The Journal of Nutrition
Nutritional Epidemiology

Intakes of Dairy Products and Dietary Supplements Are Positively Associated with Iodine Status among U.S. Children[1,2]

Cria G. Perrine,[3,5]* Kevin M. Sullivan,[3,6] Rafael Flores,[3] Kathleen L. Caldwell,[4]
and Laurence M. Grummer-Strawn[3,5]

Divisions of [3]Nutrition, Physical Activity, and Obesity and [4]Laboratory Sciences, Centers for Disease Control and Prevention, Atlanta, GA; [5]U.S. Public Health Service Commissioned Corps, Atlanta, GA; and [6]Rollins School of Public Health, Emory University, Atlanta, GA

Abstract

Although pregnant women and some groups of reproductive-age women in the US may be at risk of iodine deficiency, data also suggest that iodine intake among many U.S. children may be above requirements. Our objective was to describe the association of iodine sources with iodine status among children. We analyzed 2007–2010 NHANES data of urine iodine concentration (UIC) spot tests for children aged 6–12 y (n = 1553) and used WHO criteria for iodine status (median UIC: 100–199 μg/L = adequate; 200–299 μg/L = above requirements; ≥300 μg/L = excess). The overall median UIC was above requirements for children aged 6–12 y [211 μg/L (95% CI: 194, 228 μg/L)]. Median UIC increased by quartile of previous day dairy intake, ranging from adequate in the lowest quartile [157 μg/L (95% CI: 141, 170 μg/L)] to above requirements in the highest quartile [278 μg/L (95% CI: 252, 336 μg/L)]. Median UIC was 303 μg/L (95% CI: 238, 345 μg/L) among the 17% of children who had taken a dietary supplement containing iodine the previous day, compared with 198 μg/L (95% CI: 182, 214 μg/L) among those who had not. In adjusted regression analyses, recent dairy intake and recent supplement use were significantly positively associated with UIC levels, whereas recent grain intake was negatively associated. Adding salt to food at the table was not associated with UIC. Iodine-containing supplements are likely not needed by most schoolchildren in the US because dietary iodine intake is adequate in this age group. J. Nutr. 143: 1155–1160, 2013.

Introduction

Iodine is a required component of thyroid hormones and is necessary for growth and development. Because of iodine's critical role in fetal and early-childhood neurocognitive development, pregnant and lactating women and children <2 y of age are the primary groups targeted by efforts to ensure iodine sufficiency (1). Since the introduction of voluntary salt iodization programs in the 1920s, the overall iodine status of the U.S. population has generally been considered sufficient or even in excess of requirements (2). Urine iodine concentration (UIC) from spot urine samples is the most common indicator used for assessing the iodine status of populations (1). To monitor the iodine status of the U.S. population, the NHANES measures UIC among a representative sample of residents aged >6 y. From NHANES I (1971–1974) to the present, iodine levels in NHANES have decreased by ~50% (2,3). Although the median iodine concentration in the U.S. population is still considered sufficient despite this decrease, some data suggest that iodine intake among pregnant women may be insufficient, whereas iodine intake among school-age children (6–12 y) may be above requirements (3,4). The RDA for iodine is 90 μg/d for children aged 1–8 y and 120 μg/d for children aged 9–13 y (5).

Sources of iodine in the US include the following: dairy products, due to the use of iodine-containing cleaning products used in the milking process and iodine added to animal feed; grains and breads, because iodine can occur naturally in crops grown in iodine-rich soils or be added through the use of iodate-dough conditioners; table salt, ~70% of which is estimated to be iodized by voluntary iodization programs; marine fish, other seafood, and some seaweeds; and some dietary supplements (6–8). However, estimating people's iodine intake is complicated by substantial variation in the iodine content of foods. Because of this variation, the USDA food-composition tables, which are frequently used to estimate nutrient intake on the basis of reported food intake, do not contain data on the iodine content of U.S. foods (9). The only national data that can be used to estimate U.S. iodine intake are from the FDA's Total Diet Study (TDS), which measures iodine in samples of >250 foods from 3 locations in each of 4 regions. TDS data for 2003–2004 showed that dairy products were the single largest contributor to total iodine intake in all age-sex groups examined, other than infants, accounting for 70% of iodine intake among children aged 6 and 10 y, and that grains accounted for ~15% of iodine intake among these children.

