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Evaluation of iodine intake and status using inductively coupled plasma mass spectrometry in urban and rural areas in Benin, West Africa

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ABSTRACT

Objective: Iodine deficiency has severe pathological repercussions. The aim of this study was to evaluate iodine intake and status in adults in Benin, West Africa.
Methods: We randomly selected 420 participants ages 25 to 64 y and free of visible goiter from urban and rural settings of South Benin. The participants had a diet based on carbohydrates and fish. Urine was collected over a 24-h period and samples were assayed for iodine analysis using inductively coupled plasma mass spectrometry.
Results: We studied 401 urinary iodine samples. The overall median urinary iodine concentration (UIC) in 24-h urine was 62.9 μg/L (interquartile range: 40–96.2 μg/L). UIC was significantly lower in women than men (56.5 versus 78.6 μg/L; $P < 0.001$) and in rural versus urban areas (54.7 versus 77.8 μg/L; $P < 0.001$). In multivariate analysis, low UIC (<100 μg/L) was positively associated with women (odds ratio, 2.48; 95% confidence interval, 1.44–4.26; $P = 0.001$) and body mass index <25 kg/m^2 (odds ratio, 2.06; 95% confidence interval, 1.20–3.54; $P = 0.008$).
Conclusion: Iodine intake appeared to be fairly low in the Beninese population, according to World Health Organization criteria, and factors associated with low iodine intake were identified. Public health interventions to increase iodine intake, such as iodization of commercial salt and/or fortification of selected nutrients, should be strengthened at the national level.

Introduction

Iodine is essential to the function of several physiological processes of the body. As a mineral element, it is involved in the synthesis of thyroid hormones. The physiology involved is complex, depending on dietary intake, mechanisms of organification of iodine by the thyroid, and intra- and extrathyroid regulation [1]. A deficient dietary intake of iodine can cause several problems categorized collectively as iodine deficiency disorders (IDD), of which the most important are mental and motor deficits [2]. Indeed, an adequate concentration of thyroid

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hormone is essential for normal growth and brain development [3]. Moderate to severe iodine deficiency (ID) may cause sporadic cretinism and can reduce the average intelligence quotient by 12% to 13.5% [4]. Pregnant women need additional iodine due to increased production of thyroid hormone during pregnancy through increased renal loss and the requirements of the fetus [5]. ID during pregnancy may result in maternal and fetal goiter, cretinism, mental retardation, neonatal hypothyroidism, and the risk for miscarriage [4]. Iodine requirements are increased during lactation because of the newborn's needs [6]. Conversely, excessive iodine intake increases the risk for iodine-induced hyperthyroidism and autoimmune disease [2,7].

The World Health Organization (WHO), the United Nations Children's Fund (UNICEF), and the International Council for the Control of Iodine Deficiency Disorders (ICCIDD) recommend adding 20 to 40 mg of iodine to each kg of consumer salt [8]. Iodization of commercial salt is the most effective vehicle to increase iodine intake and is implemented in numerous countries. Recommended daily nutrient intake is 150 μg for adults and children >12 y and 250 μg for pregnant and lactating women [9]. Consumption of foods rich in iodine, such as seafood, dairy products, red meat, and vegetables can help ensure adequate iodine status.

Only a few countries (e.g., Switzerland, Scandinavian nations, Australia, the United States, and Canada) were completely iodine-sufficient before the 1990s [10,11], often because of supplementation of iodine in certain foods, mainly through mandatory iodization of salt. Since then, efforts have been made to facilitate the iodization of commercial salt in many countries. It is, however, estimated that the proportion of the world's population benefiting from iodized salt has not changed substantially from 2007 to 2011, when it was 70% to 71%, but the number of iodine-deficient countries decreased from 54 to 32, whereas the number of iodine-sufficient countries increased from 67 to 105 [11,12]. Among school-aged children (SAC), it is estimated that 241 million, or 29.8% at the world level, had insufficient iodine intake in 2011 with regional disparities, however. Southeast Asia has the largest number of SAC with low iodine intakes (76 million) and there has been little progress in Africa, where 39% (58 million) have inadequate iodine intake [11]. Benin, in West Africa, adopted universal salt iodization in 1994 [13], following a study by the Iodine Global Network (formerly the ICCIDD) showing that 19% of the population suffered from goiter and iodine intake was inadequate at a national level. A study in 2011 by the Directorate of Food and Applied Nutrition and UNICEF showed encouraging results of goiter prevalence (3.5%) among children and on the availability of iodized salt in their households [14]; however, the results (84 % of households using iodized salt) were below the 95% coverage threshold, which is one of the IDD elimination criteria. Furthermore, there are no representative national data on the consumption of iodine at the individual level in adults in Benin.

