Iodine-HealthProfessional

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Iodine  
Fact Sheet for Health Professionals  
  
This is a fact sheet intended for health professionals. For a general overview, see our consumer fact sheet.  
  
Introduction  
Iodine is a trace element that is naturally present in some foods, is added to some types of salt, and is available as a dietary supplement. Iodine is an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Thyroid hormones regulate many important biochemical reactions, including protein synthesis and enzymatic activity, and are critical determinants of metabolic activity [1,2]. They are also required for proper skeletal and central nervous system development in fetuses and infants [1].  
  
Thyroid function is primarily regulated by thyroid-stimulating hormone (TSH), also known as thyrotropin. It is secreted by the pituitary gland to control thyroid hormone production and secretion, thereby protecting the body from hypothyroidism and hyperthyroidism [1]. TSH secretion increases thyroidal uptake of iodine and stimulates the synthesis and release of T3 and T4. In the absence of sufficient iodine, TSH levels remain elevated, leading to goiter, an enlargement of the thyroid gland that reflects the body s attempt to trap more iodine from the circulation and produce thyroid hormones. Iodine may have other physiological functions in the body as well. For example, it appears to play a role in immune response and might have a beneficial effect on mammary dysplasia and fibrocystic breast disease [2].  
  
The earth s soils contain varying amounts of iodine, which in turn affects the iodine content of crops. In some regions of the world, iodine-deficient soils are common, increasing the risk of iodine deficiency among people who consume foods primarily from those areas. Salt iodization programs, which many countries have implemented, have dramatically reduced the prevalence of iodine deficiency worldwide [2,3].  
  
Iodine in food and iodized salt is present in several chemical forms including sodium and potassium salts, inorganic iodine (I2), iodate, and iodide, the reduced form of iodine [4]. Iodine rarely occurs as the element but rather as a salt; for this reason, it is referred to as iodide and not iodine. Iodide is quickly and almost completely absorbed in the stomach and duodenum. Iodate is reduced in the gastrointestinal tract and absorbed as iodide [2,5]. When iodide enters the circulation, the thyroid gland concentrates it in appropriate amounts for thyroid hormone synthesis and most of the remaining amount is excreted in the urine [2]. The iodine-replete healthy adult has about 15 20 mg of iodine, 70% 80% of which is contained in the thyroid [6].  
  
Median urinary iodine concentrations of 100 199 mcg/L in children and adults, 150 249 mcg/L in pregnant women and >100 mcg/L in lactating women indicate iodine intakes are adequate [3]. Values lower than 100 mcg/L in children and nonpregnant adults indicate insufficient iodine intake, although iodine deficiency is not classified as severe until urinary iodine levels are lower than 20 mcg/L.  
  
Recommended Intakes  
Intake recommendations for iodine and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the Institute of Medicine of the National Academies (formerly National Academy of Sciences) [2]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and gender [2], include the following:  
  
Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97% 98%) healthy individuals; often used to plan nutritionally adequate diets for individuals  
Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA  
Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals  
Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects  
Table 1 lists the current RDAs for iodine [2]. For infants from birth to 12 months, the FNB established an AI for iodine that is equivalent to the mean intake of iodine in healthy, breastfed infants in the United States.  
  
Table 1: Recommended Dietary Allowances (RDAs) for Iodine [2]  
Age Male Female Pregnancy Lactation  
Birth to 6 months 110 mcg\* 110 mcg\*  
7 12 months 130 mcg\* 130 mcg\*  
1 3 years 90 mcg 90 mcg  
4 8 years 90 mcg 90 mcg  
9 13 years 120 mcg 120 mcg  
14 18 years 150 mcg 150 mcg 220 mcg 290 mcg  
19+ years 150 mcg 150 mcg 220 mcg 290 mcg  
\* Adequate Intake (AI)  
  
The World Health Organization (WHO), United Nations Children s Fund, and the International Council for the Control of Iodine Deficiency Disorders recommend a slightly higher iodine intake for pregnant women of 250 mcg per day [3,7].  
  
