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Estimating daily salt intake based on 24 h urinary sodium excretion in adults aged 18–69 years in Shandong, China

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ABSTRACT

Objective: 24 h urinary sodium extretion was used to estimate the daily salt intake of shandong residents aged from 18 to 69 years in China.

Setting: 20 selected counties/districts in Shandong stratified by geographic region (Eastern, Central Southern and North Western) and residence type (urban vs rural).

Participants: Among 2184 randomly selected adults, 2061 provided usable 24 h urine samples. Urine volume <500 mL or male creatinine <3.81 (female creatinine <4.57) are not included in the analysis.

Results: The mean sodium level excreted over 24 h was 237.61 mmol (95% CI 224.77 to 250.44) mmol. Overall, the estimated mean salt intake was 13.90 g/day (95% CI 13.15 to 14.65). The mean salt intake among rural residents was higher than that among urban residents (14.00 vs 13.68 g; p<0.01). Salt intake in men was higher than that in women (14.40 vs 13.37 g; p<0.01). Approximately 96% of the survey participants had a dietary salt intake of ≥6 g/day.

Conclusions: The salt intake in Shandong is alarmingly higher than the current recommended amount (6 g/day). Thus, effective interventions to reduce salt intake levels to combat the increasing burden of non-communicable diseases need to be developed and implemented.

Strengths and limitations of this study

- We used the 'gold standard' 24 h urine collection to estimate salt intake.
- A limitation of the study was that only a single 24 h urine collection was obtained from each participant. A single collection will less accurately reflect 24 h sodium intake than will several collections.
- However, the day-to-day variation in sodium excretion can vary in both directions, so it is unlikely that the findings overstated the inaccuracy of the claim of a low sodium intake.

BACKGROUND

In China, hypertension is a major contributor to cardiovascular disease (CVD), which accounts for about 40% of all deaths[1] and 23% of the healthcare costs.[2] Evidence suggests that a high level of salt intake is associated with high blood pressure (BP) and a greater risk of stroke and CVD.[3–6] The National China Nutrition Surveys (1982, 1992 and 2002) and the Chinese Behavioral Risk Factor Surveillance indicated that approximately 80% of Chinese individuals consume more salt than the upper limit of the recommended salt (sodium chloride) intake (6 g/day) by the Chinese Nutritional Society (2007). In 2010, the mean salt intake among the Chinese was estimated to be 9.1 g/day in urban areas and 11.5 g/day in rural areas.[1]

Reducing salt intake is one of the easiest, most efficient and cost-effective ways to reduce the burden of CVD and healthcare costs, which would result in a substantial improvement in public health.[1 7] Globally, dietary sodium reduction has been recommended as a major strategy for the prevention and control of non-communicable diseases.[8] Several countries including Japan, the UK, Finland, Portugal and the USA have succeeded in reducing the population-wide sodium intake.[9 10] Unlike in Western countries, a major challenge to reduce sodium intake in China is that the majority of sodium comes from the salt added to home cooked food rather than from commercially processed foods. A recent study suggested that most of the dietary sodium intake (76%) was attributed to salt added during home cooking.[11] In contrast, processed foods contributed heavily to sodium intake in the UK (95%) and the USA (71%).[11] Therefore, efforts to reduce sodium intake in China should focus on reducing the sodium level in home cooked foods.

Shandong Province is one of the most populous provinces in China. Sodium intake among most Shandong residents considerably exceeds the recommended limit. In 2002, the mean daily salt intake was 12.6 g and the prevalence of hypertension was 25.1%. High salt intake has caused huge economic loss.[2] In 2011, the Chinese Ministry of Health (MOH) selected Shandong province as a national pilot area and the Shandong-MOH Action on Salt and Hypertension (SMASH) Project was set up to reduce the sodium level in the Chinese diet. To help develop effective interventions for the SMASH Project, a baseline survey was conducted in 2011 to assess salt consumption and the prevalence of hypertension among residents in Shandong. The measurement of 24 h urinary sodium excretion is considered the gold standard method for obtaining data on the sodium intake in population surveys.[1] However, in China, few studies have been conducted on the salt intake of the general population based on the 24 h urinary sodium excretion method. This study analyses the baseline survey to estimate the daily intake of dietary sodium among the general adult Shandong population (aged 18–69 years) based on 24 h urinary sodium excretion.

