinary sodium excretion, of which the most common methods were Kawasaki, INTERSALT and Tanaka [16–18]. There's also one estimation method created by Ningling Sun et al, Chinese researchers [19], we call it Sun's method here.

The purpose of our study is to validate and evaluate the accuracy and feasibility of estimating sodium intake by these approaches. In addition, considering the large difference in the amount of perspiration in different seasons, it may lead to deviations in the estimation results. Therefore, this study conducted a comparative study in summer and autumn to estimate the calculated deviation of sodium intake caused by perspiration in college students.

## **Materials And Methods**

### **Participants**

A cross-sectional survey was conducted in June and November respectively. 274 healthy volunteers aged from 18 to 25 years old from Hebei Medical University were enrolled in this study. Our study has been approved by Human Trial Ethic Inspection Committee, National Institute for Nutrition and Health, Chinese Center for Disease and Prevention. All participants provided written informed consent in this study. Our inclusion criteria was: (1) Willing and insisting on completing the survey in two seasons-summer and autumn; (2) Willing and able to collect 24-h urine; (3) For women, not be in menstruation (if in the menstrual period, postpone 24-hour urine collection until the end of the menstrual period); (4) Avoiding strenuous exercise during the urine collection period; and (5) The data collected should be complete.

### **Data Collection**

We collected the common information through questionnaire, including name, student ID, age and gender. Height, weight, waist circumference (WC) and blood pressure (BP) were measured in all participants. Then the spot time and 24-hour urine samples were collected.

## **24-hour urine collection and measurements**

All participants were given verbal instructions to collect 24-hour urine samples. Each time the urine was collected separately in standard containers, and the participant recorded the name, student number and the time of the collection, then put it to the special location. The first urine of the day was discarded and all urine over the following 24 hours were collected. The spot urine samples were as follows: morning (8–12 o'clock), afternoon (12–18 o'clock), evening (18–24 o'clock), overnight (the first urine sample in the next morning). 4 spot time urine samples were randomly selected. Then a 2 mL aliquot was taken from each of them. Finally, all urine from the same participant were carefully mixed. Total volume of the collection were measured (including the 8 mL we took before), and a 2 mL aliquot was taken. All of the urine samples were stored in a -4 °C refrigerator. Every afternoon, employees from Kingmed Diagnostics took them away, and stored in a freezer at -80 °C for testing. Urine sodium (Na), potassium (K) and creatinine (Cr) were tested. If the urine volume < 500 mL, the collection time < 20 h, or more than one time missing or large overflow, the 24-h urine sample was invalid [20].

## **Estimation of 24-h sodium excretion from spot urine samples**

Measured 24-h urinary sodium excretion (using 24-h urine sample) was calculated as follows: the sodium concentration (mmol/L) × total volume (L/day) × molecular weight of Na<sup>+</sup> (23 Na<sup>+</sup>). Predictive 24-h urinary sodium excretion from spot urinary sodium concentration were used 4 previously published equations—Kawasaki, INTERSALT, Tanaka and Sun's method. These predictive equations are listed in Table 1.

Table 1

Predictive equations for 24-h sodium excretion based on single spot urinary sodium concentrations