---

[1] Author disclosures: C. G. Perrine, K. M. Sullivan, R. Flores, K. L. Caldwell, and L. M. Grummer-Strawn, no conflicts of interest.

[2] The findings in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

* To whom correspondence should be addressed. E-mail cperrine@cdc.gov.

Manuscript received February 21, 2013. Initial review completed March 19, 2013. Revision accepted April 28, 2013.
First published online May 22, 2013; doi:10.3945/jn.113.176289.

However, TDS data do not reflect iodine intake from table salt or dietary supplements (10).

Previously, we described dairy products as an important contributor to iodine status among pregnant and reproductive age women in the US (4). Public health interventions that aim to ensure iodine sufficiency among pregnant and reproductive-age women must also be aware of the potential for excess intake of iodine among children. In this study, we sought to describe contributors to iodine intake among U.S. children aged 6–12 y, the group whose iodine status the WHO has recommended for monitoring (1).

Methods

Sample population. The source of our study sample, NHANES, uses a complex multistage probability sampling design to collect health and nutrition data representative of the civilian, noninstitutionalized U.S. population. In 1999, NHANES adopted a continuous data collection methodology, which it uses to report data in 2-y cycles. For this study, we combined data for 2007–2008 and 2009–2010. During most 2-y cycles, NHANES measures UIC of only a third of participants aged >6 y; however, in 2007–2008, it measured the UIC of the entire eligible NHANES sample. No ethical approval was required because this was secondary data analysis of publicly available, de-identified NHANES data.

Iodine status. Our estimates of iodine status were based on analyses of spot urine samples obtained from children at the NHANES mobile examination center. UIC was measured with an inductively coupled plasma dynamic-reaction cell mass spectrometer (ELAN DRC Plus; PerkinElmer Instruments) (11). The WHO recommends assessing the median UIC of spot samples from a large representative group and provides cutoffs for describing the iodine nutritional status of a population using this measure. Among children, a median UIC <100 μg/L indicates insufficient iodine intake, 100–199 μg/L is adequate, 200–299 μg/L is above requirements, and ≥300 μg/L represents excess intake. The WHO additionally recommends that no more than 20% of the population should have UIC values <50 μg/L (1).

Contributors to iodine intake. Since 2003–2004, NHANES has included two 24-h dietary recall interviews: one at the mobile examination center and a second 3–10 d later via telephone. In this analysis, we used data from only the first recall interview because it was conducted at the same time that participants' urine spot specimen was collected, and UIC is an indicator of iodine intake in the previous 1–2 d (1). NHANES conducted proxy-assisted (with help from a parent or guardian) recall interviews for children aged 6–11 y and direct interviews with children aged 12 y. We used food codes to categorize foods into 9 major consumption categories defined by the USDA Food Coding Scheme; these categories included "milk and milk products" (from here on referred to as "dairy products") and "grain products" (12). We did not include fish consumption in this analysis because fish consumption is generally low among children in the US, and in the TDS meat, fish, and poultry together accounted for only 2% of iodine intake among children (10,13). We summed all foods with a code identifying the food as a dairy product to obtain total grams of dairy consumed in the previous 24 h; the same process was repeated for grain products. We categorized dairy product consumption as any versus none, as well as by quartile of intake. We were not able to categorize grain product consumption as any versus none because 99% of children had consumed grain products in the previous 24 h. Instead, we categorized grain product consumption as above or below the median (262 g), as well as by quartile of intake.

Beginning in the 2007–2008 cycle, NHANES has included a 24-h supplement recall at the same time as the dietary recall. If children reported taking a supplement in the previous 24 h, product names were obtained and compared with a database containing information about vitamin and mineral content. We categorized participants as having consumed or not consumed a supplement containing iodine in the previous 24 h.

We categorized children's table salt use as never/rarely versus occasionally/very often on the basis of respondents' answers to a question about how frequently children added salt to food at the table. However, this question did not distinguish between iodized and noniodized salt.

Covariates. The covariates in our study were age (6–8 or 9–12 y), sex, and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or other). The "Hispanic" group was a combination of 2 NHANES racial/ethnic groups, "Mexican American" and "Other Hispanic."

