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Urinary Iodine Concentration: United States National Health and Nutrition Examination Survey 2001–2002

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Urine iodine has been measured in the U.S. population by the National Health and Nutrition Examination Survey (NHANES) since 1971. A downward trend was noted between NHANES I (320 ± 6 μg/L in 1971–1974) and NHANES III (145 ± 3 μg/L in 1988–1994). This report presents data from NHANES 2001–2002 that indicates that the U.S. median urine iodine (UI) level has stabilized since the initial drop between NHANES I and NHANES III. The median UI concentration in the U.S. population in NHANES 2001–2002 was found to be 167.8 μg/L (95% confidence interval [CI] 159.3–177.6). The NHANES 2001–2002 data confirm the current stability of the U.S. iodine intake and continued adequate iodine nutrition for the country.

Introduction

IODINE IS AN ESSENTIAL component of the thyroid hormones, which are necessary for normal growth, development, and metabolism during gestation, infancy, and throughout life. After the introduction of iodized salt and the inclusion of iodine in other foods early in the twentieth century, iodine deficiency was eliminated in the United States (1–4). In the 1970s it was thought that thyroid diseases were more commonly associated with excessive iodine intake (5). As iodine use was reduced as a dough conditioner for bread and as a sanitizing agent and feed supplement in the dairy industry, the iodine concentration in foods and iodine intake of the American public decreased (6,7).

Iodine was measured in urine samples from probability samples designed to be representative of the United States civilian noninstitutionalized population. These samples are from participants in the National Health and Nutrition Examination Survey (NHANES) conducted by the Centers for Disease Control's (CDC) national Center for Health Statistics. NHANES is a series of surveys designed to collect data on the health and nutritional status of the U.S. population. Each stage of participant selection is randomized to ensure unbiased estimates for the United States population. A 1998 study of iodine nutrition in the United States using data from NHANES showed a decrease in median urine iodine (UI) concentration from 320 ± 6 μg/L in 1971–1974 (NHANES I) to 145 ± 3 μg/L in 1988–1994 (NHANES III) (7). With the median UI concentration greater than 100 μg/L and only 11.7% of the population excreting less than 50 μg/L, the iodine nutrition of the United States was considered adequate based on those World Health Organization (WHO) guidelines that defined population adequacy (8). The greater than 50% reduction in median UI over the 20 years between the two studies was of concern and lead to the continued monitoring of iodine nutrition through subsequent NHANES studies. In 2002, a single median value of 161 μg/L was released for the 1-year NHANES 2000 data sample. The limited number of samples analyzed for urine iodine in that 1 year (NHANES 2000) did not allow enough statistical power to provide any further detailed review beyond presenting a population median urine iodine value. However, that median value suggested that the iodine nutrition for the United States had stabilized at approximately the level seen in 1988–1994 and, after 6 years, no further decrease in iodine nutrition has been found. In this report, data for the 2 years, 2001–2002, is compared to data from previous years.

Materials and Methods

In the NHANES 2001–2002 urine was collected for iodine in one third of persons ages 6 years and over, who are sampled and weighted to represent the civilian, noninstitutionalized population of the United States (Table 1) (9). Data was collected by age, gender, and raceethnicity (non-Hispanic white, non-Hispanic black, Mexican Americans, and remaining raceethnic groups). In this analysis, all groups were included in the total numbers but because of the limited sample, the remaining race ethnic groups will have limited separate analysis.

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TABLE 1. CHARACTERISTICS OF THE POPULATIONS WITH URINE IODINE MEASURED, UNITED STATES, 1988–1994 AND 2001–2002 NHANES

1988–1994			Population			
	Sample		Total		Males	Females
Age	(n)	(%)	(n)	(%)	(%)	(%)
6 years and over	20,369	100.0	209,272,161	100.0	49.2	50.8
6 to 11 years	3,058	15.0	20,838,056	10.0	5.2	4.7
12 to 19 years	3,066	15.1	26,988,580	12.9	6.6	6.3
20 to 29 years	3,412	16.8	38,181,760	18.2	9	9.2
30 to 39 years	3,244	15.9	41,392,394	19.8	9.7	10.1
40 to 49 years	2,528	12.4	32,678,397	15.6	7.6	8.0
50 to 59 years	1,810	8.9	21,668,069	10.4	5	5.3
60 to 69 years	2,236	11.0	19,593,728	9.4	4.3	5.1
70 to 74 years	1,015	5.0	7,931,177	3.8	1.7	2.1
Ethnic groups						
Non-Hispanic white	6,825	33.5	153,240,102	73.2	36.3	36.9
Non-Hispanic black	6,375	31.3	25,447,545	12.2	5.6	6.5
Mexican American	6,278	30.8	12,740,227	6.1	3.2	2.9
Remaining ethnic groups	888	4.4	17,844,287	8.5	4.1	4.4
2001–2002						
Age	(n)	(%)	(n)	(%)	(%)	(%)
6 years and over	2,892	100.0	256,677,525	100.0	48.5	51.5
6 to 11 years	375	13.0	24,734,586	9.6	5.0	4.6
12 to 19 years	843	29.1	32,346,701	12.6	6.4	6.2
20 to 29 years	329	11.4	40,290,888	15.7	7.4	8.3
30 to 39 years	312	10.8	41,509,430	16.2	7.7	8.5
40 to 49 years	278	9.6	44,601,793	17.4	8.9	8.5
50 to 59 years	229	7.9	32,463,759	12.6	6.4	6.3
60 to 69 years	219	7.6	19,062,566	7.4	2.7	4.7
70 to 74 years	307	10.6	21,667,802	8.4	4.1	4.4
Ethnic groups						
Non-Hispanic White	1,256	43.4	178,961,572	69.7	34.0	35.7
Non-Hispanic Black	696	24.1	30,629,850	11.9	5.5	6.4
Mexican American	731	25.3	20,875,978	8.1	4.2	3.9
Remaining ethnic groups	209	7.2	26,210,125	10.2	4.8	5.4

NHANES, National Health and Nutrition Examination Survey UI, urine iodine.

Urine is a nonregulated body fluid, and the concentration of iodine may vary even if the daily internal dose were kept constant. Generally, for this reason, either 24-hour urine samples must be obtained for analysis or “spot” or “grab” samples must be corrected for dilution. In healthy populations, creatinine is excreted from the body at a relatively constant rate over time, expressing iodine results per gram of creatinine can help adjust for the effects of urinary dilution. In populations with adequate nutrition, the creatinine concentration has been used to adjust for factors that may affect the concentrations of the substances being measured during the collection period. Because 24-hour urine samples are not always logistically practical, spot samples are generally obtained in population surveys. In the NHANES studies daily iodine intake would be most closely estimated by the amount of iodine excreted in the urine in 24-hours, 24-hour collections were not logistically possible. Hollowell et al. pointed out previously that usefulness of the iodine:creatinine ratio in the United States for population iodine studies has been questioned, and concluded that there may be some evidence that fasting urine samples (not casual urine samples) may give a reasonable estimate of urinary output of iodine on a population basis (7). Because there are two different approaches (use of creatinine correction or simply expressing urine iodine per volume), we presented iodine in two ways through out this report: per volume of urine and per gram of creatinine.