Sources of Iodine  
Food  
Seaweed (such as kelp, nori, kombu, and wakame) is one of the best food sources of iodine [5]. Other good sources include fish and other seafood as well as eggs (see Table 2). Iodine is also present in human breast milk [2,5] and infant formulas [8].  
  
Dairy products contain iodine. However, the amount of iodine in dairy products varies by whether the cows received iodine feed supplements and whether iodophor sanitizing agents were used to clean the cows and milk-processing equipment [9]. For example, an analysis of 59 samples of nonfat milk found a range of 38 to 159 mcg per cup (with an average of 84 mcg/cup used for Table 2) [8]. Plant-based beverages used as milk substitutes, such as soy and almond beverages, contain relatively small amounts of iodine.  
  
Most commercially prepared bread contains very little iodine unless the manufacturer has used potassium iodate or calcium iodate as a dough conditioner [10,11]. Manufacturers list dough conditioners as an ingredient on product labels but are not required to include iodine on the Nutrition Facts label [12], even though these conditioners provide a substantial amount of iodine. According to 2019 data from the U.S. Department of Agriculture (USDA) Branded Food Products Database, approximately 20% of ingredient labels for white bread, whole-wheat bread, hamburger buns, and hot dog buns listed iodate [13]. Pasta is not a source of iodine unless it is prepared in water containing iodized salt because it absorbs some of the iodine [11].  
  
Most fruits and vegetables are poor sources of iodine, and the amounts they contain are affected by the iodine content of the soil, fertilizer use, and irrigation practices [2,10]. This variability affects the iodine content of meat and animal products because of its impact on the iodine content of foods that the animals consume [14]. The iodine amounts in different seaweed species also vary greatly. For example, commercially available seaweeds in whole or sheet form have iodine concentrations ranging from 16 mcg/g to 2,984 mcg/g [15]. For these reasons, the values for the foods listed in Table 2 are approximate but can be used as a guide for estimating iodine intakes.  
  
Table 2: Iodine Content of Selected Foods [8]  
Food Micrograms (mcg)  
per serving Percent DV\*  
Bread, white, enriched, made with iodate dough conditioner, 2 slices\*\* 296 197  
Bread, whole-wheat, made with iodate dough conditioner, 2 slices\*\* 273 182  
Cod, baked, 3 ounces 146 97  
Seaweed, nori, dried, 2 tablespoons, flaked (5 g) 116 77  
Oysters, cooked, 3 ounces 93 62  
Yogurt, Greek, plain, nonfat, cup 87 58  
Milk, nonfat, 1 cup 84 56  
Iodized table salt, teaspoon 78 52  
Fish sticks, cooked, 3 ounces 57 38  
Egg, hard boiled, 1 large 31 21  
Pasta, enriched, boiled in water with iodized salt, 1 cup 30 20  
Ice cream, chocolate, cup 28 19  
Cheese, cheddar, 1 ounce 14 9  
Liver, beef, cooked, 3 ounces 14 9  
Shrimp, cooked, 3 ounces 13 9  
Tuna, canned in water, drained, 3 ounces 8 5  
Fruit cocktail in light syrup, canned, cup 5 3  
Fish sauce, 1 tablespoon 4 3  
Beef, chuck, roasted, 3 ounces 3 2  
Soy beverage, 1 cup 3 2  
Chicken breast, roasted, 3 ounces 1 1  
Apple juice, 1 cup 1 1  
Bread, whole-wheat, made without iodate dough conditioner, 2 slices\*\* 1 1  
Bread, white, enriched, made without iodate dough conditioner, 2 slices\*\* 1 1  
Sea salt, noniodized, teaspoon 1 1  
Rice, brown, cooked, cup 0 0  
Corn, canned, cup 0 0  
Broccoli, boiled, cup 0 0  
Banana, 1 large 0 0  
Soy sauce, 1 tablespoon 0 0  
Lima beans, boiled, cup 0 0  
Green peas, boiled, cup 0 0  
Pasta, enriched, boiled in water without iodized salt, 1 cup 0 0  
\*DV = Daily Value. The U.S. Food and Drug Administration (FDA) developed DVs to help consumers compare the nutrient contents of foods and dietary supplements within the context of a total diet. The DV for iodine is 150 mcg for adults and children age 4 years and older [12]. FDA does not require food labels to list iodine content unless iodine has been added to the food. Foods providing 20% or more of the DV are considered to be high sources of a nutrient, but foods providing lower percentages of the DV also contribute to a healthful diet.  
\*\*About 20% of bread products in the United States list iodate dough conditioners on their labels. Products made without these conditioners contain very little iodine.  
  
