Dietary iodine intake and urinary iodine concentration during pregnancy in Chengdu, China

doi: 10.6133/apjcn.202111/PP.0006
Published online: November 2021

Running title: Iodine nutritional status in pregnancy

Li Huang MD[1], Li Zhang Phd[2], Zhiyong Rao MM[3], Chengyu Huang Phd[4], Hui Huang Phd[1]

[1]Department of Endocrinology and Metabolism, West China Hospital, Sichuan University, Chengdu, China
[2]Departments of Obstetrics and Gynecology, West China Women's and Children's Hospital of Sichuan University, Chengdu, China
[3]Department of clinical nutrition, West China Hospital, Sichuan University, Chengdu, China
[4]Department of Nutrition and Food Hygiene, West China School of Public Health, Sichuan University, Chengdu, China

Authors' email addresses and contributions:
Hui Huang contributed to the application, design of the study and supervised the data analysis as well as manuscript; Li Huang carried it out from February 2018 to November 2019, analysed the data and writted the article; Li Zhang contributed to encourage pregnant women to participate in this study; Zhiyong Rao contributed to the 7-day dietary record scale and dietary questionnaire survey; Chengyu Huang contributed to the scheme for the salt survey in diet.

Corresponding Author: Dr Hui Huang, Department of Endocrinology and Metabolism, West China Hospital, Sichuan University, 37 Guo Xue Road, Chengdu 610041, Sichuan, China. Tel:. Email: sansan1880@126.com

ABSTRACT

Background and Objectives: An adequate iodine status during pregnancy is very important for maternal and infant health. The aim of this study was to characterize the iodine nutritional status of healthy pregnant women in Chengdu by measuring urinary iodine (UI) and analyzing dietary iodine intake. **Methods and Study Design:** Pregnant women who underwent regular antenatal examinations were invited to participate in this study. Each woman underwent UI determination and urinary creatinine (Cr) measurement and recorded the details of her diet and salt intake at the beginning and end of one week. **Results:** In total, 139 healthy pregnant women underwent UI determination in this study; among them, 116 participants completed the diet survey. The median urine iodine/creatinine (UI/Cr) of the 139 patients was 215.92 μg/g, and the median dietary iodine level of 104 patients who completed the 7-day dietary record was 230.58 μg/d. The dietary iodine sources of the pregnant women were mainly seafood (11%), iodized salt (51%), iodized multivitamins (17%) and daily food (21%). **Conclusions:** We concluded that healthy pregnant women in Chengdu had sufficient iodine nutrition. The 7-day dietary record is a nice way to evaluate dietary iodine nutritional status, and there is a strong correlation between dietary iodine intake and UI concentration.

Key Words: pregnancy, iodine nutritional status, dietary iodine intake, 7-day dietary record, urine iodine/creatinine ratio

INTRODUCTION

Iodine, an essential element in thyroid hormone synthesis, is key to healthy fetal and childhood brain development. The critical period for brain development starts in pregnancy and continues to 2 years after birth, with the first 3-5 months of the embryonic period being especially important.[1] After 12 weeks of pregnancy, the fetal thyroid gland begins to develop and secrete thyroid hormones independently, but the fetal thyroid gland matures only after 24 weeks of gestation.[2] However, the placental transport supply of maternal thyroid hormone does not decrease until the end of pregnancy.[3]

In 2013, the World Health Organization (WHO) rated China as an iodine-suitable country. The latest survey of the International Council for the Control of Iodine Deficiency Disorder (ICCIDD) in 2018 showed that the median urinary iodine (MUI) concentration of school-age children in China was 198 μg/L and that the MUI of Chinese pregnant women was 155 μg/L.[4] However, the iodine nutritional status of pregnant women varies greatly among different regions of China. Iodine deficiency in pregnancy can increase the risk of preterm delivery, abortion, stillbirth, congenital malformation and perinatal mortality, as well as pregnancy complications such as gestational hypertension and placental abruption.[3] Conversely, excessive iodine intake during pregnancy can inhibit the synthesis and secretion of thyroid hormones, a phenomenon known as the acute Wolff-Chaikoff effect. In the mother, excessive iodine intake can lead to subclinical hypothyroidism, clinical hypothyroidism or clinical hyperthyroidism, depending on the individual's amount of iodine intake, susceptibility and thyroid functional status prior to pregnancy. In the fetus, excessive iodine can cause congenital hypothyroidism.[5]

