Original Article

Assessment of iodine status and associated factors in vulnerable populations in Henan Province, China, in 2012

Jin Yang MS, Heming Zheng MS, Xiaofeng Li BS, Lin Zhu MS, Zongyu Hao BS, Gan Chen BS, Yang Liu MS, Yanli Wang MS

Department for Endemic Disease Control and Prevention, Henan Provincial Centre for Disease Control, Zhengzhou, China

Background: Iodine content in table salt was adjusted from 30-50 mg/kg to 21-39 mg/kg from March of 2012 in Henan Province, China. The vulnerable population may be at risk of iodine deficiency. **Objectives:** To determine whether the iodine intake was sufficient in vulnerable populations and to investigate what factors may be associated with iodine status in these vulnerable populations in Henan Province, China. **Methods:** A cross-sectional survey was conducted in 17 cities in Henan Province, China, from April 2012 to December 2012 to assess the iodine status in vulnerable populations, including women of reproductive-age (n=2648), pregnant women (n=39684), lactating women (n=6859), infants <2 years of age (n=16481), and children aged 8-10 years (n=3198). Questionnaires (n=4865) related to demographic and dietary factors were collected from the investigated women to identify factors that were related to iodine intake and iodine status. **Results:** The median urinary iodine concentrations (mUICs) were 205 μg/L, 198 μg/L, 167 μg/L, 205 μg/L and 200 μg/L, respectively, in reproductive-age, pregnant and lactating women, infants <2 years of age and children aged 8-10 years. Higher income, and consuming more poultry and fish in the diet had positive impact on UIC levels. Low salt intake, consuming more rice and vegetables in the diet were negative factors for UIC. **Conclusions:** Iodine status of the vulnerable populations was generally adequate in Henan Province, China, according to WHO criteria. But the mUICs were slightly above the adequate level in reproductive-age women and children aged 8-10 years. It's important to monitor the iodine status in vulnerable populations after the adjustment on iodine content in table salt.

Key Words: iodine, reproduction, pregnancy, lactation, child

INTRODUCTION

Iodine is a trace element required for the synthesis of thyroid hormones in thyroid glands, and is crucial to children's growth and development. Iodine deficiency has many adverse effects, including hypothyroidism, goiter, cretinism, stillbirths, and so on.[1] Recently, severe iodine deficiencies, such as cretinism and goiter, were no longer considered as major health problems. However, iodine deficiency in vulnerable populations is still a concern.[2] Brain development during the intrauterine period and the first 2 years of age is very sensitive to iodine sufficiency.[3] Even mild maternal iodine deficiencies during this critical period may lead to abnormalities in psychomotor and intellectual development.[4,5] Therefore, the control and surveillance of iodine deficiency is critical in vulnerable populations, including reproductive-age, pregnant and lactating women, infants and children.

China was once a country with serious epidemic iodine deficiency disorders (IDD). A universal salt iodization (USI) program has been launched in China since 1995, which lead to a significant increase in the coverage of households using qualified iodized salt and a decline in the incidence of IDD.[6] This program required that the iodine content was 35 mg/kg in table salt (the concentration of elementary iodine and the permitted range is ±15 mg/kg). From 1995 to 2011, six national IDD surveys were carried out in China.[7-12] In the recent surveys, the median urinary iodine concentrations (mUICs) of school children aged 8-10 years in China were 241 μg/L, 246 μg/L and 239 μg/L in 2002, 2005 and 2011, respectively,[10-12] which exceeded the adequate range of 100-199 μg/L recommended by WHO.[3] These results indicated that the iodine status of the country, as a whole, was classified as 'more than adequate' (200-300 μg/L). In view of this, the Ministry of Health issued a new standard that the iodine content should be 20, 25 or 30 mg/kg in table salt (the concentration of elementary iodine and the permitted range is ±30%) in September, 2011, according to the

Corresponding Author: Jin Yang, Department for Endemic Disease Control and Prevention, Henan Provincial Centre for Disease Control, No.105 Nongye Nan Road, Zhengdong New District, Zhengzhou, 450016, China.
Tel: +86-371-68089012; Fax: +86-371-68089060
Email: yangjin6429@163.com
Manuscript received 14 November 2013. Initial review completed 07 January 2014. Revision accepted 19 April 2014.
doi: 10.6133/apjcn.2014.23.4.03

actual situation in each province.[13] The new standard was implemented from March of 2012 and a period of transition was allowed.

