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 excretion 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) 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.

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. Globally, dietary sodium reduction has been recommended as a major strategy for the prevention and control of non-communicable diseases. Several countries including Japan, the UK, Finland, Portugal and the USA have succeeded in reducing the population-wide sodium intake. 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. In contrast, processed foods contributed heavily to sodium intake in the UK (95%) and the USA (71%). 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

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.
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. 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. 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 socioeconomic 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 (m²)) was calculated. Individuals with a BMI ≥24 but <28 kg/m² were defined as being overweight and those with a BMI ≥28 kg/m² 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 χ² 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; χ²=0.02, p>0.05; χ²=0.32, p>0.05; table 1).

The characteristics of each subpopulation are summarised in table 2. Of 2061 eligible samples, 1076 were
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/m², 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 (χ²=0.90, p>0.05; χ²=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. Therefore, as suggested by a number of reports, 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 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). 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

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Table 1 Distribution of included and excluded participants

| Gender | Including sample | Excluding sample |
|--------|------------------|------------------|
|        | Total n | Per cent | Urban n | Per cent | Rural n | Per cent |
| Male   | 1076    | 52.21    | 342     | 16.59    | 734     | 35.61    |
| Female | 985     | 47.79    | 311     | 15.09    | 674     | 32.7     |
| Total  | 2061    | 100      | 653     | 31.68    | 1408    | 68.32    |

| Gender | Including sample | Excluding sample |
|--------|------------------|------------------|
|        | Total n | Per cent | Urban n | Per cent | Rural n | Per cent |
| Male   | 65      | 52.85    | 18      | 14.63    | 47      | 38.21    |
| Female | 58      | 47.15    | 24      | 19.31    | 34      | 27.64    |

| Gender | Including sample | Excluding sample |
|--------|------------------|------------------|
|        | Total n | Per cent | Urban n | Per cent | Rural n | Per cent |
| Male   | 123     | 100      | 42      | 34.15    | 81      | 65.85    |

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

| Total (n=2061) | Male (n=1076) | Female (n=985) |
|----------------|---------------|----------------|
| Age (years)    | Mean SD Median| Mean SD Median | Mean SD Median |
| 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/m²)    | 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 | 16.84 | 13.31 |
| Junior high 42.06 47.72 | 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)

| Gender | Age group | Urban | Rural | Total |
|--------|-----------|-------|-------|-------|
|        | N         | Mean  | SD    | 95% CI |
| Male   | 18–29     | 85    | 241.64| 18.23 | 194.77 | 288.51 |
|        | 30–39     | 91    | 255.88| 12.30 | 224.25 | 287.50 |
|        | 40–49     | 65    | 233.33| 17.89 | 187.35 | 279.31 |
|        | 50–59     | 51    | 263.00| 12.72 | 230.28 | 295.71 |
|        | 60–69     | 50    | 239.00| 14.74 | 201.12 | 276.88 |
|        |           | 342   | 246.81| 12.46 | 214.77 | 278.85 |
| Female | 18–29     | 79    | 200.77| 13.37 | 166.40 | 235.14 |
|        | 30–39     | 79    | 236.43| 8.99  | 213.31 | 259.54 |
|        | 40–49     | 59    | 236.92| 12.03 | 204.65 | 270.18 |
|        | 50–59     | 53    | 213.23| 10.24 | 186.91 | 239.54 |
|        | 60–69     | 41    | 200.29| 11.23 | 171.42 | 229.15 |
|        |           | 311   | 219.97| 9.07  | 196.66 | 243.29 |
|        |           | 164   | 222.94| 10.65 | 195.56 | 250.32 |
|        | 30–39     | 170   | 246.19| 9.86  | 220.85 | 271.54 |
|        | 40–49     | 124   | 235.11| 12.06 | 204.10 | 266.11 |
|        | 50–59     | 104   | 238.44| 7.54  | 219.05 | 257.83 |
|        | 60–69     | 91    | 220.68| 12.40 | 188.80 | 252.56 |
|        |           | 653   | 233.82| 9.90  | 208.36 | 259.28 |

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

| Gender | Age group | Urban | Rural | Total |
|--------|-----------|-------|-------|-------|
|        | N         | Mean  | SD    | 95% CI |
| Male   | 18–29     | 85    | 14.14 | 1.07  | 11.39 | 16.88 |
|        | 30–39     | 91    | 14.97 | 0.72  | 13.12 | 16.82 |
|        | 40–49     | 65    | 13.65 | 1.05  | 10.96 | 16.34 |
|        | 50–59     | 51    | 15.39 | 0.74  | 13.47 | 17.30 |
|        | 60–69     | 50    | 13.98 | 0.86  | 11.77 | 16.20 |
|        |           | 342   | 14.44 | 0.73  | 12.56 | 16.31 |
| Female | 18–29     | 79    | 11.75 | 0.78  | 9.73  | 13.76 |
|        | 30–39     | 79    | 13.83 | 0.53  | 12.48 | 15.18 |
|        | 40–49     | 59    | 13.86 | 0.76  | 11.91 | 15.81 |
|        | 50–59     | 53    | 12.47 | 0.60  | 10.93 | 14.01 |
|        | 60–69     | 41    | 11.72 | 0.66  | 10.03 | 13.41 |
|        |           | 311   | 12.87 | 0.53  | 11.50 | 14.23 |
|        |           | 164   | 13.04 | 0.62  | 11.44 | 14.64 |
|        |           | 170   | 14.40 | 0.58  | 12.92 | 15.89 |
|        |           | 124   | 13.75 | 0.71  | 11.94 | 15.57 |
|        |           | 104   | 13.95 | 0.44  | 12.81 | 15.08 |
|        |           | 91    | 12.91 | 0.73  | 11.05 | 14.77 |
|        |           | 653   | 13.68 | 0.58  | 12.19 | 15.17 |
in Toyama (men, 224 mmol/day; women, 201 mmol/day), the USA (men, 180–190 mmol/day; women, 130–150 mmol/day) and the UK (men, 161 mmol/day; women, 127 mmol/day).

