A Dietary Iodine Questionnaire: Correlation with Urinary Iodine and Food Diaries

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Objective: It has been difficult to determine the sources of U.S. dietary iodine. This study was designed to validate a self-administered questionnaire about dietary iodine sources. Design: We constructed a questionnaire to assess iodine intake in 46 healthy Boston-area adult volunteers. Questionnaire information was correlated with subjects’ 24-hour food diaries. Spot morning urine cotinine (a metabolite of nicotine from cigarette smoking) and iodine concentrations were measured. Main outcomes: 91% of 46 subjects were women [mean (± SD) age of 38 (± 10) years]. Information from 24-hour food diaries correlated well with questionnaire data. The median urinary iodine concentration (UIC) was 140 \( \mu \text{g/L} \) (range: 18–845 \( \mu \text{g/L} \)). There were significant positive associations between intake of yogurt (\( n = 9, p = 0.01 \)) and saltwater fish (\( n = 6, p = 0.0003 \)), and an inverse correlation between bagels (\( n = 5, p = 0.0006 \)) and UIC. We found no associations between self-reported milk, iodized salt, tobacco use, or urinary cotinine and UIC. Conclusion: The questionnaire may not have been sufficiently comprehensive. Given the importance of adequate dietary iodine intake, particularly among women of childbearing age, further studies are warranted to determine important sources of dietary iodine in the United States.

Introduction

Adequate dietary iodine intake is essential for the production of the thyroid hormones, thyroxine (T4) and triiodothyronine (T3). Inadequate dietary iodine can lead to the development of goiter and hypothyroidism. Since the iodization of salt in the 1920s, U.S. dietary iodine has generally been sufficient; however, iodine intake in the United States has varied over the years due to alterations in the iodine content of foods and the consumption of iodized salt (1).

The third U.S. National Health and Nutrition Study (NHANES III, 1988–1994) demonstrated an approximate 50% reduction in median dietary iodine intake compared to NHANES I values from 1971 to 1974 (2), although the most recent NHANES study (2001–2002) suggests that U.S. iodine consumption has stabilized (3). While iodine nutrition in the United States is generally felt to be adequate, some population subgroups, particularly women of childbearing age, may be at risk for mild iodine deficiency. Among women of childbearing age (15–44 years), the median urinary iodine decreased from 294 \( \mu \text{g/L} \) (NHANES I) to 128 \( \mu \text{g/L} \) (NHANES III) (2). This is of concern because thyroid hormone, requiring adequate maternal iodine intake, is critical for neural development \textit{in utero} (4,5). Among pregnant women meeting the World Health Organization’s (WHO) recommended nutrient intake of 250 \( \mu \text{g} \) iodine daily (6), median urinary iodine values would be expected to exceed 150 \( \mu \text{g/L} \). In the United States, iodine deficiency has been eliminated by means of “silent prophylaxis.” Iodine supplementation of salt and other foods has never been mandated, and iodine content of most foods is not listed on package labels. Kidd et al. (7) obtained dietary frequency surveys and urinary iodine measurements from a sample of 754 schoolchildren between 1971 and 1972. Milk, iodized salt, and bread containing iodate conditioners were the primary sources of dietary iodine in their sample. Recently, we have reported that urinary iodine excretion in spot urine samples from 565 schoolchildren aged 6 to 12 years residing in a suburb of Boston, Massachusetts, was more than adequate with a median value of 285 \( \mu \text{g/L} \) (range: 25–1849 \( \mu \text{g/L} \)) (8). Reductions in U.S. dietary iodine since the 1970s have been variously ascribed to a possible reduction in the iodine content of dairy products, to the removal of iodate dough conditioners in commercially produced bread, to new recommendations for reduced salt intake for blood pressure control, and to the increasing use of noniodized salt in manufactured or “pre-made” convenience foods. National market-based samples performed for the U.S. Food and Drug Administration’s (FDA) Total Diet Study between 1982 and 1991 estimated that the average diet at the time contained iodine levels in excess of the current Recommended Dietary Allowance (RDA) (9,10). However, it has been over 15 years since the last market-basket analysis for U.S. iodine intake was performed (10), and it has been difficult to determine the primary sources of iodine in the current...
U.S. diet. We have recently reported that samples of Boston-area milk and some types of bread have high iodine content (11).