Henan is a province in the central China with a large population and is economically underdeveloped. In the 2002, 2005, 2011 national IDD Surveys, the mUICs in children aged 8-10 years in Henan province were 297, 315 and 201 μg/L, respectively.[10,11,14] These data indicated that the iodine status of the general population in Henan Province exceeded the adequate range of 100-199 μg/L. Iodine excess could induce thyroiditis, hyperthyroidism, hypothyroidism, and goiter.[15] So, in the latest adjustment, a new iodized salt standard of 30 mg/kg (the range is 21-39 mg/kg) was selected in Henan Province.

Some studies found that the iodine status in children aged 8-10 years may reflect the general population, but may not represent other vulnerable populations who were more sensitive to the damage of IDD.[12,16] Before the latest adjustment of salt iodine standard in China, some pregnant and lactating women were found to be iodine deficient, although most school children aged 8-10 years were classified as ‘more than adequate’.[12] In order to assess iodine status in vulnerable populations, a cross-sectional survey on reproductive-age, pregnant and lactating women, infants <2 years of age and children aged 8-10 years was conducted in Henan Province of China, in 2012. We sought to determine whether the iodine intake was adequate in vulnerable populations and to investigate the factors associated with iodine status.

METHODS

Data collection

Subjects were collected from 17 cities in Henan Province from April 2012 to December 2012. Initially, a subject was eligible to enter the study if she/he was resident in one of the investigating cities for more than 12 months. Those who had thyroid diseases or kidney diseases, or exposure to iodinated contrast medium, were excluded from the study. A multistage cluster sampling method was adopted to obtain samples that represent vulnerable populations. In stage of 1, a county was randomly selected in each city. In stage of 2, clinics or schools were randomly selected from the sampling county. Finally, in each sampling county, no less than 200 reproductive-age women, 200 pregnant women, 200 lactating women, 200 infants, and 200 school children, were recruited from the local hospitals and schools (Figure 1). Below are details for recruitment of subjects in different populations.

For reproductive-age women, family planning organizations were randomly selected within each sampling county. These women were equally enrolled regardless whether they were receiving premarital medical check or eugenic check (a free pre-pregnancy check provided by the government, including toxopasma, rubella virus, cytomegalovirus and herpes virus screening), were enrolled sequentially. Most of them were newly married women of reproductive-age.

For pregnant women, hospitals or maternal and child health (MCH) hospitals with obstetric client within each sampling county were randomly selected. The pregnant women, who were receiving prenatal care, were enrolled sequentially.

For lactating women and infants, hospitals or immunization clinics were randomly selected within each sampling county. The lactating women, who were receiving postpartum care and consent, were enrolled sequentially. The vaccinated infants <2 years of age and their mothers, were also enrolled; 50 mother-infant pairs were selected in each city on the basis of exclusive breastfeeding and availability of urine samples from both mothers and their infants.

For the above 4 groups, the medical personals in the selected institutions undertook urine sampling, filled in the registration cards, and kept the urine samples in screw-capped plastic bottles and refrigerated; these urine samples were taken to the CDC laboratory and tested every 2-3 days.

For school children, two or three primary schools were randomly selected within each sampling county. School children aged 8-10 years (half boys and half girls), who met the inclusion criteria, were enrolled. The age of the children was obtained from the school card. The investigations and tests were completed by the CDC staff.

The survey protocol was approved by the medical ethics committee from the Centre for Disease Control and Prevention. Written informed consent was obtained from all the participants.

Subjects were excluded in the final analysis if these subjects lived in the areas where water iodine concentrations exceeded 100 μg/L. A final sample of 68870 subjects was analyzed, including women of reproductive-age (n=2648), pregnant women (n=39684), lactating women (n=6859), infant <2 years (n=16481), children aged 8-10 years (n=3198). Five hundred and thirty-one breast-fed pairs were included to analyze the correlation between the UIC of infants and their mothers.

Laboratory analysis

Casual urine samples (≥10 mL) were collected from all subjects. The samples were then sealed and stored at 4°C until measurements. UIC was measured to determine iodine in urine by $As3^{+}$-$Ce4^{+}$ catalytic spectrophotometry (WS/T107-2006), a national method developed by the China's Ministry of Health.[17] All the participate laboratories passed the external quality control by China National CDC in 2012. Based on the results, the coefficient of variation for UIC in our laboratory was 2.2% at 71.5±9.0 μg/L and 1.0% at 203±10.0 μg/L.

Standard of iodine content in edible salt

The old and new standards of iodine content in table salt were 20-50 mg/kg and 21-39 mg/kg, respectively.

Evaluation criteria for iodine status

The measurement of urinary iodine excretion was used to assess the iodine status in the collected samples. The evaluation criteria for iodine status were different among different vulnerable population according to the guidelines issued by WHO.[3] The following criteria were used to classify iodine nutritional status: a mUIC of 100-199 μg/L among the general population and 150-249 μg/L among pregnant women indicated iodine sufficiency. Additionally, among the general population, a mUIC<50 μg/L indicated moderate to severe iodine deficiency.

