Dietary Iodine Intake in the Chinese Population

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Abstract

Objective To evaluate dietary iodine intake and its potential risks among the Chinese population.

Methods Individual dietary iodine intake was calculated using food consumption data multiplying by iodine concentration in foods, table salt and drinking water, followed by summing, and then compared with the corresponding age-specific reference values, including Upper Intake Level (UL) and Recommended Nutrient Intake (RNI).

Results In areas with water iodine concentration (WI) lower than 150 µg/L, 80.8% of residents had iodine intake between the RNI and UL, 5.8% higher than UL, and the remaining (13.4%) lower than RNI if iodized salt was consumed. However, in the uniodized salt consumption scenario, only 1.0% of residents between RNI and UL, 1.4% higher than UL, and a large part of residents (97.6%) lower than RNI. In areas with WI higher than 150 µg/L, all residents had iodine intake between RNI and UL if iodized salt was consumed, except 10.5% and 24.9% of residents higher than UL in areas with WI at 150‐300 µg/L and higher than 300 µg/L respectively. However, in the uniodized salt consumption scenario, only 1.5% and 1.7% of residents had higher iodine intake than UL respectively.

Conclusion The findings suggested that in general, the dietary iodine intake by the Chinese population was appropriate and safe at the present stage. People in areas with WI lower than 150 µg/L were more likely to have iodine deficiency. While people in areas with WI higher than 150 µg/L were more likely to have excessive iodine intake if iodized salt was consumed.

Key words: Iodine; Exposure assessment; Drinking water Iodine; Dietary Iodine Intake

INTRODUCTION

Iodine is a trace element in human body as an essential nutrient for the synthesis of thyroid hormones[1]. When iodine requirements are not met, thyroid hormone synthesis is impaired, resulting in hypothyroidism and a series of functional and developmental abnormalities termed as “iodine deficiency disorders (IDD)”[2]. On the other hand, excessive iodine intake may also have negative impacts to thyroid[3‐5]. Therefore, there is a need to assess population-wide iodine intake from time to time, in order to ensure the proper implementation of the universal salt iodization (USI) program aiming at controlling IDD in China.

China is one of the countries with the most severe iodine deficiency problems. Salt iodization is a worldwide recognized method for the prevention and control of IDD and was found to substantially increase the average iodine intake and consequently improve iodine status to populations[6]. Researches showed that, after the introduction of iodized salt, goiter prevalence rate among children and adolescents worldwide living in goiter-endemic areas decreased by 40%-95%[7]. Since the USI program was triggered in China for the prevention and control of IDD in 1995, the surveillance on iodine status among the population has been implemented, which has...
provided evidence for strategies in adjusting the iodine content in salt. At present, iodine is added to salt at 20-50 mg/kg in the form of potassium iodate [8].

WI is an important factor affecting iodine intake. In China, WI varies significantly in different geographical areas and higher WI areas are often embedded in lower WI areas. Based on WI and regulation of the Chinese Ministry of Health, the national regions were classified into Iodine-deficient Area (<10 μg/L), Iodine-adequate Area (10-150 μg/L) and Iodine-excessive Area (>150 μg/L) [9-10]. According to the results from five large-scale national IDD surveillances conducted in 1995-2005, the amount of iodine added to salt in the China USI program had been adjusted based on the WI in order to avoid excessive iodine status in higher WI areas. However, in recent years, there has been increasing concern on the possibility of excessive iodine intake and the potential health risks due to the national salt iodization strategy, especially among the people living in some coastal areas who believed that they had higher iodine intake from seafood. The aim of the present study was to assess the dietary iodine intake among the population in different areas stratified by WI (<150, 150-300, or ≥300 μg/L) under the condition of iodized salt or uniodized salt consumption. The consequential health risk and contributions of foods, drinking water and iodized salt to total iodine intake were also investigated.

METHODS

Calculation of Dietary Iodine Intake

Dietary iodine intake was calculated in a deterministic way by multiplying the consumed amount of a dietary source by the iodine level in that source. The main dietary sources of iodine are food, drinking water, and iodized salt. In this study, food includes kelp, laver, sea fish, and other foods (such as grain, vegetables, fruit, aquatic food) and iodine intake was calculated among 63323 residents in various parts of China.

Data Sources

Food, including salt, consumption data was mainly from the National Nutrition and Health Survey in 2002 and the drinking water consumption was uniformly assumed as the dietary reference intakes in the Chinese population [11]. Iodine concentrations from different food items, drinking water and table salt were derived from the China Food Composition Table [12] (2002 Edition), China IDD surveillance water iodine data (2002) and surveillance data of water iodine in areas with high iodine level [13] as well as China IDD surveillance salt iodine data [14](2005), respectively.

