

# BMJ Open A cross-sectional comparison study on the iodine nutritional status between rural and urban residents in Zhejiang Province, China

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**To cite:** Zou Y, Lou X, Ding G, *et al.* A cross-sectional comparison study on the iodine nutritional status between rural and urban residents in Zhejiang Province, China. *BMJ Open* 2014;**4**:e005484. doi:10.1136/bmjopen-2014-005484

► Prepublication history for this paper is available online. To view these files please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2014-005484>).

Received 16 April 2014  
Revised 27 May 2014  
Accepted 6 June 2014



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## ABSTRACT

**Objectives:** To evaluate the difference of iodine nutritional status between rural and urban residents under the universal salt iodisation policy.

**Setting:** A multistage cluster sampling technique was employed in the present cross-sectional study. In total, 3300 rural and 3300 urban households were selected where the investigation was conducted.

**Participants:** A total of 8553 rural and 8909 urban residents participated in this provincial survey.

**Primary and secondary outcome measures:** Spot urine samples were collected and the iodine concentration in urine was determined by the modified acid-digestion method.

**Results:** The median urinary iodine concentration of rural residents was 170.1 µg/L, which was higher than that of urban residents with 153.5 µg/L. For school-aged children, middle-aged people and older people, the median urinary iodine concentration of rural residents was 191.2, 160.2 and 154.0 µg/L, respectively, which was higher than that of urban residents with 166.2, 153.8 and 129.5 µg/L, respectively. Risk factors for urinary concentration of rural residents were age (OR=0.99), terrain (OR=0.83), usual intake of pickled products (OR=1.45) and non-iodised salt intake (OR=0.39), while those for urban residents were age (OR=0.99), terrain (OR=0.83), usual intake of aquatic products (OR=1.24) and non-iodised salt intake (OR=0.27) compared with iodised table salt intake.

**Conclusions:** The median urinary iodine concentration of rural residents was higher than that of urban residents although they were both falls in optimal iodine status as recommended by WHO/UNICEF/International Council for the Control of Iodine Deficiency Disorders. Iodised salt intake is the major factor which influences the iodine nutritional status mostly for rural and urban residents. The ongoing monitoring of population iodine status remains crucially important.

## INTRODUCTION

Iodine is a trace element required by the thyroid gland to produce thyroxine and triiodothyronine, thyroid hormones necessary for multiple processes related to normal

## Strengths and limitations of this study

- Iodine deficiencies were prevalent in China until the introduction of universal salt iodization (USI) in 1995. Economic development had remarkable influence on iodine intake for both rural residents and urban residents, but the difference between rural residents and urban residents under the USI policy has not been evaluated. Iodine nutritional status of rural residents and urban residents stratified by age has not been evaluated. This paper aims to explore the difference of iodine nutritional status between rural residents and urban residents 16 years after the introduction of salt iodization.
- This analysis has several limitations. Urinary iodine concentrations are highly variable and represent recent intake rather than usual intake. Due to this variation, a sample of 100 spot urine tests is needed to produce estimates of urinary iodine with a precision range of ±10%, and a sample of 500 is needed for a precision range of ±5%. Limited by the sample size, the difference of UIC between rural residents and urban residents were not found in some age group and further studies should be carried out to explore the difference. The ongoing monitoring of population iodine status remains crucially important.

growth and development. Globally, 29.8% of school-aged children (241 million) are estimated to have insufficient iodine intake.<sup>1</sup> Iodine deficiency was prevalent in China until the introduction of universal salt iodisation (USI) in 1995. In the early 1980s, surveys identified 831 000 individuals with iodine deficiency disorders (IDD) manifesting as goitre, and an additional 134 individuals with typical cretinism in Zhejiang Province. Iodised salt has been supplied in Zhejiang Province since 1995, and the median urinary iodine concentration (UIC) of children aged 8–10 years in Zhejiang Province has been adequate or sufficient

from 1995 to 2011. USI proved very effective; a provincial survey in 2000 found the virtual elimination of IDD.<sup>2</sup>

More than 90% of dietary iodine eventually appears in the urine; UIC is an excellent biomarker of recent iodine intake.<sup>3</sup> It is recommended to assess the iodine status of a population.<sup>4</sup> It is a reliable measure of exposure and a low-median value suggests that a population is at higher risk of developing thyroid disorders. Economic development had remarkable influence on iodine intake for rural and urban residents, but the difference between rural and urban residents under the USI policy has not been evaluated. Therefore, this paper aims to compare UIC of rural and urban residents in Zhejiang Province 16 years after the introduction of salt iodisation in order to explore the influence of factors of iodine nutritional status. The information obtained could provide the basis for further government policymaking.