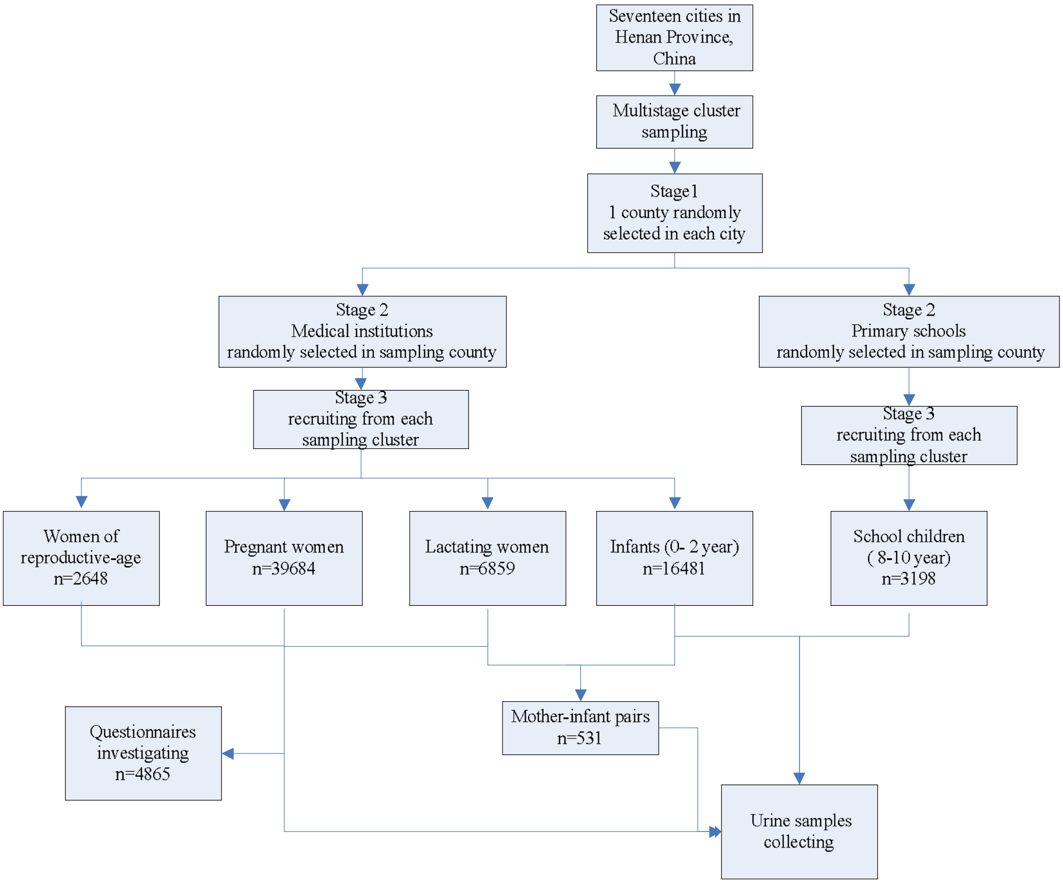

Figure 1. Flow chart of the study population

Among lactating women and infants, a mUIC≥100 µg/L was used to define iodine sufficiency; no other categorizations were used for the two groups.[3]

Questionnaires

Within each sampling country, 100 reproductive-age women, 100 pregnant women, and 100 lactating women were randomly selected to answer a questionnaire related to demographic and dietary factors on the basis of being literate and availability of urine samples. The demographic data included age, urban/rural, education, address, and income and occupation of the subject and her spouse. The dietary data included supplement of iodized oil capsule or iodine-enriched food, daily salt intake (self-rated), and all food consumed in the past three days. It was difficult to assess the accurate amount of salt intake from each subject in daily life because most of them were recruited from the clinics. Therefore, a self-rated level was used to assess daily salt intake in our survey. Because the rate of qualified iodized salt (which met the national standard, 20-50 mg/kg) in the residents has reached 95% in investigated areas, the usage of iodized salt was not included in our survey.

The questionnaires from subjects who lived in the areas where water iodine concentration exceeded 100 µg/L were also excluded. A total of 4865 questionnaires were included for final the analysis.

