Survey on sodium and potassium intake in patients with hypertension in China

Ningling Sun MD1 | Yinong Jiang MD, PhD2 | Hongyi Wang MD, PhD1 | Yifang Yuan MD1,3 | Wenli Cheng MD, PhD4 | Qinghua Han MD5 | Hong Yuan MD6 | Li Yang MD7 | Zihong Guo MD8 | Yuemin Sun MD9 | Gang Sun MD10 | Xinhua Yin MD11 | Hao Wang MD12 | Jianjun Mu MD, PhD13 | Jiguang Wang MD, PhD14

1 Institute of hypertension, People's Hospital, Peking University, Beijing, China
2 The Institute of Hypertension and Heart Failure, The 1st Affiliated Hospital of Dalian Medical University, Dalian, China
3 Department of Cardiology, Tsinghua Changgung Hospital, Tsinghua University, Beijing, China
4 Department of Hypertension, Beijing Anzhen Hospital Affiliated to Capital Medical University, Beijing, China
5 Department of Cardiology, First Hospital of Shanxi Medical University, Taiyuan, China
6 Department of Hypertension, Third Xiangya Hospital, Central South University, Changsha, China
7 Department of Geriatrics, Yan'an Affiliated Hospital of Kunming Medical University, Kunming, China
8 Hypertension ward, Fuwai Yunnan Cardiovascular Hospital, Beijing, China
9 Department of Cardiology, Tianjin Medical University General Hospital, Tianjin, China
10 Department of Cardiology, The Second Affiliated Hospital of Baotou Medical College, Baotou, China
11 Department of Cardiology, The First Affiliated Hospital of Harbin Medical University, Harbin, China
12 Department of Hypertension, Henan Provincial People's Hospital, Zhengzhou, China
13 Department of cardiology, First Hospital of Xi'an Jiaotong University, Xi'an, China
14 Shanghai Institute of Hypertension, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

Correspondence
Ningling Sun, Professor, MD mentor, The Institute of hypertension, People's Hospital, Peking University, No.11 Xizhimen South Street, Xicheng District, Beijing 100044, China. Email: sunnl@263.net
Jiguang Wang, MD, PhD, Shanghai Institute of Hypertension, Ruijin Hospital, Shanghai Jiaotong University School of Medicine, No.197, Rui Jin 2nd Road, Shanghai 200025, China. Email: jiguangw@163.com

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Abstract
Sodium and potassium intake in hypertensive patients in China is not clear. The authors aimed to investigate the distribution of sodium and potassium intake in hypertensive patients in China, and to analyze the relationship between sodium and potassium intake and blood pressure. The study was performed in 130 hospitals from 23 provinces across China from 2016 to 2019. Finally, 9501 hypertensive patients aged 54 years were included. 24 h urinary sodium and potassium excretion were measured. Distribution of urinary electrolytes were described according to age, gender and region. The association between urinary electrolytes and blood pressure was analyzed by multivariate linear regression. Hypertensive patients exhibited an average 24 h urinary sodium and potassium excretion of 156.7 ± 81.5 mmol/d and 39.2 ± 20.2 mmol/d (equivalent to sodium chloride of 9.2 g/d, potassium chloride of 2.9 g/d),...
sodium/potassium ratio (median) of 4.14 (2.92,5.73). Urinary electrolytes were lower in women than men (sodium: 171.1 vs 138.7, \( p < .05 \); potassium: 40.3 vs 37.7, \( p < .05 \)), in the elderly than in the younger (sodium: 168.7 vs 139.9, \( p < .05 \); potassium: 39.5 vs 37.5, \( p < .05 \)). For every 1 unit of Na/K ratio increase, blood pressure increased by 0.46/0.24 mmHg. Blood pressure was 2.75/1.27 mmHg higher in quartile 4 than quartile 1 of Na/K. It remains high sodium and low potassium for hypertensive patients in China. Decreased sodium, Na/K ratio and increased potassium may help for blood pressure management.

