

Preplanned Studies

Association Between Urinary Sodium and Potassium Excretion and Blood Pressure Among Non-Hypertensive Adults — China, 2018–2019

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Summary

What is already known about this topic?

High sodium and low potassium in 24 h urinary excretion were associated with elevated blood pressure.

What is added by this report?

With increasing body mass index levels, decreasing unit urinary sodium excretion was more effective in reducing systolic and diastolic blood pressure, and increasing unit urinary potassium excretion was more effective in reducing diastolic blood pressure.

What are the implications for public health practice?

Reducing sodium and increasing potassium intake was more effective in reducing blood pressure in overweight and obese non-hypertensive adults compared to underweight and normal weight adults.

Elevated blood pressure is a major risk factor for the global burden of disease, and the resulting cardiovascular diseases are the leading causes of death and disability in China (1). High sodium and low potassium diets were associated with elevated blood pressure (2). Evidence has shown that the relationship between urinary sodium and potassium and their ratio to blood pressure was affected by body mass index (BMI) (3); at present, there is limited evidence of this in non-hypertensive adults in China.

We used data from the 2018 China Chronic Disease and Risk Factor Surveillance (CCDRFS) to study the relationship among non-hypertensive adults with different BMI levels. In this study, the urinary sodium-to-potassium ratio (UNa/K ratio) did not show a significantly better correlation than urinary sodium concentration (UNaC) or urinary potassium concentration (UKC) with blood pressure. With increasing BMI levels, decreasing unit urinary sodium excretion was more effective in reducing systolic blood pressure (SBP) and diastolic blood pressure (DBP), and

increasing unit urinary potassium excretion was more effective in reducing DBP. This finding suggested that the blood pressure in overweight and obese adults was more sensitive to changes in urinary sodium and potassium excretion.

Cross-sectional data were obtained from residents aged 18 years old and above in the 2018 CCDRFS, a nationally representative survey of the Chinese population (4). Every participant had a standard questionnaire and a physical examination of blood pressure, weight, and height, and collected a random urine sample. An ion-selective electrode method was used for sodium and potassium analysis, and the enzyme-coupled sarcosine oxidase method was used for creatinine analysis. Hypertension was defined as a self-reported previous diagnosis by health professionals along with the use of anti-hypertensive medications in the past 2 weeks. Underweight was defined as $BMI < 18.5 \text{ kg/m}^2$, normal weight was $18.5 \leq BMI < 24.0 \text{ kg/m}^2$, overweight was $24.0 \leq BMI < 28.0 \text{ kg/m}^2$, and obesity was $BMI \geq 28.0 \text{ kg/m}^2$. The 24h urinary creatinine excretion (24h UCrE), 24h urinary sodium excretion (24h UNaE), and 24h urinary potassium excretion (24h UKE) were estimated from Kawasaki's equation using a random urine sample (5). A total of 184,876 participants participated in the survey, this study excluded the hypertensive population, participants with missing data in UNaC, UKC, urinary creatinine concentration (UCrC), SBP, DBP, height, and weight. A total of 146,311 non-hypertensive participants were included in this analysis.

ANOVA and Kruskal-Wallis tests were conducted to test for differences in BMI groups in normally and non-normally distributed data. The correlation of UNaC, UKC, and UNa/K ratios to blood pressure was assessed by the Spearman correlation coefficient. Multivariable linear regression was used to assess the associations of blood pressure with 24h UNaE, and 24h UKE. $P < 0.05$ was deemed significant. All

statistical analyses were conducted using SAS software (version 9.4, SAS Institute Inc., Cary, USA).

In this study, the average participant age was 53.51 years, 55.16% were female, and over 1/2 were classified as overweight (35.87%) or obesity (14.14%). The average SBP increased with BMI levels from 122.35 mmHg for underweight participants to 137.79 mmHg in obese participants, and DBP showed a similar change. UNaC, 24h UNaE, and 24h UKE increased with BMI levels (Table 1).

