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Association between urinary sodium excretion and coronary heart disease in hospitalized elderly patients in China

Chun-lin Li, Hai-jun Wang, Quan-jin Si, Jin Zhou, Kai-liang Li and Yu Ding

Abstract

Objective: This study was performed to evaluate the association between urinary sodium excretion and coronary heart disease (CHD) in hospitalized elderly patients in China.

Methods: The 24-h urinary excretion specimens of 541 patients were collected, and the serum creatinine concentration and urinary sodium/potassium ratio were measured. Associations were explored by multivariate logistic regression analysis.

Results: The mean 24-h urinary sodium excretion was 200.4 mmol, corresponding to 11.7 g of salt intake. Both of these values were higher in men than in women. The salt intake of 80- to 89-year-old patients was significantly lower than that of 70- to 79-year-old patients. The 24-h urinary sodium excretion and spot urine Na/K ratios were significantly higher in overweight/obese and hypertensive patients. The 24-h urinary sodium excretion of men who smoked was significantly higher than that of women. The spot urine Na/K ratio was significantly higher in patients with cerebral thrombosis. The urinary Na/K ratio, smoking status, and hypertension were independent risk factors for CHD.

Conclusions: This cross-sectional survey suggests that the Na/K ratio may better represent salt loading than Na excretion alone in studying the association between sodium intake and CHD. There was no association between sodium and CHD prevalence.

Keywords

Aged, coronary heart disease, sodium, dietary, sodium/potassium ratio, sodium excretion

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Department of Geriatric Cardiology, Chinese PLA General Hospital, Beijing, P.R. China

Corresponding author:
Quan-jin Si, Department of Geriatric Cardiology, Chinese PLA General Hospital, 28 Fuxing Road, Beijing 100853, P. R. China.
Email: siqjcplagh@126.com

Introduction

Globally, one of the main preventive measures against cardiovascular disease is to reduce sodium intake,[1] which is commonly achieved by a salt-restricted diet.[2] In most countries, high salt intake remains a serious public health problem; from a medical standpoint, the current recommendation for salt intake is 5 to 6 g/day. However, further limiting salt intake to 3 g/day exerts obvious adverse effects. More than half of the world's population consumes 7.5 to 15.0 g/day of salt.[3] In China, the average salt intake is approximately 9 to 12 g/day.[4]

Although salt intake has been extensively studied among people of a wide range of ages, the salt intake of older adults has seldom been reported. China is facing a serious aging problem characterized by rapid growth of the population of older people. The morbidity rate of coronary heart disease (CHD) among older adults is rapidly increasing.[5] The salt intake of most Chinese people evidently surpasses the recommended level.[6] Thus, a thorough understanding of the salt intake of high-risk populations is of great clinical significance. The aim of this study was to detect the sodium intake of Chinese older adults based on the 24-h urinary sodium excretion and evaluate the prevalence of CHD associated with salt intake.

Materials and methods

Patients

This cross-sectional survey was conducted in our hospital from June 2012 to July 2014. Patients aged $\geq$60 years who were able to independently walk indoors were selected. This study was approved by the ethics committee of our hospital, and written informed consent was obtained from all patients. All patients underwent biochemical and clinical examinations. Patients taking diuretic agents, those from whom we were unable to collect urine samples, and those with severe renal or hepatic impairment were excluded. The criterion for renal impairment was a serum creatinine level of $\geq$133 μmol/L. The criterion for hepatic impairment was an alanine transaminase level of >40 U/L.

Urine sampling protocols

Spot urine samples were collected to estimate the spot urine sodium/potassium (Na/K) ratio. Twenty-four-hour urine samples were also collected and analyzed to determine the urinary sodium excretion. The procedures were explained both orally and in written form. All samples were collected into provided bags. Urine from the same patient was completely mixed, and the volume was then measured. The urine (20 mL) was subsequently pooled and frozen at −20°C until biochemical analysis. The 24-h urinary sodium level was the mean of the results obtained on three consecutive days and expressed in units of mmol/24 h. The estimated salt intake was calculated according to the following formula: urinary sodium (mmol/L) × 24-h urine volume (L) × 58.5.[7] The blood creatinine level was determined using an automated enzymatic procedure.