Statistical analyses. Of 1668 NHANES participants aged 6–12 y with UIC data, we excluded from our analyses 4 children who reported having a current thyroid medical condition or were taking a thyroid medication and 111 children with missing data on dairy or grain product intake, supplement use, or salt use, leaving us with a final analytic sample of 1553 children. Children excluded from the analysis did not differ in race/ethnicity, age, sex, or UIC compared with those included in the analysis.

We used SAS 9.2 (SAS Institute) and SUDAAN version 10 (Research Triangle Institute) to calculate weighted estimates for median UIC and proportion of children with UIC <50 μg/L. Sample weights for UIC data were used, which accounted for the complex survey design and difference in UIC sampling. NHANES does not recommend presenting estimates for the "other" racial/ethnic group, so these data were suppressed, but the "other" racial/ethnic group is included in the overall and other stratified analyses (14). As recommended by NHANES, a relative SE of 30% was used to assess estimate reliability (14). SAS and SUDAAN are unable to give *P* values for comparing medians of groups while accounting for complex survey design, so we estimated differences in median UIC indirectly by categorizing individuals as above or below the overall median and conducting a χ^2 analysis to test the null hypothesis that all subgroups have the same median.

We also conducted linear regression analyses to assess whether consumption of dairy products, grain products, or supplements within the previous 24 h or regular salt use were significant independent predictors of UIC. UIC data were right skewed, but followed a normal distribution after natural log transformation, and we used the transformed variable as the dependent variable. Dairy product and grain product intake were expressed as continuous variables per 100 g/d (the equivalent of ~100 mL of milk or ~3 slices of bread) to aid interpretability (9). All 4 primary predictors were included in the model, as well as the study covariates (race/ethnicity, age, and sex). We tested 2-way interactions between each of the primary predictors and sex and race; however, because no interaction terms had a *P* value <0.05, we dropped all interaction terms from the model. We detected no collinearity among predictors or covariates.

Results

Slightly more than half of children were non-Hispanic white, 22.0% were Hispanic, and 14.1% were non-Hispanic black (**Table 1**). Most children had consumed some dairy products in the previous 24 h (87.6%), whereas nearly all had consumed some grain products (99.2%). Among those who had consumed dairy products, median dairy intake was 331 g, and among those who had consumed grain products, median grain intake was 270 g. The use of a supplement in the previous 24 h that was identified as containing iodine was reported by 16.5% of the sample, and 28.3% reported "occasionally/very often" adding salt to their food at the table.

The estimated median UIC among all children aged 6–12 y was 211 μg/L (**Table 2**). Results of our bivariate analyses showed that the median UIC varied significantly by dairy intake, supplement use, race/ethnicity, and age, but not by grain intake, table salt use, or sex. For nearly all subgroups analyzed, median UIC was adequate or above requirements; no subgroups had median UIC values categorized as insufficient, and only the

TABLE 1 Select sample characteristics of children aged 6–12 y, NHANES 2007–2010[1]

Characteristic	Value
Race/ethnicity, *%*	
Non-Hispanic white	56.3
Non-Hispanic black	14.1
Hispanic	22.0
Other	7.6
Males, *%*	51.3
Any dairy products consumed yesterday, *%*	87.6
Among consumers, median dairy products consumed, *g*	331
Any grain products consumed yesterday, *%*	99.2
Among consumers, median grain products consumed, *g*	270
Supplement containing iodine yesterday, *%*	16.5
Occasionally/very often use table salt, *%*	28.3

[1] Values are weighted estimates of prevalence or median, *n* = 1553.

group taking a supplement containing iodine in the previous 24 h had a median UIC just above the cutoff for excess intake (median UIC = 303 μg/L).The proportion of children with UIC concentrations <50 μg/L was 5.4%. This proportion was higher in females, those not taking a supplement containing iodine, and in children aged 9–12 y. Among all subgroups categorized, this proportion was never higher than 10%.

Median UIC increased by quartile of dairy product intake, from 157 μg/L in the lowest quartile to 278 μg/L in the highest quartile ($P < 0.001$; **Fig. 1***A*). However, median UIC did not vary by quartile of grain intake ($P = 0.2$; Fig. 1*B*).

