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A study on the influencing factors of urinary iodine concentration and the relationship between iodised salt concentration and urinary iodine concentration

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Abstract

The aim of the present study was to explore the influencing factors of urinary iodine concentration (UIC) and the relationship between iodised salt concentration and UIC in order to give suggestions for the surveillance of iodine nutrition status. For this purpose, a multi-stage cluster sampling technique was employed in the present cross-sectional study. Correlations between UIC and salt iodine concentration were evaluated by Spearmen's correlation analysis. Risk factors of having a lower UIC were identified by logistic regression analysis, and the equations of UIC and salt iodine concentration were fitted by curve regression analysis. The median UIC was found to be 162·0 (25th–75th percentile 98·2–248·6) μg/l. The UIC was correlated with salt iodine concentration (Spearman's $\rho = 0{\cdot}144$, $P<0{\cdot}05$). The multiple logistic regression analysis found the following influencing factors for having a lower UIC: age (OR 0·98, 95 % CI 0·98, 0·98, $P<0{\cdot}05$); sex (OR 0·81, 95 % CI 0·71, 0·92, $P<0{\cdot}05$); education level (OR 0·87, 95 % CI 0·83, 0·90, $P<0{\cdot}05$); status of occupation (OR 0·91, 95 % CI 0·86, 0·96, $P<0{\cdot}05$); occupation (OR 1·03, 95 % CI 1·00, 1·05, $P<0{\cdot}05$); pickled food (OR 1·24, 95 % CI 1·08, 1·42, $P<0{\cdot}05$); salt iodine concentration (OR 1·03, 95 % CI 1·02, 1·03, $P<0{\cdot}05$). The curve regression analysis found that UIC (y) and salt iodine concentration (x) could be expressed by the following equation: $y = 1{\cdot}5772x^{1{\cdot}4845}$. In conclusion, the median UIC of individuals in Zhejiang Province falls within optimal status as recommended by the WHO/UNICEF/International Council for Control of IDD. To maintain optimal iodine nutrition status, salt iodine concentration should be in the range of 16·4 to 34·3 mg/kg.

Key words: Urinary iodine concentration: Salt iodisation concentration: Influencing factors

Iodine is an essential trace element required for the normal functioning of thyroid hormones, including thyroxine and triiodothyronine. Clinical and subclinical manifestations of iodine deficiency are termed iodine-deficiency disorders (IDD). Iodine deficiencies were prevalent in China until the introduction of universal salt iodisation (USI) in 1995. In the early 1980s, surveys identified 831 000 individuals with IDD manifesting as goitre, and an additional 134 with typical cretinism in Zhejiang Province. 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[1–3]. A provincial survey conducted in 2000 found the virtual elimination of IDD, but the prevention and control of iodine deficiency is a continuous process because the concentration of iodine in the nature cannot change. It requires monitoring to be sustainable.

The iodine status of a population is defined by calculating urinary iodine concentrations (UIC) from spot urine samples collected in a representative sample and comparing the median UIC against reference ranges[4]. The daily urinary excretion of iodine closely reflects the iodine intake of populations, so the UIC of a group is considered to be a valid biomarker of the iodine nutrition status of that population[5,6].

Since excess iodine intake also could have adverse health effects, in recent years, a different standpoint on whether it is scientific and necessary to keep launching the USI programme throughout China has been adopted[3,7–11]. The uniform iodised salt criterion might not work across China because of its vast territory with different natural environmental status. Each province should adjust the iodine level in salt according to their actual situation. Therefore, it is extremely important to calculate the reasonable range of salt iodine concentration. The aim of the present study was to explore the influencing factors of UIC, and suggest the reasonable range of salt iodine concentration in order to give suggestions for the surveillance of iodine nutrition status.

Abbreviations: CDC, Center for Disease Control and Prevention; IDD, iodine-deficiency disorders; UIC, urinary iodine concentration; USI, universal salt iodisation.

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Subjects and methods

Subjects

In the present cross-sectional study, a multi-stage cluster sampling technique was employed. A total of eleven cities come under the direct jurisdiction of the Zhejiang provincial government. First, a rural-area sampling unit (county-level cities) and an urban-area sampling unit (counties) were selected from each city, respectively. Then, three investigation sites were selected from each sampling unit according to their location in the county-level cities or counties. Only one community was selected randomly from each sampled investigation site. So, a total of thirty-three rural communities and thirty-three urban communities were selected where the investigation was conducted. From each sampled community, 100 households were selected by the random sampling method according to the household registration information. Then, all members of the sampled household were interviewed and their urine samples were collected. Since the iodine requirement for pregnant women and breast-feeding women is more than that of the general population, and their urinary iodine standard is different from that of the general population, pregnant women and breast-feeding women were excluded from the present study.