UI is the most commonly used index to evaluate iodine nutritional status. The methods for determination of UI can be divided into three types: (1) urinary iodine excretion (UIE): it is considered the gold standard, but it is difficult to collect 24-hour urine samples,[6] (2) urinary iodine excretion (UIC): it is very convenient when collecting a large number of samples; however, the results vary greatly due to diet, drinking, weather and urine volume, so the MUI is generally used to assess the iodine nutritional status of a whole population,[6] (3) UI/Cr: studies have shown that gestational blood flow increases by 40% from 26-36 weeks of gestation[7] and that the glomerular filtration rate (GFR) increases during pregnancy,[8] resulting in UI dilution; UI/Cr corrects the change in the UIC caused by urine volume differences and UI dilution.[6-9] In the case of an adequate iodine supply, the iodine excreted by the human body is almost equal to the total iodine intake, and UI can directly reflect dietary iodine intake. More than 80% of the iodine consumed by humans comes from food, 10% comes from drinking water, and 0-5% comes from the air. The daily iodine intake of individuals varies greatly, making dietary iodine intake difficult to measure accurately. There is no reliable method for evaluating dietary iodine intake currently. The purpose of the present study was to understand the iodine nutritional status of healthy pregnant women in Chengdu through the determination of UI. In addition, we hypothesized that the food-based diet can be a nice way to estimate dietary iodine intake.

MATERIALS AND METHODS

Study population and data collection

To ensure reliability and validity, the study included healthy pregnant women aged 20-39 years who had lived in Chengdu for 5 years and who had normal thyroid function and good compliance at West China Women's and Children's Hospital of Sichuan University from February 2018 to November 2019. The inclusion criteria of the subjects were as follows: (1) natural conception and singleton pregnancy; (2) normal thyroid function during pregnancy, with no thyroid nodules or enlargement; (3) history of good health; and (4) compliance, defined as being serious about completing the study. The exclusion criteria of the subjects were as follows: (1) hyperemesis gravidarum, abnormal routine urinalysis, or irregular vaginal bleeding or (2) abnormal kidney function or any other conditions that may affect the functional examination.

We consecutively recruited 139 healthy pregnant women, including 72 in the second trimester and 67 in the third trimester. The first stage was missed because the maternity examinations started in the 13th week of pregnancy. All of the participants signed informed consent forms, and the Ethics Committee on Biomedical Research, West China Hospital of Sichuan University approved the study.

Urine iodine determination

UIE or UIC were obtained from each pregnant woman, and urinary Cr was simultaneously measured to obtain the UI/Cr. Urinary samples were collected when the pregnant woman completed a 7-day dietary record. UI was determined by inductively coupled plasma mass spectrometry (ICP-MS), and urinary Cr was determined by the enzyme method.

Assessment of dietary iodine intake

The sources of dietary iodine intake for pregnant women include iodine in food, iodine in water, iodized salt and iodized vitamins.

Iodine in food

The key point of the 24-hour dietary diary record was to accurately obtain the weight of iodine-containing foods in the diet. Participants were required to finish a 7-day dietary record, and only foods containing iodine were included in the dietary scale. All edible foods with iodine contents greater than 0.1 μg/100 g were selected from the Chinese food composition table (see Table 1).

All pregnant women had received special rigorous training by researchers through color food model pictures (accurately weighing the base weight of the food) or standard food models to accurately estimate the portion size for detailed recording. All subjects could contact the researcher at any time via WeChat and mobile phone.

Iodine in water

The iodine in water was ignored, as a survey in 2019 showed that our research area was in a low water-iodine province, with a median iodine level in water of 2.1 μg/L, but our study was designed in 2017 and implemented in 2018.

Iodized salt

24-Hour urinary sodium determination is the gold standard for salt quantification. Studies have shown that urinary sodium excretion accounts for 95% of salt intake,[10] however, this method is tedious and cannot rule out the influence of other factors on urinary sodium. The purpose of this study was to determine iodine intake from dietary iodized salt, and we mainly referred to the one-week salt estimation method[10] to evaluate salt intake, simultaneously used the standard person/day in the 2002 National Nutrition and Health Survey of residents (see supplementary material). The researchers gave each pregnant woman an accurate household kitchen electronic scale (accurate to 0.1 g) and asked her to weigh and record the household cooking salt strictly for one week and enter the salt brand and survey date. The standard for salt iodization is 20-30 mg/kg, and the standard for iodized salt in Chengdu and Chongqing is usually 21 mg/kg.

Iodized vitamins

The types of vitamins, units and usage are shown in Table 2.