METHODS

A cross-sectional survey was conducted in Shandong province from June 2011 to July 2011. Multistage (four-stage) cluster sampling was used to select a provincially representative sample of the adult population (aged 18–69 years). Briefly, a total of 140 counties/districts in Shandong province were stratified by geographic region (Eastern, Central Southern and North Western) and residence type (urban vs rural). Twenty counties/districts were selected (12 rural counties and 8 urban districts) for this study. Using a proportional probability sampling (PPS) method, three townships (in rural areas) or two suburbs (in urban areas) were chosen from each selected county or district. The PPS method was also used to select one village/community from each sampled township/suburb. From each chosen village/community, 42 participants were randomly chosen, resulting in a total sample size of 2184 participants.

A face-to-face interview using a close-ended questionnaire was conducted by trained public health professionals with experience in conducting interviews for similar health surveys to collect information on demographics (gender, age, education and income).

All participants were given written and verbal instructions to collect a 24 h urine sample. The first urine of the day was discarded and all urine over the following 24 h was collected in provided bottles. All bottles from the same participant were carefully mixed and the volume of urine was measured. Then a 20 mL aliquot of mixed urine was taken and immediately frozen at −20°C and sent to the laboratory for analysis.

The samples were first assayed for creatinine concentration using the picric acid method (ADICON Clinical Laboratory; CAP accredited). A sample was excluded from the analysis if the 24 h urine volume was below 500 ml or its creatinine content referred to body weight was found to be lower than the mean minus 2 S.D. from the population mean (male creatinine <3.81 mmol; female creatinine <4.57 mmol). The sodium concentration was determined using the direction selective electrode method. Daily salt intake was estimated by assessing 24 h urinary sodium excretion based on the assumption that all sodium was ingested in the form of sodium chloride.

Height, weight and waist circumference were measured in all participants. Of 2184 participants, 2061 participants with complete data were included in this analysis (response rate, 94.4%). Educational level and annual household income were used as indicators for social economic status. We divided participants into five groups based on education level: no education, primary school, junior high school, senior high school, college and higher education. Annual household income was classified into high, middle and low, according to tertiles. Body mass index (BMI=weight (kg)/height (m^2)) was calculated. individuals with a BMI ≥24 but <28 kg/m^2 were defined as being overweight and those with a BMI ≥28 kg/m^2 were considered obese.

Statistical analyses were performed using the Statistical Analysis System (SAS) V.9.3 (SAS Institute Inc, Cary, North Carolina, USA). $p<0.05$ was considered significant. All the results shown were weighted by the total demography in Shandong province. Survey weight (total weight=design weight×post-stratification weight) was used to calculate weighted proportions. Design weight was calculated to account for different factors including cluster design, strata and individual factors. The population data from Shandong province was used to generate the post-stratification weight. Means and 95% CIs were calculated for all variables and normality of the data was assessed. Analysis of variance and the χ^2 test were used to test the significance of differences between groups.

This study received ethics approval from the Ethics Committee of the Shandong Centre for Disease Control and Prevention. All participants provided written informed consent to participate in this study.

RESULTS

Study subjects

A total of 2061 participants provided urine specimens out of which 123 samples were further excluded from the analysis because of incomplete or inaccurate urine collection. There were no significant differences between included and excluded participants in terms of age, sex and residence type ($t=1.52$, $p>0.05$; $\chi^2=0.02$, $p>0.05$; $\chi^2=0.32$, $p>0.05$; table 1).

The characteristics of each subpopulation are summarised in table 2. Of 2061 eligible samples, 1076 were

Table 1 Distribution of included and excluded participants

	Including sample						Excluding sample					
	Total		Urban		Rural		Total		Urban		Rural	
Gender	n	Per cent	n	Per cent	n	Per cent	n	Per cent	n	Per cent	n	Per cent
Male	1076	52.21	342	16.59	734	35.61	65	52.85	18	14.63	47	38.21
Female	985	47.79	311	15.09	674	32.7	58	47.15	24	19.51	34	27.64
Total	2061	100	653	31.68	1408	68.32	123	100	42	34.15	81	65.85

male (52.21%) and 985 were women (47.79%). The mean age, height and BMI were 41.23 years, 163.00 cm and 24.22 kg/m^2, respectively. There were no significant differences in age and BMI between men and women ($t=0.34$, $p>0.05$; $t=0.29$, $p>0.05$). However, men were significantly taller than women ($t=37.65$, $p<0.05$). The prevalence of overweight and obese individuals was 33.72% and 18.00%, respectively, with no significant differences between men and women ($\chi^2=0.90$, $p>0.05$; $\chi^2=0.001$, $p>0.05$). Of the tested participants, 82.90% had an income <10 000 RMB and 42.60% had an education level of junior high school.

