Some Subgroups of Reproductive Age Women in the United States May Be at Risk for Iodine Deficiency

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Abstract

Consuming an adequate amount of iodine during pregnancy is critical for fetal neurologic development. Even a mild deficiency can impair cognitive ability. Important sources of iodine in the United States include dairy products and iodized salt. Although the U.S. population has traditionally been considered iodine sufficient, median urinary iodine concentrations (UIC) have decreased 50% since the 1970s. We analyzed 2001–2006 NHANES data from urine iodine spot tests for pregnant (n = 326), lactating (n = 53), and nonpregnant, nonlactating (n = 1437) women of reproductive age (15–44 y). We used WHO criteria to define iodine sufficiency (median UIC: 150–249 μg/L among pregnant women; ≥100 μg/L among lactating women; and 100–199 μg/L among nonpregnant, nonlactating women). The iodine status of pregnant women was borderline sufficient (median UIC = 153 μg/L; 95% CI = 105–196), while lactating (115 μg/L; 95% CI = 62–162) and nonpregnant, nonlactating (130 μg/L; 95% CI = 117–140) women were iodine sufficient. Dairy product consumption was an important contributor to iodine status among both pregnant and nonpregnant, nonlactating women, and those who do not consume dairy products may be at risk for iodine deficiency. Although larger samples are needed to confirm these findings, results raise concerns about the iodine status of pregnant women and women of reproductive age who are not consuming dairy products. Iodine levels among U.S. women should be monitored, particularly among subgroups at risk for iodine deficiency.

Introduction

Iodine is a trace element required by the thyroid gland to produce thyroxine and triiodothyronine, thyroid hormones necessary for multiple processes related to normal growth and development. Iodine deficiency has many adverse effects, collectively termed iodine deficiency disorders, including hypothyroidism, goiter, cretinism, stillbirths, and delayed psychomotor and cognitive development (1). The most critical period for iodine sufficiency is in utero through the first 2 y of life when maternal iodine deficiency and hypothyroidism during gestation (3). Maternal iodine deficiency and hypothyroidism have been associated with impaired cognitive and psychomotor development in offspring (4,5). Breast-fed infants are also dependent on the mother for iodine intake (6).

Globally, iodine deficiency is a major public health problem and is the greatest cause of mental retardation (7,8). The United States has primarily been considered iodine sufficient since table salt began to be voluntarily iodized in 1924 (9,10). However, today, table salt accounts for only ~15% of daily salt intake in the U.S. (11). The native content of iodine in vegetables and grains is relatively low and highly variable depending on the soil content (12). Iodine can also be found in dairy products due to iodine supplementation of cattle feed and the use of iodophor sanitizing agents for udder washes, teat dips, and cleaning milking equipment (13). The iodization of cattle feed may be done for animal health and can also be a strategy for increasing the iodine intake of the population. The iodine content of dairy products contributed by sanitizing products is usually not regulated and is a nondeliberate source of iodine. Other sources of iodine in the U.S. diet include some breads due to the use of iodate dough conditioners and some dietary supplements (14,15).

Over the past several decades, the iodine status of the U.S. population has declined by 50% from a median urinary iodine concentration (UIC) of 320 μg/L to 145 μg/L (1 μg/L = 0.079 μmol/L) according to the NHANES I (1971–1974) and NHANES II (1988–1994), respectively (16). Possible contributors to this change in iodine nutrition include decreased use of iodate dough conditioners in the baking industry, a limit set on the levels of iodine used in cattle feed, and a shift toward greater...
consumption of processed foods where salt is often not iodized (11). The FDA's Total Diet Study 2003–2004 showed that dairy products were the single largest contributor of iodine intake, accounting for 50% of total intake among adult women (17); however, this study does not account for table salt use. No researchers, to our knowledge, in the U.S. have assessed the association of dairy product intake and urinary iodine status.

Material and Methods

Data source and sample. NHANES is comprised of a complex multistage probability sampling design to collect health and nutrition data representative of the civilian, noninstitutionalized U.S. population. In 1999 a continuous data collection methodology was adopted and data were produced for 2-y cycles; sample size and power can be increased by combining 2-y cycles and combinations of 2-y cycles are still nationally representative. We combined 3 2-year cycles from 2001 to 2006. For these survey years, UIC was only measured for a random sample of one-third of the eligible NHANES sample; 1928 women of reproductive age (15–44 y) had UIC data and thus were eligible for this analysis. We excluded women who reported they had a current thyroid medical condition (n = 48), were pregnant and/or lactating (n = 46), had unknown pregnancy status (n = 48), were pregnant and ≥40 y of age (n = 3), or who had extreme or influential values for UIC (n = 2). Participants may have been excluded for more than one of these reasons, leaving a sample of 1816 women. Of these, 326 were pregnant, 53 were lactating, and 1437 were nonpregnant, nonlactating women who were also lactating and nonpregnant. We were able to obtain more stable estimates of iodine status and to examine the status of certain subgroups.