Criteria for assessing iodine nutritional status

Epidemiological criteria for UI

MUI was proposed as a widely used criterion for evaluating the overall iodine nutritional status of pregnant women by the WHO/ICCIDD/UNICEF in 2007.[11] The classification was as follows: deficient, MUI <150 μg/L; adequate, 150 ≤ MUI <249 μg/L; more than adequate, 250 ≤ MUI <499 μg/L and excessive, MUI ≥500 μg/L. The UI/Cr is considered to be the most suitable index for the evaluation of pregnant women. UI/Cr was dichotomized to less than 150 μg/g or greater than or equal to 150 μg/g on the basis of the WHO criteria for iodine deficiency or sufficiency in pregnancy.[12] This study took the UI/Cr as the main research indicator with cut-offs in which 150 μg/g ≤UI/Cr<250 μg/g indicated adequate, 250 μg/g ≤UI/Cr <500 μg/g indicated more than adequate, and UI/Cr ≥500 μg/g indicated excessive.

Criteria for evaluating dietary iodine intake

The dietary iodine intake indicators include (i) the estimated average requirement (EAR) is minimum daily average dietary intake that meets the needs of 50% of the individuals in the group; (ii) the recommended nutrient intake (RNI) is the average daily nutrient intake estimated to meet the needs of 97-98% of individuals in the population; and (iii) the tolerable upper intake level (UL), which is the tolerable daily intake of certain nutrients without harm to the individual's health. Dietary iodine intake above the UL or below the RNI may be harmful to the health of the mother and child. The dietary iodine RNI for pregnant women recommended by the European Thyroid Association (ETA)/American Thyroid Association (ATA)/The Endocrine Society (TES) is 250 μg/d. Additionally, the Chinese Nutrition Society recommends an EAR for pregnant women in China of 160 μg/d, a RNI of 230 μg/d, and a UL of 600 μg/d. The ATA and ETA believe that it is safer to keep the UL at 500 μg/d.

Statistical analysis

Data analysis was performed by means of SPSS 21. The data were tested for normality using the Kolmogorov-Smirnov test or Shapiro-Wilk test. The relationship between different iodine nutrition statuses and the intake of various iodine-containing foods was analyzed. A multiple linear regression model was established to analyze the factors influencing dietary iodine intake. The Spearman rank correlation test was used for comparison of correlations involving various iodine indexes. It is generally understood that r values >0.8 indicate a very strong correlation, r values between 0.6 and 0.8 indicate a strong correlation, r values between 0.4 and 0.59 indicate a moderate correlation, and r values <0.4 indicate a weak correlation.

RESULTS

Basic characteristics of the pregnant women

A total of 139 healthy pregnant women, including 72 in the second trimester and 67 in the third trimester, participated in the determination of UI and urinary Cr in this study. (A flowchart is provided in Figure 1). Among the participants, 62 completed the UIE, and 77 completed the UIC. In the diet survey, 116 of the 139 participants completed the dietary iodine record, 110 participants ate iodized salt and completed one week of salt intake measurements, 6 individuals ate noniodized salt, and 31 participants took iodized multivitamins during pregnancy.

Evaluation of iodine nutritional status by urinary iodine concentration

The median UI/Cr of the 139 healthy pregnant women was 215.92 μg/g. The UIE, UIC, and UI/Cr did not follow a normal distribution. The UIC measured by the three methods was the highest when the gestational week was less than 20 (the first half of pregnancy) and decreased with increasing gestational month. (Figure 2).

Characteristics and composition ratio of dietary iodine intake

The normal distribution of dietary iodine intake changed under the influence of extreme values. Dietary iodine intake ≥250 μg/d is generally considered sufficient; we took the average dietary iodine intake over seven days as the main research index. The median dietary iodine index of 104 pregnant women with complete 7-day records was 230.58 μg/d.

The dietary iodine sources of the pregnant women included mainly seafood (11%), iodized salt (51%), iodized multivitamins (17%), and daily food 21% (Figure 3).

We found that the iodine content of daily food fluctuated within 36.55~65.09 μg/d; seafood was rich in iodine, but it was not consumed every day; thus, the overall intake amount was low. Iodine deficiency would occur when the intake of iodized salt was less than 4 g/d; the iodine demand during pregnancy could be met if the intake of iodized salt was 6 g/d with appropriate seafood consumption levels. Iodine excess would occur if the intake of iodized salt was greater than 6 g/d and the pregnant woman consumed too many iodized vitamins and too much seafood at the same time. Participants exhibited four types of iodine intake patterns (Table 3): 26 participants consumed iodized salt and iodized vitamins, 84 participants consumed iodized salt and noniodized vitamins, 5 participants consumed noniodized salt and iodized vitamins, and 1 participant consumed noniodized salt and noniodized vitamins.

All pregnant women in the four abovementioned groups generally had an adequate or excessive iodine status. The multiple linear regression model of dietary iodine intake showed that kelp, shrimp, dried porphyra, iodized salt, and iodized multivitamins accounted for 91.4% of all factors, and the effect of each of the five factors on dietary iodine fluctuation could be ordered as follows: multivitamins > salt > dried porphyra > shrimp > kelp.