Salt intake

The 24 h urinary sodium level ranged from 22.05 to 750.79 mmol, with a mean of 231.10 mmol. Tables 3 and 4 show the 24 h urinary sodium excretion and estimated daily salt intake for each subpopulation. The mean sodium level excreted over 24 h was 237.61 mmol (95% CI 224.77 to 250.44 mmol), which corresponds to 13.90 g NaCl (95% CI 13.15 to 14.65 g). The mean salt intake by rural residents was more than that of urban residents (14.00 vs 13.68 g; $p<0.01$). Salt intake in men was higher than that in women (14.40 vs 13.37 g; $p<0.01$). There were no significant differences in the salt intake between age groups.

DISCUSSION

It is challenging to accurately estimate sodium intake because it is very difficult to know the exact amount of salt added during cooking (even in restaurants) and at the table. It is also difficult to estimate the amount of salt that has been left on the plate, and to determine the salt content in food and drinking water.[1] Therefore, as suggested by a number of reports,[1 3 12] the best method to determine salt intake is to measure the amount excreted in 24 h urine. In China, very few studies have measured the salt intake using 24 h urinary excretion and none have used a representative sample. Liu *et al*[13] reported an intake of 188.4 mmol/day (corresponding to 11.02 g NaCl) in a population of 48–56-year-old individuals in China, a value much smaller than that obtained in this study (224.77 mmol/24 h, 13.9 g). The current study indicates that the sodium intake is very high in a representative population of Shandong adults, higher than that in a UK population aged 19–64 years (148 mmol).[14] Salt intake by men and women was found to be 246.23 and 228.52 mmol/day, respectively, which is higher than that in the population

Table 2 Personal characteristics of the study sample by sex and age

	Total (n=2061)			Male (n=1076)			Female (n=985)		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Age (years)	41.23	13.99	39.00	41.12	14.32	39.00	41.34	13.62	39.00
Height (cm)	163.00	8.84	162.60	168.78	7.02	169.20	157.27	6.23	157.20
BMI (kg/m^2)	24.53	3.90	24.22	24.55	3.90	24.25	24.51	3.90	24.15
Overweight (%)	33.72			34.67			32.69		
Obese (%)	18.00			18.03			17.97		
Income (¥, %)									
<5000	52.24			51.1			53.45		
5000–9999	30.66			31.4			29.87		
10 000–14 999	8.35			8.27			8.44		
15 000–19 999	5.45			5.64			5.25		
20 000+	3.29			3.57			2.99		
Education (%)									
Illiteracy	13.79			7.72			20.43		
Junior	19.09			17.58			20.73		
Junior high	42.06			47.72			35.87		
Senior	15.15			16.84			13.31		
Junior college or above	9.91			10.14			9.65		

Table 3 Urinary sodium excretion of Shandong adults aged 18–69 years in 2011 (Weighted mean, SD, 95% CI mmol/24 h)