In linear regression analyses adjusting for all primary predictors of interest and covariates (**Table 3**), dairy product intake and supplement use were positively associated with UIC, whereas grain product intake and being non-Hispanic black were inversely associated with UIC. Based on this model, for every 100-g/d increase in dairy product intake, there is an increase in UIC of 5%, controlling for all other variables; on the other hand, for every 100-g/d increase in grain intake, UIC decreased by 3%. Taking a supplement containing iodine in the previous 24 h increased UIC by 23%, controlling for all other variables.

Discussion

Our results indicate it is unlikely that there is iodine deficiency among children aged 6–12 y in the US. Among all of the subgroups examined, median UIC was consistently categorized as adequate or above adequate, and the proportion of children with UIC <50 μg/L was always <10%. Because we found dairy products and dietary supplements to be important sources of iodine among children, we additionally explored the iodine status among children who had consumed neither in the

TABLE 2 Median UIC and prevalence of UIC <50 μg/L among U.S. children aged 6–12 y, NHANES 2007–2010[1]

	n	Median UIC[2]	95% CI	*P* value[3]	Prevalence of UIC <50 μg/L[2]	95% CI	*P* value[3]
		μg/L	*μg/L*		*%*	*%*	
Total	1553	211	194, 228	—	5.4	3.7, 7.7	—
Dairy intake previous day							
Yes	1341	221	200, 235	0.002	4.9	3.2, 7.2	0.16
No	212	161	142, 200		9.0	4.6, 16.9	
Grain intake previous day							
≥Median g/d	777	196	171, 223	0.10	6.3	3.8, 10.3	0.26
<Median g/d	776	221	201, 245		4.4	3.0, 6.5	
Supplement with iodine							
Yes	184	303	238, 345	<0.001	1.6[4]	0.6, 4.1	<0.001
No	1369	198	182, 214		6.1	4.3, 8.7	
Table salt use							
Occasionally/very often	360	219	195, 238	0.60	5.0	3.3, 7.3	0.53
Never/rarely	1193	208	182, 230		6.4	3.1, 12.8	
Race/ethnicity[5]							
Non-Hispanic white	456	230	207, 276	0.001	3.9	2.0, 7.5	0.11
Non-Hispanic black	396	165	148, 182		9.1	6.1, 13.5	
Hispanic	619	208	184, 232		6.3	4.3, 9.2	
Age							
6–8 y	678	234	204, 270	0.04	3.3	2.3, 4.7	0.01
9–12 y	875	194	176, 215		6.9	4.5, 10.5	
Sex							
Male	782	213	193, 238	0.55	3.0	1.8, 4.8	<0.001
Female	771	208	181, 226		7.9	5.5, 11.2	

[1] UIC, urinary iodine concentration.

[2] Values are weighted estimates.

[3] *P* values for comparison of median UIC by sociodemographic and behavioral characteristics are derived from a chi-square test comparing whether the proportion above or below the overall median differs by these groups. *P* values for comparison of proportions with UIC <50 μg/L are derived from a chi-square test.

[4] The relative SE for this estimate is >30%, suggesting that the estimate may not be stable (14).

[5] NHANES does not recommend presentation of estimates for the ''Other'' racial/ethnic group, so these data have been suppressed (14).