Since 2000, iodine has been measured for NHANES by the Iodine Laboratory of the Division of Laboratory Sciences, National Center for Environmental Health, at the CDC using inductively coupled plasma mass spectrometry (ICP-MS), (DLS Method: Urine iodine ICPMS_ITU004A) previously described (10). The method was modified to measure UI by diluting urine samples and the urine iodide standard solutions 1+9 with 1% (v/v) tetramethylammonium hydroxide (TMAH) containing 10 μg/L tellurium (Te) for internal standardization. The iodine and Te ions were measured at m/z = 127 and m/z = 130, respectively using a PerkinElmer SCIEX ELAN 6100 Inductively Coupled Plasma-Mass Spectrometer (PerkinElmer Life and Analytical Sciences, Inc., Boston, MA). Upon comparing results of ICP-MS method at the CDC with results from the laboratory that measured UI in NHANES III, using paired samples, we found that the two methods gave results that were not statically different. We concluded that the ICP-MS iodine measurements can be compared directly with the UI data from NHANES III (1). For statistical analysis, SUDAAN (11) was used to account for the complex sample survey design using sample weights.

Results

The median UI concentration in the U.S. population in 2001–2002 was 167.8 μg/L (95% CI: 159.3–177.6). Considering the UI median values from NHANES III (1988–1994): of 144.7 μg/L (95% CI: 140.4–150.9) and the median value for NHANES (2000) of 161.6 μg/L (95% CI: 149.2–172.8), the UI excretion appears to be essentially unchanged over that period of time. The decrease seen between 1971–1974 and 1988–1994 has not continued (Fig. 1). A comparison of mean and median UI values in 1988–1994 (NHANES III) and NHANES 2001–2002 is found in Table 2. The proportion of population with UI less than 50 μg/L was 11.1% + 0.8%, the same as seen in 1988–1994 (11.7% ± 0.5% < 50 μg/L). For future comparisons, we have included proportions of persons excreting less than 20 μg/L and those excreting less than 100 μg/L (Table 3). As in the 1988–1994 survey, the groups excreting UI less than 50 μg/L more than 20% were women age 40 to 49 years (27.1% ± 5.2%) and age 50 to 59 years (21.2% ± 5.7%) For women of reproductive age (age 15 to 44 years inclusive), the proportion excreting less than 50 μg/L slightly increased, from 15.3% ± 1.2% to 16.8% ± 3.0% between the two time periods, with pregnant women increasing from 6.9% ± 1.9% to 7.3% ± 2.9% (Table 4). The pattern, when iodine excretion was adjusted for creatinine concentration, was mixed in women of reproductive age, decreasing in nonpregnant but increasing in pregnant women. Details for school-age children are found in Table 5. The proportion of the population excreting UI concentrations greater than 500 μg/L was 10.1% ± 0.8% in 2001–2002 compared with 5.6% ± 0.4% in 1988–1994, and the proportion greater than 1000 μg/L was 1.8% ± 0.3% compared to 2.1% ± 0.4% in the earlier study.

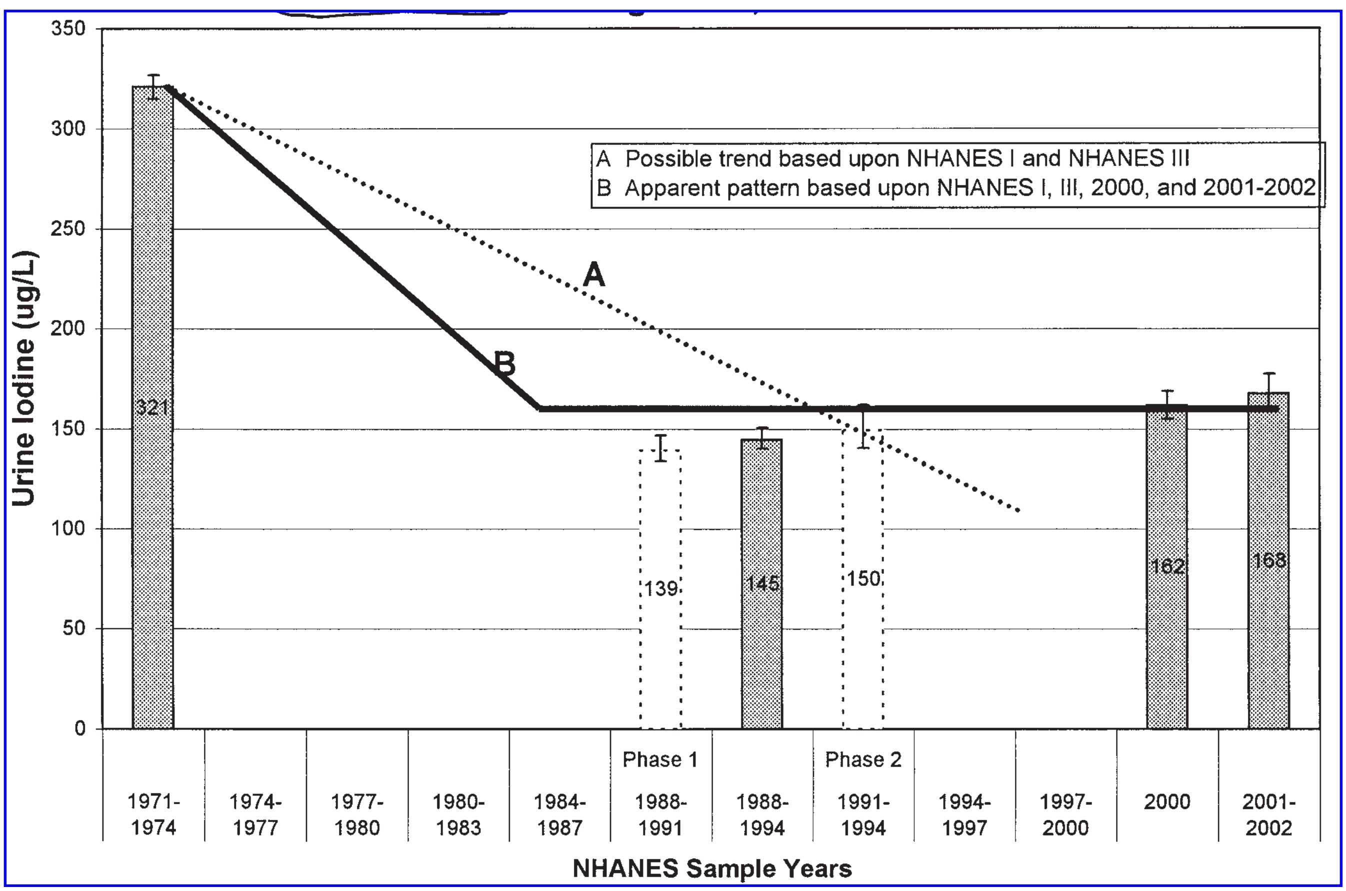

FIG. 1. Urine iodine concentration in the U.S. population National Health and Nutrition Examination Survey (NHANES) 1971–2002. The decrease in urine iodine concentration from 321 μg/L in NHANES I (1971–1974) to 145 μg/L in NHANES III 1988–1994 have not continued as suggested by the two data points (trend line A). The additional data from NHANES 2000 and NHANES 2001–2002 indicate that the change in UI concentration had probably leveled off at that time as suggested by the two phases of NHANES III (trend line B).