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 and in the China Nutrition Recommendations. In China, the high salt intake is mainly due to the high consumption of soy sauce and the tradition of adding a large amount of salt to the food both during cooking and at the table. Consistent with other studies, 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 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. In addition, high salt intake is also associated with increased risk of coronary heart disease and stroke. Therefore, public health initiatives are needed to reduce salt consumption 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. As reported by Yan et al. 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 soy 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 overestimated the inaccuracy of the claim of a low sodium intake.

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**Contributors** J-yZ, L-xY, J-T and Z-qB conceived and designed the experiments. J-yZ, J-IT and Z-qB performed the experiments. J-yZ, J-IT and Z-qB analysed the data. J-yZ, J-IT and Z-qB contributed reagents/materials/analysis tools. J-yZ, L-xY, J-IT and Z-qB wrote the manuscript.

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**Competing interests** None.

**Patient consent** Obtained.

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**REFERENCES**

1. Ministry of Health. *Annual report on health statistics*. Beijing: Peking Union Medical College Publishing House, 2010.
2. China CDC & China News. *Salt reduction and hypertension prevention*. China, 2011.
3. Brown IJ, Tzoulaki I, Candeias V, et al. Salt intakes around the world: implications for public health international. *Int J Epidemiol* 2009;38:791–813.
4. He FJ, MacGregor GA. A comprehensive review on salt and health and current experience of worldwide salt reduction programs. *J Hum Hypertens* 2009;23:363–84.
5. Hoffman IS, Cubeddu LX. Salt and the metabolic syndrome. *Nutr Metab Cardiovasc Dis* 2009;19:123–8.
6. Strazzullo P, D’Elia L, Kandala NB, et al. Salt intake, stroke and cardiovascular disease: meta-analysis of prospective studies. *BMJ* 2009;339:b4567.
7. Bibeins-Domingo K, Chertow GM, Coxson PG, et al. Projected effect of dietary salt reductions on future cardiovascular disease. *N Engl J Med* 2010;362:590–9.
8. Beaglehole R, Bonita R, Horton R, et al. Priority actions for the non-communicable disease crisis. *Lancet* 2011;377:1438–47.
9. Chan WG. Salt reduction initiatives in developed countries and lessons for China: a systematic review. http://hdl.handle.net/10722/145711 (accessed 15 Aug 2012).
10. Centers for Disease Control and Prevention. CDC grand rounds: dietary sodium reduction-time for choice. MMWR Morb Mortal Wkly Rep 2012;61:89–91.
11. Anderson CA, Appel LJ, Okuda N, et al. Dietary source of sodium in China, Japan, the United Kingdom, the United States, women and men aged 40 to 59 years: the INTERMAP study. J Am Diet Assoc 2010;110:736–45.
12. Hunter D. Biochemical indicators of dietary intake. In: Willett W, ed. Nutritional epidemiology. Oxford: Oxford University Press, 1998:174–243.
13. Liu L, Ikeda K, Yamori Y. Twenty-four hour urinary sodium and 3-methylhistidine excretion in relation to blood pressure in Chinese: results from the China-Japan Cooperative Research for the WHO-CARDIAC study. Hypertens Res 2000;23:152–7.
14. National Centre for Social Research. An assessment of dietary sodium levels among adults (aged 19–64) in the UK general population in 2008, based on analysis of dietary sodium in 24 hour urine samples. Food Standards Agency, 2008.
15. Rose G, Stamler J. The INTERSALT Study: background, methods and main results. J Hum Hypertens 1989;3:283–8.
16. Stamler J, Elliott P, Chan Q; for the INTERMAP Research Group. INTERMAP appendix tables. J Hum Hypertens 2003b;17:655–775.
17. WHO Expert Committee. Prevention of coronary heart disease. WHO Technical Report Series no. 678. Geneva: WHO, 1982.
18. Chinese Nutrition Society. The dietary guidelines for Chinese residents. Tibet, China: Tibetan People’s Publishing House, 2007:55.
19. Zhou BF, Stamler J, Dennis B, et al. INTERMAP Research Group. Nutrient intakes of middle-aged men and women in China, Japan, United Kingdom, and United States in the late 1990s: the INTERMAP Study. J Hum Hypertens 2003;17:623–30.
20. Liu L, Liu L, Ding Y, et al. Ethnic and environmental differences in various markers of dietary intake and blood pressure among Chinese Han and three other minority peoples of China: results from the WHO Cardiovascular Diseases and Alimentary Comparison (CARDIAC) Study. Hypertens Res Clin Exp 2001;24:315–22.
21. Luft FC. Salt and hypertension at the close of the millenium. Wien Klin Wochenschr 1998;110:459–66.
22. Hooper L, Bartlett C, Davey Smith G, et al. Reduced dietary salt for prevention of cardiovascular disease. Cochrane Database Syst Rev 2003;(3):CD003656.
23. Li N, Yan LL, Niu W, et al. A large-scale cluster randomized trial to determine the effects of community-based dietary sodium reduction—the China Rural Health Initiative Sodium Reduction Study. Am Heart J 2013;166:815–22.
24. Yan I, Li Y, Wu Y-F. Reducing salt intake for hypertension control: related evidence and recommendation on strategies in China. Chin J Epidemiol 2011;32:1188–91.