Cigarette smoke is converted to thiocyanates that act as potent inhibitors of iodine transport into the thyroid by competitively inhibiting the sodium/iodide symporter on the thyroid epithelial cell surface (12). The effects of cigarette smoking on dietary iodine intake and thyroid status remain unclear. A study from marginally iodine deficient areas in Denmark demonstrated an association between goiter prevalence and smoking habits (13). In another report, lactating women who smoked were noted to have decreased iodine concentrations in both their breast milk and in their infants' urine (14).

In the present study, we constructed a self-administered questionnaire to ascertain the types and quantities of iodine-containing foods and supplements in the diet and smoking behavior and to correlate the results of this questionnaire with a 24-hour food diary, and urinary iodine and urinary cotinine excretion. We intended to validate this questionnaire for use in future studies of iodine nutrition in the United States, particularly among women of childbearing age.

Materials and Methods

Subjects

During May 2004, 46 healthy, euthyroid, Boston-area adult volunteers without known recent exposure to high iodine loads were enrolled in the study. Each subject completed 24-hour food diaries, followed by an English-language questionnaire to assess dietary iodine intake. Informed consent was obtained from all study participants. All procedures followed were in accordance with the ethical methods of the local institutional review board. Fifty volunteers over the age of 18 who were able to read and write English were initially enrolled. After review of medical records, four participants were excluded from the analysis (one had a known thyroid nodule, two were previously diagnosed with hypothyroidism, and one had received an iodine load for a recent radiographic contrast study).

Questionnaire information

The questionnaire ascertained each participant’s age, sex, ethnicity, highest level of education, and place of birth (Appendix 1). Information was gathered regarding any personal or family medical history of thyroid disease, and participants’ use of iodine-containing substances, such as multivitamins, dietary supplements, thyroid hormone, intravenous contrast dye, amiodarone, antiseptic skin cleaner, and iodine-containing vaginal douches. If the participant used tobacco, the number of cigarettes smoked in the previous week was recorded. Opinions regarding iodine nutrition, including the factors influencing purchase of table salt, were also obtained.

We asked participants to record their previous 24-hour consumption of the following iodine-containing foods in a diary: table salt, seaweed, iodine-containing multivitamins, cow’s milk, cheese, yogurt, ice cream, frozen yogurt, soy sauce, eggs, nonhomemade bread, bagels, and various types of saltwater fish and shellfish. We used this 24-hour food diary to correlate subjects’ intake of iodine-containing foods with their reported intake on the dietary questionnaire and with urinary iodine levels. Iodine content of multivitamins or dietary supplements was recorded directly from the subjects’ bottles.

Collection of urine samples

Spot urine samples were collected from subjects at the time of completion of the dietary questionnaire (the morning after completion of the 24-hour food diaries). These were used for the measurement of iodine and cotinine.

Medical chart review

Medical charts were obtained from each subjects’ primary care provider. These charts were used to assess subjects’ personal or family history of thyroid disease.

Laboratory methods

Total urinary iodine concentrations (UICs) were measured spectrophotometrically by a modification of the method of Benotti et al. (15). Iodine concentrations were measured at least twice; in 95% of the samples, the initial two measurements were within 15% of each other and the two values were averaged. In the case where the initial two measurements were not within 15% of each other, a third measurement was obtained and the average of all measurements was reported. Cotinine values were measured by immunoassay (Immulite 2000, Nicotine Metabolite Assay; Diagnostic Products, Los Angeles, California).

Statistical analysis

We tested concurrent validity by determining whether data from the self-administered questionnaire correlated with data from the medical record, the 24-hour food diary, and biochemical measurements. The correlation between urine cotinine values and the self-reported number of cigarettes smoked in the previous 24 hours was assessed using Pearson’s correlation coefficient. Urinary iodine measurements were similarly correlated with questionnaire information. Multiple linear regression was used to assess for associations between reported dietary intakes and UIC. Values of p less than 0.05 were considered significant.

Results

No subjects reported use of iodine-containing vaginal douches or antiseptic skin cleaners in the previous week. Of the 46 participants included in the analysis, 91% were women with a mean (±SD) age of 38 (±10) years. Eighty-three percent of the subjects were U.S.-born (20% white, 17% black, 5% Hispanic, 1% Asian, and 2% other). Three of the eight foreign-born subjects were originally from iodine-deficient countries.