Table 2. Comparison Urine Iodine and Iodine Adjusted for Creatinine by Age and Gender and Date of Survey, NHANES III 1988–1994 and NHANES 2001–2002, United States

	UI (μg/L)								*I/Cr (μg/g creatinine)*							
	1988–1994				*2001–2002*				*1988–1994*				*2001–2002*			
Age	*Mean*	*SE*	*Median*	*95% CI*	*Mean*	*SE*	*Median*	*95% CI*	*Mean*	*SE*	*Median*	*95% CI*	*Mean*	*SE*	*Median*	*95% CI*
6 years and over	274.0	27.4	144.7	(140.4–150.9)	378.7	61.8	167.8	(159.2–177.6)	364.4	23.4	126.9	(121.9–132.6)	312.7	38.5	151.4	(142.2–164.3)
6 to 11 years	305.3	19.4	237.1	(219.6–253.9)	318.6	16.8	249.2	(220.5–291.9)	339.6	26.5	251.3	(239.2–269.6)	358.9	19.3	256.7	(223.7–319.9)
12 to 19 years	461.6	215.4	179.7	(170.8–195.0)	283.1	11.2	205.2	(191.5–215.1)	350.8	177.6	126.9	(118.0–135.2)	198.1	8.1	138.2	(129.7–147.8)
20 to 29 years	193.1	8.6	140.2	(134.7–149.8)	209.3	15.4	156.0	(137.6–174.7)	137.4	5.1	96.6	(90.6–103.3)	170.3	10.8	120.8	(105.9–132.9)
30 to 39 years	243.5	70.8	131.4	(122.6–141.1)	234.2	28.6	152.1	(137.8–183.1)	166.8	24.5	108.3	(104.0–113.1)	225.6	34.9	138.0	(117.5–150.2)
40 to 49 years	189.4	13.3	123.7	(115.8–131.8)	447.4	226.2	141.5	(117.4–172.0)	253.6	76.0	113.2	(109.8–118.8)	370.3	182.1	126.9	(104.3–161.2)
50 to 59 years	257.8	59.0	117.3	(110.5–126.4)	411.6	164.0	140.7	(123.5–172.3)	270.0	50.0	129.4	(121.2–140.6)	323.1	99.2	173.9	(138.7–19436)
60 to 69 years	256.5	24.3	133.0	(120.7–145.4)	580.4	316.9	154.0	(123.8–179.2)	297.3	68.6	143.2	(134.0–154.9)	450.9	166.0	182.5	(159.2–208.5)
70 to 74 years	372.1	95.3	134.7	(130.3–145.1)	822.6	426.3	197.3	(172.5–224.9)	394.0	65.7	168.6	(160.6–179.1)	620.9	137.2	227.6	(186.0–275.5)
Gender																
Male	297.0	46.8	160.0	(155.1–167.4)	440.1	105.2	196.1	(180.2–207.9)	343.2	42.6	119.1	(114.5–124.8)	316.3	70.1	144.8	(136.7–159.6)
Female	252.4	34.3	130.0	(124.8–136.8)	320.5	62.3	139.9	(126.1–153.7)	284.4	30.7	135.6	(129.3–142.3)	309.3	36.8	158.4	(147.1–169.4)
Ethnic groups																
Non-Hispanic white	290.4	36.0	141.6	(136.9–148.6)	403.7	79.0	168.8	(160.6–179.9)	287.9	32.1	130.5	(124.8–137.2)	348.0	52.2	164.3	(152.0–176.0)
Non-Hispanic black	215.8	12.8	144.2	(138.5–150.3)	447.5	202.1	142.7	(126.3–169.7)	172.3	18.8	96.8	(92.2–101.5)	247.7	87.6	103.7	(94.6–115.3)
Mexican American	276.1	16.9	183.4	(177.4–190.7)	268.8	21.5	187.2	(171.0–206.1)	251.9	15.9	156.5	(147.0–166.9)	234.1	17.8	154.5	(142.2–173.4)
Remaining ethnic groups	210.2	15.9	147.2	(128.7–166.0)	216.4	21.9	157.3	(127.1–198.3)	197.2	19.1	124.8	(113.2–141.7)	209.5	18.7	143.8	(130.1–181.7)

NHANES = National Health and Nutrition Examination Survey
SE = standard error; CI = confidence interval; UI = urine iodine; I/C_R = iodine adjusted for creatinine.

Table 3. Percent of Population with Low Urinary Iodine[a], by Age and Gender, U.S. Population, 2001–2002 NHANES

		Age (years)								
		6 and over	*6–11*	*12–19*	*20–29*	*30–39*	*40–49*	*50–59*	*60–69*	*70 and over*
		Percent of population under 20 μg/L								
Total	Sample size	2834	374	831	323	302	269	226	216	293
	Mean	1.5	0.7	1.0	1.9	0.6	1.9	3.0	2.5	0.4
	SE mean	0.2	0.6	0.5	1.1	0.5	1.1	0.9	1.4	0.3
Male	Mean	1.1	1.3	0.5	0.0	0.0	1.5	2.3	4.3	0.5
	SE mean	0.3	1.2	0.5	0.0	0.0	1.3	1.5	3.0	0.5
Female	Mean	2.0	0.0	1.5	3.6	1.1	2.4	3.8	1.4	0.4
	SE mean	0.4	0.0	0.8	2.1	1.0	1.9	1.2	1.4	0.4
		Percent of population under 50 μg/L								
Total	Mean	11.1	4.5	8.2	8.6	11.6	17.1	17.9	11.4	4.1
	SE mean	0.8	1.5	1.4	2.0	2.3	2.9	3.2	2.6	1.4
Male	Mean	6.7	2.8	4.0	4.8	6.6	7.7	14.6	6.7	4.9
	SE mean	0.9	1.8	0.8	1.8	2.5	2.3	5.1	3.3	2.0
Female	Mean	15.3	6.2	12.3	12.1	16.1	27.1	21.2	14.2	3.3
	SE mean	1.4	3.1	2.4	4.2	4.6	5.2	5.7	2.9	1.9
		Percent of population under 100 μg/L								
Total	Mean	28.4	15.9	21.2	26.1	31.1	37.6	34.4	33.0	20.8
	SE mean	1.5	1.9	1.5	2.9	2.2	3.8	3.2	4.0	2.0
Male	Mean	19.7	11.9	13.9	14.6	24.1	24.9	27.8	19.2	15.4
	SE mean	1.6	2.6	2.2	4.1	4.1	3.6	3.8	5.0	3.2
Female	Mean	36.6	20.1	28.7	36.2	37.4	51.1	41.2	41.1	25.8
	SE mean	2.4	3.2	1.8	6.3	4.6	5.4	5.7	4.1	3.7

[a]Low urinary iodines identified here are arbitrary cutoffs, < 20 μg/L, < 50 μg/L, and < 100 μg/L, that are being followed by the World Health Organization.