Statistical analysis

SPSS Version 17.0 was used to analyze the data. Normally distributed data was reported as the mean ± standard deviation (SD). Non-normally distributed data was reported as the median (with interquartile range, IQR). For normally distributed outcomes, t-test and ANOVA were used to test the null hypothesis that the group means were the same in two or more groups, respectively. Mann-Whitney U test or Kruskal-Wallis was used to test for differences in the distribution of non-normal continuous variables among two or more groups. Chi-squared or Fisher's exact tests, as appropriate, were used to test for association between categorical variables. To look for correlations of maternal and infant UIC, UIC from mothers and infants was natural log and Pearson correlation was performed. A multiple linear regression analysis was performed with log UIC as the dependent variable and age, education, income, occupation, supplement of iodized oil capsule or consumption of iodine-enriched food in daily life, sodium appetite, and all food types consumed in the past three days as covariates. $p<0.05$ was considered statistically significant.

RESULTS

Different mUIC levels in three subgroups of women

The average ages of reproductive-age, pregnant and lactating women were 25.8, 26.5, and 27.0, respectively. The lactating women were older than the reproductive-age women and the pregnant women ($p<0.001$). The mUIC of reproductive-age women was 205 µg/L (Table 1), which is slightly higher than the WHO criterion for sufficiency of the general population (100-199 µg/L). The mUIC of pregnant and lactating women was 198 µg/L and 167 µg/L, respectively, which met the WHO criterion for iodine sufficiency of pregnant women (150-249 µg/L) and lactating women (>100 µg/L), respectively. The mUIC of

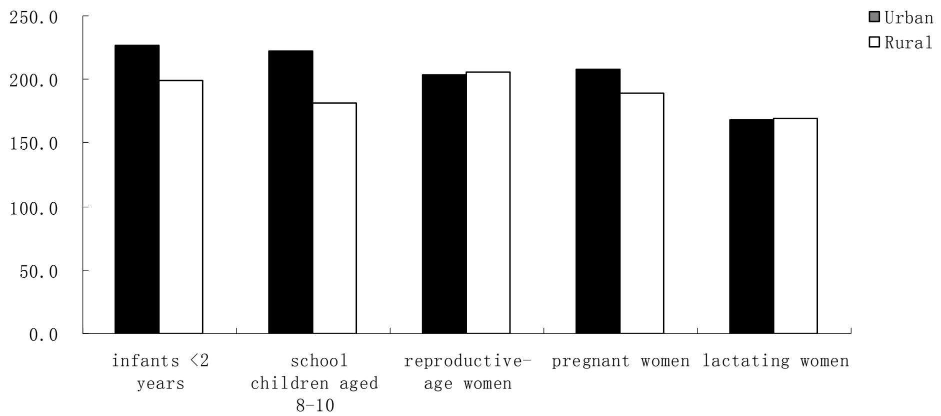

Figure 2. Differences in mUIC between urban and rural areas in different population groups. mUIC: median urinary iodine concentration.

reproductive-age women was higher than both pregnant and lactating women (p<0.05 and p<0.01).

The percentages of pregnant women (n=39684) in the first, second, and third trimester were 14.9%, 58.8%, and 26.3%, respectively. The mUICs in the three trimesters were 199 μg/L (IQR 125-285), 196 μg/L (IQR 132-283), and 192 μg/L (IQR 129-280), respectively. Differences in UIC among the three trimesters were not statistically significant (p=0.069).

The mUIC were lower in rural pregnant women compared with that in urban pregnant women (189 vs 208 μg/L; p<0.001). There were no significant differences in mUIC between rural and urban areas in reproductive-age and lactating women (p=0.067 and p=0.577) (Figure 2).

Infants and school children

The male/female ratio of infants was 1.28. The mUIC was 205 μg/L (IQR 138-294) in infants <2 years of age, which met the WHO criterion for iodine sufficiency of infants (>100 μg/L). The infants were divided into three groups according to their age: 0-0.5 years, 0.6-1 years, and 1-2 years. The mUICs of the three groups were 217 μg/L (IQR 147-298), 194 μg/L (IQR 132-289), and 188 μg/L (IQR 124-279), respectively. It showed that the mUIC of infants decreased as the age increased (p<0.01).

The mUIC in infant girls was significantly lower than that in infant boys (203 vs 209 μg/L; p<0.01) and the mUIC among rural infants compared with urban infants was less (199 vs 227 μg/L; p<0.001).

The male/female ratio of school children was 1.51. The mUIC of school children was 200 μg/L (IQR 127-306), which was slightly higher than the WHO criterion of iodine sufficiency for the general population (100-199 μg/L).

The mUIC of school children aged 8-10 years showed no significant difference among different gender groups (p=0.980), but urban school children had higher mUIC than rural ones (222 vs 181 μg/L) (p<0.001).