Spearman correlation analysis between urine iodine concentration and dietary iodine intake

The Spearman rank correlation coefficient between dietary iodine intake and the UI/Cr ratio fluctuated within 0.676~0.720 (p<0.001). Additionally, the Spearman rank correlation coefficient between dietary iodine intake and the UIE was within 0.526~0.564 (p<0.001), and that between dietary iodine intake and the UIC varied from 0.387 to 0.407 (p=0.002).

DISCUSSION

Urinary iodine analysis

UI/Cr was regarded as the main UI index in this study. The results showed that the UIE, UIC and UI/Cr were not affected by extreme values and did not always follow a normal distribution. UI/Cr of 139 healthy pregnant women was 215.92 μg/g, which indicated a suitable iodine status overall. A study in 2016 showed that in iodine-sufficient areas in China, the changes in the UIC and UI/Cr were different among pregnant women but the same among women of childbearing age.[13] A study of 981 school-age children in 2015 showed that UI/Cr from 24-h urine samples differed from UI/Cr obtained from morning spot urine samples, and even values for the same index varied greatly among different months of the year,[14] however, there have been no similar reports involving pregnant women. The Spearman rank correlation between the UIE and UI/Cr was strongest (r=0.731, p<0.001), and the correlation between the UIC and UI/Cr was moderate (r=0.534, p<0.001), which indicated that UI/Cr was the closest reliable indicator of the iodine nutritional status to the UIE because the urine volume variation and GFR during pregnancy were corrected. A study in 2020 that included 9164 early pregnant women in Shenyang, Dalian and Dandong found that UI/Cr of pregnant women decreased with increasing body mass index (BMI). When the BMI of the pregnant woman was >27.5 kg/m², the evaluation of iodine nutritional status in pregnancy by UI/Cr was unstable; therefore, UIE might be a more accurate index for evaluating iodine nutrition.[15]

The Sandell-Kolthoff spectrophotometric method is generally recommended as the standard for UI determination. The NHANES has widely used ICP-MS to determine UI since 2000. ICP-MS was added to the industry standard for the determination of UI in 2016 and was considered to be more accurate and advanced than the S-K method; the limit of detection for UI by ICP-MS is 1 μg/L.[16] A study reported that the determination difference between ICP-MS and the S-K method was 3.7 μg/L; when UIC was less than 250 μg/L, the value by the S-K method was 2.7-15.8 μg/L higher than that by ICP-MS.[16] In 2018, a study showed that the lower limit of detection of the ICP-MS method was 0.87 μg/L and that the correlation between ICP-MS and the S-K method was excellent (r=0.984).[17]

Exploration of dietary iodine intake

There are hundreds of iodine-containing foods in the diet, and dietary iodine intake varies greatly from day to day; therefore, it is difficult to obtain and measure dietary iodine intake accurately. There have been very few reports on dietary iodine intake in the past. Precise dietary iodine intake quantification depends on the type, consumption amount and frequency of iodine-containing food.[18] Considering that the 24-hour dietary recall method would be affected by recall bias in terms of the outcome, weighing the iodine-containing food would seriously affect the normal eating habits of pregnant women in the group; therefore, it is reasonable to estimate the weight of food consumed by standard food model pictures and to record the diet for 7 days. Our results supported the hypothesis that dietary records indeed accurately reflect dietary iodine intake. In fact, only a few dietary surveys can last more than 3-4 days, after which the participants will likely stop because of the tediousness of the task.[19] In a study in Denmark in 2001 that included 254 pregnant women, 115 participants completed a 4-day dietary record by means of food models, and 119 participants completed a food frequency questionnaire and UIE determination. The results revealed a moderate correlation between dietary records and the food frequency questionnaire (r=0.52), and the dietary frequency questionnaire overestimated dietary iodine intake.[20]

The WHO and Endocrine guidelines recommend a RNI for iodine intake of 250 μg/d in pregnancy.[18] Therefore, we generally considered dietary iodine intake of at least 250 μg/d to be a sufficient standard. Our study found that to achieve 250 μg/d of dietary iodine intake, we should appropriately increase the intake of seafood and daily food without changing the added salt amount of 6 g/d and that 75 μg/d of iodine from iodized supplements may be enough. Blindly increasing salt intake would increase the risk of hypertension.

Our study comprehensively assessed the effects of four dietary combination patterns of iodized salt and iodized vitamin intake on dietary iodine and found that taking iodized salt and noniodized vitamins was the best dietary model for Chinese pregnant women, with consumption of noniodized salt and noniodized vitamins being an unreasonable dietary model. In other words, pregnancy multivitamins such as Elevit in Australia, Elevit in Germany, Blackmores in Australia, and Pregnacare Max or Plus in Britain were not suitable for this group of pregnant women who ate iodized salt in Chengdu.

