Comparison of median urinary iodine concentration as an indicator of iodine status among pregnant women, school-age children, and nonpregnant women

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Abstract

Background. *Most surveys that assess the iodine status of populations target school-age children, whereas others may target nonpregnant women with the assumption that the iodine status of these groups is representative of other groups in the same population.*

Objective. *To assess whether the median urinary iodine concentration (UIC) of school-age children or nonpregnant women can be used to accurately represent the iodine status of pregnant women.*

Methods. *Using the World Health Organization Vitamin and Mineral Nutrition Information System and a literature review, we identified urinary iodine surveys that included pregnant women and school-age children and/or nonpregnant women in the same location and year using estimates from the smallest geographic level to increase the number of data points. Linear regression was used to assess the relationships between the median UIC for the comparisons.*

Results. *There were 48 survey pairs with pregnant women and school-age children (total sample sizes of 8,622 and 16,844, respectively), and 26 pairs with pregnant and nonpregnant women (sample sizes of 3,222 and 5,520, respectively). The country contributing the most data points was China. When the median UIC in school-age children or nonpregnant women indicated iodine intake was adequate or above requirements, approximately half the time pregnant women had inadequate iodine intake.*

Conclusions. *Adequate iodine nutrition status of school-age children or nonpregnant women may not indicate adequate iodine nutrition status among pregnant women. In order to assess the iodine status of pregnant women, the iodine status would need to be assessed in this group.*

Key words: Iodine deficiency, pregnancy, school-age children, urinary iodine

Introduction

Iodine is essential for the production and synthesis of thyroid hormones, which regulate many key body functions, including enzyme activity and protein synthesis [1]. Iodine deficiency occurs when iodine intake falls below required levels to maintain adequate thyroid hormone production. Its consequences include mental retardation, stillbirth, fetal brain malformations, miscarriage, poor growth, and cognitive problems [2]. The developing fetus and children 0 to 24 months of age are most susceptible to irreversible damage to the brain and central nervous system caused by iodine deficiency [3–6]. Pregnant women have a greater recommended daily iodine intake than other population groups in order to support the developing fetus [7]. It has recently been proposed by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) that the current Recommended Daily Intake (RDI) of iodine for pregnant women be increased from 200 to 250 μg, whereas school-age children (6 to 12 years of age) have an RDI of 120 μg and nonpregnant women an RDI of 150 μg [4, 7]. In this report, the term "iodine nutrition" refers to the median casual urinary iodine concentration (UIC) as a reflection of both iodine intake and iodine status [8]. Based on urinary iodine, iodine adequacy in pregnant women is defined as a median UIC between 150 and 249 μg/L and in school-age children and nonpregnant women as a median UIC between 100 and 199 μg/L [8].

Historically, surveys assessing iodine deficiency used

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results from school-age children (6 to 12 years of age) as a proxy for iodine status in the general population, frequently based on goiter measured by palpation [8]. School-age children were the group most commonly involved in these surveys because of their vulnerability and easy access through schools for population-based surveys, and it was thought they adequately represented population iodine status [8]. However, the relationship between UIC in school-age children and pregnant women remains unclear.

Data from several countries suggest that adequate iodine nutrition among school-age children and nonpregnant women may not be indicative of adequate iodine nutrition among pregnant women [9–11]. However, limited research has been performed to elucidate the relationship between the median UIC of pregnant women and that of other groups. In a global assessment of the prevalence of iodine deficiency, WHO found that the median UIC of pregnant women was lower than the median UIC of school-age children in five of six national surveys that had data for both groups [2]. In three of these surveys, iodine nutrition was adequate in school-age children, whereas pregnant women had inadequate iodine nutrition.

This investigation was performed to determine whether adequate iodine nutrition status (determined by median UIC) among school-age children or nonpregnant women could be used as a proxy of adequate iodine status of pregnant women. This topic was identified as a priority by the WHO Department of Nutrition for Health and Development in a Technical Consultation held in 2007 [7].

Methods

In 1991, WHO established the Vitamin and Mineral Nutrition Information System (VMNIS), formerly known as the Micronutrient Deficiency Information System, following a request by the World Health Assembly that surveillance of vitamin and mineral deficiencies be strengthened at the global level. As a component of the VMNIS, the WHO Global Database on Iodine Deficiency includes survey information from 1940 to the present with data on total goiter prevalence and urinary iodine [12]. Information in the database comes from the scientific literature and reports gathered from WHO regional and country offices, United Nations organizations, government health agencies, nongovernmental organizations, and academic institutions [13]. For a survey to be included in the database, the survey must have a population-based sampling method and follow standard guidelines for the assessment of total goiter prevalence and/or UI concentrations. These are publicly available de-identified data, and analyses of these data do not constitute human subjects research and therefore did not require institutional review board review.

