Short Communication

Is the current iodine content in edible salt appropriate for eliminating iodine deficiency in China

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Objective: This study was designed to measure the urinary iodine excretion of volunteers who daily consumed iodized salt and to evaluate whether the current iodine content in salt is appropriate. A field trial study was then conducted to determine how the salt iodization content should be adjusted, either to prevent iodine deficiency or to avoid excess consumption. Methods: A total of 1,099 volunteers from 399 households from urban and rural regions were selected. The levels of salt iodine and urinary iodine were measured prior to the field trial. All the households were randomly divided into four groups according to different salt iodine concentrations: group A, 6±2 mg/kg; group B, 15±2 mg/kg, group C, 24±2 mg/kg; and group D, 34±2 mg/kg. The urinary iodine levels of households were determined over five consecutive days, starting on the 27th day after the intervention. Results: Before the intervention, the median urinary iodine excretions for urban and rural residents are 294 µg/L and 509 µg/L, respectively. By contrast, urinary iodine excretion in all groups significantly declined after the intervention. The median excretions of urinary iodine on the 28th day after the intervention for all groups were 97.2 µg/L, 199 µg/L, 249 µg/L and 331 µg/L for urban residents, and 101 µg/L, 193 µg/L, 246 µg/L and 308 µg/L for their rural counterparts, respectively. Conclusions: The trial exhibits a tendency of slightly excessive iodine intake among the households under the currently recommended standard.

Key Words: iodine deficiency disorder (IDD), universal salt iodization (USI), salt iodization, urinary iodine, field trial

INTRODUCTION

Iodine deficiency disorder (IDD) is a global public health issue. China is one of the countries most severely threatened by IDD. The Chinese government has adopted responding measures to incorporate universal salt iodization (USI), which has achieved obvious progress in preventing and controlling IDD; in fact, the goal of IDD elimination has been achieved.[1,2] At present, the average iodine concentration in edible salt is 35±15 mg/kg throughout China. However, more recent data show that the average level of urinary iodine in children aged 8-10 years old who consume iodized salt has exceeded the appropriate levels for the humans.[3] Moreover, the incidence of thyroid diseases has also been increased with the excessive iodine consumption.[4] Therefore, it is essential to adjust the concentration of salt iodine to an optimal level, not only for the purpose of preventing IDD, but also from the potential side effects caused by excessive iodine intake. This trial aimed to study the iodine nutrition status of households consuming different contents of iodized salt, and to determine an appropriate content for salt iodization.

MATERIALS AND METHODS

Subjects

A total of 1,099 volunteers from 199 urban and 200 rural households participated in the study. The consents from participants were signed before the trial study. The urban households were from Hongdu Community, located in the Qingyun District of Nanchang City, and the rural households were from the remote rural areas of Huangzhou Village, Huangzhou Town, Anyi County and Nanchang City. Volunteers aged 7-12 years old were included to obtain an adequate number of children.

Intervention method

Prior to the intervention, urinary samples and iodized salt samples were collected from the selected households to determine iodine content. Demographic information including name, gender and age of all family members were recorded.

Based on age and gender, all the households in urban and rural regions were separately divided into four intervention groups: A, B, C and D. The participants in each group consumed the trial salt as a substitute, which was supplied by the National Reference Laboratory for Iodine

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Deficiency Disorders (NRLIDD). The concentrations of iodine in the trail salt were designed according to national survey data and the relevant research literatures.[1,3] Group A was provided with trial salt at an iodine content of 6±2 mg/kg (amount of iodine per kilogram salt), and the iodine content for groups B, C and D were 15±2 mg/kg, 24 ±2 mg/kg and 34±2 mg/kg, respectively.

The follow-up information of all households was collected by weekly phone calls. Some households were randomly visited to confirm the status of trial salt consumption. From the 27th day following the intervention, all the urinary samples were collected for five consecutive days. Drinking water samples were also collected to detect iodine content.

Iodine determination

The iodine contents of urine and drinking water were determined as the national standard method: A_s^{3+}-Ce^{4+} catalytic spectrophotometry conducted at the NRLIDD.[5,6] Salt iodine content was tested with the direct titration method by the chemical laboratory of the Nanchang Center for Disease Control and Prevention.[7]

Statistical analysis

A database was created by using Epinfo 2002. All data were statistically analyzed using SAS software (Version 8.2).