In this analysis, the UNa/K ratio was more strongly correlated to SBP ($r_s=0.093$) and DBP ($r_s=0.067$) than to UKC, but not more than UNaC. In the obese group, the UNa/K ratio ($r_s=0.096$) was more strongly correlated to SBP than UNaC ($r_s=0.075$) or UKC ($r_s=-0.081$). In normal weight, overweight, and obese groups, the UNa/K ratio was higher than either UNaC

or UKC in relation to DBP (Tables 2–3).

24h UNaE was directly associated with SBP (1.964 mmHg) and DBP (0.924 mmHg) for each 1 g increase in urinary sodium excretion. The 24h UKE was inversely associated with SBP (-0.617 mmHg) and DBP (-0.126 mmHg) for each 1 g increase in urinary potassium excretion. As BMI levels increased, the standardized β regression coefficient between 24h UNaE and SBP increased from 0.116 in underweight group to 0.138 in obesity group. The standardized β regression coefficient between 24h UNaE and DBP increased from 0.084 in underweight group to 0.105 in obesity group. As BMI levels increased, the standardized β regression coefficient between 24h UKE and DBP increased from -0.020 in normal weight group to -0.041 in obesity group, while the relationship between 24h UKE and SBP showed no

TABLE 1. Participant characteristics by BMI groups in non-hypertensive adults — China, 2018.

Characteristics	Total	Underweight	Normal weight	Overweight	Obesity
N*	146,311	5,004 (3.42)	68,131 (46.57)	52,489 (35.87)	20,687 (14.14)
Age (year) [†]	53.51±13.80	54.84±18.17	53.70±14.54	53.86±12.57	51.65±12.90
Gender					
Male (%)*	65,604 (44.84)	2,194 (43.84)	30,608 (44.93)	23,735 (45.22)	9,067 (43.83)
Female (%)*	80,707 (55.16)	2,810 (56.16)	37,523 (55.07)	28,754 (54.78)	11,620 (56.17)
Ethnic group					
Han (%)*	126,896 (86.73)	4,141 (82.75)	58,503 (85.87)	46,214 (88.05)	18,038 (87.19)
Other (%)*	19,415 (13.27)	863 (17.25)	9,628 (14.13)	6,275 (11.95)	2,649 (12.81)
Current smoker (%)*	36,715 (25.09)	1,482 (29.62)	18,626 (27.34)	12,155 (23.16)	4,452 (21.52)
Drinker (%)*	51,872 (35.45)	1,451 (29.00)	23,665 (34.73)	19,217 (36.61)	7,539 (36.44)
Diabetes (%)*	19,709 (13.47)	449 (8.97)	6,776 (9.95)	8,084 (15.40)	4,400 (21.27)
Cancer (%)*	3,021 (2.06)	135 (2.70)	1,399 (2.05)	1,044 (1.99)	443 (2.14)
Kidney disease (%)*	7,557 (5.17)	262 (5.24)	3,497 (5.13)	2,794 (5.32)	1,004 (4.85)
SBP (mmHg) [†]	130.66±19.00	122.35±19.69	127.24±18.63	133.10±18.36	137.79±18.44
DBP (mmHg) [†]	77.10±10.93	71.42±10.72	74.68±10.31	78.79±10.57	82.16±11.07
UNaC (mmol/L) [§]	126.00 (87.00, 169.00)	119.00 (80.00, 162.00)	124.00 (85.00, 168.00)	126.00 (88.00, 169.00)	133.00 (93.00, 175.00)
UKC (mmol/L) [§]	32.15 (20.47, 50.15)	31.12 (19.49, 49.05)	32.21 (20.46, 50.30)	32.01 (20.52, 49.98)	32.45 (20.65, 50.33)
UCrC (mmol/L) [§]	9.09 (5.70, 13.59)	8.70 (5.29, 13.49)	9.10 (5.70, 13.67)	9.06 (5.72, 13.47)	9.25 (5.73, 13.66)
UNa/K ratio [§]	3.85 (2.51, 5.69)	3.83 (2.38, 5.81)	3.79 (2.46, 5.62)	3.88 (2.55, 5.68)	4.01 (2.64, 5.90)
24h UNaE (g/d) [†]	4.64±1.46	4.16±1.47	4.44±1.39	4.76±1.47	5.11±1.53
24h UKE (g/d) [†]	1.79±0.51	1.61±0.52	1.72±0.49	1.83±0.52	1.93±0.52
24h UCrE (g/d) [†]	1.19±0.34	0.96±0.29	1.10±0.29	1.24±0.33	1.40±0.41