For analyses presented in this report, we used data from the WHO VMNIS as of December 2008 and conducted an additional literature search using PubMed. The analysis was limited to surveys that reported median UIC, collected data on pregnant women and nonpregnant women and/or school-age children, and had a sample size of 30 or more in each group. Surveys that included "women of childbearing age" or "women" were assumed to primarily represent women who were not pregnant, so from here on we refer to all of these surveys as being conducted on nonpregnant women. In the instances where the median UIC of pregnant women was stratified by trimester of pregnancy, an equally weighted median was calculated to provide an overall median UIC for pregnant women in the survey. If multiple surveys were available from the same area, the most recent was used. Urinary iodine-to-creatinine ratio results were not used, because these are considered to be unreliable due to variability in protein intake, which affects creatinine excretion [8].

As of December 2008, the WHO Database on Iodine Deficiency in the WHO VMNIS had 4,403 entries from 145 countries with urinary iodine results. These are not 4,403 independent surveys; rather, they include subestimates from the same survey, such as by population group or residence. Of the 2,344 identified estimates that met the inclusion criteria, 2,083 were for school-age children (89%), 182 were for nonpregnant women (8%), and 79 were for pregnant women (3%). We then identified which of these estimates for pregnant women were assessed in the same year and geographic area as those for school-age children or nonpregnant women. An additional literature search identified seven publications that included two or more of our population groups of interest. Of these, four surveys from three publications met the inclusion criteria for this analysis [11, 14, 15]. If the survey results were summarized at various geographic levels (e.g., at both the national and provincial levels), we used estimates from the smallest geographic level in the analysis in order to have the most possible data points. In total, 48 paired surveys with data for pregnant women and school-age children and 26 paired surveys with data for pregnant and nonpregnant women were included in this analysis.

Scatter plots were constructed between pregnant women and both school-age children and nonpregnant women using SAS, version 9.2. Regression models were run using an unweighted approach (i.e., with each data point providing an equal weight in the analysis). We also performed weighted analyses based on the number of pregnant women in the survey, the number of school-age children or nonpregnant women in the survey, and the sum of the number of pregnant women and the number of school-age children or nonpregnant women. Additionally, we performed these analysis assuming quadratic, cubic, compound, power, growth, exponential, and logistic relationships. The findings from these analyses with different weightings were consistent with the unweighted results, and none of the other models fit the data substantially better than the linear regression models presented here.

According to WHO criteria, an adequate median UIC for pregnant women is 150 to 249 µg/L, and a median UIC above requirements is 250 to 499 µg/L, where "above requirements" is specific to areas with a history of iodine deficiency where iodine-induced hyperthyroidism can occur following the introduction of iodized salt within 5 to 10 years. For nonpregnant women and school-age children, a median UIC of 100 to 199 µg/L is defined as adequate iodine nutrition, and a median UIC of 200 to 299 µg/L is above requirements [8]. For the purpose of this analysis, those with median UIC values indicating adequate iodine nutrition and those with median UIC values above requirements were combined into an "adequate or above requirements" group. These two groups are often combined and used to describe a population that does not have iodine deficiency. Median UICs below these levels are classified as indicating insufficient iodine intakes, and those above these levels are considered to indicate intakes in excess of the amount needed to prevent iodine deficiency. For regression analysis, all surveys were used in order to use the most data points possible for fitting the regression line.

Results

There were 48 survey pairs with data on median UIC for both pregnant women and school-age children (total sample sizes of 8,622 and 16,844, respectively), and 26 pairs with data on median UIC for both

TABLE 1. Geographic area, survey years, sample size, and median urinary iodine concentration (UIC) from paired surveys among pregnant women and school-age children and/or nonpregnant women[a]