Iodine status. Spot urine samples were obtained from participants at the NHANES mobile examination center. Laboratory methods for determining iodine concentration are described elsewhere (20). Because most dietary iodine is excreted in the urine, UIC is a good indicator of recent iodine intake. Urinary iodine can vary throughout the day and between days, so median UIC of spot samples from a large representative group is the recommended measure for describing the iodine nutritional status of a population (21). We used the WHO guidelines to classify iodine nutritional status (2). A median UIC of 100–199 μg/L among nonpregnant, nonlactating women and 150–249 μg/L among pregnant women indicates iodine sufficiency. Additionally, among nonpregnant, nonlactating women, a median UIC < 50 μg/L indicates moderate to severe iodine deficiency and not >20% of this group should have a UIC below 50 μg/L. Among lactating women, a median UIC ≥ 100 μg/L is used to define iodine deficiency; no other categorizations are used for this group (2).

Dairy intake. NHANES 2001–2002 included a single 24-h dietary recall conducted at the examination when urine samples were obtained. NHANES 2003–2004 and 2005–2006 included 2 24-h dietary recalls: one at the examination and a second 2 wk later via telephone. For this analysis, we used the single 24-h recall done at the examination for all survey years. We summed all foods with a code identifying them as a dairy product to obtain total grams of dairy consumed. We categorized dairy product consumption by those who had consumed any dairy product in the previous 24 h and those who had consumed none. Given the small sample of pregnant women, we did not categorize dairy product intake among this group any further. Additionally, among nonpregnant, nonlactating women, we categorized dairy consumption into quintiles of intake.

Covariates. The sociodemographic data collected in NHANES included age, race/ethnicity, and education. Data on grain intake were obtained from the 24-h dietary recall, using the same methodology as that used for dairy product intake. Because grain consumption was very common, categorization of consumers versus nonconsumers was not useful; instead, we categorized those with greater or less than the mean intake (pregnant women: 362 g/d; nonpregnant, nonlactating women: 298 g/d). Regarding supplements, participants were asked if they had used any vitamins, minerals, or other dietary supplements within the previous 30 d. If they answered yes, product names were obtained and compared with a database containing information about vitamin and mineral content. We categorized participants as having used or not used a supplement containing iodine in the previous 30 d. Participants were asked about their frequency of table salt use. We categorized use by those who reported never or rarely using table salt and those who reported sometimes or very often used. Because of the current wording of the salt questions in NHANES, we could not determine whether the table salt being used was iodized. We categorized pregnant women by trimester of pregnancy based on reported month of pregnancy.

Results

The mean age of pregnant women was 27 y. Fifty-two percent never or rarely consumed table salt, 81% were not consuming a supplement that contained iodine, and 14% consumed no dairy products in the previous 24 h. Among nonpregnant, nonlactating women, the mean age was 30 y, 56% never or rarely consumed table salt, 79% were not consuming a supplement that contained iodine, and 20% consumed no dairy products in the previous 24 h.

Among pregnant women, the overall median UIC was 153 μg/L (Table 1), which is slightly above the WHO cutoff for sufficiency (150 μg/L) (2). Among pregnant women who had...
consumed no dairy products in the previous 24 h, median UIC was 100 μg/L compared with 163 μg/L among those who had consumed dairy products in the previous 24 h. Median UIC was also below the cutoff for iodine sufficiency among various other subgroups of pregnant women; however, there were no significant differences in median UIC among the subgroups.

The overall median UIC among nonpregnant, nonlactating women was 130 μg/L and the prevalence of this group with UIC <50 μg/L was 17%, indicating iodine sufficiency. Among nonpregnant, nonlactating women median UIC differed by age group, education, race/ethnicity, and previous day dairy product intake. Among those who had not consumed any dairy products in the previous 24 h, median UIC was 106 μg/L compared with 136 μg/L among dairy product consumers. The proportion of nonpregnant, nonlactating women with UIC < 50 μg/L differed by age group and race/ethnicity. Overall median UIC among the 53 lactating women was 115 μg/L, indicating iodine sufficiency (>100 μg/L).

When stratifying dairy product intake of nonpregnant, nonlactating women into quintiles, median UIC were lesser among women in the lowest 2 quintiles of consumption compared with those in the highest 2 quintiles (P < 0.01; Fig. 1). The median UIC among nonpregnant, nonlactating women with no or low dairy product consumption was just above the cutpoint of 100 μg/L for sufficiency.