Stratified Model and Subgroups of Population

The country was divided into three strata according to WI, i.e. <150, 150-300 and ≥300 μg/L, and salt consumption was divided into two scenarios: iodized salt consumption and uniodized salt consumption. The population was divided into 13 sub-groups (i.e. under 4, 4-6, 7-10, 11-13, 14-17, over 18 years by sex and the pregnant and lactating women). The dietary iodine intake for each subgroup was calculated. In addition, the contributions of all sources of iodine to the total iodine intake in different WI areas were also calculated.

Criteria Used for the Assessment of Iodine Intake

There were several criteria established by international organizations and governments around the world to assess the dietary iodine intake, i.e. Estimated Average Requirement (EAR), Recommended Nutrient Intake (RNI), Tolerable Daily Intake (TDI) or Tolerable Upper Intake Level (UL), etc. The Chinese Nutrition Society has developed RNIs and ULs for iodine in different age-specific populations and pregnant and lactating women (Table 1). To analyze the iodine intake status, the total intake in different subpopulations was compared with EAR, RNI and UL and the proportions of population with iodine intake of <EAR, EAR-RNI, RNI-UL, or ≥UL were calculated.

Table 1. Reference Intakes for Iodine (μg/d) [15]

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>EAR</th>
<th>RNI</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4</td>
<td>-</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>4-</td>
<td>-</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>7-</td>
<td>-</td>
<td>90</td>
<td>800</td>
</tr>
<tr>
<td>11-</td>
<td>-</td>
<td>120</td>
<td>800</td>
</tr>
<tr>
<td>14-</td>
<td>-</td>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>18-</td>
<td>120</td>
<td>150</td>
<td>1000</td>
</tr>
<tr>
<td>Pregnant and Lactating Women</td>
<td>120</td>
<td>200</td>
<td>1000</td>
</tr>
</tbody>
</table>


RESULTS

In Areas with WI < 150 μg/L

Dietary iodine intakes among populations in areas with WI <150 μg/L are shown in Table 2. Under
the iodized salt consumption scenario, the average iodine intakes of all age/sex-specific groups were higher than RNI. Among the whole population, 80.8% of individuals had iodine intake between RNI and UL, 5.8% higher than UL, and 13.4% lower than RNI. Besides, 9.4% adults aged 18 or above (including pregnant and lactating women) had iodine intake below EAR.

**Table 2. Mean Dietary Iodine Intakes for Populations in Areas with Water Iodine Concentration <150 µg/L**

<table>
<thead>
<tr>
<th>Age Groups (Years)</th>
<th>Sex</th>
<th>N</th>
<th>Mean Iodine intake (µg/d)</th>
<th>Distribution (%)</th>
<th>Mean Iodine intake (µg/d)</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;RNI</td>
<td>RNI-UL</td>
<td>&gt;UL</td>
</tr>
<tr>
<td>2-</td>
<td>Male</td>
<td>669</td>
<td>212.3</td>
<td>11.4</td>
<td>88.6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>519</td>
<td>321.7</td>
<td>7.5</td>
<td>92.5</td>
<td>-</td>
</tr>
<tr>
<td>4-</td>
<td>Male</td>
<td>1276</td>
<td>334.4</td>
<td>13.5</td>
<td>86.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1109</td>
<td>368.7</td>
<td>12.8</td>
<td>87.2</td>
<td>-</td>
</tr>
<tr>
<td>7-</td>
<td>Male</td>
<td>2144</td>
<td>404.9</td>
<td>9.8</td>
<td>85.3</td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1883</td>
<td>390.6</td>
<td>9.9</td>
<td>85.9</td>
<td>4.2</td>
</tr>
<tr>
<td>11-</td>
<td>Male</td>
<td>1870</td>
<td>453.5</td>
<td>10.4</td>
<td>82.7</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1662</td>
<td>436.2</td>
<td>13.6</td>
<td>80.7</td>
<td>5.7</td>
</tr>
<tr>
<td>14-</td>
<td>Male</td>
<td>1508</td>
<td>525.4</td>
<td>13.9</td>
<td>76.7</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1310</td>
<td>466.2</td>
<td>16.9</td>
<td>76.0</td>
<td>7.0</td>
</tr>
<tr>
<td>18-</td>
<td>Male</td>
<td>22860</td>
<td>588.0</td>
<td>8.1</td>
<td>3.5</td>
<td>81.4</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>25663</td>
<td>520.5</td>
<td>10.7</td>
<td>5.1</td>
<td>78.9</td>
</tr>
<tr>
<td>Pregnant women and Lactating women</td>
<td></td>
<td>850</td>
<td>704.7</td>
<td>6.9</td>
<td>8.4</td>
<td>78.4</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>13.4</td>
<td>80.8</td>
<td>5.8</td>
</tr>
</tbody>
</table>

It was found that, under the uniodized salt consumption scenario, the proportion of the individuals with iodine intakes between RNI and UL was only 1.0% (1.4% >UL and 97.6% <RNI). Besides, the iodine intakes in 97.4% of adults with 18+ years of age (including pregnant and lactating women) were below EAR.