Methods

A questionnaire was designed to obtain general personal information about the participant's sex, age, residence and dietary habits. The questionnaire was administered face to face by trained staff through a door-to-door interview. Participants were asked to provide a salt sample from their kitchen for the determination of salt iodine concentration and urine samples for the determination of UIC. Research protocols were approved by Zhejiang Provincial Center for Disease Control and Prevention (CDC). All subjects gave written informed consent after the research protocols were carefully explained to them.

Measures

Spot urine samples and salt samples were collected and delivered to local CDC laboratory for measuring UIC. UIC was determined by the modified acid-digestion method[12]. Salt iodine concentration was determined by the direct titration method.

Statistical analysis

As continuous variables were not normally distributed, they were described as medians and 25th–75th percentiles. Spearmen's correlation analysis was used to evaluate the correlations between UIC and salt iodine concentration. To explore the risk factors of having a lower UIC, the population was divided into two groups (group 1: UIC $<100\,\mu$g/l; group 2: UIC $\geq 100\,\mu$g/l). The differences in qualitative data between the two groups were evaluated by the χ^2 test. Risk factors of having a lower UIC were identified by logistic regression analysis, and the equations of UIC and salt iodine concentration were fitted by curve regression analysis. Data processing and statistical analyses were performed using SAS 9.2 software (SAS Institute). All tests were two-sided, and the level of significance was set at $P<0{\cdot}05$.

Results

Urinary iodine concentrations of individuals living in Zhejiang Province

A total of 26 773 participants took part in the provincial survey conducted in 2011; of these participants, 23 361 provided the samples, with the response rate being 87·2 %. The median UIC of the participants was found to be 162·0 (25th–75th percentile 98·2–248·6) μg/l. Their median salt iodine concentration was found to be 29·4 (25th–75th percentile 25·8–32·9) μg/l. UIC was found to have a significant association with salt iodine concentration (Spearman's $\rho = 0{\cdot}144$, $P=0{\cdot}000$).

Comparison of characteristics according to urinary iodine concentration level

A total of 16 590 adults participated in the interview. The population was divided into two groups (group 1: UIC $<100\,\mu$g/l; group 2: UIC $\geq 100\,\mu$g/l). The differences between the two groups are presented in Table 1. Age, sex, education level, status of occupation, occupation, marine products, pickled food, dining out, smoking, thyroid disease, height and salt iodine concentration were found to be significant using the single-factor analysis ($P<0{\cdot}05$).

Multiple logistic regression analysis

The regression model was found to be significant ($\chi^2 = 302{\cdot}281$, $P=0{\cdot}000$). Age (OR 0·98, 95 % CI 0·98, 0·98), sex (OR 0·81, 95 % CI 0·71, 0·92), education level (OR 0·87, 95 % CI 0·83, 0·90), status of occupation (OR 0·91, 95 % CI 0·86, 0·96), occupation (OR 1·03, 95 % CI 1·00, 1·05), pickled food (OR 1·24, 95 % CI 1·08, 1·42) and salt iodine concentration (OR 1·03, 95 % CI 1·02, 1·03) were found to be the influencing factors for having $<100\,\mu$g/l of UIC using the multiple linear regression analysis ($P<0{\cdot}05$) (Table 2).

Curve regression analysis

The curve regression analysis found that UIC (y) and salt iodine concentration (x) could be expressed by the equation $y = 1{\cdot}5772x^{1{\cdot}4845}$ (Fig. 1). From this equation, UIC could be estimated according to salt iodine concentration. In the 2011 survey, the salt concentration was estimated to be 28.1 mg/kg, so the predicted value of UIC was 223 μg/l (actual UIC: 237 μg/l[13]), and in the 2013 survey, the salt concentration was estimated to be 24.1 mg/kg, so the predicted value of UIC was 178 μg/l (actual UIC: 178 μg/l[14]).

Application of the equation

According to the guidelines for the assessment of IDD and monitoring of their elimination, the median UIC are used to assess iodine nutrition status, such as iodine deficiency (UIC <100 μg/l; low), adequate iodine nutrition (100 ≤ UIC < 200 μg/l; normal), above the required iodine nutrition (200 ≤ UIC < 300 μg/l; sufficient) and excess iodine (UIC ≥300 μg/l; excess)[4]. Therefore, the equation of UIC (y) and salt iodine concentration (x) was used to explore the reasonable range of salt iodine concentration. Salt iodine concentration was calculated to be in the range of 16·4 to 34·3 mg/kg for the range of 100 to 300 μg UIC/l.

