Relationships between blood pressure and 24-hour urinary excretion of sodium and potassium by body mass index status in Chinese adults

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Conflicts of interest

None of the authors has any conflicts of interest.

Disclaim

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Preventionor the National Institute for Health Research or Department of Health in England.

AuthorContribution

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Z.Q.B.and L.H.W. helped in study design, J.L.T., X.L.G., X.F.Z.,and J.Y.Z. helped in data collection and data cleaning, L.X.Y., Q.H.Y., M.E.C., and J.X.M. helped in data analysis and the manuscript writing, Y.L.H., M.E. P.E.,and S.Y.A. provided significant advice and contributed to the manuscript writing and editing.

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Abstract

This study examined the impact of overweight/obese on the sodium, potassium and blood pressure associations using SMASH project baseline survey data. 24-h urine samples were collected in 1948 Chinese adults aged 18-69 years.The observed associations of sodium, potassium, sodium-potassium ratio and systolic blood pressure (SBP) were stronger in the overweight/obese population than among those of normal weight. Among overweight/obese respondents, each additional standard deviation (SD) higher of urinary sodium excretion (SD=85mmol) and potassium excretion (SD=19mmol) was associated with 1.31mmHg (95%CI, 0.37,2.26) and -1.43mmHg (95%CI, -2.23,-0.63) difference in SBP, each higher unit in sodium-potassium ratio was associated with 0.54mmHg (95%CI, 0.34, 0.75) increase in SBP. The association between sodium, potassium, sodium-potassium ratio and prevalence of hypertension among the overweight/obese was similar to that of SBP. Our study indicated that the relationships between BP and both urinary sodium and potassium might be modified by BMI status in Chinese adults.

Keywords: sodium, potassium, blood pressure, body mass index

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Abbreviations

BMI —body mass index

BP —blood pressure

CVD — cardiovascular disease

DBP —diastolic blood pressure

IOM —Institute of Medicine

OR —odds ratio

Q —quintile

SBP —systolic blood pressure

SD —standard deviation

SE —standard error

SMASH —Shandong and Ministry of Health Action on Salt and Hypertension

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Introduction

Cardiovascular disease (CVD), including heart disease and stroke, accounted for 41% of all deaths and 23% of national health care spending in China in 2005(1). Unfortunately, the prevalence of hypertension, the leading risk factor for CVD, has increased dramatically in China, from 5.1% in 1959 to 29.6% in 2009 among adults aged 18 years and older(2,3). High sodium intake, low potassium intake, and obesity all increase the risk of hypertension(4,5,6). In China, sodium intake decreased over the last 2 decades, but studies suggested that average daily intake in 2009 (4700 mg/d) was almost double the Chinese Nutrition Association recommendation (2400mg/d)(7). The average daily potassium intake among Chinese adults is very low, resulting in a high sodium-potassium ratio, indeed one of the highest in the world (5,7,8).In addition, overweight and obesity have increased remarkably in China over the past two decades; in 2010, 30.6% of Chinese adults were overweight, and 12% were obese(9,10).

The U.S. Institute of Medicine (IOM) recommended that analyses on the effects of dietary sodium on health outcomes should also examine potassium intake and account for potential confounding factors(11). In addition, accumulating evidence has suggested that in humans the response of blood pressure (BP) to changes in sodium intake may vary by body weight/BMI or the presence of the metabolic syndrome(12-16). In China, several population-based studies have linked sodium and potassium intake and their ratio with blood pressure and risk of hypertension(17-19). However, few studies have examined the relationship between sodium and potassium intake and BP in analyses stratified by BMI status(20,21). The INTERSALT study examined the Chinese subsample to assess the effect modification of BMI on the association of sodium and BP(20). However, the sample was relatively small and was based on just

3 Chinese neighborhoods. In addition, the sample was collected 20-30 years ago, when the prevalence of hypertension and obesity in China were relatively low. Therefore, we sought to understand how the association of sodium and BP might be modified by BMI status among Chinese adults in the contemporary setting.

We used baseline survey data from2011 obtained as part of the Shandong and Ministry of Health Action on Salt and Hypertension (SMASH) project to examine the association between 1) urinary sodium, urinary potassium, and their ratioand2) BP and the prevalence of hypertension. We also explored whether the associationsof sodium and potassium with BP and hypertension prevalence are modified byBMI.

Methods

Study population

The SMASH project survey was a representative cross-sectional survey of adults aged 18 to 69 years in Shandong Province, which in 2010 had 96 million residents. Using a complex, multi-stratified cluster sampling method, we selected 2112 participants for a timed 24-h urine collection from 20 counties/districts across Shandong province. A detailed description of the study design and methods for the SMASH project survey is available elsewhere(22). Our study was conducted according to Declaration of Helsinki guidelines, and all procedures involving human subjects were approved by the ethics committee of the Shandong Center for Disease Control and Prevention. Participants provided written informed consent.

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24-hour urine collection

We used the INTERSALT method to perform the 24-h urine collection(23). Each participant was instructed on this process by atrained health professional at the collection field sites. The participant was given a standard plastic container with boric acid (around 1 g) used as preservative and was told to discard the first void of the day and collect all the urine in the container during the following 24-h period including the first void from the next morning. The health professional recorded the beginning and ending time for each urine collectionand the total hours between the first and last void collected. A standard interview by questionnairewas administered to each participant at the end of the 24-h period to assess the completeness of urine collection. The volume of urine was measured on a standard platform at the field site by a laboratory technician. The samples were kept in a freezer at -20°C and delivered to the certified laboratory (ADICON Clinical Laboratory Inc.) in Jinan, Shandong.Urinary sodium and potassium were measured by the ion-selective electrode method on an Olympus AU 680 Chemistry-Immuno Analyzer; the coefficient of variation was 1.5% for sodium and 2.5% for potassium.Urinary creatinine was measured by the picric acid method using the Olympus AU640 Chemistry-Immuno Analyzer (here the coefficient of variation was 3.0%). Individual sodium and potassium excretion values were calculated from their concentration in the 24-h sample.

Anthropometric and blood pressure data

Weight, height, and BP were measured by trained health professionals using standardized methods(22). According to the Chinese guidelines for overweight and obesity(24)' normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweightis defined as a BMI of 24 to

<28. Those with a BMI≥28 are considered obese.We combined overweight or obese participants in a single group (overweight/obese) to produce more stable estimates.

BP was measured in the sitting position 3 times 5 min apart on one occasion by trained health professionals with electronic sphygmomanometer (HEM-7071, Omron Corporation). The average of the 3 measurements was used. Hypertension was defined by the Chinese guidelines on preventing and controlling hypertension and the JNC 7 as asystolic BP (SBP)≥140mmHg or a diastolic BP (DBP)≥90 mmHg, or a self-report of taking antihypertensive medication(s) in the last 2 wk(25,26).

Data analysis

An incomplete urine collection was defined as either a 24-h urinary volume less than 500ml, or a 24-h urinary creatinine volume beyond the sex-specific mean±2standard deviations (SD).We identified 88 participants with incomplete 24-h urine collection and excluded them from our analytic sample.An additional 76 participants who were underweight (BMI<18.5) were also excluded, leaving a total of 1948 adults for the data analysis.

The covariates in this analysis included age, sex, educational attainment, smoking status, frequency of drinking alcohol, physical activity, and use of antihypertensive medication(s). Data on these variables were collected by in-person interview using a standardized questionnaire. Frequency of drinking alcohol was categorized in 4 groups: nondrinker, <1 d/wk, 1-2d/wk,or≥3d/wk. Physical activity was defined by the

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frequency of leisure-time exercise: none, <3 d/wk, or ≥3 d/wk. Tobacco smoking status was categorized as none, former smoker, or current smoker. The missing values were coded as a missing group within the covariates. Ninety participants had missing values for covariates: 18 for smoking, 14 for physical activity, and 60 for drinking (2 participants had 2 missing values, and 88 had 1 missing value).

Statistical analysis

We calculated the weighted mean and standard error (SE) of the 24-h urinary sodium output, potassium output, and the sodium-potassium ratio, by the selected covariates and BMI. The sample weights were determined by the design weight and a post-stratification weight adjustment to correct for oversampling or under sampling(22,27). The Wald-F test was used to assess the differences across the categories of the covariates. We used multivariable linear regression to examine the associations of urinary sodium output, potassium output, and the sodium-potassium ratio with SBP and DBP. We estimated the adjusted β-coefficients associated with having a 1-SD-higher urinary sodium (SD=85mmol), a 1-SD-higher potassium (SD=19mmol), and a 1-unit difference in the sodium-potassium ratio among all adultsand by BMIstatus.

The dose-response relationship between urinary sodium excretion and BP while adjusting for covariates was tested for linearity through the fitting of a restricted cubic spline function(28). There is no evidence of significant departure from linearity (P=0.07-0.11). We calculated the middle value of each quintile (i.e., 10^{th}, 30^{th}, 50^{th}, 70^{th},90^{th} percentiles) of 24-h urinary sodium excretion in the total population and by BMI percentile, and we used the coefficients from the linear regression models to estimate the adjusted mean of the SBP/DBP associated with each of these values by BMI status(29). Similarly, for the SBP/DBP models with potassium or the sodium-potassium ratio, restricted cubic splines were also not significant (*P*=0.25-0.84); thus, we assumed a linear dose-response relationship for all three urinary measurements in relation to BP.

We used logistic regression to estimate the adjusted odds ratio (OR) for the associations of 24-h urinary sodium, potassium, and the sodium-potassium ratio with hypertension. Again, restricted cubic splines were not significant (*P*=0.47-0.63), suggesting linear dose-response relationships of 24-h urinary sodium, potassium, and the sodium-potassium ratio for prevalence of hypertension. Thus, we estimated the ORs comparing the mid-value of each quintile with the lowest quintile (Q5, Q4, Q3, Q2 vs. Q1) while adjusting for covariates.

In both linear and logistic regression, we used 3 models to adjust for covariates. In model 1, we adjusted for age, sex, rural/urban residency, and region; in model 2, in addition to the covariates in model 1, we adjusted for educational attainment, smoking status, drinking of alcohol, physical activity, and use of antihypertensive medication; in model 3, we further adjusted for BMI as a continuous variable.In models 1–3 for sodium excretion, we included potassium as a covariate, and for potassium excretion, we included sodium as a covariate.

We tested interactions between urinary sodium and potassium excretion, their ratio, and the broad BMI classification (normal vs. overweight/obese) by including the interaction terms in the linear or logistic regression models. We found significant interactions by BMI group for the associations between urinary sodium excretion and SBP (*P*=0.04) and DBP (*P*=0.03) and a marginally significant interaction

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for the association of the sodium-potassium ratio and SBP (*P*=0.07). We found a significant interaction by BMI classification for the association between the sodium-potassium ratio and hypertension (*P*=0.001) but not for sodium (*P*=0.10) or potassium (*P*=0.61) alone.

Sensitivity analysis

We conducted several sensitivity analyses. First, we repeated our analysis by excluding the known hypertensive participants who were taking an antihypertensive medication. Awareness of their hypertension status might have changed their intake of sodium(Supplemental Table1). Second, we also repeated our analysis by excluding the participants who had self-reported CVD or diabetes (n=71) at baseline (Supplemental Table 2). Third, we examined the distribution of 24-h urinary volume and urinary creatinine by the selected characteristics to assess the possible effects on the completeness of the urine collection(Supplemental Table3). Fourth, we repeated the analysis using alternative measures of incompleteness of urine collection based on excretion of urinary creatinine and other variables and present the results in Supplemental Tables4 to 8. Finally, we repeated the analysis by stratifying participants into three groups: normal weight, overweight and obese and presented results in Supplemental Tables 9 to 11.