In multiple linear regression analyses, dairy product intake was significantly associated with iodine status among both pregnant and nonpregnant, nonlactating women (Table 2). Based on this model, for every 100 g/d increase in dairy product intake (the equivalent of ~100 mL of milk) among pregnant women, there was an increase in UIC of 7%, controlling for all other variables in the model. Among pregnant women, the only significant covariate was a positive association between having earned a high school diploma (compared with having less than a high school diploma).
Discussion

Our results confirm that iodine nutrition among U.S. women of reproductive age has not continued to decline, but has leveled off since NHANES III (1988–1994). The iodine status of pregnant women is just above the cutoff for sufficiency; multiple subgroups of pregnant women had median UIC below the cutoff for sufficiency, although sample sizes were often small and these values did not differ significantly from other groups. Given the critical role of iodine in fetal neurologic development and the status of pregnant women at the very low end of the range indicating iodine sufficiency, continued analysis of urinary iodine by NHANES and monitoring of the iodine status of this group is essential. Although overall nonpregnant, nonlactating women were iodine sufficient, median UIC among some subgroups, including women with little or no dairy intake and greater than a high school education, were on the lower end of the range used to classify sufficiency (100–199 μg/L). Because the requirement for iodine approximately doubles during pregnancy and lactation (24,25), it is likely that many of these women, should they become pregnant, would not be iodine sufficient without increasing their iodine intake. In fact, iodization programs in several countries that were sufficient for the general population were insufficient for pregnant and lactating women (26,27).

Due to the increased need for iodine during pregnancy and lactation and some data showing that some women in these groups may not be consuming adequate iodine, the American Thyroid Association in 2006 recommended that all pregnant and lactating women in the U.S. and Canada take a supplement containing iodine (28). Our results support the need to ensure adequate iodine intake among pregnant and lactating women; however, it is unclear if the best public health strategy is to encourage taking supplements. Although the majority of pregnant women in the U.S. do take some type of prenatal vitamin or supplement, many of these supplements do not contain iodine (15), and for those that do, the iodine content often differs from the amount listed on the label (29). We found only ~20% of pregnant and nonpregnant, nonlactating women were taking supplements that contain iodine. This estimate was based on any use in the previous 30 d, which is not likely to be a sufficient frequency to ensure adequate iodine status. The prevalence would likely have been much lower with a definition that required more frequent use. This loose definition of use is likely one of the reasons we did not find an association between

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**TABLE 2** Association of urinary iodine concentration with sociodemographic and lifestyle factors among pregnant women and nonpregnant, nonlactating women of reproductive age (15–44 y), NHANES 2001–2006

<table>
<thead>
<tr>
<th></th>
<th>Pregnant, n = 296</th>
<th>Nonpregnant, nonlactating, n = 1338</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate¹ 95% CI</td>
<td>Estimate¹ 95% CI</td>
</tr>
<tr>
<td>Intercept</td>
<td>4.59 3.86, 5.32</td>
<td>5.02 4.72, 5.32</td>
</tr>
<tr>
<td>Dairy intake,² per 100 g/d</td>
<td>0.07 0.03, 0.11</td>
<td>0.05 0.03, 0.08</td>
</tr>
<tr>
<td>Grain intake,² per 100 g/d</td>
<td>−0.01 −0.07, 0.05</td>
<td>−0.02 −0.05, 0.01</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.01 −0.01, 0.04</td>
<td>−0.01 −0.02, −0.001</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; High school</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>High school diploma</td>
<td>0.42 0.01, 0.83</td>
<td>0.01 −0.17, 0.19</td>
</tr>
<tr>
<td>&gt; High school</td>
<td>−0.01 −0.35, 0.34</td>
<td>−0.19 −0.33, −0.05</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>0.03 −0.32, 0.37</td>
<td>0.12 −0.01, 0.25</td>
</tr>
<tr>
<td>Mexican-American</td>
<td>0.17 −0.18, 0.52</td>
<td>0.24 0.08, 0.39</td>
</tr>
<tr>
<td>Other</td>
<td>−0.05 −0.63, 0.53</td>
<td>0.11 −0.12, 0.34</td>
</tr>
<tr>
<td>Salt use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never/rarely</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Sometimes/very often</td>
<td>−0.06 −0.29, 0.17</td>
<td>−0.01 −0.12, 0.12</td>
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<td>Supplement with iodine</td>
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<td></td>
</tr>
<tr>
<td>No</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Yes</td>
<td>−0.03 −0.33, 0.26</td>
<td>0.27 0.11, 0.44</td>
</tr>
<tr>
<td>Trimester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Second</td>
<td>−0.16 −0.52, 0.21</td>
<td>Reference</td>
</tr>
<tr>
<td>Third</td>
<td>−0.25 −0.62, 0.11</td>
<td>—</td>
</tr>
</tbody>
</table>

¹ Values are estimates from separate linear regression analyses for pregnant women, and nonpregnant, nonlactating women. The dependent variable is the natural log of urinary iodine. R² = 0.18 for pregnant women and R² = 0.08 for nonpregnant, nonlactating women.