KEYWORDS
24 h urinary sodium and potassium excretion, hypertension, survey, urinary sodium/potassium ratio

1 | INTRODUCTION

Both sodium and potassium are crucial nutrients; however, excess sodium intake and insufficient potassium intake increase the risk of hypertension.\(^1,2\) The INTERSALT\(^3\) study found that increased 24 h urinary sodium excretion was associated with increased blood pressure. A balanced diet of sodium and potassium intake is essential for cardiovascular health. The WHO\(^4\) recommended that the daily sodium intake does not exceed 85 mmol/d, and that the daily potassium intake is at least 90 mmol/d. The “Chinese guidelines for the management of hypertension” (2018 revised edition) recommends that the daily salt intake does not exceed 100 mmol/d.\(^5\) Studies in 2012 demonstrated that the average sodium intake of Chinese residents was 10.5 g/d,\(^6\) which is equivalent to 180 mmol/day for urinary sodium excretion. However, there is a lack of data on salt intake of hypertensive patients in China, even though balance sodium and potassium pattern are important for blood pressure management in such patients. Given the pivotal role of salt intake in blood pressure management and its lack of epidemiological data on in hypertensive patients, we conducted a nationwide survey on sodium and potassium intake in hypertensive patients. The aim of our study was to: (1) describe the current epidemiology of urine electrolytes for hypertensive patients in China, especially by subgroups including age, gender, and region. (2) analyze the association between urinary electrolytes and blood pressure.

2 | METHODS

This cross-sectional study used data from the survey under China Health Action on Salt and Hypertension (CASH) program. This program aimed to reduce the average salt intake from 10.5 g/d to less than 5 g/d by 2030 in China. To evaluate sodium and potassium intake in hypertensive patients, 24 h urinary electrolytes were measured in patients with essential hypertension in 130 hospitals of 23 provinces in China between October 2016 and October 2019. This study has been approved by the ethics committee of Peking University People’s Hospital, and informed consent was obtained (NO.2016PHB074-01).

2.1 | Survey design

Hospitals were recruited according to the geographical distribution, namely each province chooses one tertiary hospital (more than 1000 beds and has hypertension ward) as the leading unit, and each tertiary hospital organizes 5–10 subordinate hospitals to participate in the study. Only hospitals that were able to conduct 24 h urinary electrolyte measurements were included. The working team gathered all researchers in each region to introduce the investigation purpose, requirements and implementation plan of the investigation, to conduct training, and to provide SOPs before participants recruitment.

2.2 | Study population

Participants were enrolled in the study according to the sequence of hospitalization in a consecutive manner. Patients’ informed consent were obtained before study. Inclusion criteria were as follows: (1) essential hypertensive patients according to 2010\(^7\) and 2018\(^5\) guidelines for the prevention and treatment of hypertension in China; (2) patients aged 18–85 years old. Hypertension was defined as follows: blood pressure was measured three times without the use of antihypertensive drugs, SBP was \( \geq 140 \text{ mmHg} \) (1 mmHg = 0.133 kPa) and DBP was \( \geq 90 \text{ mmHg} \), or patients with hypertension history and currently on antihypertensive medication with blood pressure \(< 140/90 \text{ mmHg} \). All patients had a regular diet (three meals a day) for nearly a month.

The exclusion criteria were as follows. (1) Patients with serious systemic diseases (i.e., rheumatic immunity and tumors), secondary hypertension, and other conditions that could cause structural changes, remodeling of the heart, and serious complications (i.e., cardiomyopathy, valvular heart disease, contractile heart failure, pulmonary heart disease, and atrial fibrillation). (2) Patients with severe liver and kidney disease, infection, tumors, malnutrition, severe cardiorenal insufficiency, cardiocerebral vascular events in the past 6 months (myocardial infarction and stroke), hypertensive urgency, and poorly controlled diabetes (fasting bloodglucose \( > 11.1 \text{ mmol/L} \). (3) Patients using
Other covariates