The dietary iodine sources of the pregnant women in this research were mainly seafood (11%), iodized salt (51%), iodized multivitamins (17%) and daily food (21%). In Bohai and Huang Huai Seas, as well as low-lying inland areas in Shanxi Province, high concentrations of iodine were detected in the drinking water.[21] A survey in 2019 showed that our research area was in a low water-iodine province (median iodine concentration in water: 2.1 μg/L),[22] but our study was designed in 2017 and implemented in 2018; thus, iodine in the water was ignored. A study in 2016 assessed dietary iodine intake among 31,352 people in the NHANES from 2003-2010 and concluded that the sources of dietary iodine intake included water, food, iodine supplements and iodized salt. Cooking salt accounted for approximately 80% of the total iodine intake for pregnant women, and the other three sources of iodine accounted for approximately 20% of the total iodine intake.[23] A multiple linear regression model showed that kelp, shrimp, porphyra, iodized vitamins and iodized salt accounted for 91.4% of all iodine sources; furthermore, multivitamins had the greatest influence on the fluctuation of dietary iodine intake rather than iodized salt. This strange phenomenon occurred because 116 participants in this study completed a diet survey, and 110 of them consumed iodized salt; additionally, 31 pregnant women consumed iodized vitamins, of whom 26 consumed iodized salt; therefore, vitamins had the greatest impact on dietary iodine intake based on the baseline universal consumption of iodized salt. In 2017, there was a report that the source of iodine in a typical Polish diet was mainly dairy products, fish, wine and iodized salt. In their diet, deep-sea fish are richest in iodine, followed by foods such as cheese and milk.[24] Their salt iodization strategy is different from that of China: there is usually 114.6 μg of iodine per 5 g of salt, while the standard for iodized table salt in Chengdu is usually 2100 μg/100 g. In some countries where residents consume noniodized salt, such as the United Kingdom and Norway, iodine in dairy products is the main source of dietary iodine intake; marine fish and seafood are naturally high in iodine, but they contribute little to the total dietary iodine intake unless eaten every day.[25]

Correlation analysis

Overall, the Spearman rank correlation between the UIE and UI/Cr was strongest (r = 0.731, $p<0.001$), demonstrating that the UI/Cr was the closest reliable indicator of iodine nutritional status to the traditional gold standard. In general, the correlation between dietary iodine intake and UI was lower than that between UIE and UI/Cr. Furthermore, the Spearman rank correlation between dietary iodine intake and UI/Cr was statistically strong, the Spearman rank correlation between dietary iodine intake and UIE fluctuation was moderate, and the Spearman rank correlation between dietary iodine intake and the UIC was relatively weak. Integral 7-day dietary records showed high clinical value for assessing iodine nutritional status, and the correlation between dietary iodine intake and UI was significantly higher than that with incomplete records. A study analyzing NHANES data from 2003 to 2010 found that the correlation r between dietary iodine intake and UI in pregnant women aged 14-50 years varied from 0.36 to 0.40.23

Conclusion

In this study, UI determination showed that healthy pregnant women in Chengdu were in a state of adequate iodine nutrition. UI/Cr might be a more suitable index to assess the iodine nutrition status of pregnant women than UIE. The UI concentration measured was highest when the gestational week was less than 20 (the first half of pregnancy), and it decreased with increasing gestational month.

The sources of dietary iodine intake for pregnant women included food, water, iodized salt and iodized vitamins. The 7-day dietary record proved to be a novel and useful way to assess dietary iodine intake; moreover, there was a strong correlation between dietary iodine intake and UI concentration.

ACKNOWLEDGEMENTS

We gratefully appreciate the contributions of physicians from the obstetrics clinics and thank the pregnant women from West China Women's and Children's Hospital of Sichuan University who participated in this study. We especially thank the West China School of Public Health.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors have no conflicts of interest. The study was funded by Projects of the Department of Endocrinology and Metabolism, supported by Chengdu Science and Technology Bureau, Research Funds Grant 2015-HM01-00448-SF.