Ethical issues

All selected subjects agreed to participate in the study and signed an informed consent form. The study had obtained approval from the Ethic Committee of Chinese center for Disease Control and Prevention

RESULTS

Profile

Nanchang City is located in the north of central Jiangxi Province, situated downstream of the Ganjiang and Fuhe Rivers and adjacent to Poyang Lake, which is the largest freshwater lake in China. With the highest elevation of 841.4 meters, the city is characterized to have mild and humid climate. As it is located in the subtropical monsoon zone, the city has abundant rainfall with four distinct seasons. Rice is the main crop consumed by local residents.

IDD is one of the main endemic diseases in the target region. According to a survey in 1982, the concentration of iodine in the drinking water was lower than 10 μg/L, and the goiter rate in school children was above 5%. Subsequently, since iodized salt was supplied to households in this region from 1995, the coverage rate of adequately iodized salt has significantly increased from 81% to 95%, was and has been maintained at this level. By 1999, Nanchang City had achieved its goal of completely eliminating IDD. Testing results of drinking water samples collected from the area confirmed that the iodine content of all the water samples was lower than 10 μg/L, which is appropriate for the criteria for iodine deficiency.

Follow-up study

Initially, a total of 1,099 participants from 399 urban and rural households were enrolled in this study. Ultimately, 1,050 people from 384 households were qualified for the study. The rates of missing follow-up data in urban and rural groups were 3.9% and 5.0%, respectively; and no significant difference was observed between them. Missing follow-up data mainly originated from migrant workers due to certain reasons. Independent variables were analyzed using the chi-square method. No significant differences were found among different groups. The relevant data are shown in Table 1.

Salt iodine and urinary iodine before intervention

Salt iodine

The levels of edible salt iodine from 384 households were assessed. Overall, 95% of households were consuming edible iodized salt at an average content of 36.4±5.4 mg/kg, and salt iodine was less than 20 mg/kg in two households and more than 50 mg/kg in three households. ANOVA revealed no significant difference in the salt iodine contents among four groups.

Urinary iodine

Urinary iodine contents before the intervention are listed in Table 2. Minimum content of median urinary iodine in four groups was 231 μg/L, detected in the children from urban group C, while the maximum value was 582 μg/L, obtained in the adults from rural group A. Significant difference was found in median urinary iodine among four groups by using with Kruskal-Wallis test (p <0.01). Furthermore, multiple comparisons found that there was a significant difference between the rural and the urban groups, whereas intra-group comparisons showed that there were no significant differences in terms of the re-

Table 1. General characteristics of study subjects

Groups		Number of families	Gender			School children	Women of reproductive age	Male adults
			Male	Female	Total			
Urban	A	50 (48)	62 (58)	75 (72)	137 (130)	51 (48)	26 (24)	60 (58)
	B	50 (48)	60 (56)	85 (85)	145 (141)	53 (51)	28 (28)	64 (62)
	C	49 (49)	55 (54)	74 (72)	129 (126)	42 (41)	23 (23)	64 (62)
	D	50 (48)	56 (53)	76 (72)	132 (125)	45 (43)	26 (25)	61 (57)
Rural	A	50 (48)	67 (63)	65 (62)	132 (125)	81 (75)	22 (21)	29 (29)
	B	50 (48)	76 (73)	69 (66)	145 (139)	92 (88)	16 (16)	37 (35)
	C	50 (47)	72 (66)	70 (67)	142 (133)	86 (81)	20 (19)	36 (33)
	D	50 (48)	64 (61)	73 (70)	137 (131)	94 (89)	21 (20)	22 (22)
Total		399 (384)	512 (484)	587 (566)	1099 (1050)	544 (516)	182 (176)	373 (358)

†Numbers in parentheses represents data excluding cases lacking follow-up data.
‡Group A received 6±2 mg/kg iodine, group B, 15±2 mg/kg, group C, 24±2 mg/kg, and group D, 34±2 mg/kg).