Statistical analyses were performed with SAS 9.3 (SAS Institute Inc.). All tests were 2-sided and a *P* value<0.05 was considered significant.

Results

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The mean age of the 1948 participants was 41.4 years (SD=13.9). Out of them, 907 were classified as normal weight, 684 were overweight and 357 were obese. More than half of population (53.4%) was overweight or obese, and 22.9% had hypertension.

In the population, the mean 24-h urinary sodium excretionwas235.7 (mmol) (95% confidence interval [CI], 231.6, 239.9), and the mean potassium excretion was 40.5 (mmol) (95% CI, 39.6, 41.5). The mean sodium-potassium ratio was 6.8 (95% CI, 6.6, 7.0). Mean 24-h urinary sodium and potassium excretion were both significantly higher among overweight/obese adults than among those of normal weight, though mean sodium-potassium ratio did not significantly differ (Table 1).

Among all adults, each SD increase in 24-h urinary sodium excretion value (SD=85mmol) was associated with a significant increase of 1.09mmHg (95% CI, 0.22, 1.96) in SBP after adjusting for age, sex, urban/rural status, region, educational attainment, smoking status, drinking, physical activity,use of antihypertensive medication, and urinary excretion of potassium. After additional adjustment for BMI, the association between sodium excretion and SBP was not significant (Table 2).

Each rise of 1 SD in potassium excretion (SD=19mmol) was associated with a significantly lower SBP (-0.88 mmHg; 95% CI, -1.58, -0.19) when sodium excretion and all the covariates were included in the analysis (Table 2). The association between DBP and 24-h urinary sodium excretion was not significant, as was the case for the association of DBP and potassium excretion (Table 3).The sodium-potassium ratio was positively and significantly associated with increases in SBP and DBP, with or without adjustment for BMI (Table 2 and Table 3). We

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observed stronger and more consistent associations between BP and urinary sodium excretion, potassium excretion, and their ratio in the overweight/obese population than among those of normal weight (Table 2 and Table 3).

By quintile of urinary sodium, the adjusted SBP increased from 120.9mmHg (95% CI, 119.6, 122.1) in quintile 1 to 121.6mmHg (95% CI, 119.1, 124.1) in quintile 5 (P=0.313).Among overweight/obese men and women, it increased from 124.1mmHg (95% CI, 122.2, 126.0) in quintile 1 to 127.1mmHg (95% CI, 125.2, 128.9) in quintile 5 (P=0.010) (Figure 1).

In a comparison of the highest and the lowest quintiles of sodium excretion, the OR for prevalence of hypertension in the populationas a whole, after adjustment for all covariates except for BMI,was 1.62 (95% CI, 1.13, 2.31).After additional adjustment for BMI, it was 1.30 and no longer significant (95% CI, 0.91, 1.85). In the same comparison of quintiles, the fully adjusted OR (Model 3) for potassium excretion was 0.62 (95% CI, 0.42, 0.91), and for the sodium-potassium ratio was 1.54 (95% CI, 1.23, 1.92) (Table 4). The associations of sodium, potassium, and the sodium-potassium ratio with hypertension appeared to be stronger in the overweight/obese population than among those of normal weight (Table 4).

The pattern of association remained largely unchanged by excluding the participants currently using antihypertension medications or with self-reported CVD or diabetes (Supplemental Table 1 and 2). We examined the distribution of urine volume and creatinine by participant characteristics and did not find differential levels of incompleteness (Supplemental Table 3). In addition, our results remained largely

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unchanged in sensitivity analyses conducted on subsets of the study population using 5 different creatinine criteria to exclude participants with potentially incomplete urine collections (Supplemental Table 4-8). When analyzing BMI as three groups: i.e. normal, overweight and obese, the association between sodium excretion and SBP and prevalence of hypertension were significant among the overweight participants, but not among the obese participants. (Supplement Table 9-11).

Discussion

Using a representative sample of the Shandong adult population aged 18-69 years, we estimateda high average sodium intake (235.7mmol,or 5400mg/d), a low average intake of potassium (40.5mmol,or 1500mg/d), and a very high sodium-potassium ratio (6.8). Higher sodium excretion and the sodium-potassium ratio were associated with higher BP and prevalence of hypertension, and higher potassium excretion was inversely associated with BP and hypertension risk, while the observed associations appeared to be stronger in the overweight/obese population than in adults of normal weight.

Several earlier studies have examined the association between sodium intake and BP in various Chinese populations(5,17-21,30-33), including populations in northern and southern China and multiple ethnics (Supplemental Table 12).The majority of the studies showeda positive association between sodium intake and BP(5, 19, 21, 30-33), and the association in some of these reports was attenuated after adjusting for covariates,including BMI(5, 21,33).Among these studies, 3 had examined the effect of BMI on the sodium and BP relationship(20,21,33). In the multinational INTERSALT and INTERMAP study, no significant interactions were found on the association

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between urinary sodium, potassium intake, and BP by BMI among the Chinese participants (20, 21). In the Yi migration study, a greater association between sodium and BP was found among the persons with higher levels of BMI (33). However, in the above 3 studies, the samples of Chinese participants were limited (600-900 persons), and prevalence of hypertension and obesity was low.

The role played by body weight in the association between sodium intake and BP remains open to debate (34-36). Two studies suggested that obese adolescents had greater BP response/association to sodium intake than did their lean counterparts(15,16). In the TONE study, among older obese people with hypertension, there appeared to be an interaction between sodium reduction and weight loss (13). That study found that although the combined intervention (weight loss plus reduced sodium intake) was more beneficial than either of the interventions alonein reducing BP, the effect of the 2 interventions combined was not purely additive(13). Elsewhere, the GenSalt study suggested that the metabolic syndrome, of which obesity is a major component, was associated with differential effects of salt reduction on BP, with the number of risk factors for metabolic syndrome increased, the risk of BP changes of high/low sodium dietary intervention increased(14). Moreover, an independent association of sodium intake with the risk of cardiovascular disease was found only in the overweight participants in the first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study (37).

On the other hand, some studies did not find an effect of BMI on the sodium-BP relationship (20,21,38). In the INTERSALT study, the pooled regression coefficients for the effect of sodium intake on BP did not differ between participating centers or individuals in the upper (higher) BMI group and those in the lower BMI group(20). It was suggestedin that study controlling for BMI might lead to

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overadjustment.Because sodium intake was positively associated with BMI, and BMI is better measured than sodium intake, it may dominate combined regression models, and thus the greater sodium intake among the higher-BMI participantsmight have contributed to the association of BMI with BP.

In our study, BMI was moderately correlated with 24-hr sodium excretion ($r=0.15$, $P<0.001$). Adjusting for BMI attenuated the association for the population as a whole, which was consistent with the INTERSALT study findings, although we still observed a significant statistical interaction on the multiplicative scale of sodium and the sodium-potassium ratio with BP and prevalence of hypertension. Stratified analysis by BMI category in our study showed a significant sodium-SBP association among overweight/obese participants but not among those of normal weight, suggesting the possible modification of the observed sodium-BP associations by BMI.

Our findings of effect modification by BMI status on the association between sodium intake and BP, if true, might have significant public health implications for the prevention and control of hypertension in the Shandong Province and China as a whole. In the last 30 years in China, the trends for dietary sodium intake, prevalence of overweight/obesity, and hypertension have changed significantly. In the 1980s, while dietary sodium intake was already high, the prevalence of hypertension and overweight/obesity were low (9-10).Although the consumption of sodium has decreased slightly over time(7), the prevalence of hypertension and overweight/obesity increased dramatically(2,3,10). In China in 2010, of every 10 adults, 3 were hypertensive and 4 were overweight or obese(3,9). Given the rapid increase in the prevalence of overweight and obesity in Shandong Province as well as in China as a whole and the observed effect modification by BMI status, the high sodium intake and high sodium-potassium ratio might play an increasingly important role in the increased prevalence of hypertension and subsequent risk of CVD. In Shandong Province, the SMASH project, led by the local government and agencies from multiple sectors, is taking action to reduce salt intake to 10g/d in 2015 as well as to improve hypertension control(22). Our findings in this examination of survey data from SMASH project suggest that sodium reduction should occur alongside interventions to reduce obesity such as increasing physical activity and promotion of healthy diets to achieve better hypertension control and consequent reduced risk of CVD in Shandong.

A major strength of our study was the collection of timed 24-h urine specimens from representative population samples in Shandong Province under strict quality control. Potential limitations also exist. First, having a single 24-h urinesample from the participants might be insufficient to account for within- and between-person variation in the usual sodium intake (39,40), variation that might attenuate the association with BP ("regression-dilution") as suggested by other studies(5,18,19).Second,in sensitivity analyses, we used urinary creatinine, urine volume, and body weight to assess completeness of urine collection, as we did not have an objective biomarker of completeness such as para-aminobenzoic acid (PABA)(41). Our approach might lead to the inclusion of some incomplete urine samples or to the exclusion of some complete urine samples and thus introduce an additional source of variability. Third, in our study, covariates were based on self-report and thus subject to reporting error. For example, we did not obtain information on the intensity of physical activity or the frequency of alcohol consumption. Forth, calorie intake was not available in the SMASH 2011, therefore we couldn't adjust for the total calorie intake in

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our analyses. Fifth, we observed insignificant association between 24h sodium and BP among the normal weight participants, but could not rule out the potential for reverse causality, when the participants with certain medical conditions who might be less likely to be overweight and reduce their sodium intake (42). Furthermore, we observed non-significant association of sodium and BP and prevalence of hypertension among obese participants. This non-significant association might be, at least partly, attributed to the limited sample size in the obese group, however it deserved further investigation with larger sample size. Finally, SMASH 2011 was a cross-sectional study, and observed associations should be interpreted with caution. Follow-up with repeated 24-h urine collection is desirable to evaluate the effects of sodium intake on BP and risk of hypertension and possible interactions with BMI.

In our study, the positive association of urinary sodium excretion and the inverse association of potassium excretion with SBP, DBP, and prevalence for hypertension were stronger within the overweight/obese participants than among those of normal weight.The sodium-potassium ratio was significantly associated with BP and prevalence of hypertension regardless of BMI status and appeared to be a stronger predictor for prevalence of hypertension than sodium or potassium alone.The dietary pattern of high sodium and low potassium intakes contributes to the high burden of CVD, mainly stroke, in China, and along with the emerging obesity epidemic, represents a major threat to public health. It is important to move toward lowered sodium intake and higher potassium intake in the Chinese population to help tackle the growing CVD epidemic, which has already affected the health and welfare of millions of people in this country.

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Legends for Figures

Figure 1.Systolic blood pressure values by BMI status and 24-h sodium excretion, 24-h potassium excretion, and sodium-potassium ratio

Data source: Shandong and Ministry of Health Action on Salt and Hypertension (SMASH) project 2011 survey, among adults (n=1948) in Shandong Province, China

BMI: Body mass index. According to the Chinese guidelines for overweight and obesity, overweight is defined as a BMI of 24 to <28. Those with a BMI⩾28 are considered obese.