Determination of 24 h urinary sodium and potassium

We provided 5-liter urine buckets for each patient. Under a regular diet, 24 h excreted urine was collected, from 7:00 am on the first day and including the urine at 7:00 am on the second day, with the first urine sample discarded (Figure S1). If the urine retention time was < 24 h, the patient reported urine loss, and if the 24 h total urine volume was < 500 mL, the sample was excluded. The excretion of urinary electrolytes (sodium and potassium) throughout the day was expressed by mmol/d. The amount of excreted 24-h urine sodium and potassium was calculated by multiplying the total volume of the collected urine by the concentration of sodium and potassium measured. Urine electrolyte was measured by ion selective electrode method with American Beckman’s and Roche Diagnostics biochemical testing equipment in all hospitals involved in the survey. Each laboratory must accept the inter-laboratory quality assessment of potassium equipment in all hospitals involved in the survey. We give standard sodium and potassium samples of low, medium and high concentration respectively to hospitals’ laboratory and the coefficient of variation between different hospitals must less than 10%. Pearson correlation coefficient of sodium was 0.999 and potassium was 0.986 (95% CI 0.980-0.999). We first compared gender differences for baseline characteristics.

Continuous and categorical variables were reported as mean ± SD, median (IQR), and n (%) and tested by t-test, Mann Whitney U test, and χ² test where appropriate. The sodium/potassium ratio was reported by median (mmol/d) due to skewed distribution. One-way analysis of variance was used for comparison between multiple groups and Tukey method was used for post-hoc pairwise comparison. Study population was categorized as below: (1) by age: < 45, 45–65, ≥65 years old (2) by gender: men and women (3) by geographical distribution of seven regions and their provinces: northwest (Gansu, Shanxi, and Xinjiang Uygur autonomous region), northeast (Heilongjiang, Jilin, and Liaoning), southwest (Guizhou, Sichuan, Yunnan, and Chongqing), east (Shandong, Shanghai, Zhejiang, Anhui, and Jiangxi), central (Henan and Hunan), south (Guangdong), and north China (Beijing, Tianjin, Inner Mongolia autonomous region, Shanxi, and Hebei). To analyze the association between Na/K ratio and blood pressure, multivariate linear regression analysis was conducted, adjusted for age, gender, BMI, and use of hypertensive medication. P < .05 was considered statistically significant.

3 | RESULTS

3.1 | Baseline characteristics

A total of 9501 patients with hypertension from 130 hospitals in 23 provinces were finally included (Figure 1), with an average age of 56 ± 14.4 years, and women accounting for 44% (n = 4192). Among them, 7638 completed office blood pressure measurement. The mean systolic/diastolic blood pressure was 146/88 ± 21.2/15.2 mmHg, the mean heart rate was 76 ± 13.1 bpm, and BMI was 26.3 ± 3.8 kg/m². A total of 81% of the patients received antihypertensive medication treatment (N = 6303). The percentage of antihypertensive medication use for ACEI, ARB, β-blockers, CCB and low dose diuretics (Single-Pill Combination included) was 10%, 24%, 19%, 64% and 9%, respectively. Urinary sodium was neither associated with antihypertensive medication use (p = .5645) nor diuretic use (p = .7838). The baseline characteristics of the patients are displayed in Table 1.

3.2 | Distribution of sodium, potassium, and sodium/potassium ratio in hypertensive patients

For all hypertensive patients, the mean 24-h urinary sodium was 156.8 ± 81.50 mmol/d (i.e., 9.2 g/d of sodium chloride). The mean urinary potassium was 39 ± 20.24 mmol/d (i.e., 2.9 g/d of potassium chloride). The median sodium/potassium ratio was 4.14. The proportion of patients with low (< 100 mmol/d), medium (100-200 mmol/d), and high...
TABLE 1 Characteristics of the patients