The USDA, FDA and external link disclaimerOffice of Dietary Supplements-National Institutes of Health (ODS-NIH)external link disclaimer Database for the Iodine Content of Common Foodsexternal link disclaimer [8] lists the iodine content of numerous foods and beverages.  
  
Iodized salt  
The United States, Canada, and dozens of other countries have salt-iodization programs [3,16,17]. In the United States, salt manufacturers have been adding iodine to table salt since the 1920s, although this practice is still voluntary [18]. FDA has approved the use of potassium iodide and cuprous iodide for salt iodization [19], whereas the WHO recommends the use of potassium iodate due to its greater stability, particularly in warm, damp, or tropical climates [3]. According to its label, iodized salt in the United States contains 45 mcg iodine/g salt (between 1/8 and 1/4 teaspoon); measured salt samples have an average of 47.5 50.7 mcg iodine/g salt [8,18]. However, most salt intake in the United States comes from processed foods, and food manufacturers almost always use noniodized salt in these foods. If they do use iodized salt, they must list the salt as iodized in the ingredient list on the food label [9]. Specialty salts, such as sea salt, kosher salt, Himalayan salt, and fleur de sel, are not usually iodized. Product labels will indicate if the salt is iodized or provides iodide. As shown in Table 2, noniodized sea salt provides virtually no iodine [8].  
  
Dietary supplements  
In dietary supplements, iodine is often present as potassium iodide or sodium iodide [20]. Supplements containing kelp, a seaweed that contains iodine, are also available. A small study found that people absorb potassium iodide almost completely (96.4%) [21].  
  
Many multivitamin/mineral supplements contain iodine, often at a dose of 150 mcg [20], and some, but not all, prenatal supplements contain iodine [22]. Dietary supplements containing only iodine are also available, and many contain high doses, sometimes above the UL [20]. Many dietary supplements that contain iodine are listed in the Dietary Supplement Label Database from the NIH [20]. This database contains label information from tens of thousands of dietary supplement products on the U.S. market.  
  
Iodine Intakes and Status  
Iodine intakes  
The Total Diet Study (TDS), an FDA monitoring program, provides estimated iodine intakes of the U.S. population [23]. Through the TDS program, foods that represent the average U.S. diet are purchased and analyzed for several components, including iodine. Based on analytical results from TDS food samples collected between 2008 and 2012, combined with food consumption estimates, the average daily iodine intake in the United States was 216 mcg/day, with a range from 141 to 296 mcg/day across all age and gender groups [24]. These intakes meet or exceed the EAR for all groups.  
  
TDS data do not include iodine that people obtain from the discretionary use of iodized salt [25,26]. Because many U.S. households use iodized salt, TDS data likely underestimate the true iodine intake of most U.S. residents. Data from the National Health and Nutrition Examination Survey (NHANES) collected between 1999 and 2004 indicate that 28 29% of adults use iodine-containing dietary supplements [27]; this use also adds to the population s total iodine intake.  
  
Iodine status of the general U.S. population  
Iodine status is typically assessed using urinary iodine measurements. Urinary iodine reflects dietary iodine intake directly because people excrete more than 90% of dietary iodine in the urine [4]. Spot urine iodine measurements are a useful indicator of iodine status within populations [28,29]. However, multiple 24-hour urinary iodine or multiple spot urine measurements are more accurate for individuals [4,30].  
  
Median urinary iodine concentrations, from spot samples collected as part of a large survey, can be used to characterize the iodine status of populations [31]. However, because spot samples are not a suitable indicator of individual iodine status [30], these measurements cannot be used to diagnose individual cases of iodine deficiency or to identify the proportion of a population with iodine deficiency or with excessive iodine intakes [31]. For a population of school-age children or nonpregnant adults to be iodine sufficient, median urinary iodine concentrations should be greater than 100 mcg/L and no more than 20% of the population should have values lower than 50 mcg/L [3].  
  