Abbreviations: SBP=systolic blood pressure; DBP=diastolic blood pressure; UNaC=urinary sodium concentration; UKC=urinary potassium concentration; UCrC=urinary creatinine concentration; UNa/K ratio=urinary sodium-to-potassium ratio; 24h UNaE=24h urinary sodium excretion; 24h UKE=24h urinary potassium excretion; 24h UCrE=24h urinary creatinine excretion; BMI=body mass index; SD=standard deviation; P₂₅=25th percentile; P₇₅=75th percentile.

* Data are expressed as numbers (percentages).

[†] Data are expressed as mean±SD.

[§] Data are expressed as median (P₂₅, P₇₅).

TABLE 2. Spearman correlation coefficients relating urinary sodium and potassium concentration and their ratio with SBP in non-hypertensive adults — China, 2018.

Characteristics	Total		Underweight		Normal weight		Overweight		Obesity	
	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>
UNaC (mmol/L)*	0.094 (0.089, 0.100)	<0.05	0.065 (0.036, 0.093)	<0.05	0.077 (0.069, 0.084)	<0.05	0.093 (0.085, 0.102)	<0.05	0.075 (0.061, 0.089)	<0.05
UKC (mmol/L)†	−0.069 (−0.075, −0.064)	<0.05	−0.040 (−0.068, −0.012)	<0.05	−0.059 (−0.066, −0.051)	<0.05	−0.072 (−0.080, −0.063)	<0.05	−0.081 (−0.095, −0.068)	<0.05
UNa/K ratio§	0.093 (0.087, 0.098)	<0.05	0.061 (0.033, 0.089)	<0.05	0.077 (0.070, 0.085)	<0.05	0.093 (0.085, 0.102)	<0.05	0.096 (0.082, 0.109)	<0.05

Abbreviations: UNaC=urinary sodium concentration; UKC=urinary potassium concentration; UNa/K ratio=urinary sodium-to-potassium ratio; CI=confidence interval; r_s =spearman correlation coefficient; SBP=systolic blood pressure.

* Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and urinary potassium concentration.

† Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and urinary sodium concentration.

§ Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, and kidney disease.

TABLE 3. Spearman correlation coefficients relating urinary sodium and potassium concentration and their ratio with DBP in non-hypertensive adults — China, 2018.

Characteristics	Total		Underweight		Normal weight		Overweight		Obesity	
	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>	r_s (95% CI)	<i>P</i>
UNaC (mmol/L)*	0.060 (0.054, 0.065)	<0.05	0.032 (0.004, 0.060)	<0.05	0.039 (0.031, 0.046)	<0.05	0.059 (0.050, 0.067)	<0.05	0.053 (0.039, 0.067)	<0.05
UKC (mmol/L)†	−0.052 (−0.058, −0.047)	<0.05	−0.011 (−0.039, 0.018)	0.47	−0.045 (−0.053, −0.038)	<0.05	−0.053 (−0.062, −0.045)	<0.05	−0.062 (−0.076, −0.048)	<0.05
UNa/K ratio§	0.067 (0.062, 0.072)	<0.05	0.018 (0.010, 0.047)	0.20	0.051 (0.044, 0.059)	<0.05	0.069 (0.060, 0.077)	<0.05	0.077 (0.064, 0.091)	<0.05

Abbreviations: UNaC=urinary sodium concentration; UKC=urinary potassium concentration; UNa/K ratio=urinary sodium-to-potassium ratio; CI=confidence interval; r_s =spearman correlation coefficient; DBP=diastolic blood pressure.

* Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and urinary potassium concentration.

† Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and urinary sodium concentration.

§ Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, and kidney disease.

TABLE 4. β -coefficients relating 24h urinary sodium and potassium excretion with SBP in non-hypertensive adults — China, 2018.