A provincial baseline survey was conducted to monitor the iodine status in vulnerable population, but only included 8 cities in 2011. To compare the two years of data (2011 and 2012), the data in the eight cities in 2012 were selected to recalculate the mUICs in vulnerable populations. The mUICs in reproductive-age women, pregnant and lactating women, infants in 2012 (only in the eight cities) were 212 μg/L, 198 μg/L, 163 μg/L and 207 μg/L, respectively.

Mother-infant pairs

After adjustment for month age and sex of infant, the UIC of the mothers was positively correlated with the UIC of their infants (r^2=0.223, p<0.001).

Factors associated with iodine nutritional status of women

A total of 4865 women completed the questionnaires related to sociodemographic and dietary factors. In multiple linear regression analyses, pregnant and lactating women had a lower UIC than reproductive-age women, while other confounding factors in the model were controlled (Table 2). Based on this model, those living in urban areas (compared with those living in rural areas), having income ≥2000 yuan (compared with those having income <1000 yuan) and less than high school education (compared with those having more than a high school education) had a higher UIC. Daily salt intake was positively associated with UIC. To assess dietary factors, three day food records were collected. Among them, poultry, and fish had a positive impact on UIC, while rice and vegetables were negative factors. However, there was no significant association between UIC and age, education level, iodized oil capsule, and foods like meat, milk, egg, pickled food, cereal, and beans.

DISCUSSION

Our results confirmed that iodine status of the vulnerable populations in Henan Province of China in 2012 was generally 'adequate' according to WHO criteria. However, the mUICs were 205 μg/L in reproductive-age women and 200 μg/L in children aged 8-10 years respectively, which were slightly above the adequate level (100-199 μg/L). These data indicate that the two groups of populations may be at risk of iodine excess, which can induce thyroid dysfunction, thyroiditis, hyperthyroidism, hypothyroidism, and goiter.

A new standard of iodine content in table salt was implemented in Henan Province, China, from March of 2012. Iodine content in table salt was reduced from 35 mg/kg to 30 mg/kg. In order to monitor the real changes of iodine status before and after the adjustment on iodine

Table 1. Urinary iodine concentration and demographic traits of population groups in central China

Age group	Infants (0-2 year)	School children (8-10 year)	Reproductive-age women	Pregnant women	Lactating women
n	16,481	3198	2648	39,684	6859
Men/women	9246/7235	1925/1273	All women	All women	All women
Age, (mean±SD, year)	0.7±0.6	8.9±0.8	25.8±4.5	26.5±5.7	27.0±6.4
UIC (μg/L)					
Median (IQR)	205 (138-294)	200 (127-306)	205 (134-293)	198 (131-286)	167.1 (108-258)
<50 μg/L (%)	2.0	4.5	3.6	2.3	5.4
<100 μg/L (%)	10.6	16.7	13.8	31.9	21.2
≥300 μg/L (%)	21.9	26.0	23.5	21.1	18.3

Among pregnant women, the percentage of UIC<150 μg/L instead of that of UIC<100 μg/L. IQR: Interquartile range; UIC: Urinary iodine concentration.

Table 2. Multiple linear regression models associating iodine deficiency with sociodemographic and dietary factors among women (n=4865)

Variables in equation	β	S_x	β'	t	p
Intercept	2.17	0.031		70.2	<0.001
Subgroups of women					
Newly married women of childbearing age	Reference				
Pregnant women	-0.021	0.011	-0.033	-1.88	0.047
Lactating women	-0.020	0.011	-0.031	-1.77	0.077
Urban	0.048	0.011	0.076	4.33	<0.001
Income					
<1000 yuan	Reference				
1000-1999 yuan	0.017	0.014	0.028	1.25	0.213
≥2000 yuan	0.042	0.014	0.068	3.00	0.003
Education					
< High school	Reference				
≥ High school	-0.039	0.011	-0.063	-3.62	<0.001
Daily salt intake (self-rated)					
Low	Reference				
Medium	0.055	0.019	0.057	2.87	0.004
High	0.043	0.015	0.058	2.91	0.004
The kinds of food in recent 3 days					
Poultry	0.037	0.010	0.058	3.83	<0.001
Fish	0.038	0.011	0.051	3.35	0.001
Rice	-0.026	0.010	-0.040	-2.69	0.007
Vegetable	-0.032	0.013	-0.037	-2.51	0.012

The dependent variable is log UIC. β' indicates the standardized coefficient.

content in table salt, we previously carried out a provincial baseline survey on vulnerable population in 2011. Due to a budget limitation, the 2011 survey only included 8 cities and had no dietary survey. The mUICs in reproductive-age women, pregnant and lactating women, infants in 2011 were 205 μg/L, 191 μg/L, 145 μg/L and 185 μg/L, respectively,[18] and the mUICs in 2012 (only in the eight cities) were 212 μg/L, 198 μg/L, 163 μg/L and 207 μg/L, respectively. Upon comparing the two years of data in the eight cities, there was a slight rise from 2011 to 2012 in UIC in vulnerable populations. The rise may be explained by the following reasons: the majority of salt in the market was still the old concentration salt (35 mg/kg); UIC varied highly, and different sample time and season would have an impact on UIC; iodine from iodized salt did not capture all sources of iodine in the diet; therefore it may need further adjustment of the salt iodization in the future.