Footnote: We updated Figure footnote as ‘We used 10th, 30th, 50th, 70th and 90th percentiles as the mid-value of each quintile for sodium and potassium excretion and sodium-potassium ratio. The value for P10, P30, P50, P70 and P 90 for sodium was 137.0, 188.9, 230.3, 255.4, 341.3 mmol for all population, 129.9, 178.6, 217.9, 249.5, 312.5 mmol among normal weight population, 144.4, 201.3, 239.8, 257.9 and 365.4 mmol among overweight/obese population. The value for P10, P30, P50, P70 and P 90 for potassium was 19.7, 29.2, 37.7, 47.6, 65.0 mmol for all population, 19.2, 28.3, 36.5, 45.5, 61.9 mmol among normal weight population, 20.1, 30.3, 39.0, 49.2 and 68.0 mmol among overweight/obese population. The value for P10, P30, P50, P70 and P 90 for sodium-potassium ratio was 3.4, 4.7, 5.8, 7.7, 11.0 for all population, 3.3, 4.6, 5.7, 6.4, 10.9 among normal weight population, 3.5, 4.7, 5.9, 7.8, 11.2 among overweight/obese population.’

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Table1. The weighted mean of 24-hour sodium excretion, potassium excretion, and sodium-potassium ratio by BMI status

Characteristic	All participants (n=1948)			Normal weight [a](n=907)			Overweight/Obese [a](n=1041)		
	Na (mmol)	K (mmol)	Na/K	Na (mmol)	K (mmol)	Na/K	Na (mmol)	K (mmol)	Na/K
All	235.7	40.5	6.8	223.6	38.9	6.7	246.4	42.0	6.9
Age									
<50 years	235.4	40.4	6.8	222	38.7	6.7	247.9	41.9	6.9
≥ 50 years	236.4	41.0	6.8	227.9	39.4	6.6	243.1	42.2	6.9
Sex									
Male	244.3	39.8	7.1	230	38.7	6.8	257	40.7	7.4
Female	226.3[b]	41.4	6.5 [b]	216.6 [b]	39.1	6.6	234.8 [b]	43.4 [b]	6.4 [b]
Hypertension									
Yes	245.3	40.1	7.3	223.8	39.1	6.7	243.5	42.5	6.6
No	232.9 [c]	40.7	6.7 [c]	222.7	37.3	6.7	252.7	41	7.5 [c]

a. *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

b. *Male subjects significantly different than female subjects within total, normal weight and overweight population.*

c. *Hypertensive subjects significantly different than non-hypertensive subjects within total, normal weight and overweight population.*

Table2. Adjusted association of sodium excretion, potassium excretion, and sodium-potassium ratio with systolic blood pressure by BMI status

	Na		K		Na/K	
	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value
All population						
Model 1[b]	1.34 (0.42,2.25)	0.007	-0.96 (-1.75,-0.17)	0.021	0.49 (0.33,0.64)	<0.001
Model 2[c]	1.09 (0.22,1.96)	0.018	-0.85 (-1.53,-0.16)	0.019	0.43 (0.30,0.57)	<0.001
Model 3[d]	0.46 (-0.33,1.26)	0.231	-0.88 (-1.58,-0.19)	0.016	0.37 (0.26,0.49)	<0.001
Normal weight population [e]						
Model 1[b]	-0.39 (-1.81,1.03)	0.566	-0.27 (-1.58,1.05)	0.67	0.15 (-0.15,0.44)	0.307
Model 2[c]	-0.55 (-2.00,0.89)	0.425	-0.09 (-1.27,1.08)	0.865	0.12 (-0.17,0.41)	0.395
Model 3[d]	-0.66 (-2.01,0.69)	0.313	-0.21 (-1.45,1.02)	0.717	0.12 (-0.18,0.43)	0.403
Overweight/obese population [e]						
Model 1[b]	1.90 (0.85,2.94)	0.002	-1.74 (-2.55,-0.93)	<0.001	0.67 (0.42,0.91)	<0.001
Model 2[c]	1.65 (0.73,2.58)	0.002	-1.60 (-2.39,-0.81)	0.001	0.61 (0.38,0.83)	<0.001
Model 3[d]	1.31 (0.37,2.26)	0.01	-1.43 (-2.23,-0.63)	0.002	0.54 (0.34,0.75)	<0.001

[a.] β-*coefficients for the 24hour urine sodium and potassium are presented as per one standard deviation; the estimated population standard deviation for 24-hour sodium and 24-hour potassium was 85.0mmol and 19.0mmol, respectively. P-values for interactions between 24-hour sodium, potassium excretion and BMI status were 0.04 and 0.14 for systolic blood pressure and 0.03and 0.49for diastolic blood pressure, respectively.*

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[b] *Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium excretion in the regression model for sodium and sodium in the regression model for potassium.*

[c] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[d] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[e] *According to the Chinese guidelines for overweight and obesity, normal weight is defined asa BMI(kg/m^2) of $\geq$18.5 to $<$24, while overweight is defined as a BMI of 24 to $<$28. Those with a BMI$\geq$28 are considered obese.*

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Table3. Adjusted association of sodium excretion, potassium excretion, and sodium-potassium ratio with diastolic blood pressure by BMI status

	Na		K		Na/K	
	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value
All population						
Model 1[b]	0.89 (0.10,1.67)	0.03	-0.53 (-1.30,0.24)	0.16	0.26 (0.09,0.42)	0.005
Model 2[c]	0.69 (-0.07,1.44)	0.071	-0.46 (-1.14,0.22)	0.172	0.22 (0.07,0.37)	0.006
Model 3[d]	0.05 (-0.61,0.71)	0.864	-0.50 (-1.11,0.11)	0.103	0.16 (0.03,0.29)	0.02
Normal weight population [e]						
Model 1[b]	-0.39 (-1.55,0.77)	0.478	-0.39 (-1.53,0.74)	0.471	0.07 (-0.20,0.34)	0.598
Model 2[c]	-0.60 (-1.68,0.49)	0.257	-0.29 (-1.29,0.71)	0.545	0.04 (-0.21,0.29)	0.719
Model 3[d]	-0.69 (-1.69,0.32)	0.166	-0.39 (-1.42,0.64)	0.428	0.05 (-0.21,0.30)	0.707
Overweight/obese population [e]						
Model 1[b]	1.06 (0.36,1.75)	0.006	-0.86 (-1.54,-0.18)	0.017	0.33 (0.17,0.48)	<0.001
Model 2[c]	0.91 (0.27,1.54)	0.008	-0.77 (-1.42,-0.13)	0.022	0.30 (0.15,0.44)	0.001
Model 3[d]	0.59 (-0.04,1.22)	0.064	-0.62 (-1.26,0.03)	0.062	0.24 (0.10,0.38)	0.002

[a] β-*coefficient for the sodium-potassium ratio is presented as per 1 unit change. P-values for interactions between sodium-potassium ratio and BMI status were 0.07 for systolic blood pressure and 0.12for diastolic blood pressure, respectively.*

[b] *Model 1 adjusted for age, sex, urban-rural, and regions.*

[c] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[d] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[e] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Table4.Adjusted odds for risk of hypertension, by BMI status and quintile of sodium excretion (mmol), potassium excretion (mmol), and sodium-potassium ratio

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	$P_{\_trend}$[b]	Ratio(95% CI)[a]
All population							
Na							
Mid value of quintile/ Range	137.0	188.9	230.3	255.4	341.3		22.1,750.8
Model 1[c]	1.00	1.14(1.05,1.23)	1.26(1.09,1.46)	1.34(1.12,1.62)	1.66(1.21,2.29)	0.001	1.24(1.08,1.41)
Model 2[d]	1.00	1.13(1.03,1.24)	1.25(1.06,1.47)	1.32(1.08,1.63)	1.62(1.13,2.31)	0.004	1.22(1.05,1.42)
Model 3[e]	1.00	1.07(0.98,1.17)	1.13(0.96,1.32)	1.16(0.95,1.43)	1.30(0.91,1.85)	0.110	1.11(0.96,1.29)
K							
Mid value of quintile/ Range	19.7	29.2	37.7	47.6	65.0		25.4,227.0
Model 1[c]	1.00	0.92(0.86,0.99)	0.86(0.75,0.99)	0.79(0.64,0.98)	0.69(0.49,0.97)	0.018	0.85(0.74,0.99)
Model 2[d]	1.00	0.91(0.85,0.99)	0.84(0.73,0.98)	0.77(0.61,0.97)	0.65(0.45,0.94)	0.013	0.84(0.72,0.98)
Model 3[e]	1.00	0.90(0.83,0.98)	0.83(0.71,0.96)	0.75(0.59,0.95)	0.62(0.42,0.91)	0.008	0.82(0.70,0.96)
Na/K							
Mid value of quintile/ Range	3.4	4.7	5.8	7.7	11.0		0.3,37.3

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	P_trend[b]	Ratio(95% CI)[a]
Model 1[c]	1.00	1.08(1.04,1.11)	1.15(1.07,1.23)	1.28(1.14,1.45)	1.56(1.26,1.94)	<0.001	1.06(1.03,1.09)
Model 2[d]	1.00	1.08(1.04,1.12)	1.16(1.08,1.24)	1.30(1.15,1.48)	1.61(1.29,2.01)	<0.001	1.06(1.03,1.10)
Model 3[e]	1.00	1.07(1.03,1.11)	1.14(1.07,1.23)	1.27(1.13,1.44)	1.54(1.23,1.92)	<0.001	1.06(1.03,1.09)
Normal weight population [f]							
Na							
Mid value of quintile/ Range	129.9	178.6	217.9	249.5	312.5		38.9,749.6
Model 1[c]	1.00	1.01(0.87,1.17)	1.01(0.77,1.32)	1.01(0.72,1.42)	1.02(0.57,1.83)	0.931	1.01(0.79,1.29)
Model 2[d]	1.00	0.96(0.79,1.19)	0.94(0.65,1.36)	0.92(0.58,1.47)	0.87(0.39,1.95)	0.709	0.94(0.67,1.32)
Model 3[e]	1.00	0.95(0.78,1.17)	0.92(0.64,1.33)	0.90(0.56,1.43)	0.83(0.37,1.86)	0.623	0.93(0.66,1.29)
K							
Mid value of quintile/ Range	19.2	28.3	36.5	45.5	61.9		25.1,227.0
Model 1[c]	1.00	0.92(0.84,1.01)	0.86(0.72,1.02)	0.79(0.60,1.04)	0.68(0.44,1.06)	0.063	0.85(0.71,1.03)
Model 2[d]	1.00	0.93(0.82,1.05)	0.87(0.69,1.09)	0.80(0.56,1.14)	0.70(0.40,1.24)	0.184	0.86(0.68,1.10)
Model 3[e]	1.00	0.93(0.82,1.05)	0.86(0.68,1.10)	0.80(0.55,1.15)	0.69(0.38,1.26)	0.186	0.86(0.67,1.10)