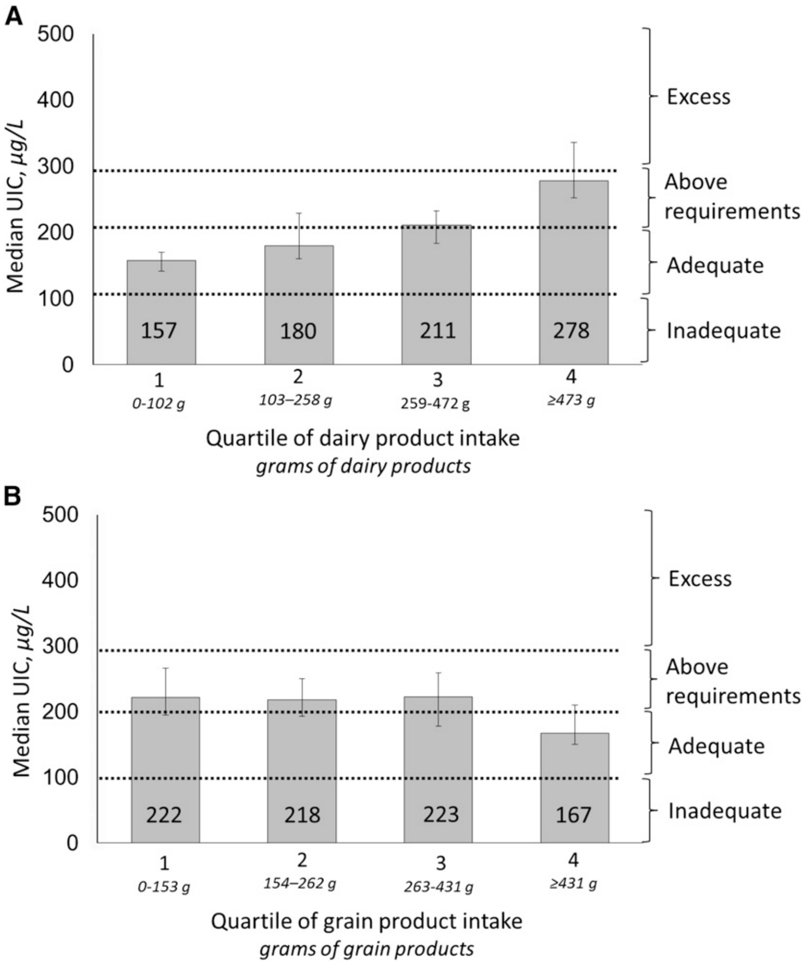

FIGURE 1 Median urine iodine concentration (UIC) among children aged 6–12 y by (*A*) quartile of dairy product intake and (*B*) quartile of grain product intake in the previous 24 h (NHANES 2007–2010). UIC varied by quartile of intake of dairy products ($P < 0.001$), but not by quartile of intake of grain products ($P = 0.2$). Error bars represent 95% CIs. *Dotted lines* show the WHO cut-points for categorization of iodine status.

previous 24 h: this included 10.5% of children in our sample, who had adequate iodine status (median UIC = 150 μg/L). This finding is reassuring, because although data are limited, some evidence suggests that even mild iodine deficiency may impair a child's cognitive development. A recent iodine supplementation trial in New Zealand showed that mildly iodine-deficient children improved their scores on picture concepts and matrix reasoning tests after they began taking iodine supplements (15).

We found several subgroups of children whose median UIC was categorized as above requirements. The meaning of this term is difficult to interpret from the public health perspective. This range of median UIC, 200–299 μg/L, is generally considered to increase the risk of iodine-induced hyperthyroidism among populations with long-standing iodine deficiency who then experience a rapid increase in iodine intake (1). Given that the U.S. population has had an adequate iodine status since the 1920s, this situation is not applicable in the US. Otherwise, median UIC values of up to 300 μg/L are generally considered safe (1,16). Results of a study in children aged 6–12 y from 5 continents showed that although median UIC values >500 μg/L were associated with increased thyroid volume, concentrations up to 500 μg/L were generally well tolerated by healthy children (17).

The only subgroup of children with a median UIC in the excessive range were those who had consumed a supplement containing iodine during the previous day, and median UIC in this group was just above the cutoff for excess (median UIC: 303 μg/L; excess is >300 μg/L). We found that 16.5% of children had consumed a supplement containing iodine in the previous 24 h. We were surprised at this relatively high proportion, which likely would have been even higher with a longer recall period. An analysis of NHANES data for 2003–2006 showed that 43% of children aged 4–8 y and 29% of children aged 9–13 y had taken some type of supplement in the previous 30 d and that 32% and 20%, respectively, had taken a multivitamin-multimineral supplement (18). This analysis did not report the type of supplements that children were taking (e.g., children's vitamin, general multivitamin). Among children in our analysis who had consumed a supplement containing iodine in the previous day, median intake was 66 μg, representing 73% of the RDA for children aged 6–8 y and 55% of the RDA for children aged 9–12 y. Given current dietary intake patterns of children, particularly dairy consumption, and the use of iodine-containing cleaning agents in the dairy production process, few children in the US are likely to need a supplement containing iodine.