Urinary iodine measurements from NHANES have been used since 1971 to monitor the iodine status of the U.S. population [32]. Since the inception of the NHANES monitoring program, urinary iodine measurements have shown that the general U.S. population is iodine sufficient. This is despite the fact that urinary iodine levels decreased by more than 50% between 1971 1974 and 1988 1994 [2,33]. Much of this decline was a result of decreased levels of iodine in milk due to the reduced use of iodine-containing feed supplements and iodophor sanitizing agents in the dairy industry [34] as well as the reduced use of iodate dough conditioners by commercial bakers. The use of erythrosine, an iodine-containing food dye commonly used in fruit-flavored breakfast cereals, also decreased during this time [34] though it is unclear to what extent this change actually affected urinary iodine levels because the bioavailability of iodine from erythrosine has been found to be low [35]. This sharp decline in urinary iodine levels caused some concern during the late 1990s that the iodine sufficiency of the U.S. population could be at risk if this trend continued [33].  
  
More recent NHANES measurements indicate that urinary iodine levels have stabilized in the general U.S. population. During 2007 2008, NHANES participants age 6 years and older had a median urinary iodine concentration of 164 mcg/L [36]. Among women of reproductive age, the median urinary iodine concentration in NHANES 2007 2014 was 119 mcg/L [37]. These values have essentially remained unchanged in the last three NHANES surveys, indicating that the dietary iodine intake of the general U.S. population has remained stable since 2000 [36].  
  
Iodine status of U.S. pregnant women  
According to the WHO, a median urinary iodine concentration of 150 249 mcg/L indicates adequate iodine nutrition during pregnancy, while values less than 150 mcg/L are considered insufficient [3,7]. Analyses of NHANES datasets from 2003 to 2014 indicate that a substantial portion of pregnant women in the United States are iodine insufficient. Median urinary iodine concentrations for pregnant women participating in NHANES surveys were 181 mcg/L in 2003 2004, 153 mcg/L in 2001 2006, 125 mcg/L in 2005 2008, and 144 mcg/L in 2007 2014 [32,36-38]. Suboptimal iodine status during pregnancy has also been observed in Australia [39].  
  
Pregnant women who do not consume dairy products may be particularly at risk of iodine insufficiency. According to NHANES 2001 2006 data, pregnant women who consumed no dairy products in the previous 24 hours had a median urinary iodine concentration of only 100 mcg/L, compared with 163 mcg/L among consumers of dairy [38]. Women who restrict their dietary salt intake also have lower urinary iodine concentrations and might be more likely to be iodine deficient than women who don t restrict salt intake [40].  
  
Overall, it appears that the general U.S. population has adequate iodine intake but that some pregnant women may be at risk for iodine deficiency. Continued national iodine monitoring is needed with more emphasis on population subgroups that are most susceptible to iodine deficiency disorders.  
  
Iodine Deficiency  
Iodine deficiency has multiple adverse effects on growth and development and is the most common cause of preventable intellectual disability in the world [41]. Iodine deficiency disorders result from inadequate thyroid hormone production secondary to insufficient iodine [5]. During pregnancy and early infancy, iodine deficiency can cause irreversible effects.  
  
Under normal conditions, the body tightly controls thyroid hormone concentrations via TSH. Typically, TSH secretion increases when iodine intake falls below about 100 mcg/day [5]. TSH increases thyroidal iodine uptake from the blood and the production of thyroid hormone. However, very low iodine intakes can reduce thyroid hormone production even in the presence of elevated TSH levels.  
  
If a person s iodine intake falls below approximately 10 20 mcg/day, hypothyroidism occurs [1], a condition that is frequently accompanied by goiter. Goiter is usually the earliest clinical sign of iodine deficiency [2]. In pregnant women, iodine deficiency of this magnitude can cause major neurodevelopmental deficits and growth retardation in the fetus as well as miscarriage and stillbirth [5]. Chronic, severe iodine deficiency in utero causes cretinism, a condition characterized by intellectual disability, deaf mutism, motor spasticity, stunted growth, delayed sexual maturation, and other physical and neurological abnormalities [5].  
  