Information from the 24-hour food diaries matched the self-reported questionnaire data. Eighty-nine percent of the participants reported regular purchasing of table salt, but only 56% considered salt iodization important. Eighty percent purchased salt based on brand, and 87% purchased salt based on packaging. Only 24% of the subjects reported using iodized table salt within the 24-hour diary period. Twenty-four percent of subjects reported use of a multivitamin, of which 55% contained 150 μg iodine. No subjects used any
other iodine-containing dietary supplements. There was a wide range in the amounts of potential iodine-containing foods consumed and reported in the 24-hour food diaries: 73% of the subjects consumed cheese, 64% bread, 47% milk, 33% eggs, 24% yogurt, 14% saltwater fish, 12% shellfish, 19% ice cream, 11% bagels, 11% soy sauce, and 6% frozen yogurt. No subjects reported ingestion of seaweed.

Median UIC was 140 μg/L (range: 18–845 μg/L). Using a multiple regression model, there were significant positive associations between intake of yogurt (p = 0.01) and saltwater fish (p = 0.0003) and UIC, while there was a significant inverse association between intake of bagels (p = 0.0006) and UIC. For each additional serving of yogurt daily, the parameter estimate in the multiple regression model was 41.3 with a 95% confidence interval (CI) of 6.5 to 76.1; for each additional serving of saltwater fish daily, the parameter estimate in the multiple regression model was 23.3 with a 95% CI of 10.9 to 35.8; for each additional serving of bagel daily, the parameter estimate in the multiple regression model was −31.4 with a 95% CI of −48.1 to −14.7. There were no associations between reported intake of iodized salt, iodine-containing multivitamins, dietary supplements, milk, cheese, ice cream, soy sauce, eggs, bread, or shellfish and UIC. There was no association between race, educational status, or family history of thyroid disease and UIC.

Fifty-four percent of the subjects had elevated urine cotinine values (>10 μg/mL). While self-reported tobacco use correlated with urine cotinine values, there were no associations between urinary cotinine (p = 0.3) or self-reported tobacco use (p = 0.8) and UIC.

Discussion

Globally, iodine deficiency is one of the four major nutritional deficiency disorders (16) and is the single most common cause of preventable mental retardation and brain damage (17). About 2.2 billion people (38% of the world’s population) live in iodine-deficient areas (18). Although iodine supplementation has virtually eliminated endemic goiter in the United States, NHANES assessments over the last 30 years have suggested that dietary iodine intake has decreased, especially among women of childbearing age (2,3). Adequate maternal dietary iodine is crucial for normal thyroid function in the developing fetus, which in turn is essential for normal neurocognitive development both in utero and in infancy.

Over 90% of ingested iodine is eventually excreted into the urine (19), and measurement of median urinary iodine values is a widely used and well-accepted method of determining iodine sufficiency in populations (17). Several previous studies have used measurement of UICs to assess the validity of questionnaires regarding food iodine content. One Danish study reported significant correlations between a food-frequency questionnaire and 4-day dietary records in classifying levels of dietary iodine (20), while Nelson et al. (21) reported use of a dietary iodine questionnaire to compare UICs in two British towns. These authors found a significant association between the reported iodine intake and measured urinary iodine excretion, but the studies lacked sufficient statistical power to use the questionnaires as valid measures of dietary iodine. Finally, a Korean study found a significant correlation between dietary iodine intake, primarily from seaweed, and urinary iodine excretion (22).

We constructed an English-language questionnaire to assess dietary iodine intake in 46 healthy Boston-area adults. Study subjects’ 24-hour food diaries correlated well with questionnaire data. However, we found no associations between self-reported milk, iodized salt, and UIC. Finally, even though cigarette smoking has been shown to inhibit iodine uptake into the thyroid, we found no association between subjects’ cigarette smoking, as assessed by self-reported smoking history, and measurement of urinary cotinine concentrations and UIC. We conclude that the questionnaire may not have been sufficiently comprehensive. Given the importance of adequate dietary iodine intake in pregnancy and lactation, and the difficulty in determining food iodine content, further studies are warranted.

The WHO definitions for adequate iodine status of a population are median urinary iodine excretion between 100–200 μg/L and less than 20% of the study population with UICs <50 μg/L (17). Median UIC in this study was 140 μg/L (range: 18–845 μg/L), and only 8% of the subjects had UICs <50 μg/L. These findings suggest that the volunteers in this study were iodine sufficient.