		Urban					Rural					Total				
Gender	Age group	N	Mean	SD	95% CI		N	Mean	SD	95% CI		N	Mean	SD	95% CI	
Male	18–29	85	241.64	18.23	194.77	288.51	196	244.81	9.85	222.52	267.10	281	243.88	8.72	225.17	262.58
	30–39	91	255.88	12.30	224.25	287.50	185	247.19	9.72	225.21	269.17	276	249.99	7.79	233.30	266.69
	40–49	65	233.33	17.89	187.35	279.31	139	247.90	7.48	230.99	264.82	204	243.59	7.40	227.72	259.47
	50–59	51	263.00	12.72	230.28	295.71	111	251.36	12.64	222.78	279.95	162	255.27	9.44	235.02	275.52
	60–69	50	239.00	14.74	201.12	276.88	103	232.24	12.62	203.69	260.79	153	234.42	9.82	213.36	255.49
	Subtotal	342	246.81	12.46	214.77	278.85	734	245.96	8.22	227.38	264.55	1076	246.23	6.87	231.49	260.96
Female	18–29	79	200.77	13.37	166.40	235.14	173	225.93	7.26	209.51	242.35	252	219.01	6.69	204.66	233.37
	30–39	79	236.43	8.99	213.31	259.54	165	234.70	9.62	212.94	256.46	244	235.27	7.11	220.01	250.53
	40–49	59	236.92	12.94	203.65	270.18	131	231.88	12.22	204.25	259.52	190	233.46	9.43	213.24	253.69
	50–59	53	213.23	10.24	186.91	239.54	111	245.28	11.41	219.48	271.09	164	234.73	8.73	216.01	253.45
	60–69	41	200.29	11.23	171.42	229.15	94	221.79	7.72	204.32	239.26	135	215.48	6.34	201.88	229.07
	Subtotal	311	219.97	9.07	196.66	243.29	674	232.32	7.72	214.85	249.79	985	228.52	5.99	215.67	241.37
Total	18–29	164	222.94	10.65	195.56	250.32	369	235.72	7.63	218.46	252.98	533	232.08	6.15	218.89	245.26
	30–39	170	246.19	9.86	220.85	271.54	350	241.06	9.11	220.44	261.68	520	242.73	6.98	227.75	257.71
	40–49	124	235.11	12.06	204.10	266.11	270	240.30	8.95	220.05	260.56	394	238.72	7.16	223.37	254.07
	50–59	104	238.44	7.54	219.05	257.83	222	248.32	9.26	227.36	269.27	326	245.03	6.68	230.70	259.37
	60–69	91	220.68	12.40	188.80	252.56	197	226.94	8.61	207.45	246.43	288	225.01	7.05	209.89	240.14
	Subtotal	653	233.82	9.90	208.36	259.28	1408	239.30	7.52	222.28	256.33	2061	237.61	5.98	224.77	250.44

Table 4 Salt intake of Shandong adults aged 18–69 years in 2011 (Weighted mean, SD, 95% CI g/24 h)

		Urban					Rural					Total				
Gender	Age group	N	Mean	SD	95% CI		N	Mean	SD	95% CI		N	Mean	SD	95% CI	
Male	18–29	85	14.14	1.07	11.39	16.88	196	14.32	0.58	13.02	15.63	281	14.27	0.51	13.17	15.36
	30–39	91	14.97	0.72	13.12	16.82	185	14.46	0.57	13.17	15.75	276	14.62	0.46	13.65	15.60
	40–49	65	13.65	1.05	10.96	16.34	139	14.50	0.44	13.51	15.49	204	14.25	0.43	13.32	15.18
	50–59	51	15.39	0.74	13.47	17.30	111	14.70	0.74	13.03	16.38	162	14.93	0.55	13.75	16.12
	60–69	50	13.98	0.86	11.77	16.20	103	13.59	0.74	11.92	15.26	153	13.71	0.57	12.48	14.95
	Subtotal	342	14.44	0.73	12.56	16.31	734	14.39	0.48	13.30	15.48	1076	14.40	0.40	13.54	15.27
Female	18–29	79	11.75	0.78	9.73	13.76	173	13.22	0.42	12.26	14.18	252	12.81	0.39	11.97	13.65
	30–39	79	13.83	0.53	12.48	15.18	165	13.73	0.56	12.46	15.00	244	13.76	0.42	12.87	14.66
	40–49	59	13.86	0.76	11.91	15.81	131	13.57	0.71	11.95	15.18	190	13.66	0.55	12.47	14.84
	50–59	53	12.47	0.60	10.93	14.01	111	14.35	0.67	12.84	15.86	164	13.73	0.51	12.64	14.83
	60–69	41	11.72	0.66	10.03	13.41	94	12.97	0.45	11.95	14.00	135	12.61	0.37	11.81	13.40
	Subtotal	311	12.87	0.53	11.50	14.23	674	13.59	0.45	12.57	14.61	985	13.37	0.35	12.62	14.12
Total	18–29	164	13.04	0.62	11.44	14.64	369	13.79	0.45	12.78	14.80	533	13.58	0.36	12.81	14.35
	30–39	170	14.40	0.58	12.92	15.89	350	14.10	0.53	12.90	15.31	520	14.20	0.41	13.32	15.08
	40–49	124	13.75	0.71	11.94	15.57	270	14.06	0.52	12.87	15.24	394	13.97	0.42	13.07	14.86
	50–59	104	13.95	0.44	12.81	15.08	222	14.53	0.54	13.30	15.75	326	14.33	0.39	13.50	15.17
	60–69	91	12.91	0.73	11.05	14.77	197	13.28	0.50	12.14	14.42	288	13.16	0.41	12.28	14.05
	Subtotal	653	13.68	0.58	12.19	15.17	1408	14.00	0.44	13.00	15.00	2061	13.90	0.35	13.15	14.65