Clinical and biochemical measurements

All patients' blood pressures were measured by trained doctors. The patients rested in a seated position for at least 5 min before the measurements. Blood pressure was measured three consecutive times, and the mean was recorded. Information about patients' recent medical histories, lifestyle habits, and medications were recorded. Hypertension was diagnosed in patients with a brachial diastolic blood pressure of $\geq$90 mmHg, brachial systolic blood pressure of $\geq$140 mmHg, and/or the use of

antihypertensive medication. The patients' peripheral venous blood specimens were taken after 8 h of overnight fasting. The total serum cholesterol concentration was determined by standardized automated methods. Diabetes mellitus was diagnosed in patients with a fasting blood glucose concentration of $\geq$7.0 mmol/L (126 mg/dL), a random blood glucose concentration of 11.1 mmol/L (200 mg/dL), or the use of anti-diabetic drugs.

Statistical analysis

Statistical analysis was performed by SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA). A P value of <0.05 was considered statistically significant. Categorical variables were examined by the χ^2 test. Continuous variables are expressed as mean $\pm$ standard deviation. Multivariate logistic regression analysis was conducted to assess the independent risk factors for CHD. Univariate logistic regression analysis was performed to select the factors associated with CHD, and variables with a P value of <0.25 were retained and evaluated.

Results

Patient characteristics by sex

Table 1 shows the baseline clinical data of the patients by sex. Of the 541 patients, 316 were men (58.4%) and 225 were women (41.6%). The mean age was 82.8 years, and the mean body mass index was 24.32 kg/m^2. There were no significant differences in age and body mass index between men and women. However, the proportion of men with a history of smoking and drinking was higher than that of women ($P < 0.05$). In addition, men were significantly more prone to hypertension, CHD, and cerebral thrombosis and ($P < 0.05$). In contrast, women had a significantly higher prevalence of dyslipidemia than did men ($P < 0.05$). Men had significantly higher levels of urinary potassium and sodium than did women ($P < 0.001$).

Urinary sodium and potassium excretion and creatinine clearance rates in different age groups

Table 2 lists the estimated daily salt intake and 24-h urinary sodium and potassium excretion of each age subgroup. The mean total 24-h urinary sodium excretion was 200.4 ± 19.1 mmol, corresponding to a mean salt intake of 11.7 ± 1.1 g. Men had a higher 24-h urinary sodium excretion and corresponding salt intake than women ($P < 0.05$). However, the creatinine clearance rate, 24-h urinary potassium level, and urinary Na/K ratio were similar between men and women. The urinary excretion levels of sodium and potassium and the creatinine clearance rate decreased with increasing age. The salt intake of patients aged 80 to 89 years was lower than that of patients aged 70 to 79 years ($P < 0.05$). The salt intake of men was significantly higher than that of women in the 70- to 79-year and >90-year subgroups ($P < 0.05$).

Association of clinical factors with urinary sodium excretion and spot urine Na/K ratio

Table 3 shows the associations of clinical and lifestyle factors with urinary sodium excretion and the spot urine Na/K ratio. Men had higher 24-h urinary sodium excretion than women ($P < 0.05$). The 24-h urinary sodium excretion levels and spot urine Na/K ratios were significantly higher in patients who were obese or overweight or who had hypertension or coronary artery disease ($P < 0.05$). The 24-h urinary sodium excretion of men who smoked was higher than that of women ($P < 0.05$). In contrast, the spot urine Na/K ratio was