| Method  | Urine sample                                 | Predictive equation for 24-h sodium excretion   |
|---|--|---|
| Kawasaki  | The second morning urine sample <sup>1</sup> | <p>Estimated sodium (mEq /day) = <math>16.3 \times [\text{spot Na (mEq/L)}/\text{spot Cr (mg/dL} \times 10) \times \text{Pr24 hCr (mg/day)}]^{0.500}</math></p> <p>Male: Pr24 hCr (mg/day) = <math>15.12 \times \text{weight (kg)} + 7.39 \times \text{height (cm)} - 12.63 \times \text{age (years)} \pm 79.9</math></p> <p>Female: Pr24 hCr (mg/day) = <math>8.58 \times \text{weight (kg)} + 5.09 \times \text{height (cm)} - 4.72 \times \text{age (years)} \pm 74.95</math></p>  |
| INTERSALT   | Spot urine sample                            | <p>Male: 24 h Estimated sodium (mg/day) = <math>23 \times [25.46 + 0.46 \times \text{spot Na (mmol/L)} - 2.75 \times \text{spot Cr (mmol/L)} \pm 0.13 \times \text{spot K (mmol/L)} + 4.10 \times \text{BMI (kg/m}^2) + 0.26 \times \text{age (years)}]</math></p> <p>Female: 24 h Estimated sodium (mg/day) = <math>23 \times [5.07 + 0.34 \times \text{spot Na (mmol/L)} - 2.16 \times \text{spot Cr (mmol/L)} \pm 0.09 \times \text{spot K (mmol/L)} + 2.39 \times \text{BMI (kg/m}^2) + 2.35 \times \text{age (years)} \pm 0.03 \times \text{age (years)}^2]</math></p>   |
| Tanaka  | Spot urine sample                            | <p>24 h Estimated sodium (mg/day) = <math>23 \times 21.98 \times \{ \text{spot Na (mEq/L)} / [\text{spot Cr (mg/ dL)} \times 10] \times \text{Pr24 hCr (mg/day)}\}^{0.392}</math></p> <p>Pr24hCr (mg/day) = <math>14.89 \times \text{weight (kg)} + 16.14 \times \text{height (cm)} - 2.04 \times \text{age (years)} \pm 244.45</math></p>  |
| Sun's   | Afternoon spot urine sample                  | <p>Male: 24 h Estimated sodium (mg/day) = <math>0.208 \times \text{Pr24hCr (mg/day)} \times [\text{spot Na (mmol/L)} / \text{spot Cr (mg/ L)}]^{0.300} \times 23</math></p> <p>Pr24hCr (mg/day) = <math>e^{6.916 - 0.007 \times \text{age (years)} - 0.002 \times \text{height (cm)} + 0.013 \times \text{weight (kg)}}</math></p> <p>Female: 24 h Estimated sodium (mg/day) = <math>0.329 \times \text{Pr24hCr (mg/day)} \times [\text{spot Na (mmol/L)} / \text{spot Cr (mg/ L)}]^{0.463} \times 23</math></p> <p>Pr24hCr (mg/day) = <math>e^{7.210 - 0.013 \times \text{age (years)} - 0.002 \times \text{height (cm)} + 0.010 \times \text{weight (kg)}}</math></p> |
| <sup>1</sup> We used the overnight urine sample instead of the second morning urine sample in this study. |  |   |

Pr24hCr, predicted 24-h urine creatinine excretion.

BMI, body mass index.

## Statistical analysis

We used SPSS 21.0 for data analysis. Continuous variables were described by mean  $\pm$  standard deviation. Paired *t*-test was used for comparison between measured values by 24-h urine collection in summer and autumn. The group bias in predicted 24-h urine excretion was calculated as the difference of estimated values and measured values for each participant; then, mean of these differences was

calculated. We used Bland-Altman plot to illustrate the relative individual differences between estimated values and measured values by 24-h urine collection. Pearson correlation was used to describe correlation. Two-sided  $P < 0.05$  was considered statistically significant.

## Results

### Basic Characteristics

Not everyone's 24-h urine collection is valid. A total of 272 participants (141 men and 131 women) completed 24-h urine collection in summer. Not all participants urinated during each time period, 220 voided in the morning, 261 in the afternoon, 267 in the evening and 272 overnight. A total of 270 participants (139 men and 131 women) completed 24-h urine collection in autumn, among which 241 voided urine in the morning. All of them urinated during other time periods. The baseline characteristics of the participants are shown in Table 2.

Table 2  
The distribution of participants' physical measurement indexes by sex

|   | <b>Total</b><br><b>(n = 274)</b> | <b>Men</b><br><b>(n = 142)</b> | <b>Women</b><br><b>(n = 132)</b> |
|---|----------------------------------|--------------------------------|----------------------------------|
| Number n(%)   | 274(100)                         | 142(51.8)                      | 132(48.2)                        |
| Age (year)  | 19.9 ± 1.8                       | 20.2 ± 1.9                     | 19.5 ± 1.6                       |
| Weight (kg)   | 61.9 ± 13.5                      | 68.9 ± 13.4                    | 54.3 ± 8.5                       |
| Height (cm)   | 166.8 ± 8.7                      | 172.8 ± 6.3                    | 160.4 ± 5.9                      |
| WC (cm)   | 73.4 ± 10.4                      | 78.6 ± 10.2                    | 67.7 ± 7.0                       |
| BMI (kg/m <sup>2</sup> )                                      | 22.1 ± 3.8                       | 23.1 ± 4.3                     | 21.1 ± 2.7                       |
| SBP1 (mmHg)   | 114.9 ± 14.0                     | 123.3 ± 12.5                   | 105.9 ± 9.1                      |
| DBP (mmHg)  | 74.4 ± 8.2                       | 77.0 ± 8.7                     | 71.6 ± 6.6                       |
| Heart rate (bpm)  | 79.9 ± 13.2                      | 78.7 ± 12.9                    | 81.3 ± 13.4                      |
| 1SBP, systolic blood pressure; DBP, diastolic blood pressure. |                                  |                                |                                  |