In bivariate analyses, grain product intake was not associated with UIC, whereas in the adjusted model, grain product intake was inversely associated with UIC. It is unclear why we found this inverse association. One possible explanation could be that high grain product consumption displaced other, better sources of iodine. Additionally, the amount of iodine in grain products can vary substantially (8), and grain product intake from 24-h dietary recalls may not be a good measure of iodine intake. The regular use of table salt was not associated with UIC. Information on 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 an association between salt use and iodine status. Iodization of salt in the US is voluntary, and

TABLE 3 Association of UIC with dietary and demographic factors among children aged 6–12 y, NHANES 2007–2010[1]

	Estimate[2]	95% CI	*P* value
Intercept	5.57	4.99, 6.15	<0.001
Dairy product intake (per 100 g/d)	0.05	0.03, 0.07	<0.001
Grain product intake (per 100 g/d)	−0.03	−0.05, −0.01	0.004
Supplement with iodine yesterday			
Yes	0.23	0.14, 0.37	<0.001
No	Reference	—	—
Frequency of table salt use			
Occasionally/very often	0.03	−0.13, 0.15	0.73
Never/rarely	Reference	—	—
Race/ethnicity[3]			
Non-Hispanic white	Reference	—	—
Non-Hispanic black	−0.26	−0.40, −0.11	<0.001
Hispanic	−0.07	−0.21, 0.08	0.37
Age			
6–8 y	0.10	−0.08, 0.28	0.28
9–12 y	Reference	—	—
Sex			
Male	Reference	—	—
Female	−0.05	−0.13, 0.03	0.24

[1] UIC, urinary iodine concentration.

[2] Weighted estimates are β-coefficients from a linear regression model in which natural log-transformed UIC was the dependent variable.

[3] NHANES does not recommend presentation of estimates for the ''Other'' racial/ethnic group, so these data have been suppressed (14).

whereas it has been estimated that ~70% of table salt in the US is iodized, it is not clear how valid this estimate is. Additionally, the majority of the salt consumed in the US is from processed and restaurant foods, not from table salt, and this salt is typically not iodized (19–21).

This analysis has several limitations. UIC values and single 24-h dietary recalls can both be highly variable and do not capture usual intake. However, because UIC is reflective of recent iodine intake, it was important to use only the 24-h recall conducted at the time urine samples were collected in order to assess the association between dairy intake and iodine status. Because iodine is not included in the USDA nutrient database we are unable to quantify iodine consumption, so instead quantified consumption of food groups known to be important contributors to iodine intake. However, the iodine content of foods included in these groups can be variable (8), and it is unknown how well these aggregate food groups capture iodine intake. UIC is generally not used as an indicator of individual iodine status, but here we used it as such in regression models to describe dietary factors associated with iodine intake. This was done to be able to adjust for other potential contributors to iodine status and demographic characteristics. Findings from the regression models were consistent with findings from bivariate analyses that used UIC as a population-level indicator. The strengths of the analysis include that we analyzed recent, nationally representative data of U.S. children and we were able to describe dietary factors that are associated with iodine status.

We found that the consumption of dairy products and the use of dietary supplements were each positively associated with UIC among U.S. children. Iodine-containing supplements are likely not needed by most schoolchildren in the US because dietary iodine intake is adequate in this age group; whether iodine should be included in supplements that are commonly consumed by children should be evaluated. Currently, there is no monitoring or regulation of the use of iodine sanitizing agents in the dairy industry, and changes in the dairy production process could lead to changes in iodine levels of dairy products, and consequentially in the iodine status of the population (22). Continued monitoring of iodine status and better understanding of the iodine content in dairy products are warranted.

Acknowledgments

C.G.P. conducted all analyses and drafted the manuscript. All authors contributed to the analytic study design, reviewed manuscript drafts, and read and approved the final manuscript.