Some studies have suggested that the increased need for iodine intake for fetal brain development begins even before women came to know about their pregnancy.[19-21] Iodine status of newly married women at reproductive-age is more significant for fetus growth than other reproductive-age women because most newly married women plan to have babies after being married as the result of one-child policy in China. Our data indicated that the mUIC in reproductive-age women was higher than that in the pregnant and lactating women, which was similar to another finding from Ningxia Province of China.[22] The mUICs were 198 μg/L in pregnant women and 167 μg/L in lactating women in our study, which were higher than that in the USA,[19] Switzerland,[23] Australia,[24] Croatia,[25] and New Zealand.[26] This probably attributed to higher household coverage rates of iodized salt and higher levels of iodine in salt. In order to improve the iodine status in pregnant and lactating women without increasing the risk of iodine excess, we suggested that special iodized salt and individual instructions about iodine supplement should been provided to the pregnant and lactating women while reducing the iodized salt concentration.

In pregnant women, the mUIC was highest in the first trimester and then decreased in the following trimesters.

But statistically the trend was not significant. Similar results were reported in a cross-sectional study conducted in Japan.[27]

The first two years of life are crucial for infants' physical and intellectual development hence iodine deficiency in this period would cause irreversible brain damage. Infants do not have enough iodine storage capacity so that they are dependent on regular supply of iodine for adequacy.[28] The mUIC levels decreased by 30 μg/L in infants, from 0-0.5 years to 1-2 years, in our study, which may be due to the failure in the use of iodine-containing adjunctive food after weaning. These facts suggest that iodine supplementation is necessary for infants who deprive of iodine rich sources.

WHO recommends that school children aged between 8-10 years are suitable for monitoring iodine nutrition in a population because of their easy availability as subjects and vulnerability to the adverse effects for iodine deficiency.[29,30] In our study, we found that rural students were more affected by threat of iodine deficiency than urban students, although iodine status of school children aged 8-10 years was sufficient in general.

UIC varied highly and reflected iodine intake over the past few days rather than usual intake.[23] Therefore, we surveyed the food types in past three days instead of food frequency questionnaire which generally overestimates the level of iodine intake.[27] Our results also confirmed that higher income, fish, poultry, high salt intake, were possible important contributors to iodine status in women. Dairy may be an important source of iodine in industrialized countries, such as Australia,[31] the USA,[19] Italy,[32] and Norway.[33] There was no significant correlation between dairy product intake and iodine status in our study. One possible reason was that the use of iodophor cleansers in the dairy industry and iodine supplementation of cattle feed resulted in milk and other dairy products containing iodine in these countries.[34]

Our results confirmed that iodine status of the vulnerable populations, as a whole, was sufficient in Henan Province, China. But these data were not enough to reflect the real change of population iodine status after adjustment on iodine salt content in table salt. So, a continuous surveillance and evaluation on iodine status in the next two years is necessary. It is also necessary for ongoing monitoring of iodized salt and other dieta-ry iodine sources in order to prevent iodine deficiency as well as iodine excess in vulnerable populations or the general population.

ACKNOWLEDGEMENTS

The authors are grateful to the women and children who participated in this study, the study coordinator, research assistants, laboratory technicians, and administrative staff who made this study possible. We thank the support of all the cooperated Centres for Disease Control and Prevention, including Zhengzhou, Kaifeng, Luoyang, Pingdingshan, Jiyuan, Anyang, Hebi, Xinxiang, Jiaozuo, Puyang, Xuchang, Luohe, Shangqiu, Zhoukou, Zhumadian, Nanyang, Xinyang. And we express our sincere appreciation to Dr Chun-yu Liu (Boston University, US) for assistance in revising the final manuscript.

AUTHOR DISCLOSURES

The study was supported by Henan Provincial Health Department and Henan Provincial Centre for Disease Control and Prevention, China. The study was funded by the transfer trust from the Central Government, Henan Public Health Special Trust, China.

The authors declare that they have no conflicts of interest.