### The variability of 24-hour urine collection in different seasons

The measured values of 24-hour urine collection are shown in Table 3. The urinary sodium excretion of the participants was  $3043.0 \pm 1223.3$  mg/day in summer and was  $3563.7 \pm 1370.0$  mg/day in autumn. This was equivalent to a salt intake of  $7.8 \pm 3.1$  g/day in summer and  $9.1 \pm 3.5$  g/day in autumn. The

difference between the two seasons was statistically significant ( $P < 0.001$ ). According to the survey in autumn, 80.4% of college students' salt intake exceeded the Chinese Nutrition Society recommended amount of 6 g/day.

Table 3  
Results of 24-hour urine measurement and water intake of college students by season

|                                | Summer          | Autumn          | t       | P       |
|--------------------------------|-----------------|-----------------|---------|---------|
| Urinary volume (mL)            | 1331.6 ± 650.3  | 1585.1 ± 654.3  | 6.124   | < 0.001 |
| Sodium excretion (mg/d)        | 3043.0 ± 1223.3 | 3563.7 ± 1370.0 | 30.388  | < 0.001 |
| Potassium excretion (mg/d)     | 1003.1 ± 362.7  | 1113.4 ± 357.2  | -25.803 | < 0.001 |
| Creatinine excretion (mg/d)    | 1283.9 ± 420.0  | 1296.2 ± 411.2  | 0.466   | 0.642   |
| Sodium-Potassium ratio (mg/mg) | 3.2 ± 1.3       | 3.4 ± 1.4       | 1.580   | 0.115   |

## Bias between mean measured and predicted 24-h urinary sodium excretions (from group levels)

Mean predicted 24-h urinary sodium excretion varied by prediction equation, the time of spot urine collection, season and sex (Table 4, Table 5).

In summer (Table 4, Fig. 1), mean bias (predicted value-measured value) with the Kawasaki equation was 891.1 mg (95% *Ci*: 769.9, 1012.4 mg). Using the INTERSALT equation, mean bias was -169.9 mg (95% *Ci*: -312.5, -27.3 mg) in the morning, -39.7 mg (95% *Ci*: -164.7, 85.3 mg) in the afternoon, -43.5 mg (95% *Ci*: -166.4, 79.5 mg) in the evening, -412.1 mg (95% *Ci*: -534.6, -289.7 mg) overnight. With the Tanaka equation, mean bias was 458.5 mg (95% *Ci*: 321.0, 596.0 mg) in the morning, 623.0 mg (95% *Ci*: 498.0, 747.9 mg) in the afternoon, 550.2 mg (95% *Ci*: 426.2, 674.2 mg) in the evening, -66.4 mg (95% *Ci*: -534.6, -289.7 mg) overnight. Using Sun's equation, mean bias was 829.9 mg (95% *Ci*: 681.7, 978.0 mg). The bias was the smallest with the INTERSALT equation with the afternoon samples (-39.7 mg). Meanwhile, the Kawasaki equation had the biggest bias of 891.1 mg.

In autumn (Table 5, Fig. 2), mean bias with the Kawasaki equation was 163.7 mg (95% *Ci*: 16.2, 311.2 mg). Using the INTERSALT equation, mean bias was -554.7 mg (95% *Ci*: -692.0, -417.3 mg) in the morning, -418.3 mg (95% *Ci*: -551.7, -284.9 mg) in the afternoon, -413.1 mg (95% *Ci*: -546.2, -280.6 mg) in the evening, -1046.7 mg (95% *Ci*: -1186.3, -907.1 mg) overnight. With the Tanaka equation, mean bias was 149.8 mg (95% *Ci*: 13.0, 286.5 mg) in the morning, 543.2 mg (95% *Ci*: 416.4, 670.0 mg) in the afternoon, 377.2 mg (95% *Ci*: 247.8, 506.5 mg) in the evening, -697.8 mg (95% *Ci*: -841.7, -553.8 mg) overnight. Using Sun's equation, mean bias was 746.6 mg (95% *Ci*: 595.9, 897.3 mg). The bias was the smallest with the Tanaka equation with the morning samples (149.8 mg). Meanwhile, the INTERSALT equation had the biggest bias of -1046.7 mg. The Sun's equation still had the big bias of 746.6 mg, second to the former one.