Since iodine content is not listed on food packaging in the United States, our questionnaire may not have captured other iodine-rich foods. Assessment of dietary iodine was excluded from the annual U.S. Total Diet Study in late 1991 due to ongoing development of analytical detection methods (23). Thus, the most recent available data regarding national dietary iodine intake is reported in the 1982–1991 U.S. Total Diet Study, in which estimated dietary iodine levels exceeded the recommended daily allowance for all groups studied (10). An assessment of the contribution of food groups to estimated intakes of nutritional elements, done as part of the 1982–1991 U.S. Total Diet Study, was the most recent national market basket survey to evaluate dietary iodine sources (24). A recent report by the FDA has urged reintroduction of iodine into national studies to assess nutritional adequacy (25). We agree and believe that a new national market basket survey should be performed to determine the most important sources of dietary iodine in the United States.

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References


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(See next page for Appendix ->)
APPENDIX 1: DIETARY IODINE QUESTIONNAIRE VALIDATION STUDY

Today’s Date: _____ / _____ / _____

A. Your background:
1. Your birth date: _____ / _____ / _____
2. Your sex: ☐ Male ☐ Female
3. Do you consider yourself (check one):
   ☐ White, not of Hispanic origin
   ☐ Black, not of Hispanic origin
   ☐ Hispanic
   ☐ Asian or Pacific Islander
   ☐ American Indian
   ☐ Other
4. What is your highest level of education?
   ☐ Less than high school
   ☐ High school graduate
   ☐ Some college
   ☐ College graduate
   ☐ Graduate school of professional degree
5. What is your place of birth?
   ☐ United States
   ☐ Other country ________________

B. Your medical history:
1. Have you ever been diagnosed with any of the following conditions:
   a. Goiter (enlarged thyroid) ☐ Yes ☐ No ☐ Don’t know
   b. Hyperthyroidism (overactive thyroid) ☐ Yes ☐ No ☐ Don’t know
   c. Hypothyroidism (underactive thyroid) ☐ Yes ☐ No ☐ Don’t know
   d. Thyroid nodule ☐ Yes ☐ No ☐ Don’t know
   e. Thyroid cancer ☐ Yes ☐ No ☐ Don’t know
2. Has any immediate family member (your grandparent, parent, sibling, or child) ever been diagnosed
   with any of the following conditions:
   a. Goiter (enlarged thyroid) ☐ Yes ☐ No ☐ Don’t know
   b. Hyperthyroidism (overactive thyroid) ☐ Yes ☐ No ☐ Don’t know
   c. Hypothyroidism (underactive thyroid) ☐ Yes ☐ No ☐ Don’t know
   d. Thyroid nodule ☐ Yes ☐ No ☐ Don’t know
   e. Thyroid cancer ☐ Yes ☐ No ☐ Don’t know
3. In the last 3 months, have you taken thyroid hormone pills (L-thyroxine, Synthroid, Levoxyl, Unithroid,
   Levothroid, Cytomel, or Armour thyroid)?
   ☐ No
   ☐ Yes
4. In the last 2 years, have you taken amiodarone (brand name Cordarone or Pacerone; a type of prescription medicine for abnormal heart rhythms)?
   ☐ No
   ☐ Yes
5. In the last 3 months, have you had any X-rays (for example, a CT scan) in which contrast dye was
   injected into your veins?
   ☐ No
   ☐ Yes
6. In the last week, have you used any iodine-containing (brown-colored) antiseptic skin cleaner?
   ☐ No
   ☐ Yes
7. For women, in the last week, have you used any iodine-containing vaginal douche?
   ☐ No
   ☐ Yes
8. Do you currently smoke cigarettes?
   □ No
   □ Yes
   8a. If yes: In the last 24 hours, how many cigarettes have you smoked? ________

C. Your understanding about dietary iodine:

1. In your opinion, do pregnancy women need:
   □ Less dietary iodine than women who are not pregnant
   □ About the same dietary iodine as women who are not pregnant
   □ More dietary iodine than women who are not pregnant
   □ I don’t know

2. Do you agree or disagree with the following statements:
   a. Iodine deficiency is an important public health problem worldwide.
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree
   b. Iodine deficiency is an important public health problem in the United States.
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree
   c. Iodine content should be listed on food packaging in the United States.
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree
   d. It is not healthy to add salt to food.
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree
   e. Lack of iodine can cause goiter (enlarged goiter).
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree
   f. Lack of iodine can cause mental retardation in children.
      □ Strongly agree
      □ Agree
      □ No opinion
      □ Disagree
      □ Strongly disagree