NHANES, National Health and Nutrition Examination Survey; SE, standard error.

Discussion

Since the report of the decrease of UI seen in 1988–1994 (7), reviews of the meaning for iodine nutrition in the United States have been mixed. Some reviews had a cautionary interpretation of the data (12,13). Using World Health Organization (WHO) guidelines (more than half the population excreting > 100 μg/L of UI and less than 20% of the population excreting < 50 μg/L), NHANES III data were interpreted to indicate that iodine nutrition in the United States was adequate (7). Dr. John Dunn supported that position in his accompanying editorial (14), "The recent urinary iodine concentrations reported . . . are within a reasonable range. In fact, they may be more desirable, because previous levels were fairly high and might contribute to the development of autoimmune thyroid disease and papillary cancer." He emphasized the importance of continued monitoring of iodine status in the United States (14). The NHANES 2001–2002 data confirm the current stability of the U.S. iodine intake and continued adequate iodine nutrition for the country. A continuation of the possible downward trend suggested by the data from 1971–1974 and 1988–1994 is not supported by data from this survey or the limited data from NHANES 2000.

With the better understanding of the role of maternal thyroxine for normal and optimal fetal and infant development, the role of iodine has taken on new importance. The requirement for iodine is known to increase during pregnancy because thyroxine production must increase to keep up with the increased protein binding occurring in the mother, renal clearance of iodine increases, and iodine must be supplied to the fetus both as the element and in the form of thyroxine (15,16). For these reasons, concern exists in several quarters about the iodine adequacy among pregnant women and other women of reproductive age (17,18). Compared to the study of 1989–1994, the median iodine among both pregnant and nonpregnant women has increased slightly. At the same time the proportion excreting less than 50 μg/L increased in the second study (6.9% $\pm$ 1.9% to 7.3% $\pm$ 2.9%) among pregnant women and among nonpregnant women (15.3% $\pm$ 1.2% to 16.8% $\pm$ 3.0%). These differences, although not statistically significant, need to be followed by continued monitoring.

A previous study using NHANES III data attempted to show the relationship of low iodine levels to thyroid deficiency, but showed only that excessive iodine, when adjusted for creatinine concentration, was significantly associated with elevated thyroid-stimulating hormone (TSH).

No effect on thyroid function as measured by either serum TSH or serum thyroxine (T_4) was found to be associated with low iodine concentration, either adjusted for creatinine or not (19). In future surveys that are designed to monitor U.S. iodine nutrition, efforts should be made to measure indicators of early thyroid deficiency, which can be linked to the population's UI measurements. In addition to TSH and T_4, other evidence of thyroid deficiency such as changes in thyroglobulin, thyroid volume, or the T_3/T_4 ratio would be appropriate additions to NHANES. The more sensitive indicator of iodine deficiency is known to be an increase in thyroglobulin (15,16,20).

A major concern in the United States is that despite apparently adequate iodine nutrition, no active control of the iodine in the food supply exists. Iodized salt is thought to be

Table 4. Women of Reproductive Age,[a] Comparison of Median and Low Urine Iodine Levels[b] and Median and Low Iodine Levels Adjusted for Creatinine,[c] by Pregnancy Status, United States, 1988–1994 and 2001–2002 NHANES

	1988–1994									2001–2002								
				< 100 μg/L		< 50 μg/L		< 20 μg/L					< 100 μg/L		< 50 μg/L		< 20 μg/L	
	No.	Median	95% CI	%	SE	%	SE	%	SE	No.	Median	95% CI	%	SE	%	SE	%	SE
Urine iodine (μg/L)																		
Total	5405	128.0	(120.9–136.4)	36.1	1.5	14.9	1.1	2.7	0.5	679	132.5	(112.1–152.5)	38.0	3.6	16.1	2.8	1.8	0.6
Pregnant	348	141.0	(124.3–180.2)	28.5	4.0	6.9	1.9	0.1	0.1	126	172.6	(75.1–229.0)	37.7	7.8	7.3	2.9	0.4	0.4
Not pregnant	5057	127.0	(120.1–135.1)	36.5	1.5	15.3	1.2	2.9	0.5	553	132.0	(111.3–147.8)	38.0	3.7	16.8	3.0	1.9	0.6
Iodine adjusted for creatinine (μg iodine/g creatinine)																		
				< 100 μg/L		< 50 μg/L		< 20 μg/L					< 100 μg/L		< 50 μg/L		< 20 μg/L	
	No.	Median	95% CI	%	SE	%	SE	%	SE	No.	Median	95% CI	%	SE	%	SE	%	SE
Total	5405	113.1	(107.0–119.8)	42.5	1.6	8.2	0.9	0.6	0.2	679	128.6	(117.7–135.3)	37.2	2.1	5.6	1.1	0.4	0.4
Pregnant	348	132.2	(112.7–160.7)	30.3	3.7	5.1	1.9	0.0	0.0	126	166.2	(113.2–208.6)	24.6	7.3	12.1	7.1	0.0	0.0
Not pregnant	5057	111.9	(105.9–118.7)	43.3	1.7	8.4	0.9	0.7	0.2	553	126.9	(111.9–136.5)	38.2	2.5	5.1	1.1	0.4	0.4

[a]Women age 15 to 44 years inclusive.
[b]Low urine iodine identified here are arbitrary levels. < 20 μg/L, < 50 μg/L, and < 100 μg/L that are being followed by the World Health Organization.
[c]Low iodine adjusted for creatinine identified here are arbitrary levels. < 25 μg/L, < 50 μg/L, and < 100 μg/L that are being followed by the World Health Organization.
NHANES, National Health and Examination Survey; CI, confidence interval; SE, standard error.