# Relative individual differences in predicted and measured 24-h urinary sodium excretion

Bland-Altman plots shows the relative individual differences between estimated values and measured values by 24-h urine collection. Figure 1 and Fig. 2 indicates good agreement between predicted and measured values.

For individuals, in the summer survey, with the INTERSALT equation, predicted 24-h urinary sodium excretion of 12 cases (5.5%) exceeded the consistency boundary ( $\pm 1.96S$ ) with the morning samples, 12 cases (4.6%) with the afternoon samples, 13 cases (4.7%) with the evening samples, 12 cases (4.4%) with the overnight samples. Using the Tanaka equation, predicted 24-h urinary sodium excretion of 10 cases (4.5%) exceeded the consistency boundary with the morning samples, 15 cases (5.7%) with the afternoon samples, 15 cases (5.6%) with the evening samples, 12 cases (4.4%) with the overnight samples. When using the Kawasaki equation to predict 24-h urinary sodium excretion with overnight samples, 15 cases (5.5%) exceeded the consistency boundary. 13 cases (5.0%) exceeded the consistency boundary with the Sun's equation with the afternoon samples. In the autumn survey, with the INTERSALT equation, predicted 24-h urinary sodium excretion of 16 cases (6.7%) exceeded the consistency boundary with the morning samples, 12 cases (4.5%) with the afternoon samples, 13 cases (4.9%) with the evening samples, 13 cases (4.8%) with the overnight samples. Using the Tanaka equation, predicted 24-h urinary sodium excretion of 15 cases (6.3%) exceeded the consistency boundary with the morning samples, 12 cases (4.5%) with the afternoon samples, 15 cases (5.6%) with the evening samples, 11 cases (4.1%) with the overnight samples. When using the Kawasaki equation to predict 24-h urinary sodium excretion with overnight samples, 14 cases (5.3%) exceeded the consistency boundary. 13 cases (4.8%) exceeded the consistency boundary with the Sun's equation with the afternoon samples.

From Fig. 1 and Fig. 2, we can also find that the difference in predicted and measured 24-h urinary sodium excretion had a consistent trend. Overestimation appears to occur at low levels of 24-h sodium excretion and underestimation at high levels.

## Individual correlations with measured 24-h urinary sodium excretion

We compared the spot urine collections at all four times in two seasons with measured 24-h sodium excretions. The correlations were from 0.406 to 0.635 (Table 4, Table 5). The correlation between 24-hour urinary sodium excretion and Sun's methods was low, with a correlation coefficient of 0.406 in summer and 0.476 in the fall. Correlation coefficients between Kawasaki, INTERSALT, Tanaka methods and 24-hour urinary sodium excretion, respectively was in the range of 0.52–0.64, except the prediction of overnight samples with Tanaka method in the fall (0.476). The correlation coefficient of Kawasaki method was the highest in summer (0.612) while that of Tanaka method with the afternoon samples was the highest in the autumn (0.635).

Table 4

Comparison of the average level of daily sodium intake estimated by the four methods with the actual measured values in summer

|                                | <b>Total<br/>(mg/d)</b> | <b>Men<br/>(mg/d)</b> | <b>Women<br/>(mg/d)</b> | <b>Predicted value-<br/>measured<br/>value(95%CI)<br/>(mg/d)</b> | <b><i>r</i></b> | <b><i>P</i></b> |
|--------------------------------|-------------------------|-----------------------|-------------------------|--|-----------------|-----------------|
| Measured 24-h sodium excretion | 3043.0 ± 1223.3         | 3372.5 ± 1304.4       | 2688.3 ± 1201.1         | Reference  | —               | —               |
| Kawasaki                       | 3934.2 ± 1058.5         | 4278.3 ± 1112.6       | 3563.7 ± 858.0          | 891.1<br>(769.9, 1012.4)   | 0.612           | < 0.001         |
| INTERSALT                      |                         |                       |                         |  |                 |                 |
| Morning                        | 2934.9 ± 775.7          | 3387.0 ± 689.8        | 2535.3 ± 528.5          | -169.9<br>(-312.5, -27.3)  | 0.537           | < 0.001         |
| Afternoon                      | 3025.7 ± 801.0          | 3940.5 ± 752.5        | 2535.3 ± 504.0          | -39.7<br>(-164.7, 85.3)  | 0.557           | < 0.001         |
| Evening                        | 3016.7 ± 791.7          | 3462.0 ± 748.4        | 2547.4 ± 518.9          | -43.5<br>(-166.4, 79.5)  | 0.559           | < 0.001         |
| Overnight                      | 2630.9 ± 771.4          | 2983.0 ± 824.6        | 2251.8 ± 478.3          | -412.1<br>(-534.6, -289.7)                                       | 0.551           | < 0.001         |
| Tanaka                         |                         |                       |                         |  |                 |                 |
| Morning                        | 3563.4 ± 712.2          | 3678.6 ± 689.6        | 3441.7 ± 718.6          | 458.5<br>(321.0, 596.0)  | 0.577           | < 0.001         |
| Afternoon                      | 3688.4 ± 739.1          | 3720.4 ± 722.5        | 3654.6 ± 757.5          | 623.0<br>(498.0, 747.9)  | 0.552           | < 0.001         |
| Evening                        | 3610.3 ± 676.6          | 3682.4 ± 685.7        | 3534.3 ± 660.9          | 550.2<br>(426.2, 674.2)  | 0.541           | < 0.001         |
| Overnight                      | 2976.6 ± 626.8          | 3038.6 ± 653.7        | 2909.8 ± 591.9          | -66.4<br>(-186.3, 53.4)  | 0.574           | < 0.001         |
| Sun's                          | 3895.3 ± 966.5          | 3768.7 ± 938.6        | 4028.8 ± 981.2          | 829.9<br>(681.7, 978.0)  | 0.406           | < 0.001         |

