National Trends in Iodine Nutrition: Is Everyone Getting Enough?

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Iodine deficiency is an important public health problem worldwide. Until the 1920s, endemic iodine deficiency disorders were prevalent in the Great Lakes, Appalachian, and Northwestern regions of the United States. Iodized salt was responsible for eliminating endemic goiter in the United States and remains the mainstay of iodine deficiency disorder eradication efforts worldwide. Although urinary iodine values have decreased by 50% since the early 1970s, the United States remains iodine sufficient. However, U.S. iodine nutrition, particularly among women of childbearing age, may remain an area worthy of public health concern. There is a wide amount of variation in the iodine content of some common foods, and the iodine content of foods is not well reflected by package labeling. There needs to be increased awareness of the importance of adequate iodine nutrition, particularly during pregnancy and lactation, among the U.S. public.

Introduction

Iodine deficiency is an important public health problem worldwide. There have been dramatic changes in U.S. dietary iodine intake over the last 80 years.

Recommended Iodine Intakes

The U.S. recommended dietary allowances (RDAs) for iodine are listed in Table 1. It is important to note that an RDA has not been established for children under the age of 1 year. Instead, adequate intakes (AIs), defined as "the recommended daily average intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate—used when an RDA cannot be determined" (1), have been established for infants. The AIs for infants were derived primarily using breast milk iodine measurements from a group of 24 lactating women sampled in 1984 (2).

Chronic ingestion of excess iodine may result in thyroid dysfunction in susceptible individuals. Tolerable upper limits for iodine exposure have been established by the Institute of Medicine (Table 1). These are defined as "the highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population" (1). For most individuals, excess iodine exposure does not result in significant fluctuations in serum thyroid hormone levels because the Wolff-Chaikoff effect provides a protective homeostatic mechanism (3). In response to rapid increases in intrathyroidal iodine, iodide organification is transiently inhibited. After several days of continuous excess iodine exposure, there is an "escape" from this phenomenon by downregulation of the sodium/iodide symporter, and thyroid hormone synthesis resumes (4). Individuals with underlying thyroid diseases, such as Hashimoto's thyroiditis, treated Graves' disease, a history of inflammatory thyroiditis, or a history of partial thyroidectomy, are susceptible to iodine-induced hypothyroidism, a failure to escape from the acute Wolff-Chaikoff effect. Patients with underlying thyroid disease, such as nodular goiter with autonomy, or euthyroid Graves' disease, are susceptible to iodine-induced hyperthyroidism, or the Jod-Basedow phenomenon. This is more common in iodine-deficient regions, where nodular goiter is more prevalent.

Monitoring for Iodine Sufficiency

A variety of surveillance techniques have been adopted to detect iodine deficiency and to monitor iodine supplementation programs. Because iodine is renally excreted, urinary iodine concentrations reflect dietary iodine sufficiency. The World Health Organization (WHO) has established guidelines for the assessment of the iodine sufficiency of populations based on spot urine iodine measurements (Table 2). Increase in thyroid size is an early response to iodine deficiency, and goiter prevalence is used as another index of population iodine deficiency (5). In the United States and elsewhere, neonatal screening programs are designed to detect congenital hypothyroidism; the frequency of elevated neonatal thyroid-stimulating hormone values is increased in severely iodine-deficient regions. Most recently, measurements of serum...
thyroglobulin, which is elevated in iodine deficiency, have been used for assessment of iodine sufficiency in populations (6).

U.S. Iodine Deficiency before 1920: The Goiter Belt

Until the 1920s, endemic iodine deficiency disorders were prevalent in the Great Lakes, Appalachian, and Northwestern regions of the United States. In the early 1900s, goiter was present in 26–70% of children living in this “goiter belt” (7). The magnitude of the problem was noted at the time of World War I, when more military recruits from northern Michigan were determined to be unfit for duty because of goiter than for any other medical reason (7). In 1917 David Marine performed studies in schoolchildren that demonstrated that goiter could be eradicated by iodine supplementation (8). Based primarily on his work, voluntary salt iodization was initiated in the United States in 1924, resulting in the elimination of the goiter belt.

The Current Status of U.S. Iodine Nutrition

The first U.S. National Health and Nutrition Examination Survey (NHANES I), conducted from 1971 to 1974, demonstrated that the median urinary iodine concentration for the U.S. population was 320 μg/L, reflecting adequate to excessive dietary iodine intake (9). By the time of NHANES III in 1988–1994, however, the median urinary iodine had fallen to 145 μg/L. The reasons for this decrease in U.S. dietary iodine intake are not clear, although some possible explanations are discussed below. Fears that this trend would continue have prompted further monitoring, but the most recent NHANES, conducted from 2001 to 2002, found that the median U.S. urinary iodine concentration had stabilized at 168 μg/L (10).