| Variable                        | All patients (N = 9501) | Men (N = 5309) | Women (N = 4192) | P value |
|---------------------------------|-------------------------|---------------|------------------|---------|
| Age (years)                     | 55.73 ± 14.13           | 52.82 ± 14.38 | 59.40 ± 12.91    | <.0001  |
| Body mass index (kg/m²)         | 26.00 ± 3.83            | 26.50 ± 3.75  | 25.37 ± 3.83     | <.0001  |
| Systemic blood pressure (mmHg)  | 146.00 ± 21.18          | 145.94 ± 21.3 | 146.08 ± 21.03   | .77     |
| Diastolic blood pressure (mmHg) | 87.78 ± 15.19           | 89.99 ± 15.51 | 85.00 ± 14.29    | <.0001  |
| Heart rate (bpm)                | 76.10 ± 13.16           | 77.05 ± 13.17 | 74.89 ± 13.04    | <.0001  |
| Sodium excretion (mmol/d)       | 156.69 ± 81.49          | 170.92 ± 85.17| 138.67 ± 72.68   | <.0001  |
| Sodium chloride (g/d)           | 9.16 ± 4.77             | 10.00 ± 4.98  | 8.11 ± 4.25      | <.0001  |
| Potassium excretion (mmol/d)    | 39.15 ± 20.24           | 40.29 ± 20.98 | 37.70 ± 19.17    | <.0001  |
| Potassium chloride (g/d)        | 2.92 ± 1.51             | 3.00 ± 1.56   | 2.81 ± 1.43      | <.0001  |
| Sodium/Potassium Ratio          | 4.14 (2.92, 5.73)       | 4.42 (3.16, 6.17) | 3.79 (2.67, 5.24) | <.0001  |
| Urine volume(ml)                | 1740 (1250, 2290)       | 1750 (1300, 2300) | 1700 (1200, 2200) | 0.0250  |
| Urinary creatine (umol/d)       | 9008 (5080, 12922)      | 11099 (6232, 14690) | 7513 (4599, 9747) | <.0001  |
| Antihypertensive drug (%)       | 6303 (81.38%)           | 3514 (80.89%) | 2789 (82.01%)    | .2121   |

Note: The data with normal distributions are expressed as (x±s). The median is used for data with non-normal distributions (P25-P75). Different scales of electrolytes were calculated as follows: sodium chloride (NaCl; g/d) = urinary sodium excretion (mmol/d) × 5.85 (g), and potassium chloride (KCl; g/d) = urinary potassium excretion (mmol/d) × 7.45 (g).

(≥200 mmol/d) urinary sodium was 26.7%, 47.9%, and 25.4%, respectively (Figure S2).

3.3 | Distribution of urinary sodium and potassium by age and gender

The age distribution was as follows: < 45 years old (n = 2170, 23%), 45–65 years old (n = 4514, 47%), and > 65 years old (n = 2817, 30%). Altogether there were 5309 men and 4192 women. The proportion of women was higher in the older age group (Figure 2A). The mean values of urinary sodium in the three groups were 169 ± 84.5 mmol/d, 161 ± 83.9 mmol/d, and 140 ± 72.1 mmol/d, respectively. Urinary sodium and potassium gradually decreased with increased age (Figure 2B). The urinary sodium, urinary potassium, and sodium/potassium ratio in women was lower than that in men (Figure 2C-D).

3.4 | Distribution of urinary sodium and potassium by urinary sodium excretion level

The average urinary sodium was 69.8 ± 21.0 mmol/d, 145.7 ± 28.0 mmol/d, and 268.8 ± 58.9 mmol/d in the low, medium, and high sodium groups, respectively. The average urinary potassium was 27.8 ± 13.1 mmol/d, 38.8 ± 17.8 mmol/d, and 49.7 ± 23.7 mmol/d, respectively (Figure S3A). High sodium intake (≥ 200 mmol/d) was significantly higher in men than women (Figure S3B). The sodium/potassium ratio was 2.72 (1.96, 3.70), 4.09 (3.09, 5.39), and 5.81 (4.48, 7.46), respectively, and greater in patients with high sodium intake, indicating an increased ratio with increased sodium intake (Figure S3C).
3.5 Distribution of urinary sodium and potassium by region

A total of 130 hospitals in 23 provinces and cities were included in this study, and 24 h urinary sodium value of > 156.8 mmol/d (i.e., sodium chloride > 9.2 g/d) were in 14 provinces and cities. Salt intake was > 6 g/d in all 23 provinces and cities involved in the study (Figure S4A), whereas potassium intake was generally insufficient (Figure S4B). Highest salt excretion (184.5 ± 77.8 mmol/d) was found in northwest China, which is equivalent to salt intake 11.1 g/d (Figure S4C). Furthermore, the urinary sodium/potassium ratio in south China (2.8(1.9,3.7)) was significantly lower than that in other areas (Figure S4D).