Table 5

Comparison of the average level of daily sodium intake estimated by the four methods with the actual measured values in autumn

|   | <b>Total<br/>(mg/d)</b> | <b>Men<br/>(mg/d)</b> | <b>Women<br/>(mg/d)</b> | <b>Predicted value-measured<br/>value(95%CI)<br/>(mg/d)</b> | <i>r</i> | <i>P</i>   |
|---|-------------------------|-----------------------|-------------------------|---|----------|------------|
| Measured<br>24-h<br><br>sodium<br>excretion | 3563.7 ±<br>1370.0      | 4034.0 ±<br>1354.6    | 3062.3 ±<br>1190.6      | Reference   | —        | —          |
| Kawasaki                                    | 3726.3 ±<br>1086.9      | 4160.9 ±<br>1141.6    | 3265.1 ±<br>803.0       | 163.7<br><br>(16.2, 311.2)                                  | 0.515    | <<br>0.001 |
| INTERSALT                                   |                         |                       |                         |   |          |            |
| Morning                                     | 3084.7 ±<br>863.2       | 3591.6 ±<br>788.6     | 2519.1 ±<br>546.7       | -554.7<br><br>(-692.0, -417.3)                              | 0.596    | <<br>0.001 |
| Afternoon                                   | 3144.3 ±<br>808.3       | 3583.6 ±<br>775.1     | 2678.1 ±<br>537.4       | -418.3<br><br>(-551.7, -284.9)                              | 0.579    | <<br>0.001 |
| Evening                                     | 3149.2 ±<br>831.0       | 3665.0 ±<br>689.0     | 2601.8 ±<br>0570.3      | -413.1<br><br>(-546.2, -280.6)                              | 0.584    | <<br>0.001 |
| Overnight                                   | 2515.9 ±<br>755.1       | 2673.7 ±<br>854.3     | 2340.2 ±<br>595.8       | -1046.7<br><br>(-1186.3, -907.1)                            | 0.522    | <<br>0.001 |
| Tanaka                                      |                         |                       |                         |   |          |            |
| Morning                                     | 3753.1 ±<br>830.3       | 4011.4 ±<br>816.6     | 3501.2 ±<br>766.5       | 149.8<br><br>(13.0, 286.5)                                  | 0.599    | <<br>0.001 |
| Afternoon                                   | 4105.8 ±<br>782.6       | 4196.7 ±<br>751.2     | 4009.3 ±<br>806.2       | 543.2<br><br>(416.4, 670.0)                                 | 0.635    | <<br>0.001 |
| Evening                                     | 3939.7 ±<br>745.1       | 4016.9 ±<br>663.3     | 3857.8 ±<br>817.8       | 377.2<br><br>(247.8, 506.5)                                 | 0.616    | <<br>0.001 |
| Overnight                                   | 2864.8 ±<br>610.0       | 2901.8 ±<br>661.1     | 2825.8 ±<br>557.1       | -697.8<br><br>(-841.7, -553.8)                              | 0.476    | <<br>0.001 |
| Sun's                                       | 4309.1 ±<br>1026.0      | 4229.3 ±<br>934.1     | 4364.0 ±<br>1105.1      | 746.6<br><br>(595.9, 897.3)                                 | 0.476    | <<br>0.001 |



## Discussion

There have long been controversies in different ways to assess sodium intake. Several formulas recognized internationally are created by foreign researchers. There is one equation, first proposed in China, created by Ningling Sun's team, Peking University People's Hospital, China using the spot urine during afternoon to predict 24-h urine excretion. However, the participants in this study were hypertension population, which makes its promotion limited. [19] We used it in our study, but the result was not ideal.