TABLE 5. SCHOOL-AGE CHILDREN, COMPARISON OF MEDIAN AND LOW URINE IODINE LEVELS[a], AND MEDIAN AND LOW IODINE LEVELS ADJUSTED FOR CREATININE,[b] UNITED STATES, 1988–1994 AND 2001–2002 NHANES

Urine Iodine (µg/L)

	1988–1994									*2001–2002*								
				< 100 µg/L		*< 50 µg/L*		*< 20 µg/L*					*< 100 µg/L*		*< 50 µg/L*		*< 20 µg/L*	
Gender/Age	*No.*	*Median*	*95% CI*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*No.*	*Median*	*95% CI*	*%*	*SE*	*%*	*SE*	*%*	*SE*
Total	6460	197.4	(187–211)	16.3	1.0	4.2	0.4	0.5	0.1	1022	221.2	(206.5–243.8)	19.4	1.0	7.0	0.9	0.9	0.5
6 to 11	3058	237.1	(220–254)	12.3	1.1	3.2	0.6	0.4	0.1	374	249.2	(220.5–291.9)	15.9	2.0	4.5	1.5	0.7	0.6
12 to 17	3402	177.3	(168–188)	19.1	1.3	5.0	0.6	0.6	0.2	648	202.4	(188.4–213.1)	22.7	1.8	9.4	1.6	1.2	0.6
Male	3191	222.0	(208–235)	13.0	0.9	2.4	0.4	0.2	0.1	475	243.9	(221.4–276.4)	13.6	1.8	3.9	0.9	1.0	0.7
6 to 11	1593	269.0	(256–295)	8.8	1.1	1.8	0.5	0.1	0.1	185	263.2	(228.8–313.5)	11.9	2.6	2.9	1.8	1.3	1.2
12 to 17	1608	191.0	(180–204)	16.0	1.3	2.8	0.6	0.2	0.2	290	222.3	(206.8–261.1)	15.2	2.7	5.0	0.9	0.7	0.7
Female	3569	178.0	(167–191)	19.7	1.5	6.2	0.7	0.8	0.2	547	193.8	(171.9–229.0)	25.2	1.9	10.1	1.6	0.9	0.5
6 to 11	1475	197.0	(182–220)	16.0	1.6	4.6	1.0	0.6	0.3	189	239.4	(189.2–302.1)	20.1	3.2	6.2	3.1	0.0	0.0
12 to 17	1794	164.0	(153–179)	22.2	2.0	7.2	0.9	1.0	0.4	358	175.1	(152.7–199.6)	29.7	2.5	13.6	2.7	1.7	1.0

Iodine Adjusted for Creatinine (µg Iodine/g creatinine)

	1988–1994									*2001–2002*								
				< 100 µg/g		*< 50 µg/g*		*< 25 µg/g*					*< 100 µg/g*		*< 50 µg/g*		*< 25 µg/g*	
Gender/Age	*No.*	*Median*	*95% CI*	*%*	*SE*	*%*	*SE*	*%*	*SE*	*No.*	*Median*	*95% CI*	*%*	*SE*	*%*	*SE*	*%*	*SE*
Total	6446	164.6	(156.4–174.4)	26.2	1.3	4.1	0.4	0.1	0.1	1016	188.7	(169.5–206.8)	19.1	1.7	2.3	0.5	0.0	0.0
6 to 11	3048	251.3	(239.2–269.6)	8.3	1.1	0.9	0.3	0.1	0.1	373	256.7	(223.7–319.9)	6.1	1.3	0.7	0.5	0.0	0.0
12 to 17	3398	122.1	(114.4–131.8)	38.8	1.9	6.3	0.6	0.0	0.0	643	137.6	(130.7–147.8)	31.6	2.7	3.9	0.8	0.0	0.0
Male	3184	178.3	(167.1–193.3)	23.2	1.4	3.5	0.6	0.0	0.0	473	206.9	(188.2–238.5)	16.2	2.4	2.1	0.8	0.0	0.0
6 to 11	1578	270.7	(255.8–297.4)	5.4	0.9	0.7	0.4	0.0	0.0	185	315.8	(284.7–362.3)	6.3	2.3	0.2	0.2	0.0	0.0
12 to 17	1606	129.7	(122.2–137.9)	35.9	2.0	5.6	0.9	0.1	0.0	288	152.4	(138.3–185.1)	26.4	2.7	4.0	1.4	0.0	0.0
Female	3262	152.6	(143.1–162.7)	29.3	1.6	4.6	0.5	0.1	0.1	543	165.8	(147.5–191.0)	21.9	2.7	2.6	0.7	0.0	0.0
6 to 11	1470	225.1	(212.6–244.3)	11.3	1.7	1.7	0.5	0.3	0.2	188	219.2	(207.5–305.5)	5.9	1.3	1.2	1.0	0.0	0.0
12 to 17	1792	114.4	(105.5–127.0)	41.8	2.3	7.0	1.0	0.0	0.0	355	127.7	(109.4–137.4)	36.4	5.0	3.8	1.1	0.0	0.0

[a]Low urine identified here are arbitrary levels, < 25 µg/L, < 50 µg/L, and < 100 µg/L, that are being followed by the World Health Organization.
[b]Low iodine adjusted for creatinine identified here are arbitrary levels, < 25 µg/L, < 50 µg/L, and < 100 µg/L, that are being followed by the World Health Organization.
NHANES, National Health and Nutrition Examination Survey.

used by approximately 60% of the population (R.L. Hanneman, personal communication). A large part of nutritional iodine comes by way of iodine found in other components of the food industry, such as milk products from its use as a sanitizing agent, through supplementation of animal feed, or in commercial bread production (6,21). This silent prophylaxis could be adversely affected by economic, market, or other inadvertent changes in food production practices. This heightens the importance of continued population monitoring coupled with biologic evidence that can be linked to thyroid health.

Conclusion

Data have been presented from NHANES 2001–2002 indicating that the U.S. median urine iodine level has stabilized since the initial drop between NHANES I and NHANES III. The NHANES 2001–2002 data confirm the current stability of the U.S. iodine intake and continued adequate iodine nutrition for the country. Because iodine nutrition in the United States is not dependent on iodization of salt and no policy in this country exerts control on the supply of iodine to the population, we believe that continuing to measure urine iodine in NHANES, as an indicator of iodine intake is important. To begin measuring the possible early biologic effects of iodine deficiency, namely an increase in thyroglobulin would be prudent. If a change in iodine supply becomes apparent from changes in urine iodine concentration or from the biologic effect on the population, identifying that change and recognizing its effect as early as possible would be important. The change in supply may only be identified through its outcomes as measured above. The hormones related to hypothyroidism, namely, decreased T_4 and elevated TSH, occur only later when deficiency is more severe.