Area	Survey year(s)	Sample size			UIC (µg/L)		
		School-age children	Nonpregnant women	Pregnant women	School-age children	Nonpregnant women	Pregnant women
Australia: New South Wales	2003/04	427	—	796	89	—	85
Bangladesh: Savar[b]	1996/97	400	—	197	73	—	96
Bulgaria: Blagoevgrad	2003	90	—	43	212	—	170
Bulgaria: Dobrich	2003	40	—	49	246.5	—	172
Bulgaria: Pazardjik	2003	90	—	72	173.5	—	151.5
Bulgaria: Pleven	2003	40	—	63	240	—	148
Bulgaria: Vrata	2003	90	—	50	203	—	170
Burundi: Bujumbura	1990/91	109	—	69	56	—	52
Burundi: Bururi	1990/91	120	—	71	18	—	30
Côte d'Ivoire: Abidjan City	1998	110	—	72	488	—	351
Côte d'Ivoire: North Central Savannah	1998	104	—	66	263	—	136
China: Beijing urban	2002	99	108	104	172	141	123
China: Beijing rural	2002	92	100	119	221	137	165
China: Guangdong urban	2002	321	338	294	264	272	182
China: Guangdong rural	2002	321	304	312	204	223	179
China: Guizhou urban	2002	100	100	100	281	247	235
China: Guizhou rural	2002	100	107	101	152	205	137
China: Inner Mongolia urban	2002	100	100	100	203	193	151
China: Inner Mongolia rural	2002	100	100	100	376	345	235
China: Jiangsu urban	2002	100	105	100	371	428	247
China: Jiangsu rural	2002	100	101	77	285	360	272
China: Liaoning urban	2002	100	100	100	196	180	167
China: Liaoning rural	2002	104	105	101	326	157	164
China: Shaanxi urban	2002	101	94	107	334	311	184
China: Shaanxi rural	2002	150	150	150	339	353	268
China: Shanghai urban	2002	94	100	100	109	128	113

continued

pregnant and nonpregnant women (total sample sizes of 3,222 and 5,520, respectively) (**table 1**). In general, pregnant women were more likely to be classified as having insufficient iodine intake than were school-age children or nonpregnant women (**table 2**). There were no surveys in which pregnant women were classified as having excessive iodine intake, i.e., a median UIC of 500 µg/L or higher.

A scatter plot comparing the median UIC of pregnant women with that of school-age children in 48 survey pairs is presented in **figure 1**, along with the regression equation and R^2. According to the regression formula, when the median UIC in school-age children is 100 µg/L, the predicted median UIC in pregnant women would be 104 µg/L. In order for the predicted median UIC in pregnant women to be, on average, at least 150 µg/L, the median UIC in school-age children would need to be at least 178 µg/L. Of the 34 survey pairs in which school-age children had an adequate or above-requirements iodine intake based on median UIC, pregnant women were classified as having inadequate iodine nutrition in 16 (47%) of the surveys (**table 2**). In the six surveys in which school-age children had inadequate iodine intake based on median UIC, pregnant women were classified as having inadequate iodine nutrition in all six.

A scatter plot comparing the median UIC in pregnant women with that in nonpregnant women in 26 survey pairs is presented in **figure 2**, along with the regression equation and R^2. According to the regression formula, when the median UIC in nonpregnant women is 100 µg/L, the predicted median UIC in pregnant women would be 124 µg/L. In order for the predicted median UIC in pregnant women to be, on average, at least 150 µg/L, the median UIC in nonpregnant women would need to be at least 154 µg/L. Of the 19 surveys

TABLE 1. Geographic area, survey years, sample size, and median urinary iodine concentration (UIC) from paired surveys among pregnant women and school-age children and/or nonpregnant women[a] *(continued)*

Area	Survey year(s)	Sample size			UIC (µg/L)		
		School-age children	Nonpregnant women	Pregnant women	School-age children	Nonpregnant women	Pregnant women
China: Shanghai rural	2002	106	102	100	130	147	114
China: Sichuan urban	2002	100	100	100	141	107	129
China: Sichuan rural	2002	100	100	99	231	163	171
China: Tianjian urban	2002	100	100	100	165	295	156
China: Tianjian rural	2002	100	100	100	419	404	350
China: Xinjiang urban	2002	103	87	91	244	147	131
China: Xinjiang rural	2002	92	95	91	163	181	196
Fiji: Suva	1994	67	—	50	94	—	137
Fiji: Sigatoka	1994	39	—	43	20	—	74
Guatemala: San Pedro Sacatepequez[b]	1996/97	458	—	174	181	—	120
India: Durdwan	2003	—	100	267	—	130	144
India: Rajasthan State	2004	1,200	—	360	139	—	127
Iran (Islamic Republic of): Ilam	1996–98	100	—	100	202	—	190
Iran (Islamic Republic of): Isfahan	1996–98	100	—	116	250	—	212
Iran (Islamic Republic of): Rasht	1996–98	100	—	102	312	—	338
Iran (Islamic Republic of): Tehran	1996–98	103	—	120	193	—	186
Ireland: Dublin	1997	—	1,063	86	—	70	129
Nepal	1997/98	1,450	1,169	132	144	112	134
Philippines	2003	4,665	—	583	201	—	142
Romania	2004/05	2,327	—	1,595	104	—	73
Switzerland	2004	386	—	279	141	—	249
Thailand: Bangkok[b]	2007/08	302	—	302	200	—	108
Former Yugoslav Republic of Macedonia	2001	929	—	382	164.5	—	141
USA[b]	2003/04	315	492	90	229	131	181

a. Indicates that there were no data or the sample did not meet inclusion criteria.
b. Survey results from literature review; all other results from the WHO Vitamin and Mineral Nutrition Information System.