Our study used the spot urine collections at all 4 times (morning, afternoon, evening and overnight) to estimate the 24-hour urinary sodium excretion. According to the Bland-Altman plots, in summer, the bias with the INTERSALT equation was the smallest. 94.5 ~ 95.4% of the individuals were distributed within the consistency boundary. In view of the autumn survey, predicted values with Tanaka equation with morning samples and the Kawasaki equation with overnight samples were most accurate. 93.7% and 94.5% of the individuals were distributed within the consistency boundary. Although the estimated results of the four methods were fluctuant, it can be seen that the predicted values with the Kawasaki and the Sun's equations were overestimated and the INTERSALT method was underestimated. For the predicted values with the Tanaka equation, all results were overestimated without the overnight samples in both seasons. The amount of salt intake maybe an important reason of the estimated deviation. It is possible that people in different countries with different sodium intakes need different methods to estimate the 24-hour sodium intake[21].

From the view of correlation coefficient, the four methods we used in estimating the 24-hour urinary sodium excretion with spot urine samples also fluctuated. In the summer survey, the predicted values with Kawasaki equations had the highest correlation (0.612), which may due to the large amount of physical activities during daytime and perspiration, and less sweating at rest at night. However, in the autumn, the highest correlation was 0.635 and 0.616 respectively when Tanaka equation was used with afternoon and evening urine samples. Therefore, if the time point urine estimation method is adopted, overnight urine samples are the best in summer. For one reason that the overnight collection has a higher volume [22], it may be a better predictor. But in other seasons, it is recommended to use the afternoon or evening collection with the Tanaka equation, for the high correlation with the gold standard.

Although Kawasaki used the second urine sample in the morning of the Japanese population and obtained a correlation coefficient of 0.73 [18], Tanaka used the random urine samples of the Japanese population with a similar estimated method only obtained the correlation of 0.54 [16]. In a US study, all values estimated by time-point urine samples with prediction equations were moderately correlated with measured 24-h urinary sodium excretion, 0.40–0.60 [21]. In our study (in autumn), the correlation coefficient of Kawasaki method was 0.52, the INTERSALT method was 0.58 ~ 0.60, Tanaka method was

0.48 ~ 0.64, and Sun's method was 0.48. The difference in correlations indicates that when using estimated methods to predict the 24-h sodium excretion with different random urine samples, it will fluctuate due to ethnic differences or the different time of urine collection.

In this study, we also explored the applicability of the 24 h urine collection (gold standard) in different seasons. The results showed that compared with autumn, the daily urine sodium excretion reduced about 520.7 mg (1.3 g synthetic salt). The dietary survey showed that there was no significant difference in sodium intake between the two seasons. Therefore, when using the 24-h urine collection to estimate sodium intake, we should avoid summer. If it has to in summer, an undervalued value should be added.

Our study had potential limitations. First, we just collected the 24-h urine for one day in each study. It is likely that the correlations observed are different if we had been collected on a different day. Second, we used the overnight urine sample instead of the second morning urine sample, which may result in bias for the predicted sodium excretion with Kawasaki formulae. Finally, we purposefully selected participants aged from 18 to 25 year-old which cannot represent the whole population in china. Thus, it is not known whether our results apply to younger or older persons and populations.

## Conclusions

Estimation of sodium intakes among young adults using the 4 methods have varying degrees of bias and volatility in different times and seasons. Currently, there is a lack of assessment methods suitable for healthy Chinese populations. We are conducting further research to develop a suitable method for evaluating sodium status in order to assess the salt intake amount in Chinese population.

### Declarations

## Declarations

**Ethics approval and consent to participate:** This study was approved by the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention.

**Consent for publication:** Not Applicable.

**Availability of data and materials:** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests:** The authors declare that they have no competing interests.