References

1. Marine D, Kimball OP 1922 The prevention of simple goiter. Am J Med Sci 163:34–39.
2. Kimball OP 1949 Endemic goiter—A food deficiency disease. J Am Diet Assoc **25:**112–115.
3. Altland JK, Brush BE 1952 Goiter prevention in Michigan. Results of thirty years' voluntary use of iodized salt. J Michigan State Med Soc **51:**985–989.
4. Markel H 1987 When it rains it pours: Endemic goiter, iodized salt, and David Murray Cowie, M.D. Am J Public Health **77:**219–229.
5. Braverman LE 1994 Iodine and the thyroid: 33 years of study. Thyroid **4:**351–356.
6. Pennington JAT, Schoen SA 1996 Total Diet Study: Estimated dietary intakes of nutritional elements, 1982–1991. Internat J Vit Nutr Res **66:**350–362.
7. Hollowell JG, Staehling NW, Hannon WH, Flanders DW, Gunter EW, Maberly GF, Braverman LE, Pino S, Miller DT, Garbe PL, DeLozier DM, Jackson RJ 1998 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 **83:**3401–3408.
8. WHO/UNICEF/ICCIDD 1996 Indicators for Assessing Iodine Deficiency Disorders and Their Control Through Salt Iodization. WHO/Nut pp. 94–96.
9. NHANES 2001–2002 Data Files, Data, Docs, Codebooks, SAS Code www.cdc.gov/nchs/about/major/nhanes/nhanes01-02.htm (Last accessed March 1, 2005).
10. Caldwell KL, Maxwell CB, Makhmudov A, Pino S, Braverman LE, Jones RL, Hollowell JG 2003 Use of inductively coupled plasma mass spectrometry to measure urinary iodine in NHANES 2000: Comparison with previous method. Clin Chem **49:**1019–1021.
11. Shah BV, Barnwell BG, Bieler GS 1997 SUDAAN users manual, Release 7.5. Research Triangle Park, NC, Research Triangle Institute.
12. Lee K, Bradley R, Dwyer J, Lee SL 1999 Too much versus too little: The implications of current iodine intake in the United States. Nutr Rev **57:**177–181.
13. Utiger RD 1999 Maternal hypothyroidism and fetal development. N Engl J Med **41:**601–602.
14. Dunn JT 1998 What's happening to our iodine? J Clin Endocrinol Metab **83:**3398–3400.
15. Glinoer D, DeNayer P, Bourdoux P, Lemone M, Robyn C, Van Steirteghem A, Kinhaert J, Lejeune B 1990 Regulation of maternal thyroid function during pregnancy. J Clin Endocrinol Metab **71:**276–287.
16. Glinoer D, DeNayer P, Delange F, Lemone M, Toppet B, Spehl M, Grun J-P, Kinthaert J, Lejeune B 1995 A randomized trial for the treatment of mild iodine deficiency during pregnancy: Maternal and neonatal effects. J Clin Endocrinol Metab **80:**258–269.
17. Glinoer D 2001 Pregnancy and iodine. Thyroid **11:**471–481.
18. Delange F 2004 Optimal iodine nutrition during pregnancy, lactation and the neonatal period. Int J Endocrinol Metab **2:**1–12.
19. Hollowell JG, McClain MR, Palomaki GE, Haddow JE 2004 Relationships between urinary iodine and total thyroxine (T_4) and thyroid stimulating hormone (TSH) concentration in the U.S. population [Abstract]. Program and Abstracts of the 76th Annual Meeting of the American Thyroid Association, Vancouver, Canada. Thyroid **14:**721.
20. Missler U, Gutekunst R, and Wood WG. 1994 Thyroglobulin is a more sensitive index of iodine deficiency than thyrotropin: Development and evaluation of dry blood spot assayus for thyrotropin and thyroglobulin in iodine deficient areas. Eur J Clin Chem Clin Biochem **32:**137–143.
21. Pearce EN, Pino S, He X, Bazrafshan HR, Lee SL, Braverman LE 2004 Sources of dietary iodine: Bread, cows' milk, and infant formula in the Boston area. J Clin Endocrinol Metab **89:**3421–3424.

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2. Lene H.S. Veiga, Gila Neta, Briseis Aschebrook-Kilfoy, Elaine Ron, Susan S. Devesa. 2013. Thyroid Cancer Incidence Patterns in Sao Paulo, Brazil, and the U.S. SEER Program, 1997–2008. *Thyroid* **23**:6, 748-757. [Abstract] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links]
3. Kevin M. Sullivan, Cria G. Perrine, Elizabeth N. Pearce, Kathleen L. Caldwell. 2013. Monitoring the Iodine Status of Pregnant Women in the United States. *Thyroid* **23**:4, 520-521. [Citation] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links] [Supplemental Material]
4. Dr. Kathleen Caldwell, Dr. Yi Pan, Dr. Mary E. Mortensen, Dr. Amir Makhmudov, Ms. Lori Merrill, Dr. John Moye. Iodine Status in Pregnant Women in the United States: National Children's Study and National Health and Nutrition Examination Survey. *Thyroid* **0**:ja. . [Abstract] [Full Text PDF] [Full Text PDF with Links]
5. Ji Youn Lee, Stephanie L. LeeThyroid Disease and Women 883-897. [CrossRef]
6. Aya Hisada, Kazuhisa Shimodaira, Takashi Okai, Kiyohiko Watanabe, Hiroaki Takemori, Takumi Takasuga, Yumiko Noda, Miyako Shirakawa, Nobumasa Kato, Jun Yoshinaga. 2012. Serum levels of hydroxylated PCBs, PCBs and thyroid hormone measures of Japanese pregnant women. *Environmental Health and Preventive Medicine* . [CrossRef]
7. Amber Wise, Fred Parham, Daniel A. Axelrad, Kathryn Z. Guyton, Christopher Portier, Lauren Zeise, R. Thomas Zoeller, Tracey J. Woodruff. 2012. Upstream adverse effects in risk assessment: A model of polychlorinated biphenyls, thyroid hormone disruption and neurological outcomes in humans. *Environmental Research* **117**, 90-99. [CrossRef]
8. Peter Heitland, Helmut D. KösterApplications of ICP-MS in Human Biomonitoring Studies 367-395. [CrossRef]
9. Jonghyeon Choi, Hyo-Sik Kim, Duck Jin Hong, Hyunsun Lim, Jeong-Ho Kim. 2012. Urinary iodine and sodium status of urban Korean subjects: A pilot study. *Clinical Biochemistry* **45**:7-8, 596-598. [CrossRef]
10. Hossien Delshad, Atieh Amouzegar, Parvin Mirmiran, Ladan Mehran, Fereidoun Azizi. 2012. Eighteen Years of Continuously Sustained Elimination of Iodine Deficiency in the Islamic Republic of Iran: The Vitality of Periodic Monitoring. *Thyroid* **22**:4, 415-421. [Abstract] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links]
11. Angela M. Leung, Elizabeth N. Pearce, Lewis E. Braverman. 2011. Iodine Nutrition in Pregnancy and Lactation. *Endocrinology and Metabolism Clinics of North America* **40**:4, 765-777. [CrossRef]
12. The American Thyroid Association Taskforce on Thyroid Disease During Pregnancy and Postpartum, Alex Stagnaro-Green, Marcos Abalovich, Erik Alexander, Fereidoun Azizi, Jorge Mestman, Roberto Negro, Angelita Nixon, Elizabeth N. Pearce, Offie P. Soldin, Scott Sullivan, Wilmar Wiersinga. 2011. Guidelines of the American Thyroid Association for the Diagnosis and Management of Thyroid Disease During Pregnancy and Postpartum. *Thyroid* **21**:10, 1081-1125. [Citation] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links]
13. David R Huber, Benjamin C Blount, David T Mage, Frank J Letkiewicz, Amit Kumar, Ruth H Allen. 2011. Estimating perchlorate exposure from food and tap water based on US biomonitoring and occurrence data. *Journal of Exposure Science and Environmental Epidemiology* **21**:4, 395-407. [CrossRef]
14. Lluis Vila, Mateu Serra-Prat, Alfonso de Castro, Elisabet Palomera, Roser Casamitjana, Gustavo Legaz, Celia Barrionuevo, José A. Muñoz, Ana J. García, Sanjay Lal-Trehan, Amparo García, Josep Durán, Manel Puig-Domingo. 2011. Iodine nutritional status in pregnant women of two historically different iodine-deficient areas of Catalonia, Spain. *Nutrition* . [CrossRef]
15. Kathleen L. Caldwell, Amir Makhmudov, Elizabeth Ely, Robert L. Jones, Richard Y. Wang. 2011. Iodine Status of the U.S. Population, National Health and Nutrition Examination Survey, 2005–2006 and 2007–2008. *Thyroid* **21**:4, 419-427. [Abstract] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links] [Supplemental Material]
16. Gregory A. Brent, Terry F. DaviesHypothyroidism and Thyroiditis 406-439. [CrossRef]
17. Stephen LaFranchiThyroid Development and Physiology 1894. [CrossRef]
18. Stephen LaFranchiGoiter 1905-1909. [CrossRef]
19. Sun Y. Lee, Angela M. Leung, Xuemei He, Lewis E. Braverman, Elizabeth N. Pearce. 2010. Iodine Content in Fast Foods: Comparison Between two Fast-Food Chains in the United States. *Endocrine Practice* **16**:6, 1071-1072. [CrossRef]
20. Tracey J. Woodruff. 2010. Bridging epidemiology and model organisms to increase understanding of endocrine disrupting chemicals and human health effects. *The Journal of Steroid Biochemistry and Molecular Biology* . [CrossRef]