## PARTICIPANTS AND METHODS

### Participants

There are 11 cities under the direct jurisdiction of the Zhejiang provincial government, including Hangzhou, Ningbo, Wenzhou, Jiaxing, Huzhou, Shaoxing, Jinhua, Quzhou, Zhoushan, Taizhou and Lishui, under which there are 32 districts, 22 county-level cities and 36 counties. A multistage cluster sampling technique was employed in the present cross-sectional study.

First, a rural area sampling unit (county-level cities) and an urban area sampling unit (counties), respectively, were selected from each city. Then three investigation sites were selected from each sampling unit according to their location in the county-level cities or counties and one community was selected randomly from the sampled investigation site. So totally, 33 rural and 33 urban communities were selected where the investigation was conducted. In every sampled community, 300 households were selected by the random sampling method according to the household registration information. Then every member of the sampled household was interviewed and their urine sample was collected.

### Methods

A questionnaire was designed to obtain general personal information, which included gender, age, residence, information of diet habits, etc. The questionnaire was administrated face to face by trained staff through a door-to-door interview.

### Measures

Spot urine samples were collected and delivered to the local Center for Disease Control and Prevention laboratory for measuring UIC, which was determined by the modified acid-digestion method (method for determination of iodine in urine by As<sup>3+</sup>-Ce<sup>4+</sup> catalytic spectrophotometry, WS/T 107-2006, Ministry of Health People's Republic of China).

### Statistical analysis

As continuous variables were not normally distributed, they were described as the median, 25th and 75th centiles. The differences between rural and urban residents were evaluated by a non-parametric test (Mann-Whitney test). In order to explore the risk factors of UIC, we divided UIC into two concentration groups (group 1: less than 300 µg/L; group 2: equal to or more than 300 µg/L). The following variables were selected as covariates in the models of UIC: age group (0, 1–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–), gender (male/female), terrain (coastal areas, plain areas or mountain areas), pickled products intake (few or usual), aquatic products intake (few or usual), table salt type (iodised salt or non-iodised salt), salt appetite, dietary patterns and education. Multiple logistic regression was used to explore the influence factors of UIC. Data processing and statistical analyses were performed using SAS V.9.2 software. All tests were two sided and the level of significance was set at  $p < 0.05$ .

## RESULTS

### UIC of people living in rural and urban areas stratified by age

A total of 8553 rural and 8909 urban residents participated in the present survey; the median (25th and 75th centile) of UIC in rural and urban residents was found to be 170.1 (103.9 and 259.8) µg/L and 153.5 (92.0 and 237.5) µg/L, respectively. UIC of rural and urban residents was presented by age in [table 1](#).

UIC of rural residents was higher than that of urban residents ( $Z = -10.570$ ,  $p = 0.000$ ). When stratified by age, for 10–, 45–, 60–, 65–, 70–, 75– and 80-year-old people, there were significant differences between rural and urban residents with the same direction ([table 2](#)).

### UIC of people living in rural and urban areas stratified by age group (preschool-aged children, school-aged children, adolescents, young people, middle-aged people and older people groups)

In [table 2](#), we combined age groups to preschool-aged children (3–6 years), school-aged children (7–12 years), adolescents (13–18 years), young people (19–39 years), middle-aged people (40–59 years) and older people (60 years and above). Children aged 0–2 years were not included. The median (25th and 75th centile) of UIC in rural and urban residents was found to be 170.1 (103.9 and 259.8) µg/L and 153.5 (92.0 and 237.4) µg/L, respectively. UIC of rural and urban residents is presented by age groups in [table 2](#).

UIC of rural residents was higher than that of urban residents ( $Z = -7.365$ ,  $p = 0.000$ ). When stratified by age group, for school-aged children, middle-aged people and older people, there were significant differences between rural and urban residents with the same direction. However, there were no significant differences between rural and urban residents for preschool-aged children, adolescents and young people ([table 2](#)).