REFERENCES

1. Association CN. Guidelines for iodine supplementation for Chinese residents 2018. (In Chinese)
2. Ming Q. Iodine nutrition of pregnant women and offspring brain development. International Reproductive Health/Family Planning. 2016;35:445-8 (In Chinese)
3. de Escobar GM, Obregon MJ, del Rey FE. Maternal thyroid hormones early in pregnancy and fetal brain development. Best Pract Res Clin Endocrinol Metab. 2004;18:225-48. doi: 10.1016/j.beem.2004.03.012
4. IGN Iodine Global Network 2018. Available from: http://www.ign.org/.
5. Burgi H. Iodine excess. Best Pract Res Clin Endocrinol Metab. 2010;24:107-15. doi: 10.1016/j.beem.2009.08.010

6. Vejbjerg P, Knudsen N, Perrild H, Laurberg P, Andersen S, Rasmussen LB et al. Estimation of iodine intake from various urinary iodine measurements in population studies. Thyroid. 2009;19:1281-6. doi: 10.1089/thy.2009.0094
7. Chesley LC. Plasma and red cell volumes during pregnancy. Am J Obstet Gynecol. 1972;112:440-50. doi: 10.1016/0002-9378(72)90493-0
8. Davison JM, Dunlop W. Renal hemodynamics and tubular function in normal human pregnancy. Kidney Int. 1980;18:152-61. doi: 10.1038/ki.1980.124
9. Vought R, London W, Lutwak L, Dublin TD. Reliability of estimates of serum inorganic iodine and daily fecal and urinary iodine excretion from single causal specimens. J Clin Endocrinol Metab. 1963; 23:1218-28. doi: 10.1210/jcem-23-12-1218
10. Zhang L, Zhao F, Zhang P, Gao J, Liu C, He FJ et al. A pilot study to validate a standardized one-week salt estimation method evaluating salt intake and its sources for family members in China. Nutrients. 2015;7:751-63. doi: 10.3390/nu7020751.
11. WHO Secretariat, Andersson M, de Benoist B, de Benoist B, Delange F, Zupan J. Prevention and control of iodine deficiency in pregnant and lactating women and in children less than 2-years-old: conclusions and recommendations of the Technical Consultation. Public Health Nutr. 2007;10:1606-11. doi: 10.1017/S1368980007361004
12. Bath SC, Steer CD, Golding J, Emmett P, Rayman MP. Effect of inadequate iodine status in UK pregnant women on cognitive outcomes in their children: results from the Avon Longitudinal Study of Parents and Children (ALSPAC). Lancet. 2013;382:331-7. doi: 10.1016/S0140-6736(13)60436-5
13. Li C, Peng S, Zhang X, Xie X, Wang D, Mao J. The urine iodine to creatinine as an optimal index of iodine during pregnancy in an iodine adequate area in China. J Clin Endocrinol Metab. 2016; 101:1290-8. doi: 10.1210/jc.2015-3519
14. Chen W, Wu Y, Lin L, Tan L, Shen J, Pearce EN et al. 24-hour urine samples are more reproducible than spot urine samples for evaluation of iodine status in school-age children. J Nutr. 2016;146:142-6. doi: 10.3945/jn.115.215806
15. Luo J, Li C, Zhang X, Shan Z, Teng W. Reference intervals of the ratio of urine iodine to creatinine in pregnant women in an iodine-replete area of China. Biol Trace Elem Res. 2020;199:62-9. doi: 10.1007/s12011-020-02133-8
16. Caldwell K, Maxwell C, Makhmudov A, Pino S, Braverman LE, Jones RL et al. Use of inductively coupled plasma mass spectrometry to measure urinary iodine in NHANES 2000: comparison with previous method. Clin Chem. 2003;49:1019-21. doi: 10.1373/49.6.1019
17. Yu S, Yin Y, Cheng Q, Han J, Cheng X, Guo Y et al. Validation of a simple inductively coupled plasma mass spectrometry method for detecting urine and serum iodine and evaluation of iodine status of pregnant women in Beijing. Scand J Clin Lab Invest. 2018;78:501-7. doi: 10.1080/00365513.2018.1512150
18. Zimmermann MB, Andersson M. Assessment of iodine nutrition in populations: past, present, and future. Nutr Rev. 2012;70:553-70. doi: 10.1111/j.1753-4887.2012.00528.x

19. Ren S. Food nutrition and hygiene. Second Edition. China Light Industry Publishing House, Beijing, China; 2019. pp. 179-181.
20. Rasmussen L, Ovesen L, Bülow I, Jørgensen T, Knudsen N, Laurberg P et al. Evaluation of a semi-quantitative food frequency questionnaire to estimate iodine intake. Eur J Clin Nutr. 2001;55:287-92. doi: 10.1038/sj.ejcn.1601156
21. Shen H, Liu S, Sun D, Zhang S, Su X, Shen Y et al. Geographical distribution of drinking-water with high iodine level and association between high iodine level in drinking-water and goitre: a Chinese national investigation. Br J Nutr. 2011;106: 243-7. doi: 10.1017/S0007114511000055
22. Lili Z, Jinshu L, Xuanbo S, Furong Wu, Hongbang J. Investigation of iodine contents in drinking water in Sichuan Province in 2017. J Prev Med Inf. 2019;35. (In Chinese)
23. Juan W, Trumbo P, Spungen J, Dwyer JT, Carriquiry AL, Zimmerman TP et al. Comparison of 2 methods for estimating the prevalences of inadequate and excessive iodine intakes. Am J Clin Nutr. 2016;104:888S-97S. doi: 10.3945/ajcn.115.110346
24. Glabska D, Malowaniec E, Guzek D. Validity and reproducibility of the iodine dietary intake questionnaire assessment conducted for young Polish women. Int J Environ Res Public Health. 2017; 14. doi: 10.3390/ijerph14070700
25. Sang Z, Wei W, Zhao, Zhang G, Chen W, Liu H et al. Thyroid dysfunction during late gestation is associated with excessive iodine intake in pregnant women. J Clin Endocrinol Metab. 2012;97: E1363-9. doi: 10.1210/jc.2011-3438.