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**Authors' contributions:** study design, J.Z., Y.M. and W.G.; validation, W.G., J.L. and Z.Z.; investigation, W.G., Z.Z. and J.L.; data analysis, W.G.; writing—original draft preparation, W.G.; writing—review and editing,

Y.M. and J.Z.; supervision, Y.M. and Z.Z.; project administration, Z.Z.. All authors have read and agreed to the published version of the manuscript.

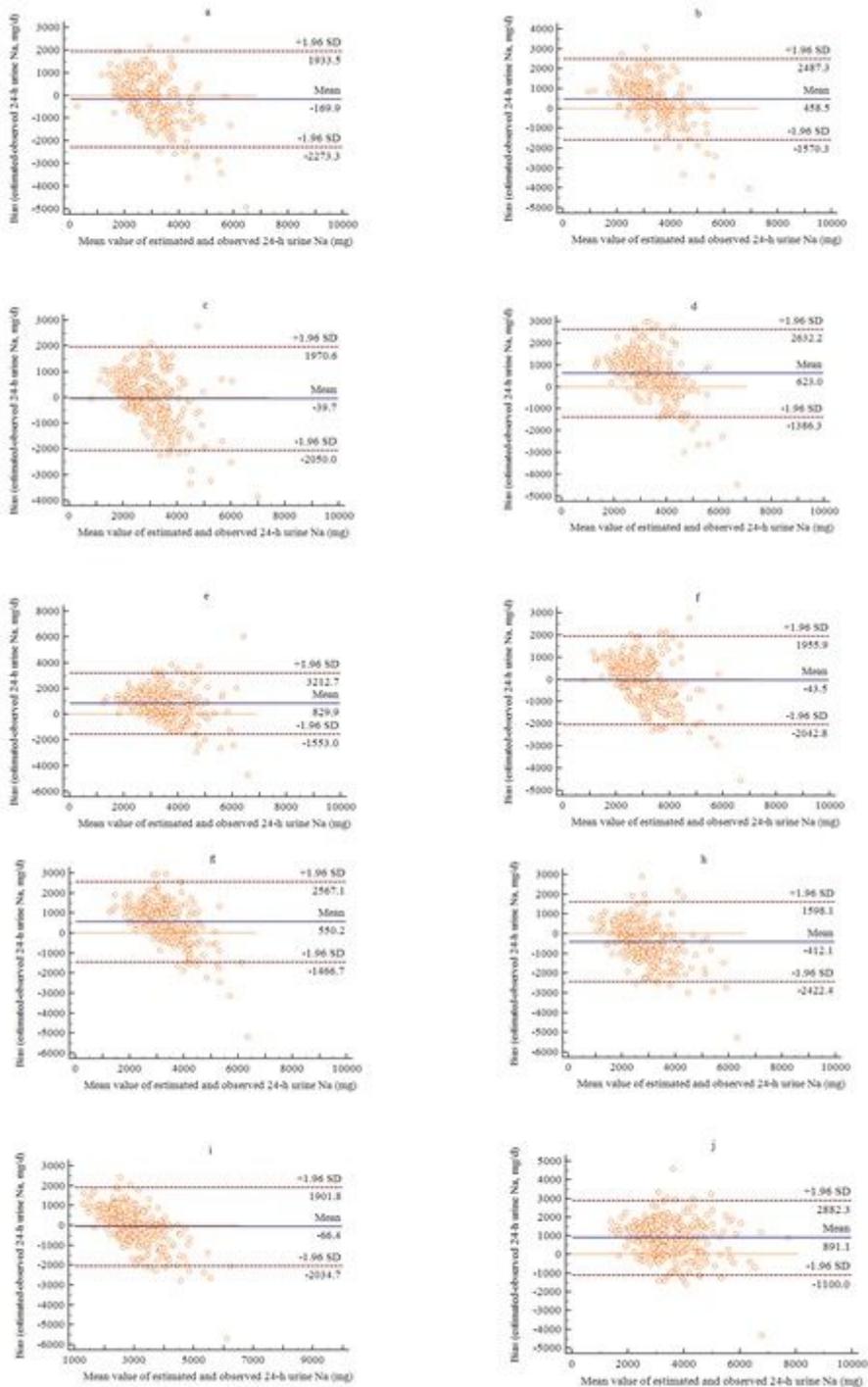
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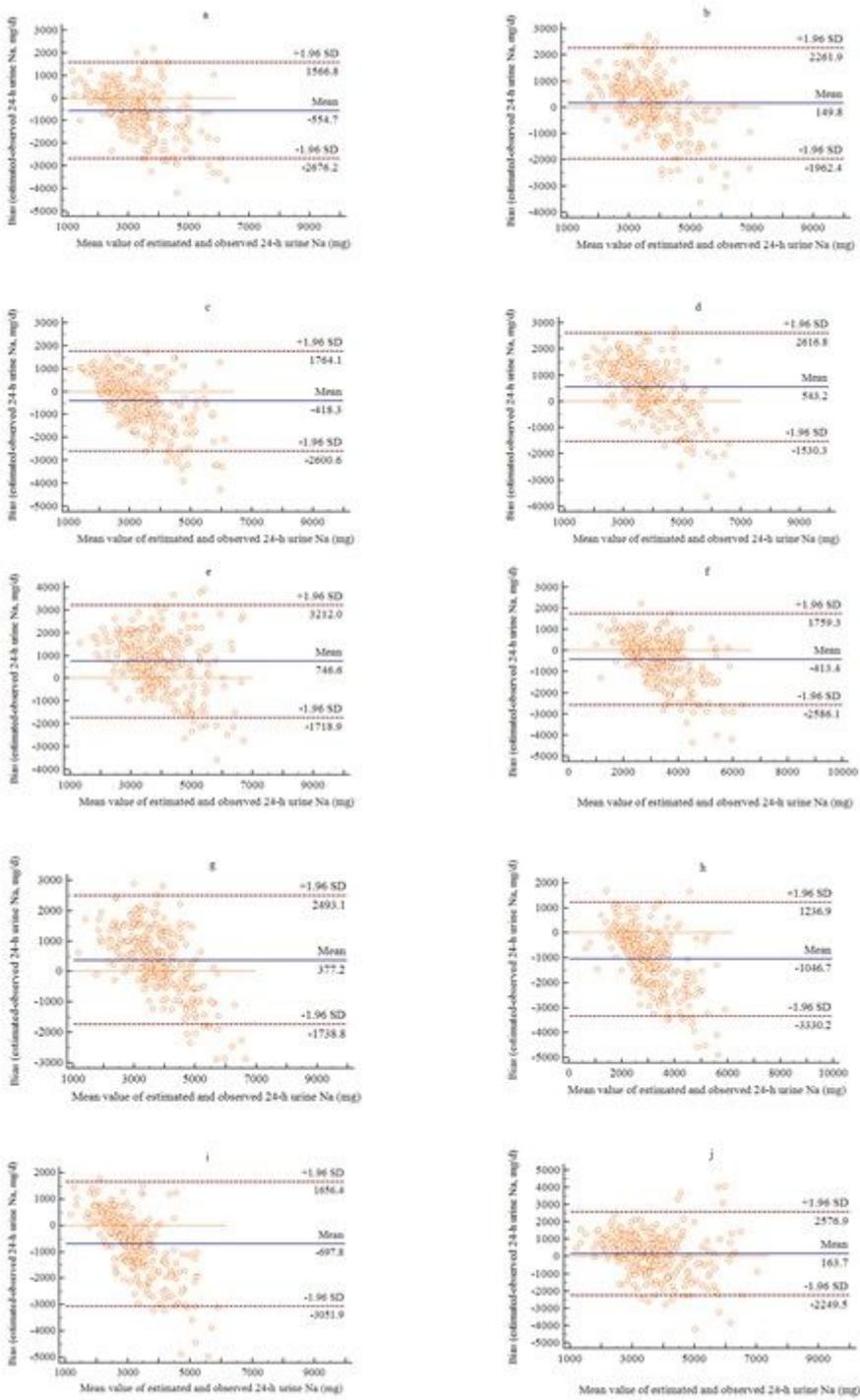
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## Figures



**Figure 1**

Bland-Altman plot of the bias(difference) between predicted and measured 24-h urinary sodium excretion in summer, based on INTERSALT equation(a) and Tanaka equation(b) in the morning, INTERSALT equation(c), Tanaka equation(d) and Sun’s equation(e) in the afternoon, INTERSALT equation(f) and Tanaka equation(g) in the evening, and INTERSALT equation(h), Tanaka equation(i) and Kawasaki equation(j) overnight.



**Figure 2**

Bland-Altman plot of the bias(difference) between predicted and measured 24-h urinary sodium excretion in autumn, based on INTERSALT equation(a) and Tanaka equation(b) in the morning, INTERSALT equation(c), Tanaka equation(d) and Sun's equation(e) in the afternoon, INTERSALT equation(f) and Tanaka equation(g) in the evening, and INTERSALT equation(h), Tanaka equation(i) and Kawasaki equation(j) overnight.