In infants and children, less severe iodine deficiency can also cause neurodevelopmental deficits such as somewhat lower than average intelligence as measured by IQ [1,42,43]. Mild to moderate maternal iodine deficiency has also been associated with an increased risk of attention deficit hyperactivity disorder in children [44]. In adults, mild to moderate iodine deficiency can cause goiter as well as impaired mental function and work productivity secondary to hypothyroidism. Chronic iodine deficiency may be associated with an increased risk of the follicular form of thyroid cancer [45].  
  
Groups at Risk of Iodine Inadequacy  
Historically, iodine deficiency was endemic in mountainous regions of the United States and Mexico, and in the so called goiter belt around the Great Lakes [46]. Thanks to a more national food supply, iodized salt, and other factors, overt iodine deficiency is now uncommon in North America. International efforts since the early 1990s have dramatically reduced the incidence of iodine deficiency worldwide, but some groups of people are still at risk of inadequate iodine intake. Iodine insufficiency remains a public health problem in 25 countries with a total population of about 683 million people [47]. The following groups are among those most likely to have inadequate iodine status.  
  
People who do not use iodized salt  
The use of iodized salt is the most widely used strategy to control iodine deficiency. Currently, about 88% of households worldwide use iodized salt, but iodine insufficiency is still prevalent in certain regions, particularly Southeast Asia, sub-Saharan Africa, and Eastern Europe [47,48].  
  
Pregnant women  
During pregnancy, the RDA for iodine increases from 150 to 220 mcg/day [2]. Surveys indicate that many pregnant women in the United States might consume insufficient amounts of iodine even if they do not have signs or symptoms of overt iodine deficiency [36]. The impact, if any, of this insufficient intake on fetal development is not known.  
  
Vegans and people who eat few or no dairy products, seafood, and eggs  
Seafood, eggs, milk, and milk products are among the best sources of iodine. Vegans, people with certain food allergies or lactose intolerance, and others who consume no or minimal amounts of these foods might not obtain sufficient amounts of iodine [49,50].  
  
People living in regions with iodine-deficient soils  
Iodine-deficient soils produce crops that have low iodine levels. Mountainous areas (e.g., Himalayas, Alps, and Andes regions) and river valleys prone to flooding (especially in South and Southeast Asia) are among the most iodine-deficient regions in the world [5]. People living in these areas are at risk of iodine deficiency unless they consume iodized salt or foods produced outside the iodine-deficient area.  
  
People with marginal iodine status who eat foods containing goitrogens  
Consumption of foods that contain goitrogens, substances that interfere with the uptake of iodine in the thyroid, can exacerbate iodine deficiency [2]. Foods high in goitrogens include soy, cassava, and cruciferous vegetables (e.g., cabbage, broccoli, and cauliflower). Deficiencies of iron and/or vitamin A may also be goitrogenic [51]. These issues are of concern primarily for people living in areas prone to iodine deficiency [6]. For most people, including most of the U.S. population, who have adequate iodine intakes and eat a variety of foods, the consumption of reasonable amounts of foods containing goitrogens is not a concern.  
  
Iodine and Health  
Due to its important role in fetal and infant development and thyroid hormone production, iodine is a critical nutrient for proper health at all life stages. This section focuses on four areas of biomedical research examining iodine s role in health and disease: fetal and infant development, cognitive function during childhood, fibrocystic breast disease, and radiation-induced thyroid cancer.  
  
Fetal and infant development  
Iodine sufficiency during pregnancy is extremely important for proper fetal development. During early pregnancy, when fetal thyroid gland development is incomplete, the fetus depends entirely on maternal T4 and, therefore, on maternal iodine intake [52]. Production of T4 increases by approximately 50% during pregnancy [53], requiring a concomitant increase in maternal iodine intake. Sufficient iodine intake after birth is also important for proper physical and neurological growth and maturation.  
  