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	P_trend[b]	Ratio(95% CI)[a]
Na/K							
Mid value of quintile/ Range	3.3	4.6	5.7	7.4	10.9		0.7,28.7
Model 1[c]	1.00	1.01(0.96,1.05)	1.01(0.93,1.10)	1.02(0.87,1.19)	1.03(0.79,1.36)	0.796	1.00(0.97,1.04)
Model 2[d]	1.00	1.00(0.93,1.07)	1.00(0.88,1.14)	1.00(0.79,1.27)	1.00(0.66,1.53)	0.992	1.00(0.95,1.06)
Model 3[e]	1.00	1.00(0.93,1.07)	1.00(0.88,1.14)	1.00(0.79,1.26)	1.00(0.66,1.52)	0.996	1.00(0.95,1.06)
Overweight/Obese population[f]							
Na							
Mid value of quintile/ Range	144.4	201.3	239.8	257.9	365.4		22.1,750.8
Model 1[c]	1.00	1.14(1.03,1.26)	1.26(1.06,1.51)	1.35(1.07,1.69)	1.67(1.13,2.48)	0.005	1.24(1.05,1.46)
Model 2[d]	1.00	1.15(1.03,1.28)	1.28(1.06,1.55)	1.37(1.08,1.74)	1.72(1.14,2.60)	0.005	1.25(1.06,1.49)
Model 3[e]	1.00	1.10(0.99,1.23)	1.20(0.99,1.45)	1.26(0.98~ 1.60)	1.48(0.97,2.26)	0.046	1.18(0.99,1.40)
K							
Mid value of quintile/ Range	20.1	30.3	39.0	49.2	68.0		4.69,155.17
Model 1[c]	1.00	0.90(0.83,0.98)	0.82(0.70,0.96)	0.74(0.58,0.95)	0.62(0.41,0.91)	0.009	0.82(0.69, 0.96)

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	$P_{\_trend}$[b]	Ratio(95% CI)[a]
Model 2[d]	1.00	0.89(0.81,0.98)	0.80(0.67,0.96)	0.71(0.54,0.94)	0.58(0.37,0.90)	0.008	0.79(0.66,0.96)
Model 3[e]	1.00	0.90(0.82,0.99)	0.82(0.68,0.98)	0.73(0.56,0.96)	0.60(0.39,0.94)	0.013	0.81(0.67,0.97)
Na/K							
Mid value of quintile/ Range	3.5	4.7	5.9	7.8	11.2		0.34,37.25
Model 1[c]	1.00	1.10(1.05,1.14)	1.19(1.10,1.29)	1.38(1.20,1.59)	1.77(1.37,2.28)	<0.001	1.08(1.04,1.12)
Model 2[d]	1.00	1.10(1.06,1.14)	1.20(1.12,1.29)	1.39(1.22,1.59)	1.81(1.44,2.28)	<0.001	1.08(1.05,1.11)
Model 3[e]	1.00	1.09(1.04,1.13)	1.17(1.08,1.27)	1.33(1.15,1.53)	1.66(1.29,2.14)	<0.001	1.07(1.03, 1.11)

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[a] *For urinary sodium and potassium excretion, ORs are for per one standard deviation (SD) increase in excretion. For sodium-potassium ratio, ORs is per unit change.*

[b] *P-value for trend across percentiles of urinary excretion of sodium, potassium or sodium-potassium ratio based on F-test; all tests were two-tailed. P-values for interactions between 24hour sodium, potassium and sodium-potassium ration and BMI status on risk for hypertension were 0.10, 0.61, and 0.001 respectively.*

[c] *Model 1 adjusted for age, sex, urban-rural, and regions.*

[d] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[e] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[f] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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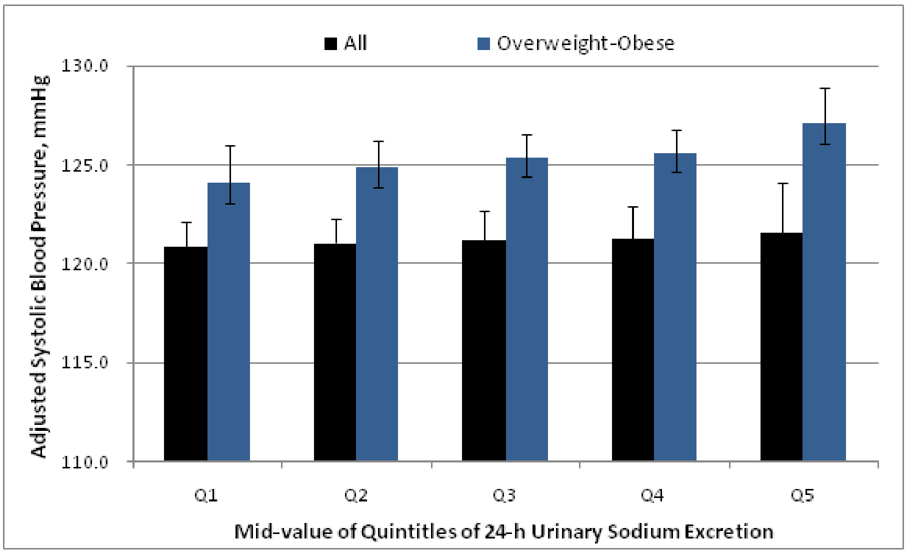
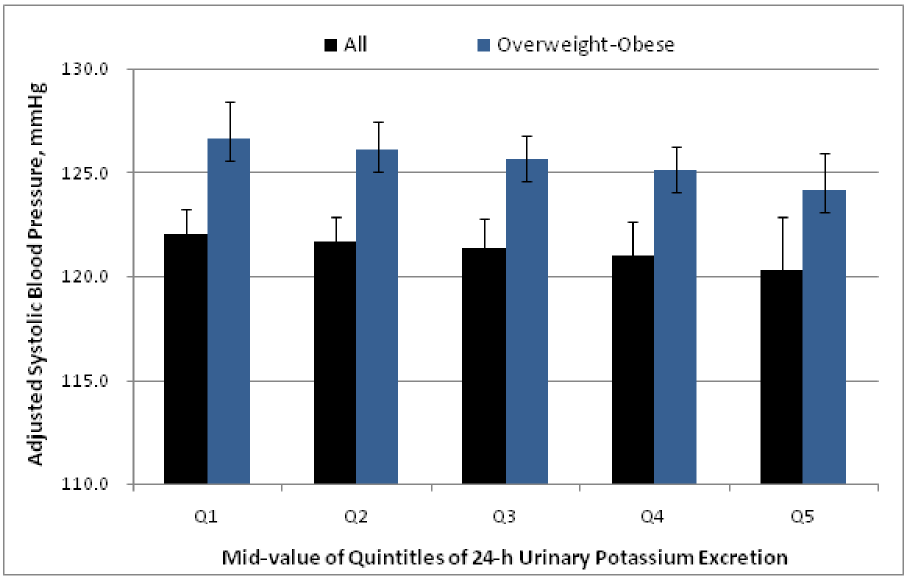
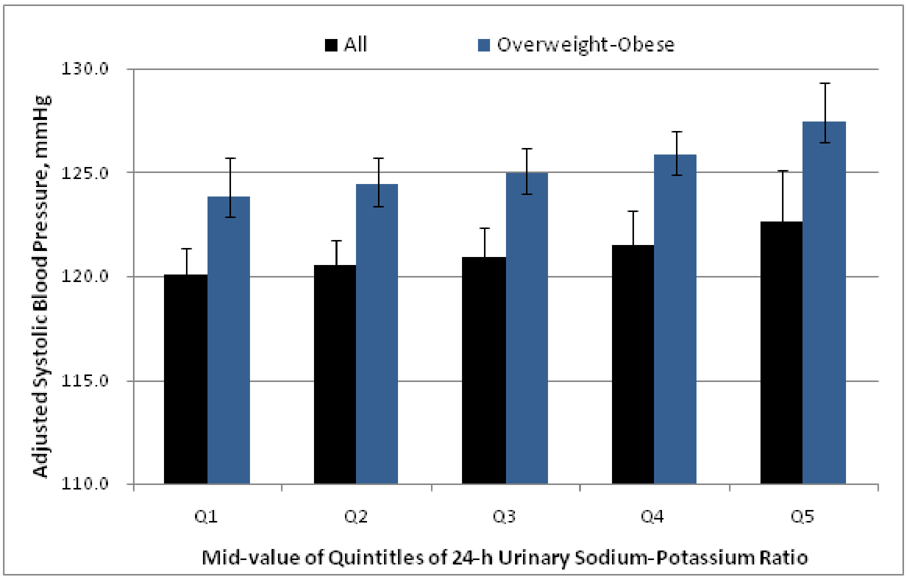


■ All
■ Overweight-Obese
Adjusted Systolic Blood Pressure, mmHg
130.0
125.0
120.0
115.0
110.0
Q1
Q2
Q3
Q4
Q5
Mid-value of Quintitles of 24-h Urinary Sodium Excretion



■ All
■ Overweight-Obese
Adjusted Systolic Blood Pressure, mmHg
130.0
125.0
120.0
115.0
110.0
Q1
Q2
Q3
Q4
Q5
Mid-value of Quintitles of 24-h Urinary Potassium Excretion



■ All
■ Overweight-Obese
Adjusted Systolic Blood Pressure, mmHg
130.0
125.0
120.0
115.0
110.0
Q1
Q2
Q3
Q4
Q5
Mid-value of Quintitles of 24-h Urinary Sodium-Potassium Ratio

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Online Supplemental Material

Supplemental Table1 Association of urinary sodium, potassium and sodium-potassium ratio with blood pressure exclude participants taking anti-hypertensive medications (n=1823 with 877 normal weight and 946 overweight/obese)

	SBP		DBP	
	β-coefficient (95% CI)[1]	p-value	β-coefficient (95% CI) [1]	p-value
All population				
Sodium excretion				
Model 1[2]	1.37 (0.48,2.26)	0.01	0.86 (0.10,1.61)	0.03
Model 2[3]	1.07 (0.15,1.99)	0.03	0.65 (-0.10,1.40)	0.08
Model 3[4]	0.42 (-0.43,1.26)	0.31	0.01 (-0.66v0.68)	0.98
Potassium excretion				
Model 1[2]	-0.88 (-1.82,0.06)	0.06	-0.50 (-1.37,0.37)	0.23
Model 2[3]	-0.76 (-1.61,0.08)	0.07	-0.43 (-1.23,0.37)	0.27
Model 3[4]	-0.83 (-1.65,-0.01)	0.05	-0.50 (-1.22,0.23)	0.16
Sodium-potassium ratio				
Model 1[2]	0.44 (0.23,0.65)	0.00	0.26 (0.06,0.45)	0.01
Model 2[3]	0.39 (0.19,0.59)	0.00	0.22 (0.05,0.40)	0.01
Model 3[4]	0.33 (0.16,0.50)	0.00	0.16 (0.01,0.31)	0.03
Normal weight population[5]				
Sodium excretion				
Model 1[2]	-0.28 (-1.65,1.09)	0.67	-0.39 (-1.54,0.77)	0.48
Model 2[3]	-0.62 (-2.06,0.82)	0.37	-0.64 (-1.72,0.44)	0.23
Model 3[4]	-0.69 (-2.04,0.66)	0.29	-0.70 (-1.71,0.31)	0.16