3.6 Relationship between sodium/potassium ratio and office blood pressure

Univariate analysis showed that urinary sodium excretion had a non-linear trend with systolic blood pressure (Figure 3A) but a linear association with diastolic blood pressure (Figure 3B). However, for urinary potassium, both systolic and diastolic blood pressure gradually decreased with the increase of potassium (Figure 3A, Figure 3B). As for the association between Na/K ratio and blood pressure, participants in the highest Na/K quartile had the highest systolic and diastolic blood pressure (Figure 3C). Then, we used two methods to analyze the relationship between office blood pressure and urinary sodium/potassium ratio. In multiple linear regression analysis, we found that with 1 unit increase of Na/K, blood pressure increased 0.46/0.24 mmHg (Table 2). In categorical variable analysis, participants were divided according to sodium/potassium ratio quartile (Q1: < 2.93, Q2: 2.9–4.1, Q3: 4.7–5.8, Q4: > 5.8), office blood pressure increased with Na/K category after adjusting for age, gender, BMI, and anti hypertensive medication use. Blood pressure in Na/K Q4 increased by 2.75/1.27 mmHg compared with Q1 (Table 3 and Figure 3C).

4 DISCUSSION

China is a country with a high incidence of hypertension and cerebral stroke. High sodium intake can significantly increase blood pressure and increase cerebrovascular risk in sensitive patients. As such, moderate reductions in sodium intake can effectively reduce blood pressure. Excessive sodium intake, insufficient potassium intake, and a low sodium/potassium intake ratio are important risk factors for hypertension in China. The INTERSALT study found that every 100 mmol/d (i.e. 2.3 g/d) increase in 24 h urinary sodium excretion was associated with an average increase in systolic/diastolic blood pressure by 5–7/2–4 mmHg. The survey also found that the average intake of cooking salt in Chinese residents aged ≥18 was 10.5 g/din 2012.
Two meals a day (results of our other questionnaire investigation study, people do not eat at home; about 60% of them eating out for at least one meal in two days). As the salt content of takeaway and fast food cannot be guaranteed, this warrants further attention. With the urbanization of the country, the dietary patterns and habits have undergone significant changes. Most young people do not eat at home: about 60% of them eating out for at least two meals a day (results of our other questionnaire investigation study, data on file). As the salt content of takeaway and fast food cannot be controlled, it is likely that young people eat a diet with higher sodium content. On the contrary, the elderly are more likely to maintain traditional family eating habits. At present, the supply of low-sodium chloride in the market, the nation’s popularization of education regarding salt intake, and controlling the amount of salt used for cooking have begun to show effects. Our results suggest that the salt control strategies introduced within families could spread to every corner of society.

According to the regional distribution of salt content in hypertensive patients, China, northwest China had the highest salt content with an increased sodium/potassium ratio, whereas the intake of sodium chloride was the lowest in south China with a urinary sodium/potassium ratio significantly lower than those in other regions. This further demonstrates the special salt diet pattern in China: ‘high in the north, low in the south’. High sodium and low potassium were associated with increased blood pressure. A recent study in a general Chinese population, which used 24 h-recall as measurement of diet electrolytes, showed similar findings for regional differences between north and south China.

The focus of this study: a large-scale epidemiological survey involving 130 hospitals in 23 provinces of China was conducted to examine the salt intake status of Chinese hypertensive patients. Our study also assessed salt intake levels of hypertensive patients of different ages. All the participating hospitals performed the implementation plan according to the unified SOP. In this study, we used 24 h urinary sodium and potassium excretion as the gold standard for evaluating salt intake.

Our study suggested an excessive sodium but insufficient potassium consumption and a consequent high sodium/potassium intake ratio in Chinese hypertensive patients. The average intake was 9.2 g/d, 2.9 g/d for sodium and potassium, respectively. The median Na-K ratio was 4.14. The WHO and 2030 China Health Action Plan set the goal to reduce sodium intake to < 5 g/d. Our study revealed that sodium intake was > 6 g/d in 73% of hypertensive patients and < 5 g/d in only 19% of hypertensive patients (data not shown). On the other hand, only 2% achieved the recommended potassium level of above 90 mmol/d. Increased sodium could increase plasma volume and activate sympathetic activity, which increased peripheral vascular resistance, reduced arterial elasticity, and increased blood pressure. Salt restriction and supplementation of potassium can partially improve high blood pressure. Salt restriction in hypertensive patients brought by health education has facilitated blood pressure management. It is inspiring to see the great reduction of salt consumption in the Chinese population from 10.5 g/d to 9.2 g/d. The effect of salt reduction intervention was also reported in a recent study in one province in China. The progress on salt restriction is due to the efforts of our government, associations, and salt control workers. However, there still remains a lot to be done for sodium restriction and potassium supplement.