Research suggests that infants are more sensitive to the effects of iodine deficiency than other age groups, as indicated by changes in their TSH and T4 levels in response to even mild iodine deficiency [54]. Although severe iodine deficiency disorders are uncommon in the United States, mild to moderate iodine insufficiency during pregnancy may subtly affect fetal development [4,55-59]. A meta-analysis of 6,180 mother-child pairs from three birth cohorts in the Netherlands, Spain, and the United Kingdom found that verbal IQ assessed in children at 1.5 to 8 years of age was lower if their mothers had lower iodine status in their first trimester of pregnancy [43]. To accommodate increased iodine needs during pregnancy and lactation, the iodine RDA is 220 mcg/day for pregnant women and 290 mcg/day for lactating women [2]. Similarly, the WHO recommends 250 mcg/day during pregnancy and lactation [3].  
  
Despite the importance of iodine for proper fetal development, the effects of iodine supplements during pregnancy on infant and child neurodevelopment in particular are inconclusive. Two randomized clinical trials had a similar study design in which iodine was provided from early pregnancy to delivery (150 or 200 mcg/day iodine as potassium iodide) and assessed child cognition using the same tool at age 1.5 or 2 years [60,61]. Iodine supplementation had no effect on child cognitive, language, or motor scores [62]. One of these trials also assessed children at age 5 6 years and continued to find no benefit on child neurodevelopment from the mother s use of iodine [60].  
  
Breast milk contains iodine, although concentrations vary based on maternal iodine levels. Infants who are exclusively breastfed depend on maternal iodine sufficiency for optimal development. In a study of 57 healthy lactating women from the Boston area, median breast milk iodine content was 155 mcg/L [63]. Based on reported infant iodine needs and the typical volume of breast milk consumed, the authors calculated that 47% of the women may have been providing their infants breast milk containing insufficient amounts of iodine. During the weaning period, infants not receiving iodine-containing complementary foods may also be at risk of iodine deficiency, even in countries with iodized salt programs [64,65].  
  
To ensure that adequate amounts of iodine are available for proper fetal and infant development, several national and international groups recommend iodine supplementation during pregnancy, lactation, and early childhood. For women living in countries with weak, sporadic, or uneven iodized salt distribution, the WHO recommends iodine supplementation for all women of childbearing age to achieve a total iodine intake of 150 mcg/day. For pregnant and lactating women in these countries, iodine intakes of 250 mcg/day from both supplements and dietary sources are recommended [3,7]. WHO recommendations for these countries also include breastfeeding through 24 months of age, combined with complementary foods fortified with iodine for children between the ages of 7 24 months [7].  
  
The American Thyroid Association recommends that women who are planning a pregnancy, currently pregnant, or lactating should supplement their diet with 150 mcg/day iodine in the form of potassium iodide [66]. Similarly, the American Academy of Pediatrics recommends that women who are pregnant, planning to become pregnant, or lactating take a daily supplement providing at least 150 mcg iodine and use iodized salt [67].  
  
The use of iodine-containing dietary supplements by pregnant and lactating women in the United States appears to be low compared to current recommendations. Of 59 best-selling prenatal multivitamin supplements on the market in 2016 2017, only 34 contained iodine [22]. The median iodine content was 150 mcg per daily serving, with a range of 25 to 290 mcg; 25 of the 34 provided iodine as potassium iodide. According to 2011 2014 NHANES data, 72.2% of pregnant woman took any dietary supplement, but only 17.8% of them took an iodine-containing product [68]. Among lactating women, 75% took a dietary supplement, but only 19% of them took an iodine-containing product.  
  
Results from a 2010 study, however, raise some questions as to the safety of widespread iodine supplementation in areas of relative iodine sufficiency. In this cross-sectional study, pregnant women living in Spain had a significantly increased risk of hyperthyrotropinemia (TSH >3 microU/mL) if they consumed iodine supplements in doses 200 mcg/day compared with those who consumed doses <100 mcg/day [69]. These findings suggest that taking higher doses of supplemental iodine during pregnancy could induce thyroid dysfunction in some women and underscore the need for additional research into the effects on maternal thyroid function of iodine supplementation during pregnancy.  
  