	SBP		DBP	
	β-coefficient (95% CI)[1]	p-value	β-coefficient (95% CI)[1]	p-value
Potassium excretion				
Model 1[2]	-0.21 (-1.42,1.01)	0.72	-0.32 (-1.46,0.83)	0.56
Model 2[3]	-0.06 (-1.17,1.05)	0.90	-0.23 (-1.26,0.80)	0.64
Model 3[4]	-0.18 (-1.37,1.00)	0.74	-0.33 (-1.39,0.73)	0.52
Sodium-potassium ratio				
Model 1[2]	0.17 (-0.10,0.44)	0.21	0.07 (-0.20,0.33)	0.60
Model 2[3]	0.11 (-0.17,0.39)	0.40	0.03 (-0.21,0.28)	0.79
Model 3[4]	0.12 (-0.17,0.41)	0.40	0.04 (-0.21,0.29)	0.76
Overweight/obese population[5]				
Sodium excretion				
Model 1[2]	1.92 (0.78,3.05)	0.00	1.03 (0.31,1.76)	0.01
Model 2[3]	1.68 (0.59,2.77)	0.01	0.91 (0.21,1.61)	0.01
Model 3[4]	1.31 (0.24,2.39)	0.02	0.57 (-0.13,1.27)	0.10
Potassium excretion				
Model 1[2]	-1.68 (-2.65,-0.71)	0.00	-0.88 (-1.69,-0.06)	0.04
Model 2[3]	-1.56 (-2.50,-0.63)	0.00	-0.80 (-1.61,0.00)	0.05
Model 3[4]	-1.42 (-2.36,-0.48)	0.01	-0.68 (-1.48,0.13)	0.09
Sodium-potassium ratio				
Model 1[2]	0.60 (0.34,0.86)	0.00	0.35 (0.16,0.54)	0.00
Model 2[3]	0.56 (0.31,0.82)	0.00	0.33 (0.14,0.51)	0.00
Model 3[4]	0.50 (0.26,0.73)	0.00	0.27 (0.10,0.44)	0.00

[1] β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[2] *Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium in each model.*

[3] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity. We also included the potassium in the regression for sodium and sodium in the regression for potassium in each model.*

[4] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[5] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Online Supplemental Material

Supplemental Table2. Adjusted association of 24hour urinary sodium, potassium and sodium-potassium ratio by excluding the participants with self-reported chronic disease (n=1877 with 888 normal weight and 989 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	1.32 (0.40~2.24)	0.008	0.85 (0.07~1.62)	0.035
Model 2[4]	0.98 (0.09~1.88)	0.034	0.59 (-0.14~1.32)	0.106
Model 3[5]	0.39 (-0.41~1.19)	0.317	-0.02 (-0.66~0.62)	0.944
Potassium excretion				
Model 1[3]	-0.85 (-1.67~-0.03)	0.043	-0.49 (-1.34~0.36)	0.239
Model 2[4]	-0.77 (-1.49~-0.05)	0.038	-0.42 (-1.18~0.34)	0.258
Model 3[5]	-0.79 (-1.49~-0.08)	0.032	-0.44 (-1.13~0.25)	0.194
Sodium-potassium ratio				
Model 1[3]	0.48 (0.30~0.66)	<0.001	0.26 (0.08~0.44)	0.008
Model 2[4]	0.42 (0.26~0.58)	<0.001	0.22 (0.05~0.38)	0.014
Model 3[5]	0.35 (0.21~0.50)	<0.001	0.15 (-0.00~0.30)	0.051
normal weight population[6]				
Sodium excretion				
Model 1[3]	-0.44 (-1.88~1.00)	0.522	-0.43 (-1.59~0.74)	0.445
Model 2[4]	-0.63 (-2.09~0.83)	0.373	-0.64 (-1.71~0.43)	0.219

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 3[5]	-0.73 (-2.09~0.63)	0.268	-0.73 (-1.72~0.26)	0.138
Potassium excretion				
Model 1[3]	-0.13 (-1.48~1.22)	0.839	-0.32 (-1.49~0.85)	0.570
Model 2[4]	0.02 (-1.17~1.22)	0.967	-0.23 (-1.26~0.81)	0.649
Model 3[5]	-0.09 (-1.35~1.17)	0.879	-0.32 (-1.38~0.74)	0.527
Sodium-potassium ratio				
Model 1[3]	0.13 (-0.17~0.44)	0.366	0.06 (-0.22~0.34)	0.666
Model 2[4]	0.11 (-0.19~0.41)	0.450	0.03 (-0.23~0.29)	0.797
Model 3[5]	0.11 (-0.20~0.42)	0.463	0.03 (-0.23~0.29)	0.792
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	1.94 (0.86~3.03)	0.002	1.03 (0.32~1.73)	0.008
Model 2[4]	1.61 (0.57~2.64)	0.005	0.81 (0.17~1.45)	0.016
Model 3[5]	1.31 (0.25~2.37)	0.019	0.53 (-0.13~1.19)	0.109
Potassium excretion				
Model 1[3]	-1.65 (-2.54~-0.75)	0.001	-0.82 (-1.59~-0.06)	0.036
Model 2[4]	-1.56 (-2.42~-0.69)	0.002	-0.75 (-1.46~-0.04)	0.041
Model 3[5]	-1.38 (-2.23~-0.53)	0.004	-0.57 (-1.29~0.14)	0.109
Sodium-potassium ratio				
Model 1[3]	0.65 (0.39~0.91)	<0.001	0.33 (0.17~0.49)	0.001

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 2[4]	0.59 (0.35~0.84)	<0.001	0.30 (0.14~0.45)	0.001
Model 3[5]	0.53 (0.31~0.76)	<0.001	0.24 (0.08~0.39)	0.006

[1] *Among the 1948 participants with complete 24h urine collected, 71 participants were self-reported to have chronic disease (34 were self-reported to have diabetes, 14 were stroke, 36 were CHD), leaving 1877 participants for the sensitive analysis.*

[2] β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3] *Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[4] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Online Supplemental Material

Supplemental Table 3 Distribution of 24-hour urinary volume and urinary creatinine by selected demographics, SMASH baseline survey, 2011

	24-hour urine volume			24-hour urine creatinine	
	N	Median	(25^{th}–75^{th})	Median	(25^{th}–75^{th})
Age					
<50years	1359	1400	1070~1800	8.8	6.8~11.2
≥ 50years	589	1530	1162~2000	7.6	6.1~9.8
Gender					
male	1030	1450	1110~1900	10	7.3~12.2
female	918	1420	1070~1820	7.5	6.2~8.9
City					
urban	619	1500	1120~1920	8.9	6.8~11.3
rural	1329	1400	1080~1820	8.2	6.5~10.6
Region					
south-central	773	1440	1100~1830	8	6.3~10.7
north-west	679	1450	1130~1900	8.2	6.6~10.6
east	496	1400	1020~1820	9	7.1~11.2
Education years					
0-9years	1473	1440	1080~1850	8.2	6.5~10.5
9-12years	297	1390	1055~1870	9	6.9~11.4
>12years	178	1498	1150~1800	9.6	7~12.4
Occupation					
Farmer or fisherman	947	1420	1100~1850	7.9	6.4~10.3
Manufacture worker	285	1350	1040~1900	9.6	6.9~11.7
Businessman	168	1425	1080~1760	9.1	7~11.3
Office worker/technicians	183	1510	1190~1980	9.2	6.9~11.8
Students	150	1355	1070~1640	8.4	7~11.4
Houseworker/retired /unemployed	212	1545	1105~1955	8.1	6.5~9.8
Physical activity					
none	1563	1440	1100~1850	8.2	6.5~10.6
<3times/wk	94	1418	1090~1685	10.2	7.4~12.5
≥3times/wk	271	1470	1095~1920	9	7~11.5
BMI status					
normal weight	907	1400	1060~1820	7.9	6.2~10.1
overweight	684	1450	1105~1850	8.5	6.8~10.9
obesity	357	1460	1100~1940	9.6	7.3~11.9

Online Supplemental Material

Supplemental Table 4 Association of 24hour urinary sodium, potassium and sodium-potassium ratio by Reinivuo's criteria (n=1415 with 604 normal weight and 811 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	1.07 (0.21,1.94)	0.01	0.95 (0.38,1.51)	0.00
Model 2[4]	0.74 (-0.13,1.60)	0.10	0.71 (0.13,1.29)	0.02
Model 3[5]	-0.06 (-0.91,0.78)	0.88	-0.06 (-0.60,0.47)	0.81
Potassium excretion				
Model 1[3]	-0.62 (-1.43,0.19)	0.13	-0.48 (-1.02,0.05)	0.07
Model 2[4]	-0.50 (-1.29,0.29)	0.21	-0.40 (-0.93,0.13)	0.14
Model 3[5]	-0.57 (-1.33,0.19)	0.14	-0.46 (-0.94,0.02)	0.06
Sodium-potassium ratio				
Model 1[3]	0.39 (0.12,0.66)	0.00	0.28 (0.10,0.46)	0.00
Model 2[4]	0.31 (0.05,0.57)	0.02	0.23 (0.05,0.40)	0.01
Model 3[5]	0.23 (-0.02,0.48)	0.07	0.15 (-0.01,0.31)	0.07
normal weight population[6]				
Sodium excretion				
Model 1[3]	-0.36 (-1.66,0.94)	0.58	-0.18 (-1.02,0.66)	0.67
Model 2[4]	-0.80 (-2.12,0.51)	0.23	-0.66 (-1.52,0.20)	0.13
Model 3[5]	-0.91 (-2.22,0.39)	0.17	-0.75 (-1.60,0.09)	0.08
Potassium excretion				
Model 1[3]	0.03 (-1.15,1.22)	0.95	-0.53 (-1.30,0.24)	0.17

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 2[4]	0.23 (-0.94,1.39)	0.70	-0.38 (-1.14,0.38)	0.33
Model 3[5]	0.12 (-1.03,1.28)	0.83	-0.47 (-1.22,0.27)	0.22
Sodium-potassium ratio				
Model 1[3]	0.05 (-0.35,0.44)	0.82	0.10 (-0.15,0.36)	0.43
Model 2[4]	-0.02 (-0.41,0.37)	0.92	0.03 (-0.23,0.28)	0.83
Model 3[5]	0.01 (-0.38,0.39)	0.98	0.05 (-0.20,0.30)	0.70
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	1.13 (-0.00,2.26)	0.05	0.83 (0.12,1.55)	0.02
Model 2[4]	0.90 (-0.25,2.05)	0.12	0.76 (0.02,1.50)	0.04
Model 3[5]	0.49 (-0.65,1.63)	0.40	0.35 (-0.37,1.07)	0.34
Potassium excretion				
Model 1[3]	-1.33 (-2.40,-0.26)	0.01	-0.64 (-1.31,0.04)	0.06
Model 2[4]	-1.23 (-2.28,-0.19)	0.02	-0.61 (-1.28,0.06)	0.08
Model 3[5]	-1.15 (-2.18,-0.12)	0.03	-0.53 (-1.17,0.12)	0.11
Sodium-potassium ratio				
Model 1[3]	0.57 (0.22,0.92)	0.00	0.32 (0.10,0.54)	0.01
Model 2[4]	0.48 (0.13,0.83)	0.01	0.29 (0.06,0.51)	0.01
Model 3[5]	0.40 (0.06,0.75)	0.02	0.21 (-0.01,0.42)	0.06

[1] Reinivuo H, Valsta LM, Laatikainen T, Tuomilehto J, Pietinen P.Sodium in the Finnish diet: II trends in dietary sodium intake and comparison between intake and 24-h excretion of sodium. Eur J Clin Nutr 2006; 60: 1160-7. Reinivuo's criterion to classify incompleteness of 24hour urine collection is urinary creatinine

level<6mmol/d plus a total urine volume<1000ml/d. Based on Reinivuo's criterion, 659 participants in our study was classified as incompleteness urine collection and excluded, further 38 participants were excluded for low body weight and leaving 1415subject for final analysis. Given the large numbers of participants excluded, we didn't use the weighted means for the association study, and used the sampled means for association study. Proc Reg statement was used for the analysis.