Moreover, our study also showed that among hypertensive patients, sodium intake is 17% higher in those younger than 45 years compared with those older than 65 years. Additional analysis showed similar results after BMI was adjusted (data not shown), which suggested that the higher consumption of salt may not simply be due to higher consumption of food but higher sodium content instead. This warranted further attention. With the urbanization of the country, the dietary patterns and habits have undergone significant changes. Most young people do not eat at home: about 60% of them eating out for at least two meals a day (results of our other questionnaire investigation study, data on file). As the salt content of takeaway and fast food cannot be controlled, it is likely that young people eat a diet with higher sodium content. On the contrary, the elderly are more likely to maintain traditional family eating habits. At present, the supply of low-sodium chloride in the market, the nation’s popularization of education regarding salt intake, and controlling the amount of salt used for cooking have begun to show effects. Our results suggest that the salt control strategies introduced within families could spread to every corner of society.

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### Table 2: Office blood pressure and sodium/potassium ratio as continuous variable

|                      | Model 1 (N = 7638) | Model 2 (N = 6950) |
|----------------------|--------------------|--------------------|
|                      | Beta (95% CI)      | p                  | Beta (95% CI)      | p                  |
| Systolic blood pressure (mmHg) | 0.43 (0.22, 0.64) | <.0001             | 0.46 (0.24, 0.69) | <.0001             |
| Diastolic blood pressure (mmHg)  | 0.59 (0.43, 0.74) | <.0001             | 0.24 (0.10, 0.38) | .0008              |

Note: Model 1 is the univariate model. Model 2 adjusted for age, gender, BMI, and history of antihypertensive medication (Blood pressure for every 1 unit increase in sodium to potassium ratio).

### Table 3: Office blood pressure and quartiles of the sodium/potassium ratio

| Sodium/potassium ratio | Model 1 (N = 7638) | Model 2 (N = 6950) |
|------------------------|--------------------|--------------------|
| Q2                     | -0.50 (-1.92, 0.91) | .484               | -0.14 (-1.04, 0.77) | .768               |
| Q3                     | 0.94 (-0.46, 2.34)  | .188               | 0.28 (-0.62, 1.17)  | .546               |
| Q4                     | 2.75 (1.34, 4.15)   | .0001              | 1.27 (0.37, 2.17)   | .006               |

Note: the model adjusted for age, gender, BMI, and antihypertensive medication. #: P values for different quartile levels compared to the reference group (Q1 is a reference group). *P values of the relationship between whole quartile and blood pressure. Sodium/potassium ratio: Q1: < 2.91, Q2: 2.91-4.14, Q3: 4.14-5.72, Q4: > 5.72.
FIGURE 3  A) The sodium/potassium ratio under different systolic blood pressure (SBP) levels. B) The sodium/potassium ratio under different diastolic blood pressure (DBP) levels. C) The correlation of blood pressure (BP) and sodium/potassium ratio quartiles

Limitations of this study: In consideration of the financial limitations and maneuverability of the study, most 24 h urine collections were performed only once. And not all of the participants tested for urinary creatinine. The results would be more accurate with multiple urine collections to account for day-to-day variation as well as urinary creatinine measurement to adjust for urine sample completion. Besides, information about season and temperature was not collected, which may affect urinary electrolytes excretion and will be considered in following study. In addition, this study did not include certain provinces and cities (i.e., Tibet and Qinghai), which should be further covered in the future.

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Note: Experts from regions providing more than 300 cases are listed as coauthors.

CONFLICTS OF INTEREST

The authors have no conflict of interest to declare.