21. R. W. Leggett. 2010. A Physiological Systems Model for Iodine for Use in Radiation Protection. *Radiation Research* **174**:4, 496-516. [CrossRef]

22. I Gunnarsdottir, B E Gunnarsdottir, L Steingrimsdottir, A Maage, A J Johannesson, I Thorsdottir. 2010. Iodine status of adolescent girls in a population changing from high to lower fish consumption. *European Journal of Clinical Nutrition* **64**:9, 958-964. [CrossRef]

23. Gregory A. Brent. 2010. Environmental Exposures and Autoimmune Thyroid Disease. *Thyroid* **20**:7, 755-761. [Abstract] [Full Text HTML] [Full Text PDF] [Full Text PDF with Links]

24. Angela Leung, Elizabeth N Pearce, Lewis E Braverman. 2010. Role of iodine in thyroid physiology. *Expert Review of Endocrinology & Metabolism* **5**:4, 593-602. [CrossRef]

25. Diana L. Fitzpatrick, Michelle A. Russell. 2010. Diagnosis and Management of Thyroid Disease in Pregnancy. *Obstetrics and Gynecology Clinics of North America* **37**:2, 173-193. [CrossRef]

26. Pieter L. Jooste, Emmerentia Strydom. 2010. Methods for determination of iodine in urine and salt. *Best Practice & Research Clinical Endocrinology & Metabolism* **24**:1, 77-88. [CrossRef]

27. Angela M. Leung, Elizabeth N. Pearce, Lewis E. Braverman. 2010. Perchlorate, iodine and the thyroid. *Best Practice & Research Clinical Endocrinology & Metabolism* **24**:1, 133-141. [CrossRef]

28. Ji Hyun Lee, Ok-Ja Ji, Min-Jung Song, Hyung-Doo Park, Hee Kyung Kim, Sun Wook Kim, Jae Hoon Chung, Soo-Youn Lee. 2010. Determination of Urinary Iodine Concentration by Inductively Coupled Plasma-mass Spectrometry in Thyroid Cancer Patients on Low-iodine Diet. *The Korean Journal of Laboratory Medicine* **30**:4, 351. [CrossRef]

29. Tsedash Zewdie, C. Mark Smith, Michael Hutcheson, Carol Rowan West. 2009. Basis of the Massachusetts Reference Dose and Drinking Water Standard
for Perchlorate. *Environmental Health Perspectives* . [CrossRef]

30. Roy Phitayakorn, Divya Narendra, Sarah Bell, Christopher R. McHenry. 2009. What Constitutes Adequate Surgical Therapy For Benign Nodular Goiter?. *Journal of Surgical Research* **154**:1, 51-55. [CrossRef]

31. Caterina Mian, Pantaleo Vitaliano, Dina Pozza, Susi Barollo, Mariangela Pitton, Giovanna Callegari, Elena Di Gianantonio, Anna Casaro, Davide N acamulli, Benedetto Busnardo, Franco Mantero, Maria Elisa Girelli. 2009. Iodine status in pregnancy: role of dietary habits and geographical origin. *Clinical Endocrinology* **70**:5, 776-780. [CrossRef]

32. Fereidoun Azizi, Peter Smyth. 2009. Breastfeeding and maternal and infant iodine nutrition. *Clinical Endocrinology* **70**:5, 803-809. [CrossRef]

33. Alexander Kulczycki, Xiangbing Wang. 2009. Iodine Deficiency in Minority Populations of New Jersey. *The Endocrinologist* **19**:2, 62-63. [CrossRef]

34. Angela M. Leung, Elizabeth N. Pearce, Tara Hamilton, Xuemei He, Sam Pino, Anne Merewood, Lewis E. Braverman. 2009. Colostrum iodine and perchlorate concentrations in Boston-area women: a cross-sectional study. *Clinical Endocrinology* **70**:2, 326-330. [CrossRef]

35. K SULLIVAN. 2009. Iodine deficiency as a cause of autism. *Journal of the Neurological Sciences* **276**:1-2, 202-202. [CrossRef]

36. Václav Zamrazil, Radovan Bílek, Jarmila Čeř;ovská, Marcela Dvořáková, Petra Hoskovcová, Ivan ŠterzlEvaluation of Iodine Prophylaxis in the Czech Republic 835-845. [CrossRef]

37. Offie P. SoldinIodine Status Reflected by Urinary Concentrations 1129-1137. [CrossRef]

38. Purnendu K. Dasgupta. 2009. Perchlorate: a cause for iodine deficiency?. *Environmental Chemistry* **6**:1, 7. [CrossRef]

39. Stefanie Leniszewski, Richard Mauseth. 2009. Goiter and Multiple Food Allergies. *International Journal of Pediatric Endocrinology* **2009**, 1-3. [CrossRef]

40. Stefanie Leniszewski, Richard Mauseth. 2009. Goiter and Multiple Food Allergies. *International Journal of Pediatric Endocrinology* **2009**:1, 628034. [CrossRef]

41. Ebenezer A. Nyenwe, Samuel Dagogo-Jack. 2009. Iodine Deficiency Disorders in the Iodine-Replete Environment. *The American Journal of the Medical Sciences* **337**:1, 37-40. [CrossRef]