in Toyama (men, 224 mmol/day; women, 201 mmol/day),[10 15] the USA (men, 180–190 mmol/day; women, 130–150 mmol/day)[16] and the UK (men, 161 mmol/day; women, 127 mmol/day).[16]

The salt intake in China is double the upper limit of the recommended intake of 80–110 mmol/day (5–6 g salt/day) by the World Health Organization in 1982[17] and in the China Nutrition Recommendations.[18] In China, the high salt intake is mainly due to the high consumption of soya sauce and the tradition of adding a large amount of salt to the food both during cooking and at the table.[3 19 20] Consistent with other studies,[3 5 19] salt intake in men (14.4 g) was higher than that in women (13.9 g) in Shandong, possibly because of the higher overall food intake by men and the differences in food habits between men and women. In most populations, salt intake is high and well above the daily recommended values. Now the resident health records are being established in Shandong province, it is necessary to evaluate and record the salt intake for individuals by the FFQ or other methods, especially among patients with chronic disease and high-risk individuals; it is very important to focus on the salt intake of individuals and to persuade them to change the habit of high salt intake.

Strong and consistent evidence from animal studies, clinical trials and epidemiological data from within and across populations suggests that high salt intake is an important risk factor for high BP among hypertensive and normotensive individuals.[21] In addition, high salt intake is also associated with increased risk of coronary heart disease and stroke.[22] Therefore, public health initiatives are needed to reduce salt consumption[3 4] and, in turn, lower the burden of CVDs and increase life expectancy. The government needs to focus and resolve this severe situation. Salt reduction must be undertaken. Health education and promotion based on media campaigns, as well as timely community-based initiatives to limit the amount of salt added to food by individuals, would increase public awareness. Meanwhile, it is necessary to collaborate with restaurants and food industries to reduce excessive salt. Such public health approaches can be simple, at low cost and effective. Indeed, campaigns such as the SMASH and the China Rural Health Initiative Sodium Reduction Study are already underway.[23] As reported by Yan *et al*,[24] in China, measures for salt reduction will include government initiatives, health education and promotion, promotion of low sodium salt in food processing companies and restaurants. In Shandong, education through radio, television, internet and movies is underway to improve the knowledge of residents about low-salt diets. To bring about behavioural changes, salt spoons have been provided for every family in the entire province. Key groups comprising governors, medical personnel and stakeholders from the food processing enterprise and restaurants are trained. Local standards for the amount of salt in soya sauce pickles and other dishes in the cuisine of Shandong have been formulated. The results from this study could be useful in these endeavours.

A limitation of the study was that only a single 24 h urine collection was obtained from each participant. A single collection will less accurately reflect 24 h sodium intake than will several collections. However, the day-to-day variation in sodium excretion can vary in both directions, so it is unlikely that the findings overstated the inaccuracy of the claim of a low sodium intake.

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Contributors J-yZ, L-xY, J-lT and Z-qB conceived and designed the experiments. J-yZ, J-lT and Z-qB performed the experiments. J-yZ, J-lT and Z-qB analysed the data. J-yZ, J-xM, X-lG, W-hZ, X-fZ, J-hL and JC contributed reagents/materials/analysis tools. J-yZ, L-xY, J-lT and Z-qB wrote the manuscript.

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Competing interests None.

Patient consent Obtained.

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