[2]β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3]*Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium excretion in the regression model for sodium and sodium in the regression model for potassium.*

[4]*Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5]*Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6]*According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Online Supplemental Material

Supplemental Table 5 Association of 24hour urinary sodium, potassium and sodium-potassium ratio by WHO's criteria (n=1546 with 717 normal weight and 829 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	1.61 (0.77,2.45)	0.00	1.14 (0.60,1.68)	0.00
Model 2[4]	1.08 (0.23,1.92)	0.01	0.83 (0.27,1.39)	0.00
Model 3[5]	0.25 (-0.58,1.08)	0.56	-0.02 (-0.54,0.49)	0.94
Potassium excretion				
Model 1[3]	-0.16 (-1.02,0.71)	0.72	-0.06 (-0.62,0.50)	0.83
Model 2[4]	-0.06 (-0.89,0.78)	0.89	0.02 (-0.54,0.57)	0.96
Model 3[5]	-0.43 (-1.24,0.38)	0.30	-0.36 (-0.87,0.14)	0.16
Sodium-potassium ratio				
Model 1[3]	0.38 (0.11,0.65)	0.01	0.21 (0.03,0.38)	0.02
Model 2[4]	0.26 (-0.00,0.53)	0.05	0.14 (-0.04,0.31)	0.13
Model 3[5]	0.24 (-0.02,0.49)	0.07	0.11 (-0.05,0.27)	0.16
normal weight population[6]				
Sodium excretion				
Model 1[3]	0.47 (-0.80,1.74)	0.47	0.07 (-0.72,0.86)	0.86
Model 2[4]	-0.16 (-1.43,1.11)	0.80	-0.54 (-1.35,0.27)	0.19
Model 3[5]	-0.22 (-1.49,1.04)	0.73	-0.59 (-1.39,0.20)	0.14
Potassium excretion				
Model 1[3]	0.20 (-1.08,1.49)	0.75	-0.29 (-1.09,0.51)	0.48

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 2[4]	0.39 (-0.84,1.62)	0.53	-0.14 (-0.92,0.64)	0.72
Model 3[5]	0.19 (-1.03,1.42)	0.76	-0.31 (-1.08,0.46)	0.43
Sodium-potassium ratio				
Model 1[3]	0.07 (-0.32,0.45)	0.74	0.00 (-0.24,0.24)	0.99
Model 2[4]	-0.02 (-0.40,0.36)	0.92	-0.09 (-0.32,0.15)	0.48
Model 3[5]	0.02 (-0.35,0.40)	0.90	-0.05 (-0.29,0.19)	0.68
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	1.55 (0.42,2.68)	0.01	0.96 (0.25,1.66)	0.01
Model 2[4]	1.27 (0.11,2.42)	0.03	0.87 (0.13,1.60)	0.02
Model 3[5]	0.79 (-0.34,1.93)	0.17	0.42 (-0.28,1.13)	0.24
Potassium excretion				
Model 1[3]	-1.09 (-2.25,0.06)	0.06	-0.47 (-1.19,0.26)	0.21
Model 2[4]	-1.00 (-2.13,0.13)	0.08	-0.43 (-1.15,0.28)	0.24
Model 3[5]	-1.04 (-2.15,0.06)	0.06	-0.48 (-1.16,0.21)	0.17
Sodium-potassium ratio				
Model 1[3]	0.67 (0.29,1.05)	0.00	0.36 (0.13,0.60)	0.00
Model 2[4]	0.55 (0.18,0.93)	0.00	0.32 (0.08,0.55)	0.01
Model 3[5]	0.51 (0.14,0.87)	0.01	0.27 (0.05,0.50)	0.02

[1] WHO Regional Office for Europe. Estimation of sodium intake and output: review of methods and recommendations for epidemiological studies. Report on a WHO meeting by the WHO collaborating center for research and training in cardiovascular disease.Geneva: World Health Organization. 1984. WHO's criterion to classify incompleteness of 24hour urine collection is ratio of urinary creatinine (mg/d)to body

weight (kg) <10.8 or >25.2.Based on WHO's criterion, 506 participants in our study was classified as incompleteness urine collection and excluded, further 50 participants were excluded for low body weight, and leaving 1546subject for final analysis. Given the large numbers of participants excluded, we didn't use the weighted means for the association study, and used the sampled means for association study. Proc Reg statement was used for the analysis.

[2]β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3]*Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[4]*Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5]*Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6]*According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Online Supplemental Material

Supplemental Table 6 Association of 24hour urinary sodium, potassium and sodium-potassium ratio by Malekshah's criteria (n=1289 with 577 normal weight and 712 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	1.84 (0.89,2.79)	0.00	1.36 (0.76,1.95)	0.00
Model 2[4]	1.32 (0.36,2.28)	0.01	1.10 (0.48,1.72)	0.00
Model 3[5]	0.41 (-0.54,1.36)	0.39	0.17 (-0.42,0.75)	0.58
Potassium excretion				
Model 1[3]	-0.26 (-1.26,0.74)	0.61	-0.14 (-0.77,0.49)	0.67
Model 2[4]	-0.15 (-1.11,0.82)	0.77	-0.07 (-0.69,0.56)	0.83
Model 3[5]	-0.50 (-1.44,0.44)	0.30	-0.43 (-1.00,0.14)	0.14
Sodium-potassium ratio				
Model 1[3]	0.48 (0.17,0.78)	0.00	0.27 (0.08,0.46)	0.01
Model 2[4]	0.35 (0.06,0.65)	0.02	0.20 (0.01,0.39)	0.04
Model 3[5]	0.30 (0.02,0.59)	0.04	0.15 (-0.03,0.33)	0.09
normal weight population[6]				
Sodium excretion				
Model 1[3]	0.36 (-1.13,1.86)	0.63	0.10 (-0.81,1.01)	0.83
Model 2[4]	-0.27 (-1.78,1.23)	0.72	-0.50 (-1.43,0.44)	0.30
Model 3[5]	-0.37 (-1.87,1.13)	0.63	-0.57 (-1.50,0.35)	0.23
Potassium excretion				
Model 1[3]	0.46 (-1.05,1.98)	0.55	-0.11 (-1.04,0.81)	0.81

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 2[4]	0.58 (-0.87,2.03)	0.43	-0.01 (-0.91,0.88)	0.97
Model 3[5]	0.41 (-1.03,1.86)	0.57	-0.15 (-1.04,0.75)	0.75
Sodium-potassium ratio				
Model 1[3]	0.04 (-0.41,0.50)	0.86	-0.02 (-0.30,0.26)	0.88
Model 2[4]	-0.02 (-0.46,0.42)	0.92	-0.09 (-0.36,0.18)	0.51
Model 3[5]	0.00 (-0.43,0.44)	0.98	-0.07 (-0.34,0.20)	0.61
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	1.91 (0.66,3.16)	0.00	1.24 (0.47,2.01)	0.00
Model 2[4]	1.72 (0.44,3.01)	0.01	1.22 (0.41,2.03)	0.00
Model 3[5]	1.22 (-0.05,2.49)	0.06	0.75 (-0.03,1.52)	0.06
Potassium excretion				
Model 1[3]	-1.43 (-2.74,-0.12)	0.03	-0.78 (-1.58,0.03)	0.06
Model 2[4]	-1.31 (-2.60,-0.02)	0.05	-0.73 (-1.53,0.08)	0.08
Model 3[5]	-1.31 (-2.57,-0.05)	0.04	-0.72 (-1.49,0.05)	0.07
Sodium-potassium ratio				
Model 1[3]	0.76 (0.35,1.17)	0.00	0.43 (0.18,0.68)	0.00
Model 2[4]	0.66 (0.25,1.06)	0.00	0.39 (0.14,0.65)	0.00
Model 3[5]	0.60 (0.20,0.99)	0.00	0.34 (0.10,0.58)	0.01

[1] Malekshah AF, Kimiagar M, Saadatian-Elahi M, Pourshams A, Nouraie M, Goglani G, et al.Validity and reliability of a new food frequency questionnaire compared to 24 h recalls and biochemical measurements: pilot phase of Golestan cohort study of esophageal cancer. Eur J Clin Nutr 2006; 60: 971-7. Malekshal's criterion to classify incompleteness of 24hour urine collection is ratio of urinary creatinine (mg/d)to body

weight (kg) <11 or >20.Based on Malekshal's criterion, 774 participants in our study was classified as incompleteness urine collection and excluded, further 49 participants were excluded for low body weight, and leaving 1289 subject for final analysis. Given the large numbers of participants excluded, we didn't use the weighted means for the association study, and used the sampled means for association study. ProcReg statement was used for the analysis.

[2]β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3]*Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[4]*Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5]*Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6]*According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Supplemental Table 7 Adjusted association of 24hour urinary sodium, potassium and sodium-potassium ratio by Joossens and Geboers's criteria (n=1304 with 659 normal weight and 645 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	1.28 (0.42,2.13)	0.00	1.07 (0.49,1.65)	0.00
Model 2[4]	0.86 (-0.01,1.73)	0.05	0.79 (0.20,1.39)	0.01
Model 3[5]	-0.08 (-0.93,0.77)	0.85	-0.16 (-0.70,0.39)	0.57
Potassium excretion				
Model 1[3]	-0.28 (-1.12,0.56)	0.51	-0.12 (-0.68,0.45)	0.69
Model 2[4]	-0.21 (-1.03,0.61)	0.61	-0.06 (-0.61,0.50)	0.84
Model 3[5]	-0.49 (-1.27,0.30)	0.23	-0.33 (-0.84,0.17)	0.19
Sodium-potassium ratio				
Model 1[3]	0.26 (-0.03,0.55)	0.08	0.20 (-0.00,0.40)	0.05
Model 2[4]	0.20 (-0.09,0.48)	0.18	0.15 (-0.05,0.35)	0.14
Model 3[5]	0.15 (-0.12,0.43)	0.28	0.10 (-0.07,0.28)	0.25
normal weight population[6]				
Sodium excretion				
Model 1[3]	0.29 (-0.99,1.57)	0.65	0.08 (-0.74,0.90)	0.85
Model 2[4]	-0.23 (-1.51,1.05)	0.72	-0.38 (-1.22,0.45)	0.37
Model 3[5]	-0.48 (-1.75,0.79)	0.46	-0.60 (-1.41,0.22)	0.15
Potassium excretion				