² The change in UIC associated with a 1 g/d change in dairy product or grain intake is not very meaningful. We expressed dairy product or grain intake per 100 g/d of these products. The point estimates can be interpreted as the change in the natural log of UIC expected per 100 g/d increase in dairy product and grain intake.

high school education) and iodine status. Among nonpregnant, nonlactating women, for every 100 g/d increase in dairy product intake, there was an increase in UIC of 5%. Among this group of women, age was inversely associated with iodine status, as was having more than a high school education (compared with less than a high school education). Being Mexican-American (compared with non-Hispanic white) and taking a supplement with iodine were positively associated with UIC.
supplement use and iodine status among pregnant women. Another reason supplements may not be the ideal strategy for ensuring iodine status among pregnant women is that one-half of all pregnancies in the U.S. are unplanned, and the increased need for iodine intake for fetal brain development begins before many women may know they are pregnant (3,30).

To address the iodine needs of the population, the United States began fortifying table salt in the 1920s. However, today most salt in the U.S. diet comes from processed foods rather than added table salt and most of it is not iodized (31,32). In this analysis, approximately one-half of the women reported they never or rarely added table salt to their food. Given changes in dietary habits, including greater intake of processed foods and more foods being consumed away from home (33), new strategies may be needed to ensure sufficient iodine intake among all women of reproductive age. Our results confirm that dairy products are an important contributor to iodine status among both pregnant and nonpregnant women of reproductive age in the United States. The natural iodine concentration of milk is rather low; however, supplementing cattle feed with iodine and the use of iodophors as disinfectants in the milking process can increase the iodine content of dairy products (34,35). Several countries have successfully used mandatory iodine fortification of cattle fodder to ensure adequate iodine nutrition of the population (36). The USDA has set a limit on the amount of iodine that can be supplemented in cattle feed, but the use of iodophor disinfectants is not regulated or monitored in the U.S. Thus, the levels of iodine present in dairy products in the U.S. can vary substantially and it is unclear how much of the iodine comes from supplemented cattle feed versus the use of iodophor disinfectants. The accidental contribution of iodine to dairy products through iodophor disinfectants is an important source of dietary iodine in many countries (12,37,38). Australia is an example of a country that was iodine sufficient for decades until changes in dairy industry practices inadvertently reduced the iodine content of dairy products, contributing to iodine deficiency among the population (39). While dairy plays such an important role in iodine nutrition, increased monitoring of iodine levels among the population, as well as increased understanding of the sources and levels of iodine in dairy, is warranted. It is concerning that an important source of iodine in the U.S. diet partially occurs by accident and is susceptible to change with little notice.

This analysis has several limitations. Urinary iodine concentrations are highly variable and represent recent intake rather than usual intake. Due to this variation, a sample of 100 spot urine tests is needed to produce estimates of urinary iodine with a precision range of $\pm 10\%$, and a sample of 500 is needed for a precision range of $\pm 5\%$ (40). A major weakness of this analysis is that sample sizes of lactating women and stratified groups of pregnant women were small, and estimates of iodine among these groups should be interpreted with caution. Additionally, a single 24-h dietary recall does not capture usual dietary intake. However, given that UIC is reflective of recent iodine intake, it was important to have 24-h recalls that were conducted at the time urine samples were obtained to assess the association between dairy product intake and iodine status. Information regarding supplements and salt use did not necessarily indicate recent intake and we were unable to determine whether the table salt used was iodized, which may explain why we did not find consistent associations between these factors and iodine status. The strengths of this study include that these recent data are the only source of nationally representative estimates of iodine status among pregnant, lactating, and nonpregnant/nonlactating women of reproductive age in the United States and that we could control for multiple factors in our regression models.

Based on our findings, there may be subgroups of pregnant and reproductive age women in the U.S. who are at risk for iodine deficiency. Continued monitoring of iodine levels among U.S. women of reproductive age is essential, including among larger samples of pregnant women, to confirm whether certain subgroups are iodine deficient. Additionally, further research is needed to explore determinants of iodine nutrition among pregnant and lactating women and how iodine status changes throughout pregnancy.

**Acknowledgments**

C.G.P. and K.H. conducted the analysis; C.G.P. drafted the manuscript; and C.G.P., K.H., M.K.S., and K.M.S. all contributed to the analytic design and reviewed and approved the final manuscript.

**Literature Cited**