Table 1. Distribution of the characteristics of individuals living in Zhejiang Province, stratified by urinary iodine concentration (UIC) level

(Mean values and standard deviations; number of residents and percentages; medians and interquartile ranges)

	UIC < 100 μg/l (*n* 4445)		UIC ≥ 100 μg/l (*n* 12 145)		
	n	%	*n*	%	*P*
Age (years)					0·000
Mean	47·8		43·7		
SD	18·8		19·4		
Sex					0·000
Male	1732	23·9	5529	76·1	
Female	2713	29·1	6616	70·9	
Education					0·004
Illiterate	776	28·3	1968	71·7	
Primary school	1547	26·8	4228	73·2	
Junior middle school	1321	25·7	3819	74·3	
Senior middle school	421	25·7	1216	74·3	
Technical secondary school	86	26·4	240	73·6	
Junior college	150	27·4	397	72·6	
College	144	34·2	277	65·8	
Status of occupation					0·000
Employed	2268	23·6	7323	76·4	
Retired	542	39·6	827	60·4	
Student	273	23·6	885	76·4	
Unemployed	1362	30·5	3110	69·5	
Occupation					0·000
Manager	270	31·7	582	68·3	
Scientific researcher	79	38·7	125	61·3	
Clerk	251	28·7	623	71·3	
Businessman	273	24·0	863	76·0	
Worker	448	27·5	1179	72·5	
Farmer	366	23·1	1221	76·9	
Agricultural labourers	688	22·0	2444	78·0	
Others	2070	28·8	5108	71·2	
Eat marine products					0·000
Less than once a week	2831	23·8	9065	76·2	
More than two times a week	1614	34·4	3080	65·6	
Pickled food					0·000
No	3832	27·9	9923	72·1	
Yes	613	21·6	2222	78·4	
Dining out					0·000
Equal or less than 2	3659	27·4	9714	72·6	
3–6 times a week	559	26·1	1585	73·9	
More than 6 times a week	227	21·2	846	78·8	
Smoking					0·000
Yes	721	21·6	2622	78·4	
Quit	135	26·4	377	73·6	
No	3589	26·4	10014	73·6	
Thyroid disease					0·015
No	4369	26·7	11994	73·3	
Yes	76	33·5	151	66·5	
Height (cm)					0·025
Mean	159·4		158·5		
SD	19·4		19·9		
Weight (kg)					0·066
Mean	57·8		57·3		
SD	12·7		13·7		
BMI (kg/cm^2)					0·549
Mean	22·7		22·9		
SD	3·9		22·8		
Salt iodine concentration (mg/kg)					0·000
Median	28·3		29·6		
Interquartile range	17·9		6·8		

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Table 2. Risk factors of having urinary iodine concentration <100 μg/d in Zhejiang Province in 2011

(Odds ratios and 95 % confidence intervals)

	OR	95 % CI	Wald	*P*
Sex	0·81	0·71, 0·92	10·44	0·001
Age	0·98	0·98, 0·98	99·98	0·000
Education level	0·87	0·83, 0·90	43·81	0·000
Status of occupation	0·91	0·86, 0·96	11·71	0·001
Occupation	1·03	1·00, 1·05	3·99	0·046
Pickled food	1·24	1·08, 1·42	9·72	0·002
Salt iodine concentration	1·03	1·02, 1·03	109·47	0·000

Discussion

UIC is a good marker of the recent dietary intake of iodine. In the present study, the median UIC of the population living in Zhejiang Province was found to be 162·0 μg/l, indicating optimal iodine intake. Since October 2000, the salt iodisation level was set at 35 mg/kg, and the survey was conducted in 2011, the findings of which suggested that iodine nutrition status was in the normal level according to the guidelines of the WHO/UNICEF/International Council for Control of IDD[4] under the USI period, with the salt iodisation level being set at 35 mg/kg. Meanwhile, since the 75th percentile of UIC was found to be 248·6 μg/l, the iodisation level set could be suggested to be adjusted down. In fact, after the survey, since 2013, China has adopted a new iodised salt standard of 25 or 30 mg/kg according to the actual situation in each province (autonomous region, municipality)[15].

In China, iodised salt is the main vehicle for iodine supplementation. Salt contributed 63·5 % of food iodine[11]. A study in Shanghai has reported that iodised salt contributed 63·5 % of the total dietary iodine, while aquatic products contributed 5·03 %, with 14·9 % by the laver and kelp, which were markedly lower than the contribution of iodised salt. Iodised salt intake is the main factor that influence iodine intake[16]. Our previous study conducted in part of the cities of Zhejiang Province has shown that the proportions of iodine intake through water, salt and other foods (other foods refer to all the foods containing iodine in addition to water and salt) were 1·70, 76·41 and 21·89 %, respectively[17]. Consistent with previous studies in China, the present study showed that salt iodine concentration was 29·4 mg/kg, which was within the range of China's current iodised salt standard, and UIC was closely correlated with salt iodine concentration. The present results indicate that iodised salt is the main dietary source of iodine among the population living in Zhejiang Province. Consequently, it provides support that the USI programme is necessary for the individuals residing in Zhejiang Province.