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 1[3]	0.05 (-1.17,1.27)	0.94	-0.32 (-1.10,0.46)	0.42
Model 2[4]	0.28 (-0.89,1.46)	0.63	-0.16 (-0.93,0.60)	0.67
Model 3[5]	0.14 (-1.03,1.30)	0.82	-0.29 (-1.04,0.46)	0.45
Sodium-potassium ratio				
Model 1[3]	0.10 (-0.30,0.50)	0.62	0.07 (-0.18,0.33)	0.58
Model 2[4]	0.02 (-0.37,0.41)	0.93	0.00 (-0.25,0.26)	0.99
Model 3[5]	0.03 (-0.36,0.41)	0.89	0.01 (-0.24,0.26)	0.94
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	1.10 (-0.07,2.27)	0.06	0.84 (0.06,1.62)	0.03
Model 2[4]	0.94 (-0.26,2.14)	0.12	0.75 (-0.05,1.56)	0.07
Model 3[5]	0.37 (-0.83,1.56)	0.55	0.19 (-0.58,0.97)	0.62
Potassium excretion				
Model 1[3]	-1.06 (-2.20,0.08)	0.07	-0.35 (-1.10,0.40)	0.36
Model 2[4]	-1.06 (-2.19,0.06)	0.06	-0.37 (-1.12,0.38)	0.34
Model 3[5]	-1.10 (-2.21,-0.00)	0.05	-0.41 (-1.12,0.31)	0.26
Sodium-potassium ratio				
Model 1[3]	0.48 (0.04,0.92)	0.03	0.30 (0.01,0.59)	0.04
Model 2[4]	0.45 (0.01,0.89)	0.05	0.29 (-0.01,0.58)	0.06
Model 3[5]	0.39 (-0.05,0.82)	0.08	0.22 (-0.06,0.50)	0.12

[1] *Joossens JV, Geboers J. Monitoring salt intake of the population: methodological considerations.Wageningen: Department of Human Nutrition, Agricultural University. 1984. Joossens and*

Geboers's criterion to classify incompleteness of 24hour urine collection is gender specific ratio of urinary creatinine (mmol/d) to body weight (kg) <0.6.Based on Joossens and Geboers's criterion, 740 participants in our study was classified as incompleteness urine collection and excluded, further 68 participants were excluded for low body weight, and leaving 1304 subject for further analysis. Given the large numbers of participants excluded, we didn't use the weighted means for the association study, and used the sampled means for association study. Proc reg statement was used for the analysis.

[2]β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3]*Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[4]*Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5]*Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6]*According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Supplemental Table 8 Adjusted association of 24hour urinary sodium, potassium and sodium-potassium ratio by Knuiman's criteria (n=917 with 499 normal weight and 418 overweight/obese)[1]

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
All population				
Sodium excretion				
Model 1[3]	0.97 (0.03,1.90)	0.04	0.82 (0.16,1.48)	0.01
Model 2[4]	0.66 (-0.29,1.61)	0.17	0.58 (-0.10,1.25)	0.09
Model 3[5]	-0.26 (-1.18,0.66)	0.57	-0.36 (-0.98,0.26)	0.26
Potassium excretion				
Model 1[3]	-0.28 (-1.22,0.66)	0.56	0.09 (-0.57,0.76)	0.78
Model 2[4]	-0.22 (-1.14,0.71)	0.65	0.15 (-0.51,0.81)	0.65
Model 3[5]	-0.58 (-1.46,0.31)	0.20	-0.22 (-0.81,0.38)	0.47
Sodium-potassium ratio				
Model 1[3]	0.22 (-0.11,0.54)	0.20	0.14 (-0.09,0.37)	0.25
Model 2[4]	0.18 (-0.15,0.51)	0.28	0.10 (-0.13,0.33)	0.39
Model 3[5]	0.17 (-0.14,0.48)	0.28	0.09 (-0.12,0.30)	0.38
normal weight population[6]				
Sodium excretion				
Model 1[3]	0.15 (-1.24,1.53)	0.84	-0.09 (-1.01,0.83)	0.85
Model 2[4]	-0.22 (-1.62,1.19)	0.76	-0.41 (-1.35,0.52)	0.39
Model 3[5]	-0.42 (-1.81,0.98)	0.56	-0.61 (-1.53,0.31)	0.19

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Potassium excretion				
Model 1[3]	-0.43 (-1.81,0.96)	0.55	-0.23 (-1.15,0.69)	0.62
Model 2[4]	-0.19 (-1.57,1.18)	0.78	-0.09 (-1.01,0.83)	0.84
Model 3[5]	-0.35 (-1.71,1.02)	0.62	-0.24 (-1.14,0.66)	0.60
Sodium-potassium ratio				
Model 1[3]	0.20 (-0.24,0.65)	0.37	0.09 (-0.20,0.39)	0.55
Model 2[4]	0.14 (-0.30,0.58)	0.53	0.04 (-0.26,0.33)	0.80
Model 3[5]	0.16 (-0.28,0.60)	0.47	0.06 (-0.23,0.35)	0.70
overweight/obese population[6]				
Sodium excretion				
Model 1[3]	0.70 (-0.58,1.99)	0.28	0.55 (-0.37,1.46)	0.24
Model 2[4]	0.51 (-0.82,1.83)	0.45	0.43 (-0.52,1.38)	0.37
Model 3[5]	-0.27 (-1.57,1.03)	0.68	-0.24 (-1.16,0.67)	0.60
Potassium excretion				
Model 1[3]	-0.89 (-2.17,0.39)	0.17	-0.14 (-1.05,0.77)	0.77
Model 2[4]	-0.89 (-2.17,0.38)	0.17	-0.17 (-1.09,0.74)	0.71
Model 3[5]	-0.97 (-2.20,0.25)	0.12	-0.24 (-1.11,0.62)	0.58
Sodium-potassium ratio				
Model 1[3]	0.39 (-0.13,0.91)	0.14	0.22 (-0.15,0.59)	0.25
Model 2[4]	0.33 (-0.20,0.86)	0.22	0.20 (-0.18,0.58)	0.31

	SBP		DBP	
	β-coefficient (95% CI)[2]	p-value	β-coefficient (95% CI)[2]	p-value
Model 3[5]	0.26 (-0.25,0.77)	0.32	0.13 (-0.23,0.49)	0.48

[1] *Knuiman JT, Hautvast JG, van der Heyden L, Geboers J, Joossens JV, Tornqvist H, et al.A multi-centre study on completeness of urine collection in 11 European centres. I. Some problems with the use of creatinine and 4-aminobenzoic acid as markers of the completeness of collection. Hum Nutr Clin Nutr 1986; 40: 229-37. Knuiman's criterion to classify incompleteness of 24hour urine collection is gender specific ratio of urinary creatinine (mmol/d) to body weight (kg) <0.7.Based on Knuiman's criterion, 1143 participants in our study was classified as incompleteness urine collection and excluded, further 52 participants were excluded for low body weight, and leaving 917 subject for further analysis. Given the large numbers of participants excluded, we didn't use the weighted means for the association study, and used the sampled means for association study. Proc reg statement was used for the analysis.*

[2] β-*coefficient for the 24hour urine sodium and potassium is presented as per one standard deviation; the estimated population standard deviation for 24hour sodium and 24hour potassium was 85.0mmol and 19.0mmol, respectively.* β-*coefficient for the sodium-potassium ratio is presented as per 1 unit.*

[3] *Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[4] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[5] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[6] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Online Supplemental Material

Supplemental Table 9. Adjusted association of sodium excretion, potassium excretion, and sodium-potassium ratio with systolic blood pressure by BMI status

	Na		K		Na/K	
	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value
All population						
Model 1[b]	1.34 (0.42,2.25)	0.007	-0.96 (-1.75,-0.17)	0.021	0.49 (0.33,0.64)	<0.001
Model 2[c]	1.09 (0.22,1.96)	0.018	-0.85 (-1.53,-0.16)	0.019	0.43 (0.30,0.57)	<0.001
Model 3[d]	0.46 (-0.33,1.26)	0.231	-0.88 (-1.58,-0.19)	0.016	0.37 (0.26,0.49)	<0.001
Normal weight population [e]						
Model 1[b]	-0.39 (-1.81,1.03)	0.566	-0.27 (-1.58,1.05)	0.670	0.15 (-0.15,0.44)	0.307
Model 2[c]	-0.55 (-2.00,0.89)	0.425	-0.09 (-1.27,1.08)	0.865	0.12 (-0.17,0.41)	0.395
Model 3[d]	-0.66 (-2.01,0.69)	0.313	-0.21 (-1.45,1.02)	0.717	0.12 (-0.18,0.43)	0.403
Overweight [e]						
Model 1[b]	2.47 (0.76,4.17)	0.008	-1.28 (-2.52,-0.04)	0.044	0.57 (0.24,0.89)	0.002
Model 2[c]	2.05 (0.28,3.81)	0.026	-1.18 (-2.43,0.08)	0.065	0.53 (0.22,0.85)	0.002
Model 3[d]	2.07 (0.36,3.79)	0.021	-1.28 (-2.50,-0.05)	0.042	0.57 (0.27,0.87)	0.001
obese						
Model 1[b]	0.48 (-1.04,2.01)	0.509	-2.66 (-4.19,-1.14)	0.002	0.64 (0.26,1.01)	0.003
Model 2[c]	0.45 (-0.99,1.89)	0.515	-2.41 (-4.06,-0.76)	0.007	0.59 (0.18,1.00)	0.008
Model 3[d]	0.43 (-0.98,1.85)	0.524	-2.35 (-4.00,-0.69)	0.009	0.59 (0.17,1.00)	0.009

[a.] β-*coefficients for the 24hour urine sodium and potassium are presented as per one standard deviation; the estimated population standard deviation for 24-hour sodium and 24-hour potassium was 85.0mmol and*

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19.0mmol, respectively. P-values for interactions between 24-hour sodium, potassium excretion and BMI status were 0.04 and 0.14 for systolic blood pressure and 0.03and 0.49 for diastolic blood pressure, respectively.

[b] *Model 1 adjusted for age, sex, urban-rural, and regions. We also included the potassium excretion in the regression model for sodium and sodium in the regression model for potassium.*

[c] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[d] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[e] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Supplemental Table 10. Adjusted association of sodium excretion, potassium excretion, and sodium-potassium ratio with diastolic blood pressure by BMI status

	Na		K		Na/K	
	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value	β-coefficient (95% CI)[a]	p-value
All population						
Model 1[b]	0.89 (0.10,1.67)	0.03	-0.53 (-1.30,0.24)	0.16	0.26 (0.09,0.42)	0.005
Model 2[c]	0.69 (-0.07,1.44)	0.071	-0.46 (-1.14,0.22)	0.172	0.22 (0.07,0.37)	0.006
Model 3[d]	0.05 (-0.61,0.71)	0.864	-0.50 (-1.11,0.11)	0.103	0.16 (0.03,0.29)	0.02
Normal weight population [e]						
Model 1[b]	-0.39 (-1.55,0.77)	0.478	-0.39 (-1.53,0.74)	0.471	0.07 (-0.20,0.34)	0.598
Model 2[c]	-0.60 (-1.68,0.49)	0.257	-0.29 (-1.29,0.71)	0.545	0.04 (-0.21,0.29)	0.719
Model 3[d]	-0.69 (-1.69,0.32)	0.166	-0.39 (-1.42,0.64)	0.428	0.05 (-0.21,0.30)	0.707
Overweight [e]						
Model 1[b]	0.82 (-0.10,1.73)	0.075	-0.47 (-1.37,0.43)	0.279	0.27 (0.06,0.47)	0.014
Model 2[c]	0.58 (-0.40,1.57)	0.224	-0.41 (-1.31,0.49)	0.348	0.25 (0.05,0.45)	0.020
Model 3[d]	0.61 (-0.27,1.49)	0.161	-0.50 (-1.33,0.33)	0.219	0.28 (0.10,0.46)	0.005
Obese						
Model 1[b]	0.72 (-0.04,1.48)	0.063	-1.32 (-2.28,-0.36)	0.011	0.27 (-0.02,0.56)	0.065
Model 2[c]	0.61 (-0.14,1.37)	0.102	-1.20 (-2.19,-0.21)	0.021	0.25 (-0.06,0.57)	0.108
Model 3[d]	0.59 (-0.21,1.38)	0.138	-1.10 (-2.15,-0.05)	0.041	0.25 (-0.07,0.57)	0.119