Table 1. The content of iodine for food products

Food group and food	Serving size	Iodine µg/100 g
Staple food		
Pancake	150-250 g	7.9
Fresh meat buns	80 g	3.2
Rice		2.3
Dumplings	20-30 g	12
Tangyuan		3.5
Vegetables		
Chinese cabbage	20-30 g	10
Spinach		24
Potato, onion, parsley, eggplant		1.2
Green pepper	80-100 g	9.6
Tomato	200-250 g	2.5
Luffa, cucumber, squash		0.2
Algae		
Kelp (dry)		36240
Kelp		113.9
Porphyra (dry)		4323
Undaria pinnatifida		15878
Sea sedge		289.6
Fruits		
Orange, kumquat	200-300 g	5.3
Red grapes	10 g	2
Pineapple	200-250 g	4.1
Winter jujube	20-30 g	6.7
Persimmon	200-300 g	6.3
Durian	150 g	5.6
Pitaya		0.4
Meat		
Lean pork	50 g (half of the palm of a small hand)	1.7
Lean beef		10.4
Chicken		12.4
Squab		16.3
Roast squab		61.1
Crispy intestine	4 slices, approximately 50 g	49.6
Hot dog	60-120 g	38.8
Ham sausage		46.2
Sausage	5-10 g (slice)	91.6
Dried meat floss		37.7
Fish		
Grass carp	50 g (half of the palm of a small hand)	6.4
Carp		4.7
Herring		6.5
Hairtail		5.5
Yellow croaker		5.8
Grouper		6.5
Pomfret		7.7
Cuttlefish, squid, inkfish		13.9
Tuna		14
Mackerel		3.5
Shrimp and shellfish		
Shelled shrimps	5 slices, approximately 150 g	82.5
Dried small shrimps		364.5
Shrimp paste		166.5
Mussel	40 g	346
Eggs and dairy products		
Egg	60 g	27.2
Duck egg		5
Preserved egg		6.8
Quail egg, pigeon egg	5 slices, approximately 60 g	37.6
Soft-shelled turtle egg		18.5
Yogurt		0.9

Table 1. The content of iodine for food products (cont.)

Food group and food	Serving size	Iodine µg/100 g
Bean products		
Soybean	30 g (handful)	9.7
Kidney bean		4.7
Tofu pudding, tofu		7.7
Dried bean curd, sheets of bean curd	30-50 g	46.2
Nuts and snacks		
Walnut kernel	30 g (handful)	10.4
Peanut		2.7
Almond		8.4
Pine nut kernel		12.3
Hazelnut kernel		6.3
Pistachio		37.9
Instant noodles		8.4
Filled cookies	10 g (slice)	3.4
Condiments		
Soy sauce, vinegar		2.4
Chicken essence		26.7
Pepper powder		8.2

Table 2. Vitamins consumed during pregnancy

Vitamin	Iodine content/µg	Usage
Elevit in China	0	qd
Elevit in Australia	220	qd
Elevit in Germany	150	qd
Materna in China	150	qd
Materna in Italy	225	qd
Blackmores in Australia	75	bid
Pregnacare Max	75	bid
Pregnacare Plus	150	qd
Afalin · run Kang	50	qd

Table 3. Four dietary iodine intake patterns

Dietary iodine	Iodized salt + iodized vitamins	Iodized salt + noniodized vitamins	Noniodized salt + iodized vitamins	Noniodized salt + noniodized vitamins
n	26	84	5	1
Iodized salt (µg/d)	105ug	126	-	-
Iodized vitamins (µg/d)	150	-	150	-
Daily food/d (µg/d)	52.41	45.45	63.76	18.68
Seafood/week (µg)	42.91	83.92	185.62	403.65
Dietary iodine (µg/d)	326.68	217.95	296.21	76.34
UI/Cr (µg/g)	265.97	194.59	280.49	283.85