**Table 1** Urinary iodine concentration (median, 25% and 75%) of people living in rural and urban areas stratified by age, Zhejiang Province, China

	Rural areas		Urban areas		Z	p Value
	N	Median (25%, 75%; µg/L)	N	Median (25%, 75%; µg/L)		
0–	55	188.4 (106.5, 326.6)	32	141.6 (102.3, 208.6)	–1.937	0.053
1–	209	186.0 (117.5, 264.3)	140	176.5 (91.2, 265.8)	–0.653	0.514
5–	335	176.7 (116.0, 274.6)	343	171.0 (112.2, 258.5)	–0.642	0.521
10–	369	198.7 (123.8, 288.5)	350	173.3 (108.1, 258.4)	–2.646	0.008
15–	208	190.5 (108.5, 275.0)	244	181.0 (102.4, 264.2)	–0.907	0.364
20–	304	163.6 (104.4, 252.8)	287	191.2 (111.0, 288.1)	–0.166	0.096
25–	416	167.6 (98.1, 258.8)	508	166.2 (99.0, 257.7)	–0.103	0.918
30–	500	173.3 (101.8, 261.8)	483	173.9 (108.2, 264.5)	–0.460	0.645
35–	594	178.0 (110.2, 269.9)	666	172.6 (105.3, 253.6)	–1.778	0.075
40–	813	170.1 (105.0, 254.7)	832	168.3 (104.8, 246.5)	–0.447	0.655
45–	872	169.0 (106.5, 259.4)	828	150.8 (90.5, 236.5)	–3.647	0.000
50–	936	152.0 (96.0, 241.9)	962	148.1 (85.6, 231.8)	–1.897	0.058
55–	1049	151.3 (97.8, 240.0)	1078	148.7 (87.3, 238.0)	–1.310	0.190
60–	796	155.0 (95.8, 251.1)	869	137.0 (81.5, 218.0)	–4.071	0.000
65–	451	154.2 (91.5, 236.9)	478	125.2 (72.8, 204.8)	–3.932	0.000
70–	305	151.2 (91.5, 236.9)	340	121.7 (73.9, 219.2)	–3.842	0.000
75–	210	155.8 (92.1, 233.3)	297	127.5 (76.4, 200.2)	–2.990	0.003
80–	101	156.6 (103.3, 228.4)	125	137.0 (73.8, 219.2)	–1.979	0.048
85–	30	133.9 (76.3, 194.4)	47	118.0 (70.1, 166.6)	–0.752	0.452
Total	8553	170.1 (103.9, 259.8)	8909	153.5 (92.0, 237.5)	–10.570	0.000

### Multiple logistic regression analysis

In the *multiple* logistic regression analysis, UIC was divided into two levels based on the current WHO classification system. In order to explore the risk factors of UIC, we divided UIC into two concentration groups (group1: less than 300 µg/L; and group 2: equal to or more than 300 µg/L). The regression models for rural and urban areas were both significant ( $\chi^2=251.267$ ,  $p=0.000$ ; and  $\chi^2=316.136$ ,  $p=0.000$ , respectively). Multiple logistic regression showed that the potential risk factors for urinary concentration of rural residents were age (OR=0.99, 95% CI 0.99 to 0.99), terrain (OR=0.83, 95% CI 0.76 to 0.91), usual intake of pickled products (OR=1.45, 95% CI 1.25 to 1.67), non-iodised salt intake (OR=0.39, 95% CI 0.31 to 0.49) compared with iodised table salt intake, and the potential risk factors for urinary concentration of urban residents were age (OR=0.9, 95% CI 0.98 to 0.99), terrain (OR=0.83, 95%

CI 0.75 to 0.93), usual intake of aquatic products (OR=1.24, 95% CI 1.04 to 1.47), non-iodised salt intake (OR=0.27, 95% CI 0.19 to 0.39) versus iodised table salt intake (table 3).