Table 2. Medians of urinary iodine pre- and post-intervention (μg/L)

Groups		School children		Women of reproductive age		Male adults		Total	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Urban	A	354	107	242	96.2	278	102	279	97.2
	B	293	174	332	170	318	210	304	199
	C	231	252	341	225	299	249	276	249
	D	280	336	251	329	295	336	291	331
Rural	A	456	105	428	92.8	582	92.7	493	101
	B	519	194	503	193	556	192	519	193
	C	511	245	561	244	537	248	531	246
	D	472	302	499	335	568	346	498	308

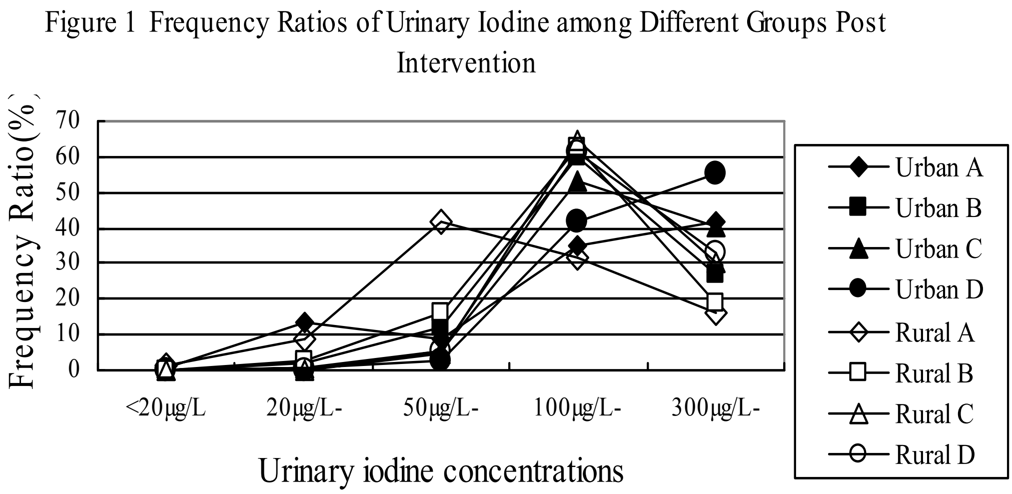

Figure 1. Frequency ratios of urinary iodine among different groups post intervention.

sults for children, women of reproductive aged and male adults. No significant differences in urinary iodine levels were observed among four groups prior to the intervention.

Urinary iodine after intervention

Comparisons of urinary iodine collected at different time points

Kruskal-Wallis test revealed that there were no significant differences in the median values of urinary iodine contents from different groups on different days after the intervention. Thus, the iodine content tested on any of the five consecutive days represents the subjects' state post-intervention. Consequently, we chose the data from the 28^{th} day of the intervention for further analysis.

Comparisons of urinary iodine in different populations

The minimum content of median urinary iodine on the 28^{th} day among all four groups was 92.7 μg/L, in rural group A, and the maximum was 346 μg/L, in rural group D. There were significant differences among four groups (p <0.01). Further comparisons revealed that there were significant differences in the groups that consumed different contents of iodized salt (p <0.01). However, there was no significant difference in the data for children, women of reproductive age or other adults who consumed same contents of iodized salt. There was also no significant difference between the rural and urban groups that consumed same contents of iodized salt. The relevant results were shown in Table 2.

Frequency distribution of urinary iodine

Figure 1 shows the frequency distributions of urinary iodine in the groups that consumed different contents of iodized salt. No matter where the participants come from, the proportion of the population with urinary iodine content <100 μg/L decreased as the iodized salt content increased, whereas the proportion with urinary iodine content >300 μg/L displayed an increasing trend. In groups B and C, the distribution was concentrated primarily within the range of 100-300 μg/L, and lower frequencies were found at the >300 μg/L and <100 μg/L levels. The frequency distribution basically satisfies the standards for population iodine nutrition.