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[a] β-*coefficient for the sodium-potassium ratio is presented as per 1 unit change. P-values for interactions between sodium-potassium ratio and BMI status were 0.07 for systolic blood pressure and 0.12for diastolic blood pressure, respectively.*

[b] *Model 1 adjusted for age, sex, urban-rural, and regions.*

[c] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use.*

[d] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[e] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m^2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Supplemental Table 11.Adjusted odds for risk of hypertension, by BMI status and quintile of sodium excretion, potassium excretion, and sodium-potassium ratio

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	$P_{\_trend}$[b]	Ratio(95% CI)[a]
All population							
Na							
Model 1[c]	1.00	1.14(1.05,1.23)	1.26(1.09,1.46)	1.34(1.12,1.62)	1.66(1.21,2.29)	0.001	1.24(1.08,1.41)
Model 2[d]	1.00	1.13(1.03,1.24)	1.25(1.06,1.47)	1.32(1.08,1.63)	1.62(1.13,2.31)	0.004	1.22(1.05,1.42)
Model 3[e]	1.00	1.07(0.98,1.17)	1.13(0.96,1.32)	1.16(0.95,1.43)	1.30(0.91,1.85)	0.110	1.11(0.96,1.29)
K							
Model 1[c]	1.00	0.92(0.86,0.99)	0.86(0.75,0.99)	0.79(0.64,0.98)	0.69(0.49,0.97)	0.018	0.85(0.74,0.99)
Model 2[d]	1.00	0.91(0.85,0.99)	0.84(0.73,0.98)	0.77(0.61,0.97)	0.65(0.45,0.94)	0.013	0.84(0.72,0.98)
Model 3[e]	1.00	0.90(0.83,0.98)	0.83(0.71,0.96)	0.75(0.59,0.95)	0.62(0.42,0.91)	0.008	0.82(0.70,0.96)
Na/K							
Model 1[c]	1.00	1.08(1.04,1.11)	1.15(1.07,1.23)	1.28(1.14,1.45)	1.56(1.26,1.94)	<0.001	1.06(1.03,1.09)
Model 2[d]	1.00	1.08(1.04,1.12)	1.16(1.08,1.24)	1.30(1.15,1.48)	1.61(1.29,2.01)	<0.001	1.06(1.03,1.10)
Model 3[e]	1.00	1.07(1.03,1.11)	1.14(1.07,1.23)	1.27(1.13,1.44)	1.54(1.23,1.92)	<0.001	1.06(1.03,1.09)
Normal weight population[f]							
Na							

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	P_trend[b]	Ratio(95% CI)[a]
Model 1[c]	1.00	1.01(0.87,1.17)	1.01(0.77,1.32)	1.01(0.72,1.42)	1.02(0.57,1.83)	0.931	1.01(0.79,1.29)
Model 2[d]	1.00	0.96(0.79,1.19)	0.94(0.65,1.36)	0.92(0.58,1.47)	0.87(0.39,1.95)	0.709	0.94(0.67,1.32)
Model 3[e]	1.00	0.95(0.78,1.17)	0.92(0.64,1.33)	0.90(0.56,1.43)	0.83(0.37,1.86)	0.623	0.93(0.66,1.29)
K							
Model 1[c]	1.00	0.92(0.84,1.01)	0.86(0.72,1.02)	0.79(0.60,1.04)	0.68(0.44,1.06)	0.063	0.85(0.71,1.03)
Model 2[d]	1.00	0.93(0.82,1.05)	0.87(0.69,1.09)	0.80(0.56,1.14)	0.70(0.40,1.24)	0.184	0.86(0.68,1.10)
Model 3[e]	1.00	0.93(0.82,1.05)	0.86(0.68,1.10)	0.80(0.55,1.15)	0.69(0.38,1.26)	0.186	0.86(0.67,1.10)
Na/K							
Model 1[c]	1.00	1.01(0.96,1.05)	1.01(0.93,1.10)	1.02(0.87,1.19)	1.03(0.79,1.36)	0.796	1.00(0.97,1.04)
Model 2[d]	1.00	1.00(0.93,1.07)	1.00(0.88,1.14)	1.00(0.79,1.27)	1.00(0.66,1.53)	0.992	1.00(0.95,1.06)
Model 3[e]	1.00	1.00(0.93,1.07)	1.00(0.88,1.14)	1.00(0.79,1.26)	1.00(0.66,1.52)	0.996	1.00(0.95,1.06)
Overweight[f]							
Na							
Model 1[c]	1.00	1.25(1.10, 1.42)	1.50(1.20, 1.89)	1.68(1.25, 2.24)	2.44(1.48, 4.02)	<0.001	1.45(1.18, 1.78)
Model 2[d]	1.00	1.25(1.07, 1.45)	1.49(1.14, 1.95)	1.66(1.18, 2.33)	2.39(1.32, 4.32)	0.002	1.44(1.12, 1.84)
Model 3[e]	1.00	1.27(1.09, 1.46)	1.53(1.17, 1.98)	1.71(1.23, 2.38)	2.52(1.42, 4.48)	0.001	1.47(1.16, 1.87)
K							

		Odds Ratio(95% CI)[a]						Overall Odds Ratio(95% CI)[a]
		Q1	Q2	Q3	Q4	Q5	$P_{\_trend}$[b]	
	Model 1[c]	1.00	0.89(0.78, 1.00)	0.80(0.63, 1.01)	0.70(0.49, 1.01)	0.56(0.31, 1.02)	0.039	0.79(0.61, 1.01)
	Model 2[d]	1.00	0.87(0.74, 1.02)	0.77(0.57, 1.04)	0.66(0.42, 1.06)	0.51(0.24, 1.09)	0.059	0.76(0.55, 1.04)
	Model 3[e]	1.00	0.85(0.71, 1.00)	0.73(0.53, 1.00)	0.61(0.37, 1.00)	0.45(0.20, 1.01)	0.034	0.71(0.51, 1.00)
Na/K								
	Model 1[c]	1.00	1.13(1.06, 1.21)	1.26(1.11, 1.44)	1.52(1.21, 1.92)	2.12(1.40, 3.21)	<0.001	1.10(1.05, 1.17)
	Model 2[d]	1.00	1.14(1.06, 1.23)	1.29(1.12, 1.49)	1.59(1.23, 2.05)	2.29(1.45, 3.59)	<0.001	1.12(1.05, 1.18)
	Model 3[e]	1.00	1.17(1.08, 1.26)	1.35(1.16, 1.57)	1.71(1.30, 2.25)	2.60(1.59, 4.25)	<0.001	1.13(1.06, 1.21)
Obese[f]								
Na								
	Model 1[c]	1.00	0.97(0.85, 1.10)	0.95(0.75, 1.19)	0.93(0.70, 1.25)	0.89(0.54, 1.47)	0.607	0.95(0.77, 1.17)
	Model 2[d]	1.00	1.00(0.87, 1.14)	1.00(0.79, 1.26)	1.00(0.74, 1.34)	0.99(0.59, 1.66)	0.973	1.00(0.80, 1.24)
	Model 3[e]	1.00	1.00(0.87, 1.14)	0.99(0.78, 1.26)	0.99(0.73, 1.35)	0.99(0.58, 1.67)	0.959	0.99(0.80, 1.24)
K								
	Model 1[c]	1.00	0.91(0.82, 1.01)	0.84(0.68, 1.03)	0.76(0.55, 1.04)	0.64(0.38, 1.07)	0.062	0.83(0.67, 1.03)
	Model 2[d]	1.00	0.90(0.79, 1.03)	0.83(0.64, 1.06)	0.74(0.50, 1.10)	0.62(0.33, 1.17)	0.107	0.82(0.63, 1.07)
	Model 3[e]	1.00	0.91(0.79, 1.04)	0.83(0.64, 1.08)	0.75(0.50, 1.13)	0.63(0.32, 1.22)	0.131	0.82(0.62, 1.09)
Na/K								

	Odds Ratio(95% CI)[a]						Overall Odds
	Q1	Q2	Q3	Q4	Q5	$P_{\_trend}$[b]	Ratio(95% CI)[a]
Model 1[c]	1.00	1.03(0.95, 1.12)	1.07(0.91, 1.25)	1.12(0.84, 1.50)	1.23(0.74, 2.06)	0.379	1.03(0.96, 1.10)
Model 2[d]	1.00	1.04(0.95, 1.14)	1.09(0.91, 1.30)	1.16(0.84, 1.60)	1.31(0.74, 2.31)	0.313	1.04(0.96, 1.12)
Model 3[e]	1.00	1.05(0.95, 1.15)	1.09(0.91, 1.30)	1.17(0.84, 1.61)	1.32(0.74, 2.35)	0.306	1.04(0.96, 1.12)

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[a] *For urinary sodium and potassium excretion, ORs are for per one standard deviation (SD) increase in excretion. For sodium-potassium ratio, ORs is per unit change.*

[b] *P-value for trend across percentiles of urinary excretion of sodium, potassium or sodium-potassium ratio based on F-test; all tests were two-tailed. P-values for interactions between 24hour sodium, potassium and sodium-potassium ration and BMI status on risk for hypertension were 0.10, 0.61, and 0.001 respectively.*

[c] *Model 1 adjusted for age, sex, urban-rural, and regions.*

[d] *Model 2 adjusted for all factors in Model 1 plus educational attainment, smoking status, alcohol intake, physical activity, and anti-hypertensive medication use. We also included the potassium in the regression model for sodium and sodium in the regression model for potassium.*

[e] *Model 3 adjusted for all factors in Model 2 plus BMI as a continuous variable.*

[f] *According to the Chinese guidelines for overweight and obesity, normal weight is defined as a BMI(kg/m2) of ≥18.5 to <24, while overweight is defined as a BMI of 24 to <28. Those with a BMI≥28 are considered obese.*

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Supplemental Table 12. The observational studies on the association between sodium intake and blood pressure in Chinese population (from urine collection samples)

Study	N	Urine samples collected	Sodium-BP association	Is BMI adjusted?	Regression coefficient sodium and SBP (mmHg/1 mmol)
INTERSALT Chinese, 1988 (5)	600	24h urine	positive	Yes	0.03-0.08
Kesteloot et al, 1987 (30)	2008	24h urine	positive	No	0.028-0.039
He et al,1991 (31)	419	24h urine	positive	Yes	0.02
Tian et al, 1995 (19)	663	24h urine	positive	Yes	0.03
Liu et al, 2000 (32)	619	24h urine	positive	Yes	0.038
Zhao et al, 2004 (21)	839	24h urine	positive	Yes	Without BMI:0.024 With BMI:0.016

[1]The value was the product of regression coefficient and deviation of urinary sodium (25mmol/l).

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