Table 1. Patients' characteristics

	Total (n = 541)	Men (n = 316)	Women (n = 225)
General condition			
Age, years	82.8 ± 3.5	86.8 ± 4.2	80.9 ± 3.5
BMI, kg/m^2	24.32 ± 3.2	23.73 ± 2.0	25.30 ± 2.6
Smoking	93	72*	21
Drinking	211	142*	69
SBP, mmHg	133.7 ± 18.1	132.3 ± 18.0	134.5 ± 17.6
DBP, mmHg	78.7 ± 9.6	77.7 ± 8.9	79.6 ± 9.5
Scr, μmol/L	139.2 ± 19.5	138.9 ± 19.3	141.9 ± 20.5
Basic disease			
Hypertension	366	226*	140
CHD	287	175*	112
DM	362	201	161
Cerebral thrombosis	209	127*	82
Dyslipidemia	275	146	129*
Medication use			
Aspirin	402	245	157
Clopidogrel	238	121	117
Statins	364	202	162
Beta blockers	258	154	104
Nitrates	244	132	112
ACEI/ARB	248	141	107
CCB	297	182	115
Urinary measurements			
Urine volume, L	2.8 ± 0.9	3.1 ± 0.3	2.6 ± 0.8
Urine Na excretion, mmol/L	193.4 ± 32.1	213.6 ± 36.2**	189.2 ± 39.8
Urine K excretion, mmol/L	23.8 ± 3.1	24.6 ± 4.5**	21.7 ± 4.6

Data are presented as mean ± standard deviation or number of patients.
CHD, coronary heart disease; DM, diabetes mellitus; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; Scr, serum creatinine; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker.
*$P < 0.05$, men vs. women; **$P < 0.001$, men vs. women.

higher in patients with cerebral thrombosis ($P < 0.05$). Men and women had similar spot urine Na/K ratios, and the 24-h urinary sodium excretions of patients with cerebral thrombosis (yes versus no) and dyslipidemia (yes versus no) were not significantly different.

Multivariate logistic regression analysis

Multivariate logistic regression analysis was performed using the presence versus absence of CHD as the dependent variable. Age, smoking status, drinking status, the creatinine clearance rate, urinary sodium and potassium excretion, and the urinary Na/K ratio were included as independent variables (Table 4). An increased urinary Na/K ratio (odds ratio [OR], 1.20; 95% confidence interval [CI], 1.128–1.525; $P = 0.008$), smoking status (OR, 1.316; 95% CI, 1.103–1.359; $P = 0.007$), and hypertension (OR, 1.328; 95% CI, 1.101–1.412; $P = 0.013$) were independently associated with a higher risk of CHD.

Table 2. Urinary sodium and potassium excretion and creatinine clearance rate in different age groups

Sex	Age group, years	n	Urinary Na excretion (mmol/24 h)	Urinary K excretion (mmol/24 h)	Na/K ratio	CCR (mL/min)	Salt intake (g/d)
Men	60–69	75	223.6 ± 18.2	70.1 ± 15.3	3.29 ± 1.56	153.6 ± 20.1	13.1 ± 1.1
	70–79	94	218.3 ± 19.1	68.0 ± 14.7	3.31 ± 1.33	151.2 ± 19.8	12.7 ± 1.1
	80–89	96	182.5 ± 20.7	57.3 ± 13.6	3.35 ± 1.26	133.4 ± 18.6	10.6 ± 1.2
	≥90	51	178.4 ± 17.8	47.6 ± 12.2	3.26 ± 1.80	103.5 ± 20.5	10.4 ± 1.0
	Subtotal	316	211.4 ± 19.5	60.6 ± 13.8	3.32 ± 1.72	134.5 ± 20.5	12.4 ± 1.1
Women	60–69	77	217.1 ± 19.3	68.2 ± 17.6	3.28 ± 2.06	150.1 ± 24.0	12.7 ± 1.5
	70–79	53	195.7 ± 22.4	65.6 ± 16.9	3.38 ± 1.83	150.3 ± 21.2	11.4 ± 1.4
	80–89	65	175.9 ± 23.2	60.3 ± 12.8	3.51 ± 1.41	137.8 ± 23.4	10.3 ± 1.1
	≥90	30	166.0 ± 19.9	45.9 ± 13.1	3.40 ± 1.21	119.6 ± 18.7	9.7 ± 1.6
	Subtotal	225	200.2 ± 17.6	59.5 ± 12.7	3.36 ± 1.81	138.5 ± 20.5	11.7 ± 1.0
Total	60–69	152	221.6 ± 31.1	68.3 ± 19.5	3.24 ± 1.93	151.2 ± 26.9	12.9 ± 1.8
	70–79	147	205.8 ± 27.7	66.2 ± 18.5	3.20 ± 1.71	150.7 ± 21.8	12.0 ± 1.6
	80–89	161	181.1 ± 19.8	58.9 ± 16.6	3.37 ± 1.62	135.9 ± 19.5	10.6 ± 1.2
	≥90	81	172.5 ± 18.2	47.7 ± 13.1	3.65 ± 1.80	101.0 ± 19.9	10.1 ± 1.1
	Subtotal	541	200.4 ± 19.1	59.6 ± 17.3	3.36 ± 1.91	138.5 ± 20.5	11.7 ± 1.1