Groups	24h UNaE (g/d)*			24h UKE (g/d)†		
	β	Standardized β	<i>P</i>	β	Standardized β	<i>P</i>
Underweight	1.545	0.116	<0.05	−0.855	−0.023	0.13
Normal weight	1.582	0.118	<0.05	−1.128	−0.030	<0.05
Overweight	1.639	0.131	<0.05	−1.566	−0.044	<0.05
Obesity	1.657	0.138	<0.05	−1.197	−0.034	<0.05
Total	1.964	0.151	<0.05	−0.617	−0.016	<0.05

Abbreviations: 24h UNaE=24h urinary sodium excretion; 24h UKE=24h urinary potassium excretion; SBP=systolic blood pressure.

* Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and 24h urinary potassium excretion.

† Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and 24h urinary sodium excretion.

trend (Tables 4–5).

DISCUSSION

This study found that BMI affected the relationship

between urinary sodium and potassium on blood pressure. The UNa/K ratio was more strongly than UKC in relation to SBP and DBP, but not than UNaC. With increasing BMI levels, decreasing unit urinary sodium excretion was more effective in

TABLE 5. β -coefficients relating 24h urinary sodium and potassium excretion with DBP in non-hypertensive adults — China, 2018.

Groups	24h UNaE (g/d)*			24h UKE (g/d) [†]		
	β	Standardized β	P	β	Standardized β	P
Underweight	0.612	0.084	<0.05	0.441	0.021	0.19
Normal weight	0.636	0.086	<0.05	-0.416	-0.020	<0.05
Overweight	0.702	0.098	<0.05	-0.797	-0.039	<0.05
Obesity	0.760	0.105	<0.05	-0.862	-0.041	<0.05
Total	0.924	0.124	<0.05	-0.126	-0.006	<0.05

Abbreviations: 24h UNaE=24h urinary sodium excretion; 24h UKE=24h urinary potassium excretion; CI=confidence interval; DBP=diastolic blood pressure.

* Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and 24h urinary potassium excretion.

[†] Adjusted by age, sex, race, current smoker, drinker, diabetes, cancer, kidney disease, and 24h urinary sodium excretion.

reducing SBP and DBP, and increasing unit urinary potassium excretion was more effective in reducing DBP. These findings suggested that reducing sodium and increasing potassium intake could better lower blood pressure. This was especially true in overweight and obese non-hypertensive adults, whose blood pressures were more sensitive to changes in urinary sodium and potassium.

Some studies have shown that the UNa/K ratio was cross-sectionally associated with blood pressure, and suggested to use it for practical sodium reduction and potassium increase instead of either urinary sodium or potassium alone (6). In the correlation studies with blood pressure, the UNa/K ratio did not show a significant predominance over UNaC and UKC.

In this study, decreasing UNaE or increasing UKE had a significantly greater effect on reducing SBP than DBP. It was consistent with prior findings (7–8). Also, UNaE had a greater effect on blood pressure than UKE. Some studies of gene polymorphisms have shown that Asians might be more sensitive to salt (9). In another study among Chinese adults, SBP changes was more sensitive to UKE than UNaE (10). They speculated that it might have been due to the relatively lower potassium intake, making the participants sensitive to increased potassium intake.

Most studies used BMI as an adjusted factor in analytical models analyzing the relationship between urinary sodium and potassium and blood pressure (10–11), but this study grouped BMI into separate models. The INTERMAP study found that controlling for BMI resulted in attenuation of the relationship between 24h UNaE and blood pressure in a multivariate regression analysis, and normal weight and obese participants manifested significant positive relations between blood pressure and urinary sodium,

but relations were weaker for overweight people (3). In this study, the regression of unit urinary sodium or potassium excretion on blood pressure changes was stronger in overweight and obese participants, relative to underweight and normal weight participants.

The gold standard for estimating individual daily sodium and potassium intake was 24h urine collection. We did not collect 24h urine and used the Kawasaki method to estimate 24h UNaE and 24h UKE by random urine, which may result in overestimation or underestimation (11).

In conclusion, the higher the BMI, the more likely the blood pressure is to be high, and the stronger the effect will be of reducing sodium and increasing potassium intake to lower blood pressure instead. The government departments should formulate policies related to sodium reduction and potassium increase, and implement salt reduction and healthy weight projects of “China Healthy Lifestyle for All.” The public is advised to reduce sodium and increase potassium intake to lower blood pressure and prevent cardiovascular disease.

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