### DISCUSSION

Globally, in 2011, 32 countries and 1.88 billion people remained iodine deficient, including 241 million school-children, who had insufficient dietary iodine intake.<sup>5</sup> Salt iodisation has been recognised as the most effective and cost-efficient strategy to prevent IDD because salt is consumed daily by everybody and by all age groups.<sup>6</sup> USI was conducted in the Zhejiang Province from 1995. Since October 2000, the iodisation level was set at 35 mg/kg. Presently, surveillance of iodine nutritional status is mainly aimed at school-aged children<sup>4</sup> because they are a convenient population, easy to reach through

**Table 2** Urinary iodine concentration (median, 25% and 75%) of people living in rural and urban areas stratified by age group, Zhejiang Province, China

	Rural areas		Urban areas		Z	p Value
	N	Median (25%, 75%; µg/L)	N	Median (25%, 75%; µg/L)		
Preschool-aged children (3–6)	238	180.9 (117.9, 275.0)	186	181.6 (118.2, 251.7)	–0.776	0.438
School-aged children (7–12)	464	191.2 (116.7, 284.5)	423	166.2 (107.6, 250.8)	–2.355	0.019
Adolescents (13–18)	288	192.5 (117.1, 287.6)	371	186.0 (106.0, 276.0)	–1.068	0.286
Young people (19–39)	1839	171.0 (105.0, 262.0)	1978	174.2 (105.2, 261.0)	–0.435	0.664
Middle-aged people (40–59)	3670	160.2 (100.2, 248.0)	3700	153.8 (91.6, 239.0)	–3.587	0.000
Older people (60 years and above)	1893	154.0 (92.4, 245.5)	2156	129.5 (77.2, 206.1)	–7.772	0.000
Total	8392	170.1 (103.9, 259.8)	8814	153.5 (92.0, 237.4)	–7.365	0.000

**Table 3** Risk factors of urinary iodine concentration of people living in rural and urban areas, Zhejiang Province, China

Rural areas*	OR	95% CI	Wald	p Value	Urban areas*	OR	95% CI	Wald	p Value		
Age group	0.99	0.99	0.99	6.04	0.014	Age group	0.99	0.98	0.99	64.24	0.000
Terrain	0.83	0.76	0.91	17.73	0.000	Terrain	0.83	0.75	0.93	11.29	0.001
Pickled products intake	1.45	1.25	1.67	25.26	0.000	Pickled products intake					
Aquatic products intake						Aquatic products intake	1.24	1.04	1.47	6.01	0.014
Salt type	0.39	0.31	0.49	67.64	0.000	Salt type	0.27	0.19	0.39	53.15	0.000

\*Regression model in rural areas:  $\chi^2=251.267$ ,  $p=0.000$ ; Regression model in urban areas:  $\chi^2=316.136$ ,  $p=0.000$ .

school-based surveys and usually representative of the general population. In this study, with the multistage cluster sampling method, all members of the sampled households were investigated covering all age groups. We have known that participants who were the main labour migrants in the rural areas may influence the constituent ratio of age and this situation often exists in the survey. So we compared UIC between rural and urban residents stratified by age group in order to control for the influence of age.

Iodine intake should be modest and appropriate. UIC, with the appropriate sampling method, is currently the most practical biochemical maker for iodine. Our result indicated that the median UIC of rural and urban residents was 170.1 and 153.5  $\mu\text{g/L}$ , respectively. According to the WHO/UNICEF/International Council for the Control of IDD (ICCIDD),<sup>7</sup> the recommended dietary allowance of iodine for an adult man is 150  $\mu\text{g/day}$ , and the upper daily tolerable intake level of iodine is 1000  $\mu\text{g/day}$  according to the Chinese Nutrition Society<sup>8</sup>; according to the report of the Ministry of Health of China,<sup>9</sup> salt contributed 63.5% of food iodine and 24.6% of salt iodine was lost in cooking. Based on these criteria and the result of this study, the current dietary iodine intake of rural and urban residents was 355.3 and 320.6  $\mu\text{g/day}$ , respectively, suggesting that the diet iodine intake in the Zhejiang Province is sufficient and safe.