Data are presented as mean ± standard deviation.
Na/K ratio, sodium/potassium ratio; CCR, creatinine clearance rate.
Salt intake was estimated as follows: urinary sodium (mmol/L) × 24-h urine volume (L) × 58.5 g.

Discussion

Measurement of 24-h urine sodium excretion has been considered a reliable method of salt intake estimation and has been performed in many epidemiologic and clinical studies.[8] However, salt intake has infrequently been estimated using 24-h urinary samples in China, and older adults have not been targeted. The present study has three main findings. First, most Chinese older adults consume a much higher salt level than that recommended by the World Health Organization (5 g/day).[9] The mean salt intake of men and women in the present study was 12.4 and 11.7 g/day, respectively. These levels are lower than those of other studies, most of which have shown a sodium intake of around 5.5 to 6.0 g/day. The urine volumes showed no indication of undercollection; thus, the findings likely reflect the diets of people as they age. Second, the salt intake and creatinine clearance rate gradually decreased with age. Third, a high urinary Na/K ratio was an independent risk factor for CHD.

We are the first to investigate the salt intake of elderly adults in China. Our survey of salt intake showed that salt consumption among Chinese older adults markedly surpasses the recommended upper limit by the World Health Organization. In China, pickled foods and high soy sauce consumption contribute to this large salt intake.[10] The significantly greater salt intake by men than women can be explained by their different food habits and higher overall food intake. A recent study of Chinese postmenopausal women in Hong Kong showed that increased fruit intake and decreased sodium in soup is a valid strategy for reducing sodium loading.[11]

High salt intake is well documented as a main risk factor for hypertension.[12] Some studies have indicated a positive association between the prevalence of cardiovascular disease and high sodium intake.[13]

Table 3. Association of clinical factors with urinary sodium excretion and spot urine Na/K ratio