Literature Cited

1. WHO; UNICEF; International Council for the Control of Iodine Deficiency Disorders. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for program managers. 3rd ed. Geneva: World Health Organization; 2007.
2. Hollowell JG, Staehling NW, Hannon WH, Flanders DW, Gunter EW, Maberly GF, Braverman LE, Pino S, Miller DT, Garbe PL, et al. Iodine nutrition in the United States. Trends and public health implications: iodine excretion data from National Health and Nutrition Examination Surveys I and III (1971–1974 and 1988–1994). J Clin Endocrinol Metab. 1998;83:3401–8.
3. Caldwell KL, Makhmudov A, Ely E, Jones RL, Wang RY. Iodine status of the U.S. population, National Health and Nutrition Examination Survey, 2005–2006 and 2007–2008. Thyroid. 2011;21:419–27.
4. Perrine CG, Herrick K, Serdula MK, Sullivan KM. Some subgroups of reproductive age women in the United States may be at risk for iodine deficiency. J Nutr. 2010;140:1489–94.
5. Institute of Medicine. Dietary Reference Intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington: National Academies Press; 2001.
6. Gregory CO, Serdula MK, Sullivan KM. Use of supplements with and without iodine in women of childbearing age in the United States. Thyroid. 2009;19:1019–20.
7. Dasgupta PK, Liu Y, Dyke JV. Iodine nutrition: iodine content of iodized salt in the United States. Environ Sci Technol. 2008;42:1315–23.
8. Pearce EN, Pino S, He X, Bazrafshan HR, Lee SL, Braverman LE. Sources of dietary iodine: bread, cows' milk, and infant formula in the Boston area. J Clin Endocrinol Metab. 2004;89:3421–4.
9. U.S. Department of Agriculture. National nutrient database for standard reference, release 25. 2012 [cited 2012 Nov 5]. Available from: http://www.ars.usda.gov/ba/bhnrc/ndl.
10. Murray CW, Egan SK, Kim H, Beru N, Bolger PM. US Food and Drug Administration's Total Diet Study: dietary intake of perchlorate and iodine. J Expo Sci Environ Epidemiol. 2008;18:571–80.
11. Caldwell KL, Maxwell CB, Makhmudov A, Pino S, Braverman LE, Jones RL, Hollowell JG. Use of inductively coupled plasma mass spectrometry to measure urinary iodine in NHANES 2000: comparison with previous method. Clin Chem. 2003;49:1019–21.
12. U.S. Department of Agriculture/Agriculture Research Service. Food surveys products and surveys: food coding scheme [cited 2013 Jan 24]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=12074#overview.
13. Keast DR, Fulgoni VL 3rd, Nicklas TA, O'Neil CE. Food sources of energy and nutrients among children in the United States: National Health and Nutrition Examination Survey 2003–2006. Nutrients. 2013;5:283–301.
14. National Center for Health Statistics/Centers for Disease Control and Prevention. NHANES analytic guidelines (June 2004 version). 2004 [cited 2013 Feb 14]. Available from: http://www.cdc.gov/nchs/data/nhanes/guidelines1.pdf.
15. Gordon RC, Rose MC, Skeaff SA, Gray AR, Morgan KM, Ruffman T. Iodine supplementation improves cognition in mildly iodine-deficient children. Am J Clin Nutr. 2009;90:1264–71.
16. Zimmermann MB, Aeberli I, Andersson M, Assey V, Yorg JA, Jooste P, Jukic T, Kartono D, Kusic Z, Pretell E, et al. Thyroglobulin is a sensitive measure of both deficient and excess iodine intakes in children and

indicates no adverse effects on thyroid function in the UIC range of 100–299 μg/L: a UNICEF/ICCIDD Study Group report. J Clin Endocrinol Metab. 2013;98:1271–80.

17. Zimmermann MB, Ito Y, Hess SY, Fujieda K, Molinari L. High thyroid volume in children with excess dietary iodine intakes. Am J Clin Nutr. 2005;81:840–4.
18. Bailey RL, Gahche JJ, Lentino CV, Dwyer JT, Engel JS, Thomas PR, Betz JM, Sempos CT, Picciano MF. Dietary supplement use in the United States, 2003–2006. J Nutr. 2011;141:261–6.
19. Mattes RD, Donnelly D. Relative contributions of dietary sodium sources. J Am Coll Nutr. 1991;10:383–93.
20. Centers for Disease Control and Prevention. Vital signs: food categories contributing the most to sodium consumption—United States, 2007–2008. MMWR Morb Mortal Wkly Rep. 2012;61:92–8.
21. Pearce EN. National trends in iodine nutrition: is everyone getting enough? Thyroid. 2007;17:823–7.
22. Li M, Ma G, Boyages SC, Eastman CJ. Re-emergence of iodine deficiency in Australia. Asia Pac J Clin Nutr. 2001;10:200–3.