Between the NHANES I and NHANES III, the risk for low urinary iodine values increased most dramatically among women of childbearing age (15–44 years) (Fig. 1). This is of concern because thyroid hormone, requiring adequate maternal iodine intake, is critical for neural development in utero. The median urinary iodine value in pregnant women (n = 208) from NHANES I was 327 μg/L, with 1% of the women sampled having urinary iodine levels <50 μg/L. The median urinary iodine level among pregnant women from NHANES III (n = 348) was 141 μg/L, with 6.9% having urinary iodine levels <50 μg/L (9). The most recent NHANES, conducted in 2001–2002, demonstrated that urinary iodine values in pregnant women appear to have stabilized. The median urinary iodine value was 173 μg/L for the 126 pregnant women sampled, with 7.3% having urinary iodine levels <50 μg/L (10). A recent sample of spot urine specimens from 100 healthy pregnant Boston-area women had a median urinary iodine of 149 μg/L, with urinary iodine levels ranging from 13 to 1200 μg/L (11).

Several studies have examined urinary iodine in samples of school-aged U.S. children. At the time of NHANES I, the median urinary iodine value for children aged 6–11 was 421 μg/L; this value had fallen to 237 μg/L by the time of NHANES III (9). Since then, urinary iodine values in U.S. children, as for other groups, appear to have stabilized. The

![Figure 1](https://example.com/iodine_concentration.png)
median urinary iodine in a 1996 sample of 302 Atlanta children was 282 μg/L (12); that in a 2002 sample of 565 Boston-area children was 289 μg/L (13); and that in the most recent NHANES (2001–2002; n = 374) was 249 μg/L (10). Children’s urinary iodine values are consistently higher than those of U.S. adults, and boys’ urinary iodine values are consistently higher than those of girls.

Infants who are breastfed are reliant on maternal iodine intake for adequate iodine nutrition (14). Available iodine is avidly concentrated in the breast, due to increased expression of the sodium/iodide symporter in mammary tissue during lactation (15). Current data regarding iodine sufficiency among lactating U.S. women are very limited. The median breast milk iodide level in a 1984 sample of 37 U.S. women was 146 μg/L (2). Breast milk iodine content was measured in a sample of 57 lactating Boston-area women; the median value was 155 μg/L (16). Kirk et al. (17) recently described a median breast milk iodide value of 33.5 μg/L in a sample of 23 U.S. women recruited via the Internet, substantially lower than the only other recent samples.

Sources of Iodine in the U.S. Diet

Sources of iodine in the diet of U.S. adults have been difficult to identify, in part because there are a wide variety of potential sources, and food iodine content is not listed on packaging.

Iodized salt was responsible for eliminating the goiter belt in the United States, and remains the mainstay of iodine deficiency disorder eradication efforts worldwide. In the United States, salt iodization has never been mandated. Approximately 70% of salt sold for household use in the United States is fortified with 100 ppm potassium iodide, so that one teaspoon of iodized table salt contains approximately 400 μg iodine (18). However, household table salt accounts for only about 15% of daily salt intake in the United States. The salt used in manufacturing many processed foods may not be iodized. Possible reasons for the decrease in U.S. iodine consumption between the early 1970s and the 1990s include (i) recommendations for reduced salt intake for blood pressure control and (ii) increasing use of noniodized salt in processed foods (19).

U.S. milk iodine content increased by 300–500% between 1965 and 1980, primarily because of changes in cattle feeds (20). In 1986 the allowable amount of organic iodine ethylenediamine dihydroiodine (EDDI) in cattle feed was limited to 10 mg per cow daily, resulting in decreases in the iodine content of U.S. cows’ milk. This is another probable reason for the decrease in U.S. dietary iodine intake between the 1970s and 1990s. Iodophor disinfectant pre- and postmilking teat dips and udder washes, which are widely used in the United States, contain up to 1% available iodine, and are absorbed through the skin and subsequently incorporated into cows’ milk (21,22). The importance of iodophor dairy cleaners has been seen recently in Australia, where studies in various populations in the late 1980s consistently demonstrated median urinary iodine concentrations around 200 μg/L (23). This was true despite the fact that only about 10% of table salt sold in Australia is iodized (24). However, in more recent studies of different populations in Sydney and Melbourne, all groups had median urinary iodine values <100 μg/L (25,26). This decrease has been attributed, at least in part, to the recent replacement of iodophors with noniodine-based cleansers in the dairy industry (27). The iodine content of 18 varieties of cows’ milk from Boston-area supermarkets was recently measured (28). The average iodine content of milk in this sample was 110 μg per cup (464 μg/L), with iodine content being slightly higher in the winter than in the summer. Another recent study examined 39 samples of cows’ milk from around the United States and found that the average iodide content was 89.2 μg/L (17).