	n	Urinary sodium excretion (mmol/24 h)	Spot urine Na/K ratio
Sex			
Men	316	211.4 ± 19.5	3.32 ± 1.72
Women	225	200.2 ± 17.6	3.36 ± 1.81
P		0.0001	0.7930
Obesity			
Normal weight (BMI < 24 kg/m^2)	223	201.4 ± 19.5	3.25 ± 1.82
Obese/overweight (BM ≥ 24 kg/m^2)	318	223.2 ± 17.6	3.58 ± 1.81
P		0.0001	0.0378
Drinking			
Yes	211	203.6 ± 16.0	3.32 ± 1.62
No	330	200.8 ± 17.5	3.39 ± 1.73
P		0.0612	0.6382
Smoking			
Yes	93	241.4 ± 15.5	3.42 ± 1.55
No	448	210.2 ± 18.6	3.17 ± 1.49
P		0.0001	0.14
Hypertension			
Yes	366	236.4 ± 18.5	3.62 ± 1.31
No	205	215.2 ± 17.2	3.36 ± 1.25
P		0.0001	0.0211
Coronary artery disease			
Yes	287	208.5 ± 16.3	3.56 ± 1.52
No	254	205.6 ± 15.9	3.26 ± 1.39
P		0.0372	0.0174
Type 2 diabetes			
Yes	362	221.2 ± 19.1	3.39 ± 1.22
No	179	218.2 ± 16.6	3.34 ± 1.51
P		0.0735	0.6793
Cerebral thrombosis			
Yes	209	208.1 ± 17.7	3.46 ± 1.26
No	332	205.8 ± 15.8	3.16 ± 1.60
P		0.1163	0.0219
Dyslipidemia			
Yes	275	210.9 ± 19.6	3.39 ± 1.62
No	266	195.2 ± 17.3	3.21 ± 1.50
P		0.0519	0.1809

Data are presented as mean ± standard deviation unless otherwise indicated.
Na/K ratio, sodium/potassium ratio; BMI, body mass index.

Cumulative evidence has shown that decreasing salt intake to <5 g/day can mitigate cardiovascular disease by >17% and the stroke incidence by >23%.[14] He and MacGregor[15] suggested that even a minor salt reduction of 2.3 g/day could reduce the prevalence of cardiovascular disease onset by 20%.

Our results indicate that the urinary Na/K ratio is an independent risk factor

Table 4. Multivariate logistic regression analysis of relevant factors of coronary heart disease

Variable	β	SE	Wald	OR (95% CI)	*P*
Age	0.015	0.013	1.681	0.936 (0.910–1.005)	0.090
BMI	0.123	0.072	3.117	1.135 (0.908–1.013)	0.105
Smoking	0.058	0.030	4.501	1.311 (1.092–1.379)	0.007
SBP	0.125	0.026	3.528	1.205 (0.902–1.315)	0.128
Na/K ratio	0.139	0.063	6.212	1.210 (1.125–1.520)	0.008
CCR	0.078	0.071	1.108	1.075 (0.945–1.200)	0.075
DM	0.052	0.042	2.618	1.041 (0.980–1.127)	0.099
Hypertension	0.012	0.005	6.832	1.321 (1.111–1.422)	0.013
Dyslipidemia	0.015	0.025	3.528	1.105 (0.862–1.215)	0.138

BMI, body mass index; CCR, creatinine clearance rate; Na/K ratio, urinary sodium/potassium ratio; DM, diabetes mellitus; SE, standard error; OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure.

for CHD, which may be explained by several mechanisms. First, kidney function declines with age, especially in elderly patients.[16] Older adults have about a 20% decrease in the maximum urinary osmolality compared with younger patients.[17] Likewise, in the present study, the creatinine level and urinary sodium excretion decreased as age increased. Thus, compared with sodium excretion, the urinary Na/K ratio better reflects the association between sodium and CHD. Second, potassium and sodium in the diet could reflect the coordination of nutrients because high levels are closely associated with increased prevalences of cardiovascular disease and adverse events.[18] The detrimental effects of high salt intake can be relieved by dietary supplementation of potassium.[19] Alimentary control and dietary diversification are features of individuals at lower risk of developing CHD.[20]

However, our study still has several limitations. First, because the patients' diseases were determined with a self-reported questionnaire, the identification may not have been accurate. Second, urine samples were collected in 24 h, so dilution bias may have been present due to individual variations within 1 day. Third, this cross-sectional study failed to explore the causal association between sodium intake and CHD. Regardless, further studies are ongoing in our group.

Elderly Chinese adults in the present study had much higher salt intake than the currently recommended level (6 g/day). Several factors may affect the association between CHD and sodium intake. There was no association between sodium and CHD prevalence. Furthermore, measurement of the Na/K ratio may better represent salt loading than measurement of Na excretion alone.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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