D. Sources of iodine in your diet:

1. Has any health care provider ever discussed how much iodine you have in your diet?
   □ No
   □ Yes

2. Do you ever buy table salt?
   □ No
   □ Yes
   2a. If yes: Which factors do you consider when choosing salt?
      □ Price
      □ Brand
      □ Packaging
      □ Iodized or Non-Iodized
      □ Other
3. In the last 24 hours, have you added table salt to your food?
   ☐ No
   ☐ Yes
3a. If yes: What kind of salt?
   ☐ Iodized
   ☐ Non-Iodized
   ☐ Don’t know
4. In the last 24 hours, have you eaten any seaweed (sometimes called nori, wakame, kombu, or dulse) or kelp?
   ☐ No
   ☐ Yes → (number of servings ________)
5. In the last 24 hours, have you taken a multivitamin?
   ☐ No
   ☐ Yes
5a. If yes: Was the multivitamin:
   ☐ regular
   ☐ pre-natal
5b. If yes: Was the multivitamin:
   ☐ prescription
   ☐ non-prescription (over the counter)
5c. If yes: What brand was the multivitamin? ______________
5d. If yes: Did the multivitamin contain iodine?
   ☐ Yes
   ☐ No
   ☐ Don’t know
6. In the last 24 hours, have you taken any other dietary supplements (including vitamins, minerals, herbal preparations, or amino acids)?
   ☐ No
   ☐ Yes
5e. If yes: Please list below:
   Supplement type: __________________________
   Brand: ________________________________
   Amount in last 24 hours: ______________
7. In the last 24 hours, have you had any of the following dairy products to eat or drink?
   a. Cow’s milk ☐ No ☐ Yes → (number of glasses _____)
   b. Cheese ☐ No ☐ Yes → (number of 2 oz. servings _____)
   c. Yogurt ☐ No ☐ Yes → (number of containers _____)
   d. Ice cream ☐ No ☐ Yes → (number of scoops _____)
   e. Frozen yogurt ☐ No ☐ Yes → (number of scoops _____)
8. In the last 24 hours, did you drink any soy milk?
   ☐ No
   ☐ Yes → (number of glasses _____)
9. In the last 24 hours, did you have any soy sauce?
   ☐ No
   ☐ Yes
9a. If yes: What brand of soy sauce? __________
    (number of one tablespoon servings ________)
10. In the last 24 hours, have you eaten any eggs?
    ☐ No
    ☐ Yes → (number of eggs _____)
11. In the last 24 hours, have you eaten any bread that was not home-made?
    ☐ No
    ☐ Yes
11a. If yes: please list below:
    Type (white, wheat, etc) __________________________
    Brand ________________________________
    Number of slices in the last 24 hours ______________
12. In the last 24 hours, have you eaten any bagels?
    ☐ No
    ☐ Yes
12a. If yes:  
   What brands were the bagels? ____________________________  
   How many bagels? ____________________________________  

13. In the last 24 hours, have you eaten any other types of breads or rolls?  
   □ No  
   □ Yes  
13a. If yes:  
   Type _______________________________________________  
   Brand _______________________________________________  
   Number of slices in the last 24 hours __________________

14. In the last 24 hours, how many 3-ounce servings of each of the following types of saltwater fish have you eaten?  
   (a 3-ounce serving is the size of a deck of playing cards.)  
   a. Cod (number of servings __________)  
   b. Grouper (number of servings __________)  
   c. Haddock (number of servings __________)  
   d. Halibut (number of servings __________)  
   e. Herring (number of servings __________)  
   f. Mackerel (number of servings __________)  
   g. Perch (number of servings __________)  
   h. Salmon (number of servings __________)  
   i. Sea Bass (number of servings __________)  
   j. Swordfish (number of servings __________)  
   k. Tilapia (number of servings __________)  
   l. Tuna (number of servings __________)  
   m. Other * (number of servings __________)  
   *list other types of fish: ______________________

15. In the last 24 hours, how many 4-ounce (approximately ½ cup) servings of each of the following types of shellfish have you eaten?  
   a. Clams (number of servings __________)  
   b. Crabmeat (number of servings __________)  
   c. Lobster (number of servings __________)  
   d. Mussels (number of servings __________)  
   e. Oysters (number of servings __________)  
   f. Scallops (number of servings __________)  
   g. Shrimp (number of servings __________)

Were any survey questions unclear or difficult to answer? If so, please comment here:  
________________________________________________________________________  
________________________________________________________________________  
________________________________________________________________________

Do you have any suggestions for improving this survey?  
________________________________________________________________________  
________________________________________________________________________  
________________________________________________________________________

How long did it take for you to complete the survey? ___________ minutes

Thank you very much for participating in this study.