**In Areas with WI 150-300 µg/L**

Table 3 showed dietary iodine intakes among populations from areas with WI between 150 and 300 µg/L. Under the iodized salt consumption scenario, the mean dietary iodine intakes in all age/sex-specific groups from these areas were higher than those from areas with WI<150 µg/L. Among the whole population, 89.5% of individuals had iodine intake between RNI and UL and the remaining (10.5%) higher than UL.

It can also be found that, under the uniodized salt consumption scenario, the mean dietary iodine intakes in all age/sex-specific groups from these areas were higher than those from areas with WI<150 µg/L. Among the whole population, 89.5% of individuals had iodine intake between RNI and UL and the remaining (10.5%) higher than UL.

**Table 3. Mean Dietary Iodine Intakes for Populations in Areas with Water Iodine Concentration between 150 and 300 µg/L**

<table>
<thead>
<tr>
<th>Age Groups (Years)</th>
<th>Sex</th>
<th>N</th>
<th>Mean Iodine intake (µg/d)</th>
<th>Distribution (%)</th>
<th>Mean Iodine intake (µg/d)</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RNI-UL</td>
<td>&gt;UL</td>
<td></td>
</tr>
<tr>
<td>2-</td>
<td>Male</td>
<td>669</td>
<td>373.3</td>
<td>100.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>519</td>
<td>482.7</td>
<td>100.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4-</td>
<td>Male</td>
<td>1276</td>
<td>514.3</td>
<td>100.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1109</td>
<td>548.6</td>
<td>100.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7-</td>
<td>Male</td>
<td>2144</td>
<td>604.8</td>
<td>91.4</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1883</td>
<td>590.5</td>
<td>91.5</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>11-</td>
<td>Male</td>
<td>1870</td>
<td>693.4</td>
<td>85.2</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1662</td>
<td>676.1</td>
<td>87.1</td>
<td>12.9</td>
<td></td>
</tr>
<tr>
<td>14-</td>
<td>Male</td>
<td>1508</td>
<td>765.2</td>
<td>79.6</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1310</td>
<td>706.1</td>
<td>83.7</td>
<td>16.3</td>
<td></td>
</tr>
</tbody>
</table>

Under the iodized salt consumption scenario, the mean dietary iodine intakes among males older than 7 years and females older than 11 years (including pregnant and lactating women) were above UL and the mean iodine intakes for other age groups stayed between RNI and UL. Among all the population, 75.1% of individuals had iodine intake between RNI and UL, with the remaining 24.9% higher than UL.

It was also found that, under the uniodized salt consumption scenario, the mean dietary iodine intakes among all age/sex-specific groups were above RNI. The proportion of the individuals with iodine intakes between RNI and UL was 98.5% (the remaining 1.5% ≥ UL).

### Contributions to Total Dietary Iodine Intake from Various Food Items

The contributions of various food items, table salt and drinking water to the total dietary iodine intakes in areas with varied WI concentrations are presented in Figure 1. When iodized salt was consumed, regardless of cooking loss, 84.2% of iodine intake by people in areas with WI concentration <150 μg/L was attributed to iodized salt. The contribution of drinking water raised with the increase of WI, which was about 45.4% and 60.4% in areas of WI in the range of 150-300 μg/L and higher than 300 μg/L, respectively.
iodine intake

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China
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iodine
These water iodine
districts) across 9 provinces (regions and municipalities)
735 villages and towns of 109 counties (cities,
areas in China, with diagnosed IDD cases in 27
720
survey conducted in the 1990s, there were around
are water iodine

When uniodized table salt was consumed, regardless of cooking loss, 78.7% of iodine intake by
people in areas with WI<150 μg/L was attributed to
food. However, in areas with WI higher than 150
μg/L, drinking water was the main source of iodine
intake. The contribution of drinking water raised
with the increase of WI, which was about 89.8% and
93.9% in areas of WI in the range of 150-300 μg/L
and higher than 300 μg/L, respectively.