REFERENCES

1. Zimmermann MB, Jooste PL, Pandav CS. Iodine-deficiency disorders. Lancet. 2008;372:1251-62. doi: 10.1016/S01406-737(08)61005-3.
2. Granston MM, Ryan MA, Smith TC, Sevick CJ, Brodine SK. Hypothyroidism among military infants born in countries of varied iodine nutrition status. BMC Endocr Disord. 2010;10: 2. doi: 10.1186/1472-6823-10-2.
3. WHO, UNICEF, and ICCIDD. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for program managers. 3rd ed. Geneva: WHO; 2007.
4. Yarrington C, Pearce EN. Iodine and pregnancy. J Thyroid Res. 2011;934104. doi: 10.4061/2011/934104.
5. Skeaff SA. Iodine deficiency in pregnancy: the effect on neurodevelopment in the child. Nutrients. 2011;3:265-73. doi: 10.3390/nu3020265.
6. Li S, Zheng Q, Xu J, Gorstein J, Wang H, Dong H. Iodine excess or not: analysis on the necessity of reducing the iodine content in edible salt based on the national monitoring results. Asia Pac J Clin Nutr. 2011;20:501-6.
7. Chen J, Li Z, Xu H, Zhang Z, Lui J, Wu J et al. China iodine deficiency disorders monitoring in 1995. Beijing: People's Medical Publishing House; 1999. (In Chinese)
8. Chen J, Li Z, Xu H, Hao Y, Zhang Z, Lui J et al. China iodine deficiency disorders monitoring in 1997. Beijing: People's Medical Publishing House; 1999. (In Chinese)
9. Chen X, Li Z, Hao Y, Xu H, Liu S, Zhang Z et al. China iodine deficiency disorders monitoring in 1999. Beijing: People's Medical Publishing House; 2002. (In Chinese)
10. Chen X, Sun D, Liu S, Shen H, Xu H, Li Z et al. China iodine deficiency disorders monitoring in 2002. Beijing: People's Medical Publishing House; 2003. (In Chinese)
11. Xiao D, Sun D, Bai H, Liu S, Shen H, Liu J et al. China iodine deficiency disorders monitoring in 2005. Beijing: People's Medical Publishing House; 2007. (In Chinese)
12. Shen H. The problems and challenges for China after achieving the national elimination IDD standard. Chin J Prev Med. 2013;47:5-7. (In Chinese)
13. China's Ministry of health. GB26878-2011 national food safety standards: iodine content in edible salt. Beijing: Standards Press of China; 2011. (In Chinese)
14. Zheng H, Li X, Yang J. Investigation on iodine deficiency disoroders status in Henan Province. Chin J Endemiol. 2013; 32:35-7. (In Chinese)
15. Pennington JAT. Iodine toxicity. Springfield, VA: national technical information service, US department of commerce; 1989.
16. Yan Y. A survey on iodine nutrition in 5 groups of target population in China. Chin J Endemiol. 2003;22:141-3. (in Chinese)
17. China's Ministry of health. WS/T107-2006 method for determination of iodine in urine by As3+Ce4+catalytic spectrophotometry. Beijing: Chinese Criteria Publi-shing House; 2006. (in Chinese)
18. Yang J, Zheng H, Chen G. Iodine nutritional status of the vulnerable population in Henan province in 2011. Chin J Prev Med. 2013;47:14-17. (In Chinese)
19. Perrine CG, Herrick K, Serdula MK, Sullivan KM. Some subgroups of reproductive age women in the United States may be at risk for iodine deficiency. J Nutr. 2010;140:1489-94. doi: 10.3945/jn.109.120147.