Since the introduction of iodised salt, we have been monitoring the iodine nutrition status based on UIC only in children aged 8–10 years, and this survey of the entire population provides baseline data for further studies in the general population. From the present study, it appears that individuals who ate marine products more than two times per week (Table 1) were more likely to have a UIC of <100 μg/l. Although marine products might be expected to contain significant iodine levels and increase UIC, the population who ate marine products were those living in the island areas with a low coverage rate of iodised salt. Moreover, the multiple logistic regression analysis found age, sex, education level, status of occupation, occupation, pickled food and salt iodine concentration to be the influencing factors for having a lower UIC. Individuals with a different age, education level and occupation may have different attitudes and behaviours towards using iodised salt. Some individuals have the point of view that they have more access and opportunity to consume seafood with sufficient iodine levels as part of their daily diet, especially those living in the islands, because of which they prefer to use non-iodised salt. In addition, individuals living in rural areas may be especially prone to higher salt consumption resulting from eating habit that included more coarse and pickled foods[18]. Therefore, iodised salt may be the most important factor influencing the UIC.

Since UIC could be adjusted by salt iodine concentration, an equation was fitted by curve regression analysis, which found that UIC (y) and salt iodine concentration (x) could be expressed by the equation $y = 1{\cdot}5772x^{1{\cdot}4845}$. With this equation, the suggested range of salt iodine concentration could be estimated for optimal UIC. Based on this equation, salt iodine concentration was calculated to be in the range of 16·4 to 34·3 mg/kg for the range of 100–300 μg UIC/l. This equation was used to estimate UIC when the information obtained was limited and the surveillance frequency increased, and can be used as a reference for future studies. Due to the high variation in the UIC of an individual, the WHO recommends the use of the median UIC of a given population to assess the iodine status of that population. In fact, community data are obtained from individual data. In the present study, the equation was set up using individual data rather than community data in order to ensure the validity and authenticity of the data, and to improve the efficiency of the statistics; otherwise, using the median of community data may reduce the differences between the individuals. In addition, the aforementioned curve regression equation was the actual situation of the correlation between iodised salt intake and UIC for individuals living in Zhejiang Province. The USI programme was launched in 1995 in China. Our previous study conducted in part of the cities of Zhejiang

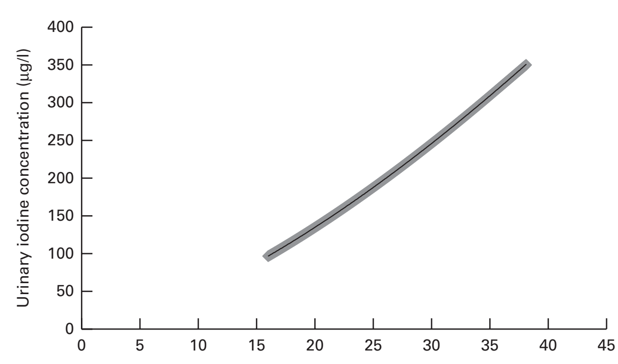

Fig. 1. Curve regression of urinary iodine concentration (y) and salt iodine concentration (x) ($y = 1{\cdot}5772x^{1{\cdot}4845}$).

Province has shown that table salt was the major source of iodine intake of individuals living in Zhejiang Province[17]. The percentage of households using adequately iodised salt will affect the median UIC. In 2011, the coverage rate of iodised salt was 95·06 %[13], suggesting that the USI policy achieved significant results. For the individuals living in this area, the equation was useful for estimating the suggested range of salt iodine concentration for optimal UIC. For individuals, there may be special circumstances, for example greater consumption of marine products that have high levels of iodine, but this situation was based on the individual level rather than on the population level.

The present study has several limitations. UIC are highly variable and represent the recent dietary intake of iodine rather than the usual intake. Due to this variation, a sample of 100 spot urine test samples is needed to produce the estimates of UIC with a precision range of ± 10 %, and a sample of 500 is needed for a precision range of ± 5 %[19].

In conclusion, in the present cross-sectional survey, the median UIC of individuals living in Zhejiang Province falls within the range of optimal iodine status as recommended by the WHO/UNICEF/International Council for Control of IDD. Age, sex, education level, status of occupation, occupation, pickled food and salt iodine concentration were found to be the influencing factors for having a lower UIC. The suggested salt iodine concentration was 16·4 to 34·3 mg/kg. The present study provides important information and reference for the monitoring of iodine nutrition status during the annual surveillance.

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The authors' contributions are as follows G. D., X. L. and Y. Z. were responsible for the study design; Y. Z. was involved in the data collection and analysis, and writing and revision of the manuscript; Z. M. took part in the field investigation and data collection; W. Z. was in charge of laboratory detection; J. Z. and G. M. took part in the field investigation.

None of the authors has any conflicts of interest to declare.

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