Taken as a whole, these findings indicate that increased public awareness of iodine s importance during pregnancy and lactation is warranted and that further research into the effects of iodine supplementation during pregnancy is needed. Many researchers, as well as the American Thyroid Association, stress the importance of continued iodine status monitoring among women of reproductive age [1,4,32,38,56,70,71].  
  
Cognitive function during childhood  
The effects of severe iodine deficiency on neurological development are well documented. Results from several studies suggest, for example, that chronic, moderate to severe iodine deficiency, particularly in children, reduces IQ by about 12 13.5 points [53]. A 2004 Cochrane Review concluded that iodine supplementation in children living in areas of iodine deficiency appears to both positively affect physical and mental development and decrease mortality with only minor and transient adverse effects [72].  
  
The effects of mild iodine deficiency during childhood are more difficult to quantify. Some research suggests that mild iodine deficiency is associated with subtle neurodevelopmental deficits and that iodine supplementation might improve cognitive function in mildly iodine-deficient children [52].  
  
In a 2009 randomized, placebo-controlled study, 184 children age 10 13 years in New Zealand with a median urinary iodine concentration of 63 mcg/L received iodine supplements (150 mcg/day) or placebo for 28 weeks [73]. Iodine supplementation improved iodine status (median urinary iodine concentration after supplementation was 145 mcg/L) and significantly improved measures of perceptual reasoning and overall cognitive score compared with children taking a placebo. These findings suggest that correcting mild iodine deficiency in children could improve certain components of cognition. Additional research is required to fully understand the effects of mild iodine deficiency and iodine supplementation on cognitive function.  
  
Fibrocystic breast disease  
Fibrocystic breast disease is a benign condition characterized by lumpy, painful breasts and palpable fibrosis. It commonly affects women of reproductive age, but it can also occur during menopause, especially in women taking estrogens [74]. Breast tissue has a high concentration of iodine, especially during pregnancy and lactation [4,75]. Some research suggests that iodine supplementation might be helpful for fibrocystic breast disease, although a specific mechanism of action has not been established [76] and data are limited.  
  
In a double-blind study, researchers randomly assigned 56 women with fibrocystic breast disease to receive daily supplements of iodine (70 to 90 mcg I2/kg body weight) or placebo for 6 months [74]. At treatment completion, 65% of the women receiving iodine reported decreased pain compared with 33% of women in the placebo group. A more recent randomized, double-blind, placebo-controlled clinical trial had similar findings. In this study, researchers randomly assigned 111 women (18 50 years of age) with fibrosis and a history of breast pain to receive tablets containing 0 mcg, 1,500 mcg, 3,000 mcg, or 6,000 mcg of iodine per day [76]. After 5 months of treatment, women receiving doses of 3,000 or 6,000 mcg iodine had a significant decrease in breast pain, tenderness, and nodularity compared with those receiving placebo or 1,500 mcg iodine. The researchers also reported a dose-dependent reduction in self-assessed pain. None of the doses was associated with major adverse events or changes in thyroid function test results.  
  
Although the results of these studies are promising, more research is needed to clarify iodine s role in fibrocystic breast disease. Moreover, the doses used in these studies (approximately 1,500 6,000 mcg per day) are several times higher than the iodine UL of 1,100 mcg for adults. Doses of this magnitude should only be used under the guidance of a physician [2].  
  
Radiation-induced thyroid cancer  
Nuclear accidents can release radioactive iodine into the environment, increasing the risk of thyroid cancer in exposed individuals, especially children [77,78]. Thyroidal uptake of radioactive iodine is higher in people with iodine deficiency than in people with iodine sufficiency. For this reason, iodine-deficient individuals have a particularly high risk of developing radiation-induced thyroid cancer when exposed to radioactive iodine.  
  