School-aged children are most commonly used as a sentinel population subgroup;<sup>4</sup> therefore, the WHO/UNICEF/ICCIDD use urinary concentration from school-aged children to classify a population's iodine status. Based on the previous assessment of iodine nutritional status of school-aged children,<sup>10 11</sup> this study indicated the difference of UIC between rural and urban school-aged children, suggesting that school-aged children constitute the most important target population that should be paid more attention. We also found the difference of UIC between rural and urban middle-aged people and older people, although they were both falls in optimal iodine status as recommended by WHO/UNICEF/ICCIDD, suggesting that they could be included in further surveys of iodine nutrition in community if condition will permit, and further studies on the factors induced the difference should be carried out to help to ensure the optimal intake both in rural and urban areas for middle-aged and older people.

Since this paper aims to compare the UIC of rural and urban residents in the Zhejiang Province 16 years after the introduction of salt iodisation by the multiple cluster sampling survey, the differences between rural and urban residents were compared stratified by age group. The investigation was based on the households, and differences of UIC between rural and urban residents were not found among preschool-aged children and adolescent groups limited by their sample size. Young people often eat outside for work reasons; this may reduce the differences between urban and rural areas among these people on diet intake of iodine to a certain extent.

The USI denotes that all edible salt including cooking salt and salt added to manufactured food should be iodised. Traditionally, rural areas have experienced a lower iodine nutritional status due to the economic status and culture of an agrarian lifestyle and lack of health education. However, our study indicated that this is no longer the case, and rural residents have a higher UIC than urban residents, and both of them were in the optimum interval of iodine nutrition interval suggested by the WHO.<sup>4</sup> Results by multiple logistic regression method indicated that for rural residents, people with young age, living in coastal areas, usually intake pickled products, and intake iodised salt could have higher UIC compared with those without these factors. Urban residents with young age, living in coastal areas, usually intake aquatic products, and intake iodised salt could have higher UIC compared with those without these factors. Results by multiple logistic regression method suggested that table iodised salt intake is the major factor which influences the iodine nutritional status mostly for rural and urban residents, this is consisted with Wu *et al's*<sup>12</sup> report under the USI policy.<sup>13</sup> For rural and urban residents, age is also an influencing factor for UIC, and this result is similar to Pfeiffer *et al's*<sup>14</sup> work of NHANES. Salt iodisation assures iodine nutrition in Zhejiang where environmental iodine is widely lacking. In the Zhejiang rural areas, the iodine intake of residents mainly comes from cooking salt for a few manufactured food items in their daily menu. Residents of rural areas may be especially prone to higher salt consumption resulting from eating habits that included more coarse and pickled foods, and this may be one of the causes that induce the difference in iodine levels between rural and urban residents. For rural and urban

residents, people living in coastal areas had higher UIC than those who were not, and this is consistent with a study carried out in Italy and Sudan;<sup>15 16</sup> for urban residents, those who usually consume aquatic products have higher UIC than those who do not. Aquatic products could help to improve the iodine national status as supplements of iodised salt, although the consumption of aquatic products for iodine intake is low.<sup>9 17 18</sup> Zhejiang Province, located in the southern part of the Yangtze River Delta of the southeast coast of China, lies in the east of the East China Sea, enjoying a vast territory and tropical zones with mountains, hills, plains and coastal terrain. Consequently, it is necessary to consider factors such as rural and urban territories, terrains and living habits when implementing the USI programme and evaluating the iodine nutritional status.

This analysis has several limitations. UICs are highly variable and represent recent intake rather than usual intake. Owing to this variation, a sample of 100 spot urine tests is needed to produce estimates of urinary iodine with a precision range of  $\pm 10\%$ , and a sample of 500 is needed for a precision range of  $\pm 5\%$ .<sup>19</sup> Based on our findings, we find that there are differences between rural and urban residents in iodine levels, but the falls in the optimal iodine status are as recommended by the WHO/UNICEF/ICCIDD. Iodised salt intake is the major factor which influences the iodine nutritional status mostly for rural and urban residents. The ongoing monitoring of population iodine status remains crucially important. Further, monitoring of UIC should differentiate between rural and urban areas.

**Contributors** GD, XL and YZ were responsible for the study design. YZ was responsible for the data collection and analysis, paper writing and revision. ZM and GM took part in the field investigation and data collection. WZ was in charge of laboratory detection.

**Funding** This study was supported by the Zhejiang Province science and technology fund (2009C03010-1).

**Competing interests** None.

**Patient consent** Obtained.

**Ethics approval** Zhejiang Provincial Center for Disease Control and Prevention.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** No additional data are available.

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