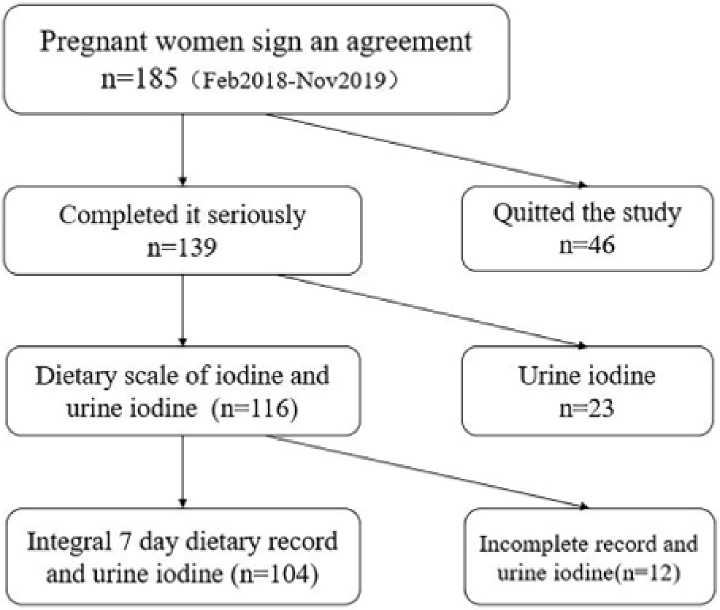

Figure 1. Flowchart of participants.

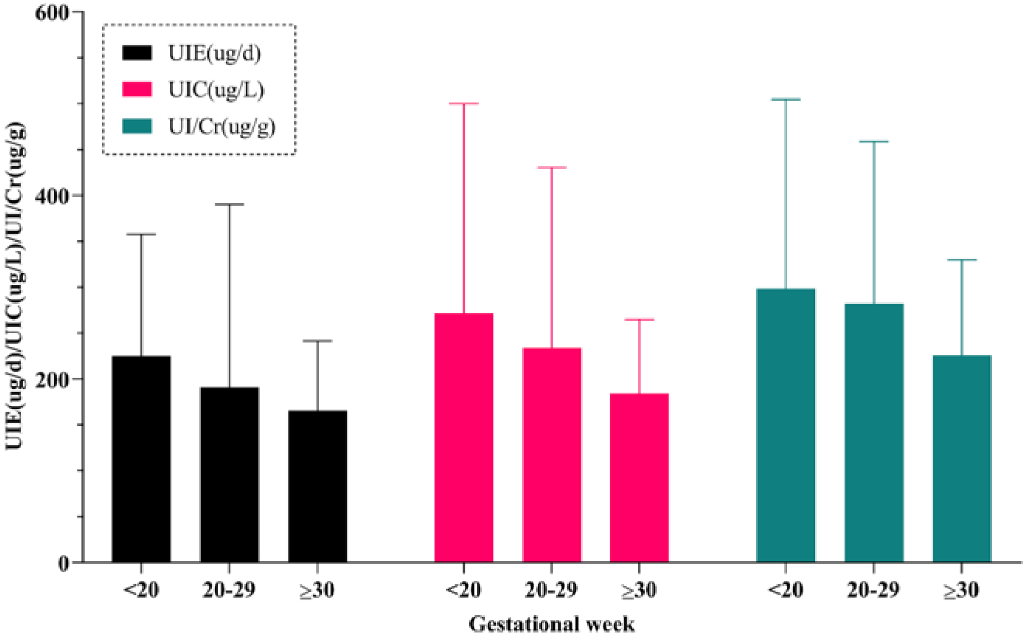

Figure 2. Urine iodine concentration changes with gestational week.

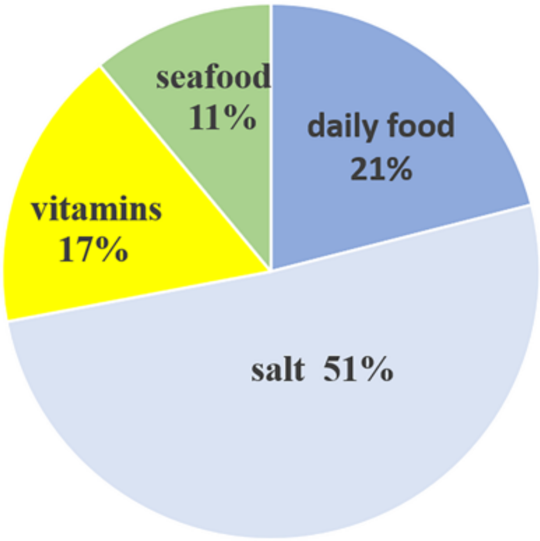

Figure 3. Source of dietary iodine intake.