FDA has approved potassium iodide as a thyroid-blocking agent to reduce the risk of thyroid cancer in radiation emergencies involving the release of radioactive iodine [77]. FDA recommends that exposed people take a daily pharmacological dose (16 130 mg potassium iodide, depending on age) until the risk of significant radiation exposure ends [77,78]. Potassium iodide was widely used in Poland following the 1986 Chernobyl accident and childhood thyroid cancer rates did not increase substantially in subsequent years [79]. In areas where iodide prophylaxis was not used, such as Belarus and Ukraine, where many children were mildly iodine deficient, the incidence of thyroid cancer sharply increased among children and adolescents [77].  
  
Health Risks from Excessive Iodine  
High intakes of iodine can cause some of the same symptoms as iodine deficiency including goiter, elevated TSH levels, and hypothyroidism because excess iodine in susceptible individuals inhibits thyroid hormone synthesis and thereby increases TSH stimulation, which can produce goiter [2,80]. Iodine-induced hyperthyroidism can also result from high iodine intakes, including when iodine is administered to treat iodine deficiency. Studies have also shown that excessive iodine intakes cause thyroiditis and thyroid papillary cancer [2,80]. Cases of acute iodine poisoning are rare and are usually caused by doses of many grams. Acute poisoning symptoms include burning of the mouth, throat, and stomach; fever; abdominal pain; nausea; vomiting; diarrhea; weak pulse; and coma [2].  
  
Responses to excess iodine and the doses required to cause adverse effects vary [81]. Some people, such as those with autoimmune thyroid disease and iodine deficiency, may experience adverse effects with iodine intakes considered safe for the general population [2,5].  
  
The FNB has established iodine ULs for food and supplement intakes (Table 3). In most people, iodine intakes from foods and supplements are unlikely to exceed the UL [2]. Long-term intakes above the UL increase the risk of adverse health effects. The ULs do not apply to individuals receiving iodine for medical treatment, but such individuals should be under the care of a physician [2].  
  
Table 3: Tolerable Upper Intake Levels (ULs) for Iodine [2]  
Age Male Female Pregnancy Lactation  
Birth to 6 months Not possible to establish\* Not possible to establish\*  
7 12 months Not possible to establish\* Not possible to establish\*  
1 3 years 200 mcg 200 mcg  
4 8 years 300 mcg 300 mcg  
9 13 years 600 mcg 600 mcg  
14 18 years 900 mcg 900 mcg 900 mcg 900 mcg  
19+ years 1,100 mcg 1,100 mcg 1,100 mcg 1,100 mcg  
\* Formula and food should be the only sources of iodine for infants.  
  
Interactions with Medications  
Iodine supplements have the potential to interact with several types of medications. A few examples are provided below. Individuals taking these medications on a regular basis should discuss their iodine intakes with their health care providers.  
  
Antithyroid medications  
Antithyroid medications, such as methimazole (Tapazole), are used to treat hyperthyroidism. Taking high doses of iodine with antithyroid medications can have an additive effect [81] and could cause hypothyroidism.  
  
Angiotensin-converting enzyme inhibitors  
Angiotensin-converting enzyme (ACE) inhibitors, such as benazepril (Lotensin), lisinopril (Prinivil and Zestril), and fosinopril (Monopril), are used primarily to treat high blood pressure. Taking potassium iodide with ACE inhibitors can increase the risk of hyperkalemia (elevated blood levels of potassium) [81].  
  
Potassium-sparing diuretics  
Taking potassium iodide with potassium-sparing diuretics, such as spironolactone (Aldactone) and amiloride (Midamor), can increase the risk of hyperkalemia [81].  
  
Iodine and Healthful Diets  
The federal government s 2020 2025 Dietary Guidelines for Americans notes that Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy).   
  
For more information about building a healthy dietary pattern, refer to the Dietary Guidelines for Americansexternal link disclaimer and the USDA s MyPlate.external link disclaimer  
  
The Dietary Guidelines for Americans describes a healthy dietary pattern as one that  
  
Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.  
Milk and milk products contain iodine.  
Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.  
Some fish contain high amounts of iodine. Eggs are also good sources of iodine.  
Limits foods and beverages higher in added sugars, saturated fat, and sodium.  
Limits alcoholic beverages.  
Stays within your daily calorie needs.  
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