42. Offie P. Soldin, Danielle SoldinTrimester-Specific Changes in Maternal Thyroid Hormones 402-409. [CrossRef]

43. Agnes N. Pedersen, Lone Banke RasmussenIodine intake in the European elderly 1139-1146. [CrossRef]

44. David R. Parker. 2009. Perchlorate in the environment: the emerging emphasis on natural occurrence. *Environmental Chemistry* **6**:1, 10. [CrossRef]

45. Sheila A. SkeaffIodine Nutrition in Pregnancy 1259-1264. [CrossRef]

46. Michael B Zimmermann, Pieter L Jooste, Chandrakant S Pandav. 2008. Iodine-deficiency disorders. *The Lancet* **372**:9645, 1251-1262. [CrossRef]

47. Tracey J. Woodruff, Lauren Zeise, Daniel A. Axelrad, Kathryn Z. Guyton, Sarah Janssen, Mark Miller, Gregory G. Miller, Jackie M. Schwartz, George Alexeeff, Henry Anderson, Linda Birnbaum, Frederic Bois, Vincent James Cogliano, Kevin Crofton, Susan Y. Euling, Paul M.D. Foster, Dori R. Germolec, Earl Gray, Dale B. Hattis, Amy D. Kyle, Robert W. Luebke, Michael I. Luster, Chris Portier, Deborah C. Rice, Gina Solomon, John Vandenberg, R. Thomas Zoeller. 2008. Meeting Report: Moving Upstream—Evaluating Adverse Upstream End Points for Improved Risk Assessment and Decision-Making. *Environmental Health Perspectives* **116**:11, 1568-1575. [CrossRef]

48. G CHARNLEY. 2008. Perchlorate: Overview of risks and regulation. *Food and Chemical Toxicology* **46**:7, 2307-2315. [CrossRef]

49. Luc G. T. Morris, Andrew G. Sikora, David Myssiorek, Mark D. DeLacure. 2008. The Basis of Racial Differences in the Incidence of Thyroid Cancer. *Annals of Surgical Oncology* **15**:4, 1169-1176. [CrossRef]

50. Kevin M. Sullivan. 2008. The Interaction of Agricultural Pesticides and Marginal Iodine Nutrition Status as a Cause of Autism Spectrum Disorders. *Environmental Health Perspectives* **116**:4, A155-A155. [CrossRef]

51. Elizabeth N. Pearce, Emily Oken, Matthew W. Gillman, Stephanie L. Lee, Barbarajean Magnani, Deborah Platek, Lewis E. Braverman. 2008. Association of First-Trimester Thyroid Function Test Values with Thyroperoxidase Antibody Status, Smoking, and Multivitamin Use. *Endocrine Practice* **14**:1, 33-39. [CrossRef]

52. Joseph G Hollowell, James E Haddow. 2007. The prevalence of iodine deficiency in women of reproductive age in the United States of America. *Public Health Nutrition* **10**:12A. . [CrossRef]

53. Offie P Soldin, Danielle Soldin, Marisol Sastoque. 2007. Gestation-Specific Thyroxine and Thyroid Stimulating Hormone Levels in the United States and Worldwide. *Therapeutic Drug Monitoring* **29**:5, 553-559. [CrossRef]

54. Ebenezer A. Nyenwe, Samuel Dagogo-Jack. 2007. Recognizing Iodine Deficiency in Iodine-Replete Environments. *New England Journal of Medicine* **357**:12, 1263-1264. [CrossRef]

55. Elizabeth N. Pearce. 2007. National Trends in Iodine Nutrition: Is Everyone Getting Enough?. *Thyroid* **17**:9, 823-827. [Abstract] [Full Text PDF] [Full Text PDF with Links]

56. Benjamin C Blount, Liza Valentin-Blasini, John D Osterloh, Joshua P Mauldin, James L Pirkle. 2007. Perchlorate Exposure of the US Population, 2001–2002. *Journal of Exposure Science and Environmental Epidemiology* **17**:4, 400-407. [CrossRef]

57. Elaheh Ainy, Arash Ordookhani, Mehdi Hedayati, Fereidoun Azizi. 2007. Assessment of intertrimester and seasonal variations of urinary iodine concentration during pregnancy in an iodine-replete area. *Clinical Endocrinology*, ahead of print070630051835003-???. [CrossRef]

58. E MAZZAFERRI. 2007. Iodine Supplementation for Pregnancy and Lactation—United States and Canada: Recommendations of the American Thyroid AssociationHollowell JG, for The Public Health Committee of the American Thyroid Association (Lawrence, Kan; New York Presbyterian Hosp; Boston Med Ctr; et al) Thyroid 16:949–951, 2006§. *Yearbook of Endocrinology* **2007**, 223-226. [CrossRef]

59. 2006. Iodine Nutrition — More Is Better. *New England Journal of Medicine* **355**:14, 1500-1501. [CrossRef]

60. Robert D. Utiger. 2006. Iodine Nutrition — More Is Better. *New England Journal of Medicine* **354**:26, 2819-2821. [CrossRef]

61. Thien-Giang Bach-Huynh, Jacqueline Jonklaas. 2006. Thyroid Medications During Pregnancy. *Therapeutic Drug Monitoring* **28**:3, 431-441. [CrossRef]

62. Andrea B. Kirk. 2006. Environmental perchlorate: Why it matters. *Analytica Chimica Acta* **567**:1, 4-12. [CrossRef]

63. Benjamin C. Blount, Liza Valentin-Blasini. 2006. Analysis of perchlorate, thiocyanate, nitrate and iodide in human amniotic fluid using ion chromatography and electrospray tandem mass spectrometry. *Analytica Chimica Acta* **567**:1, 87-93. [CrossRef]

64. Cal Baier-Anderson. 2006. Risk assessment, remedial decisions and the challenge to protect public health: The perchlorate case study. *Analytica Chimica Acta* **567**:1, 13-19. [CrossRef]

65. P. Kalyani Martinelango, Gülçin Gümüş, Purnendu K. Dasgupta. 2006. Matrix interference free determination of perchlorate in urine by ion association–ion chromatography–mass spectrometry. *Analytica Chimica Acta* **567**:1, 79-86. [CrossRef]

66. Cal Baier-Anderson, Benjamin Blount, Judy LaKind, Daniel Naiman, Sharon Wilbur, Shirlee Tan. 2006. Estimates of Exposures to Perchlorate from Consumption of Human Milk, Dairy Milk, and Water, and Comparison to Current Reference Dose. *Journal of Toxicology and Environmental Health Part A* **69**:4, 319. [CrossRef]

67. Benjamin C. Blount, James L. Pirkle, John D. Osterloh, Liza Valentin-Blasini, Kathleen L. Caldwell. 2006. Urinary Perchlorate and Thyroid Hormone Levels in Adolescent and Adult Men and Women Living in the United States. *Environmental Health Perspectives* . [CrossRef]