DISCUSSIONS

Albeit in various degrees, most areas in China
are water iodine-deficient areas. According to a
survey conducted in the 1990s, there were around
720 million people living in water iodine-deficient
areas in China, with diagnosed IDD cases in 27 128
villages of 1 807 counties. On the other hand, there
were more than 30 millions of people living in water
iodine-excess areas based on the data available from
a survey conducted in 2005, mainly distributed in the
735 villages and towns of 109 counties (cities,
districts) across 9 provinces (regions and municipalities).
These water iodine-excessive areas are focally distributed
but often embedded in water iodine-deficient or water
iodine-adequate areas.

The goal of eliminating endemic iodine-deficiency
disease has been achieved since USI policy was
widely implemented in many nations including
China[16]. On the other hand, there were reports on
the adverse effects caused by high amounts of
iodine intake[17]. Exposure to excessive iodine
occurred via food[18], drinking water[19],
medication[20], and iodized salt or iodinated oil[21].
Thus, it is important to monitor the iodine intake
among various population groups in order to assess
both the positive and negative effects of the national
USI program.

The present study was mainly focused on the
iodine intake using national surveillance data and
food composition data as well as IDD surveillance
data and it was found that in general, the iodine
intake in the Chinese population was at an
appropriate and safe level in areas with WI lower
than 150 μg/L. At the individual level, the proportion
of individuals with iodine intake <RNI was higher
than that >UL, indicating that the health risks
associated with iodine deficiency outweighed those
with iodine excess. This was especially true when
uniodized table salt was consumed. Therefore, the
results strongly support that the USI Program should
be implemented on a continuous basis to further
lower the risk of iodine deficiency in population in
areas with WI lower than 150 μg/L.

In areas with WI between 150 and 300 μg/L, if
uniodized salt was used, the iodine intake in the
local people would be maintained at an appropriate
and safe level; moreover, 10.5% of the local people
would have excessive iodine intake should they use
iodized salt. In areas where WI was higher than 300
μg/L, if residents consumed iodized table salt, the
mean iodine intakes among males older than 7 years
and females older than 11 years (including pregnant
and lactating women) were above UL and 24.9% of
individuals had iodine intake higher than UL which
indicated a high risk of excessive iodine intake. On
the other hand, had they consumed uniodized table salt, their relative risk of iodine deficiency was quite
low. These results support the current strategy that
USI is not applied to areas with high WI in China. But
in a few areas where WI is extremely high, even if
iodized salt is not used, it is possible that a
significant proportion of population may have
excessive intakes of iodine. It is recommended that
related research should be carried out to assess the
long term health impact of excessive intake of iodine
from drinking water.

The iodine rich food, such as kelp and laver, was
consumed both in low frequency and quantity and
contributed only to a very low percentage
(1.6%-3.0%) of the dietary iodine intakes regardless
of whether the population takes iodized or uniodized
salt in areas of varied iodine concentration in water,
suggesting that iodine rich food had little effect on
the total iodine intake.
Iodine status of the population can be measured by assessing dietary intake or by measuring iodine excretion in the urine. Urinary iodine level in 24-h samples is now widely accepted as one of the best and most cost-effective way to monitor iodine deficiency at community level\(^22\). According to nationwide survey, the median urinary iodine (MUI) level in the Chinese population was 246.3 µg/L in 2005 after the added iodine in salt was reduced from 20-60 mg/kg to 20-50 mg/kg in 2000. Although it exceeded the appropriate level of MUI, the risk of causing adverse health effects was considered low\(^23\).

In iodine deficiency areas in China in 2009, MUI of children between 8-10 years of age was 192.3 µg/L indicating that the iodine nutritional status of the population in the above areas was appropriate and safe in general. But the percentage of individuals with MUI below 100 µg/L was 21.4%, suggesting that dietary iodine intake were more likely inadequate among these children\(^24\). In high water iodine areas in 2005, however, the MUI value exceeded 300 µg/L and the proportion of individuals with urinary iodine \(\geq 300 \, \mu g/L\) reached 74%. It is expected that high MUI will be controlled after the supply of uniodized salt to these high WI areas. In general, the MUI data is in consistent with our findings in dietary iodine intake that the iodine nutritional status in the general Chinese population is at an appropriate and safe level. However, due to the distinct regional disparity in the distribution of iodine concentration in water across the country, there are still population groups with iodine intake below the adequate level as well as population groups with excessive iodine intake.

It should be noted that loss of iodine during cooking is not under consideration in the assessment. On average, iodine loss from salt have been reported up to 20% during cooking\(^25\). Also, it would be more appropriate if real consumption data of drinking water was used, instead of the assumed recommended drinking water consumption data.

Overall, the iodine nutritional status in the Chinese population is at an appropriate and safe level. Guidance for different localities should be specialized in order to lower the risk of iodine deficiency in population of low WI areas and, at the same time, to avoid the risk of iodine excess for those people living in high WI areas.

ACKNOWLEDGEMENTS

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