20. Pérez-López FR. Iodine and thyroid hormones during pregnancy and postpartum. Gynecol Endocrinol. 2007;23: 414-28. doi: 10.1080/09513590701464092.
21. Finer LB, Henshaw SK. Disparities in rates of unintended pregnancy in the United States, 1994 and 2001. Perspect Sex Reprod Health. 2006;38:90-6. doi: 10.1111/j.19312393.2006. tb00065.x.
22. Wu H, Li L, You W, Mao C. Analysis of monitoring results of urinary iodine levels of 5 special groups in Ningxia. Chin J Endemiol. 2011;30:173-5. (In Chinese)
23. Andersson M, Aeberli I, Wüst N, Piacenza AM, Bucher T, Henschen I et al. The Swiss iodized salt program provides adequate iodine for school children and pregnant women, but weaning infants not receiving iodine-containing complementary foods as well as their mothers are iodine deficient. J Clin Endocrinol Metab. 2010;95:5217-24. doi: 10.1210/jc. 2010-0975.
24. Blumenthal N, Byth K, Eastman CJ. Iodine intake and thyroid function in pregnant women in a private clinical practice in Northwestern Sydney before mandatory fortification of bread with iodised salt. J Thyroid Res. 2012; 2012:798963. doi: 10.1155 /2012/798963.
25. Kusić Z, Jukić T, Rogan SA, Juresa V, Dabelić N, Stanicić J et al. Current status of iodine intake in Croatia - the results of 2009 survey. Coll Antropol. 2012;36:123-8.
26. Brouqh L, Jin Y, Shukri NH, Wharemate ZR, Weber JL, Coad J. Iodine intake and status during pregnancy and lactation before and after government initiatives to improve iodine status, in Palmerston North, New Zealand: a pilot study. Matern Child Nutr. 2013. doi: 10.1111/mcn.120 55.
27. Fuse Y, Shishiba Y, Irie M. Gestational changes of thyroid function and urinary iodine in thyroid antibody-negative Japanese women. Endocr J. 2013;60:1095-106. doi: 10.15 07/endocrij.EJ13 -0184.
28. Remer T, Johner SA, Gärtner R, Thamm M, Kriener E. Iodine deficiency in infancy - a risk for cognitive development. Dtsch Med Wochenschr. 2010;135:1551-6. doi: 10.10 55/s-0030-1262446.
29. WHO, UNICEF, and ICCIDD. Indicators for assessing iodine deficiency disorders and their control through salt iodinization. Geneva, Switzerland: World Health Organization; 1994. (WHO/NUT/94.6).
30. WHO, UNICEF, and ICCIDD. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers. Geneva, Switzerland: World Health Organization; 2001. (WHO/NHD/01.1)
31. Li M, Ma G, Boyages SC, Eastman CJ. Re-emergence of iodine deficiency in Australia. Asia Pac J Clin Nutr. 2001;10: 200-3. doi: 10.1046/j.1440-6047.2001.00254.x.
32. Mian C, Vitaliano P, Pozza D, Barollo S, Pitton M, Galleqari G et al. Iodine status in pregnancy: role of dietary habits and geographical origin. Clin Endocrinol (Oxf). 2009; 70:776-80. doi: 10.1111/j.1365-2265.2008.03416.x.
33. Brantsæter AL, Haugen, Julshamm K, Alexander J, Meltzer HM. Evaluation of urinary iodine excretion as a biomarker for intake of milk and dairy products in pregnant women in the Norwegian mother and child cohort study (MoBa). Eur J Clin Nutr. 2009;63:347-54. doi: 10.1038/sj.ejcn.1602952.
34. Pearce EN, Pino S, He X, Bazrafshan HR, Lee SL, Braverman LE. Sources of dietary iodines bread, cows' milk, and infant formula in the Boston area. J Clin Endocrinol Metab. 2004;89:3421-4. doi: 10.121 0/jc.2003-032002.

Original Article

Assessment of iodine status and associated factors in vulnerable populations in Henan Province, China, in 2012

Jin Yang MS, Heming Zheng MS, Xiaofeng Li BS, Lin Zhu MS, Zongyu Hao BS, Gan Chen BS, Yang Liu MS, Yanli Wang MS

Department for Endemic Disease Control and Prevention, Henan Provincial Centre for Disease Control, Zhengzhou, China

2012 年中国河南省重点人群的碘营养状况及影响因素

背景：从 2012 年 3 月起，中国河南省食盐中碘浓度从 30-50 mg/kg 调整到 21-39 mg/kg。由于食盐中碘浓度的下调，重点人群可能有碘缺乏的风险。**目的：**了解河南省重点人群的碘营养状况是否适宜，并探索与碘营养相关的影响因素。**方法：**从 2012 年 4 月至 2012 年 12 月，在中国河南省的 17 个城市对重点人群的碘营养状况开展横断面调查，包括育龄妇女 2648 名、孕妇 39684 名、哺乳期妇女 6859 名、0-2 岁婴幼儿 16481 名和 8-10 岁儿童 3198 名。通过问卷形式收集调查对象的人口学因素和膳食情况，共收集问卷 4865 份。**结果：**2012 年河南省育龄妇女、孕妇、哺乳期妇女、0-2 岁婴幼儿和 8-10 岁儿童的尿碘中位数分别为 205 µg/L、 198 µg/L、 167 µg/L、 205 µg/L 和 200 µg/L。高收入、膳食中摄入更多的禽类和鱼类因素与尿碘浓度呈正相关，而低盐膳食、膳食中摄入更多的大米和蔬菜与尿碘浓度呈负相关。**结论：**按照 WHO 的标准，河南省重点人群的碘营养状况总体适宜，但育龄妇女和 8-10 岁儿童的尿碘浓度略高于适宜水平。食盐中碘浓度调整后，对重点人群的碘营养状况进行监测是十分必要的。

关键词：碘、生育、妊娠、哺乳、儿童