in which nonpregnant women had an adequate or above-requirements iodine status based on median UIC, pregnant women were classified as having inadequate iodine status in 9 surveys (47%) (**table 2**). In the one survey in which nonpregnant women had inadequate iodine intake, the pregnant women also had inadequate iodine intake.

Discussion

School-age children have commonly been the target group for assessing the iodine nutrition of the population. This is reflected in data from the WHO Global Database on Iodine Deficiency in VMNIS, where school-age children comprise 70% of the total database entries (89% of entries eligible for this analysis). Since the developing fetus is highly susceptible to damage from iodine deficiency, assuring iodine sufficiency in pregnant women is an important public health goal. Therefore, it is important to determine whether iodine nutrition among school-age children and nonpregnant women can be used as a proxy for iodine nutrition among pregnant women in the same population.

In these analyses, we found that when the median UIC in school-age children or nonpregnant women indicated an iodine intake that was adequate or above requirements, approximately half of the time pregnant women had an iodine intake that was inadequate. Therefore, it cannot be assumed that when school-age children or nonpregnant women are classified as having an adequate or above-requirements intake of iodine, pregnant women will also have an adequate or above-requirements intake of iodine. Surveying a representative sample of pregnant women of sufficient size can be logistically challenging and expensive; however, to assess the iodine status of pregnant women, urinary iodine among pregnant women should be surveyed.

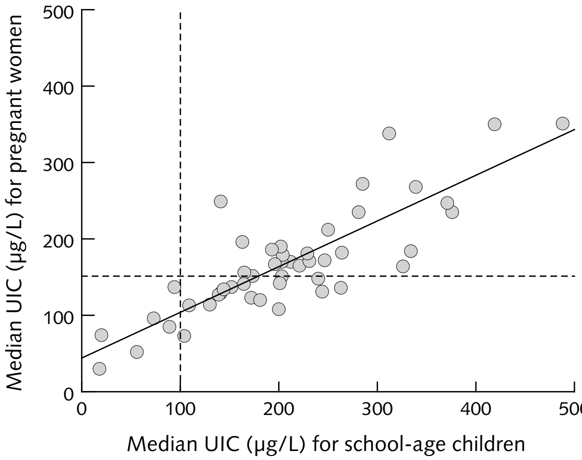

FIG. 1. Scatter plot of median urinary iodine concentration (UIC) of pregnant women and school-age children (n = 48). Each point represents a survey pair. The horizontal dashed line indicates the cutoff value for inadequate median UIC for pregnant women (< 150 μg/L), and the vertical dashed line indicates the cutoff value for inadequate median UIC for school-age children (< 100 μg/L). The regression line equation is $y = 44.59 + 0.59(x)$, and $R^2 = 0.69$

There are a variety of explanations for the discrepancy in categorization of iodine nutrition in different target groups in the same population. One major factor is probably that the cutoff for iodine sufficiency, based on median UIC, is 50 μg/L lower for school-age children and nonpregnant women than for pregnant women (100 and 150 μg/L, respectively). This higher cutoff for pregnant women reflects the higher requirement for daily iodine intake during pregnancy. The recommended iodine intake for pregnant women (250 μg/L) is approximately 1.5 to 2 times the recommended intake for school-age children (120 μg/L)

TABLE 2. Survey pairs by median urinary iodine concentration (UIC) range with corresponding interpretation of iodine intake among pregnant women with school-age children and with nonpregnant women

	Iodine intake by pregnant women (median UIC range)			
Iodine intake (median UIC range)	Insufficient (< 150 μg/L)	Adequate or above requirements (150–499.9 μg/L)	Excessive (≥ 500 μg/L)	Total
School-age children				
Insufficient (< 100 μg/L)	6	0	0	6
Adequate or above requirements (100–299.9 μg/L)	16	18	0	34
Excessive (≥ 300 μg/L)	0	8	0	8
Total	22	26	0	48
Nonpregnant women				
Insufficient (< 100 μg/L)	1	0	0	1
Adequate or above requirements (100–299.9 μg/L)	9	10	0	19
Excessive (≥ 300 μg/L)	0	6	0	6
Total	10	16	0	26