AUTHOR CONTRIBUTIONS

Ningling Sun proposed the concept and design of this paper, participated in the research and provided a large number of research data. Jiguang Wang supervised the conduct of the study and gave timely guidance. Yifang Yuan conducted data analysis and was part of the writing of Methods and Results, Ningling Sun wrote the Introduction, and Discussion and fully discussed the research data with the statisticians. Dr. Sun and Jiguang Wang reviewed and edited the manuscript and contributed to the discussion section. Other coauthors have suggested modifications to the manuscript. All the authors contributed to data collection and discussion of the paper.

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ORCID

Ningling Sun MD https://orcid.org/0000-0003-0378-2813
Yuemin Sun MD https://orcid.org/0000-0002-5404-9972
Jianjun Mu MD, PhD https://orcid.org/0000-0002-0335-3528

REFERENCES

1. Mozaffarian D, Fahimi S, Singh GM, et al. Global sodium consumption and death from cardiovascular causes. N Engl J Med. 2014;371:624-634.
2. Binia A, Jaeger J, Hu Y, Singh A, Zimmermann D. Daily potassium intake and sodium-to-potassium ratio in the reduction of blood
pressure: a meta-analysis of randomized controlled trials. *J Hypertens*. 2015;33:1509-1520.
3. Intersalt Cooperative Research Group. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. *BMJ*. 1988;297:319-328.
4. World Health Organization. Guideline: Sodium Intake for Adults and Children. WHO. 2012 ISBN 978 92 4 150483 6.
5. Revision Committee of China Guidelines for the prevention and treatment of hypertension. Chinese guidelines for the management of hypertension (2018 revised edition). *Chin J Cardiovasc Med*. 2019;24(1):1-46.
6. Bureau of disease control and prevention, national health and family planning commission. Report on nutrition and chronic diseases of Chinese residents. *Beijing: People’s Medical Publishing House*. 2015;11:33-50.
7. Liu LS. Chinese guidelines for the management of hypertension (2010 revised edition). *Chin J Hypertens*. 2011;19:701-743.
8. Shen C, Ge J. Epidemic of cardiovascular disease in China. *Circulation*. 2018;138:342-344.
9. Wang W, Jiang B, Sun H, et al. NESS-China investigators. Prevalence, incidence, and mortality of stroke in China: results from a Nationwide Population-Based Survey of 480,687 Adults. *Circulation*. 2017;135:759-771.
10. Grillo A, Salvi L, Coruzzi P, Salvi P, Parati G. Sodium intake and hypertension. *Nutrients*. 2019;11:pii:E1970.
11. Vollmer WM, Sacks FM, Ard J, et al. DASH-Sodium Trial Collaborative Research Group. Effects of diet and sodium intake on blood pressure: subgroup analysis of the DASH-sodiumtrial. *Ann Intern Med*. 2001;135:1019-1028.
12. Filippini T, Violi F, D’Amico R, Vinceti M. The effect of potassium supplementation on blood pressure in hypertensive subjects: a systematic review and meta-analysis. *Int J Cardiol*. 2017;230:127-135.
13. Poorolajal J, Zeraati F, Soltanian AR, Sheikh V, Hooshmand E, Maleki A. Oral potassium supplementation for management of essential hypertension: a meta-analysis of randomized controlled trials. *PLoS One*. 2017;12:e0174967.
14. http://www.nhc.gov.cn/guihuaxxs/s3585u/201907/e9275fb95d5b
15. Xu A, Ma J, Guo X, et al. Association of a Province-wide intervention with salt intake and hypertension in Shandong Province, China, 2011–2016. *JAMA Intern Med*. 2020:e200904.
16. Huang L, Wang H, Wang Z, Wang Y, Zhang B, Ding G. Associations of dietary sodium, potassium, and sodium to potassium ratio with blood pressure-regional disparities in China. *Nutrients*. 2020;12(2):366.
17. Kyung Kim M, Kwon M, Rhee M-Y, et al. Dose–response association of 24-hour urine sodium and sodium to potassium ratio with nighttime blood pressure at older ages. *Eur J Prev Cardiol*. 2019;26(9):952-960.
18. Rust P, Ekmekcioglu C. Impact of salt intake on the pathogenesis and treatment of hypertension. *Adv Exp Med Biol*. 2017;956:61-84.

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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