DISCUSSION

Iodine nutrition status of the local population

Iodine is an essential trace element for the human body but its intake should be modest and appropriate. In iodine-deficient regions, the iodine content of drinking water is usually insufficient. As an effective intervention strategy, salt iodization has been proven to be a simple and effective route for iodine supplementation. The USI denotes that all edible salt including cooking salt and salt added to manufactured food should be iodized. In rural areas and suburbs, iodine intake of residents mainly come from cooking salt for a few manufactured food items in their daily menu. The salt iodization content needs to be adjusted according to the urinary iodine level of the population. In 2001, the WHO proposed an epidemiological principle for assessing population iodine nutrition: the median, population-level urinary iodine should be in the range of 100-300 μg/L and the urinary iodine content of the majority should be distributed within the range of 100-300 μg/L.

In our study, the median urinary iodine of women of reproductive age and male adults in urban ranged from 242 μg/L to 341 μg/L before the intervention, and from 231 μg/L to 354 μg/L for children. The median urinary iodine from women of reproductive age and male adults in rural areas ranged from 428 μg/L to 582 μg/L, and from 472 μg/L to 519 μg/L for children. The results showed that the urinary iodine levels of urban and rural populations were close to or much higher than the upper limit of the recommended range. Residents of rural areas may be especially prone to higher salt consumption resulting from eating habit that included more coarse and pickled foods.

Appropriate content of salt iodization

In this study, four different contents of iodized salt were used for field intervention trials. Based on the results obtained for the median urinary iodine concentrations and the frequency distribution of urinary iodine, the appropriate content range for edible salt iodization is 15-25 mg/kg. The adjustment of salt iodine content from the current 35 ±15 mg/kg mg/kg to 15-25 mg/kg will be more economical. Iodine concentration in salt will be reduced approximately by 15 mg per kilogram salt on average. As around 8.8 million tons of edible iodized salt are consumed each year nationwide, 13.2 tons of iodine (equals to 22.4 tons of KIO_3), equivalent to USD 560,000 (approximately USD 25,000 per ton KIO_3) would be saved each year; moreover, the adjustment of salt iodine content will effectively prevent the undesirable side effects caused by excessive iodine consumption.

The experience provided by other countries has shown that a content of 15-25 mg/kg of salt iodine is appropriate. In addition, China enjoys a vast territory and abundant resources, spanning frigid, temperate and tropical zones with mountains, hills, plains and coastal terrain. Consequently, it is necessary to consider factors such as geography, climate and living habits when implementing the USI program.

CONCLUSION

The trial exhibits a tendency of slight excessive iodine intake among the study households under the current USI standards, and proposes that a content of 15-25 mg/kg of salt iodine is appropriate for salt iodization. Our study addresses an important public health issue that has emerged since the adoption of universal salt iodization in China, and raises the urgent need for adjustments of the current level of universal iodization, and will provide important reference data for future policy making in controlling iodine deficiency and excess.

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AUTHOR DISCLOSURES

The authors declare that they have no competing interests.

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中国消除碘缺乏病现行食用盐加碘量是否适宜？

目的：本文采用现场干预实验设计，研究食用不同浓度碘盐的志愿者的尿碘水平，评价目前的食盐加碘量是否适宜，以及如何调整加碘量以达到既控制碘缺乏病又避免碘过量。方法：399 户城市和农村志愿者家庭，共 1,099 人参加了该现场实验。现场实验前检测食盐含碘量及参加者的尿碘含量。将参加家户随机分成四个组，分别提供含碘量为 6±2 mg/kg、15±2 mg/kg、24±2 mg/kg 及 34±2 mg/kg 的碘盐。干预后第 27 天开始，连续 5 天采集所有参加者尿样，检测尿碘含量。结果：干预前，城市组和农村组居民尿碘中位数分别为 294 µg/L 與 509 µg/L；干预后，各組参加者的尿碘均显著下降。干预后第 28 天，城市 4 个组的尿碘中位数分别为 97.2 µg/L、199 µg/L、249 µg/L 與 331 µg/L；农村 4 组的尿碘中位数分别为 101 µg/L、193 µg/L、246 µg/L 與 308 µg/L。结论：本研究显示按照目前的食盐加碘量，居民碘摄入量呈轻度偏高趋势。

关键词：碘缺乏病、普遍食用盐碘化、碘盐、尿碘、现场试验