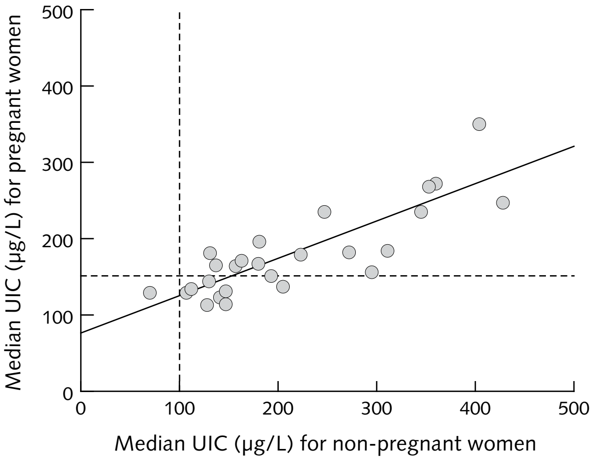

FIG. 2. Scatter plot of median urinary iodine concentration (UIC) of pregnant women and nonpregnant women ($n = 26$). Each point represents a survey pair. The horizontal dashed line indicates the cutoff value for inadequate median UIC for pregnant women (< 150 μg/L), and the vertical dashed line indicates the cutoff value for inadequate median UIC for nonpregnant women (< 100 μg/L). The regression line equation is $y = 76.14 + 0.48(x)$, and $R^2 = 0.73$

and nonpregnant women (150 μg/L). Many pregnant women may not be able to meet this increased requirement for iodine without a change in dietary behavior and/or supplement use. Some studies suggest that there is little change in dietary behavior during pregnancy [16, 17], whereas others suggest there are changes, particularly related to specific dietary recommendations for pregnant women. For example, pregnant women may decrease their consumption of fish because of the risk of exposure to mercury or increase their intake of meat and dairy in order to consume more protein [18, 19]. Both fish and dairy can be good sources of iodine, depending on the source of the fish and dairy production practices, and greater or lesser consumption of these foods during pregnancy may affect iodine status [20, 21]. Another important source of iodine is supplements. Pregnant women are more likely to take supplements than nonpregnant women; however, these supplements often do not contain iodine [22, 23]

There are several limitations to our study, including the availability of a small number of surveys for each analysis. We obtained the greatest number of data points possible by using estimates from the lowest administrative level; however, these estimates may not necessarily be independent. The country that contributed the most data points to the analysis was China, which accounted for 22 (46%) of the pairs of school-age children and pregnant women and 22 (85%) of the pairs of nonpregnant and pregnant women. Excluding China from the regression models for school-age children and pregnant women did not substantially change the regression equations and did not change the interpretation of our findings; we were unable to do the same with nonpregnant and pregnant women because of an insufficient number of data points. Surveys among pregnant women are often limited due to the logistical challenges of identifying adequate samples of this group. Although the data used for this analysis are limited, use of the WHO VMNIS with additional literature searches allowed us to identify the largest possible sample of surveys with urinary iodine data for pregnant women and either nonpregnant women or school-age children. Another limitation is the unknown accuracy of the reported survey results, despite WHO's application of a standardized methodology for including surveys in the Global Database on Iodine Deficiency. Likewise, UIC laboratory testing may have varied levels of quality. Several groups are working toward ensuring high-quality iodine assessments, including Ensuring the Quality of Urinary Iodine Procedures (EQUIP), a global free service provided by the US Centers for Disease Control and Prevention. As of December 2009, 95 laboratories from 45 countries were participating in the program. It was not possible to determine whether the data included in this analysis were from laboratories participating in such programs. Finally, the UIC cutpoint for categorizing iodine sufficiency (≥ 100 μg/L) was determined at a consultation of WHO/UNICEF/International Council for the Control of Iodine Deficiency Disorders (ICCIDD) in 1992 and was based on preventing goiter in school-age children [24]. Further categorization of iodine status and extrapolation to other populations was based on an expert committee, taking into account, in part, the daily iodine requirements and excretion of iodine, and may not adequately capture the iodine status of some groups.

Conclusions

Our findings indicate that adequate or above-requirements iodine nutrition among school-age children or nonpregnant women does not necessarily reflect adequate or above-requirements iodine nutrition among pregnant women. Additional surveys collecting urinary iodine data from pregnant women and other target groups would assist in further clarifying these relationships.

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