Commercially baked breads have been another major source of iodine in the U.S. diet. Iodate bread conditioners were widely used in the 1960s; conditioners are added to bread to maintain freshness. London et al. (29) in 1965 reported that bread was a source of large quantities of dietary iodine with iodine content as high as 150 μg per slice. This was considered to be a cause of decreasing radioactive iodine uptakes in the United States during the 1960s (30,31). The use of iodate bread conditioners has decreased, probably contributing to the reduction in dietary iodine levels between the 1970s and the early 1990s. In 2002 the iodine content of 20 different breads from Boston-area supermarkets was measured (28). Three varieties of bread contained >300 μg iodine per slice (313.5–587.4 μg), while the average iodine content in the other 17 brands was 10 μg iodine/slice. The labeling of bread packages did not accurately predict the content of iodine.

The iodine content of 17 varieties of infant formula sold in the Boston area was also recently measured; it ranged from 84 to 224 μg/L, similar to concentrations found in breast milk (16).

Other sources of iodine in the U.S. diet are eggs, meat, and poultry. Iodine in eggs is found primarily in the yolk, and a large egg contains about 29 μg of iodide (32). The amount of iodine in meat and poultry is highly variable, depending largely on the amount of iodine supplementation of animals’ feed. Seafood can also be an excellent source of dietary iodine, containing 2–10 times as much iodine as meats (33), but iodine content varies widely depending on the type of seafood and location (34). In general, saltwater seafood contains more iodine than fresh water seafood does. Edible seaweeds may contain up to 2500 μg iodine per gram (35), but they are not a major component of the U.S. diet. Erythrosine dye (FDC Red #3) is sometimes described as a major contributor to U.S. dietary iodine intake, but this is probably not the case. First, this colorant is no longer widely used in U.S. foods. Second, the iodine contained in erythrosine is not readily bioavailable: only about 1% of iodine in ingested erythrosine is actually absorbed (36).

Medications are important sources of iodine for some individuals, but probably do not contribute substantially to overall U.S. iodine intake (Table 3). Amiodarone, an antiarrhythmic agent frequently used in the United States (37), contains 75 mg iodine per 200 mg tablet. Iodinated intravenous radiographic contrast agents contain up to 320 mg of iodine per mL. Some topical antiseptics contain iodine. Systemic absorption of iodine from topical antiseptics is generally not clinically significant except in patients with severe burns (38) and in preterm infants (39). Use of iodine-containing vaginal douches has declined over the last 15 years, but remains a common practice among some groups of U.S. women (40); frequent use has been shown to increase serum and urine iodine concentrations (41). In the past, there were several iodine-containing antiasthmatic medications and expectorants in the U.S. market; however,
Table 3. Iodine-Containing Medications Currently Marketed in the United States

<table>
<thead>
<tr>
<th>Medication</th>
<th>Iodine content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amiodarone</td>
<td>75 mg/200 mg tablet</td>
</tr>
<tr>
<td>Iodoquinol</td>
<td>134 mg/tablet</td>
</tr>
<tr>
<td>Povidone-iodine</td>
<td>10 mg/mL</td>
</tr>
<tr>
<td>Povidone-iodine topica Infantis</td>
<td>10 mg/mL</td>
</tr>
<tr>
<td>Iodinated intravenous contrast dye</td>
<td>150–320 mg/mL</td>
</tr>
<tr>
<td>SSKI</td>
<td>25 mg/drop</td>
</tr>
<tr>
<td>Lugol’s solution</td>
<td>5 mg/drop</td>
</tr>
</tbody>
</table>

these are no longer available. Some dietary supplements may contain large amounts of iodine; these are not regulated by the U.S. Food and Drug Administration (FDA), and the prevalence of such supplement use is unknown.

Finally, multivitamins may be an important source of iodine in the United States. Of the various formulations on the U.S. market, 51% of adult multivitamins contain iodine; most of those include 150 μg daily (42). About 45% of children’s multivitamin formulations in the United States contain iodine, and none of the infant liquid multivitamin formulations marketed in the United States contain iodine (42). Currently, only 44 of 69 (64%) prenatal multivitamins marketed in the United States contain any iodine; of those, only 15% contain more than 150 μg, and most contain less than the 220 μg daily recommended for pregnant women or the 290 μg daily recommended during lactation (42). Based on concerns about adequate iodine intake in the perinatal period, the National Academy of Sciences recently recommended that consideration be given to adding iodine to all prenatal vitamins (43). The American Thyroid Association has also recently recommended that women in the U.S. and Canada receive dietary supplements containing 150 μg of iodine daily during pregnancy and lactation and that all U.S. prenatal multivitamins contain 150 μg of iodine (44).

Conclusions

Although urinary iodine values have decreased by 50% since the early 1970s, the United States remains iodine sufficient. However, U.S. iodine nutrition, particularly among women of childbearing age, may remain an area worthy of public health concern. There is a wide amount of variation in the iodine content of some common foods, and the iodine content of foods is not well reflected by package labeling. There needs to be increased awareness of the importance of adequate iodine nutrition, particularly during pregnancy and lactation, among the U.S. public. Women of childbearing age should be encouraged to use iodine-containing multivitamins. Finally, there is a need for larger and more systematic studies of iodine nutrition in different U.S. populations and for routine monitoring of food iodine content.

Acknowledgment

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