Iodine consumption is based on specific assays of urine samples. Because 90% of dietary iodine consumed is excreted in the urine [15], urinary iodine serves as a good reflection of recent dietary iodine intake and therefore of iodine status, and a result in 24-h urine is the reference technique [16,17]. Several methods are available to measure urinary iodine; the most common is flame spectrophotometry using the Sandell-Kolthoff reaction [18]. Other techniques, such as microplaques, semiquantitative methods, automated methods, and inductively coupled plasma mass spectrometry (ICP-MS) are also reported [16,18]. ICP-MS, although expensive, is considered the most accurate [16].

The present study aimed to assess dietary iodine intake and selected factors in adults in urban (Bohicon) and rural (Tanvè) areas of south Benin using 24-h urine testing.

Methods

Ethics and study population

The research protocol was approved by the Ethics Committee of the Faculty of Health Sciences, University of Abomey-Calavi (Benin). Eligible individuals were adults between ages 25 and 64 y and lived in the city of Bohicon or the district of Tanvè for at least 6 mo. They all gave informed consent. Bohicon and Tanvè are two areas south of Benin in the Zou department, which is farther to the sea than any other department in the south of the country. Bohicon is a city with 113 091 inhabitants. Tanvè is a district of the town of Agbangnizoun and had a population of 8034 in 2002 [19]. These two areas were chosen because of their ethnic similarity (predominance of Fon: 93% and 98% in Bohicon and Tanvè, respectively) [20,21]; and the similarity of their eating habits, with diets based on cereals, tubers, legumes, and fish; meat and dairy products are less available [22].

Sampling

Apparently healthy individuals were selected between November 2012 and September 2013. Of the 420 participants, 210 lived in the urban area and 210 in the rural area. The eligible sample was stratified by age (25–34, 35–44, 45–54, and 55–64 y). The study was conducted using a cluster sampling technique with probability proportional to size, as proposed by the WHO-STEPS (Stepwise Approach to Surveillance) survey for risk factors for noncommunicable diseases [23] and the proposed evaluation of immunization coverage in developing countries [24–26]. The population sampled comprised residents of all city neighborhoods or villages. This information was provided by the National Institute of Statistics and Economic Analysis. Thirty clusters were selected in each of the two zones. In each household, a man or a woman was selected alternately and according to the predefined age groups. We excluded eligible individuals who did not give their informed consent, any person with visible goiter or with a physical or mental condition (including speech and understanding impediments, mental illness, pregnancy, and menstruation) that could make the collection of urine samples or answering the questionnaire difficult, and those who were enrolled but failed to return to the health center for subsequent visits.

Anthropometric and dietary survey measures

Weight was measured using an electronic scale to the nearest 0.1 kg (E753, Seca, Hamburg, Germany). Height was measured in the standing position with a measuring rod (SECA 0.1 cm). Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). A semiquantitative food frequency questionnaire (FFQ) adapted from a FFQ instrument on salt developed by the George Institute for the WHO [27] covering the major food groups rich in iodine (dairy, eggs, fish and seafood, meat, vegetables, fruits) [28] was administered, and a diet diversity score was constructed. For each food group, a partial score (0–1) based on weekly frequency consumption was performed by dichotomizing persons with high versus low weekly consumption of iodine-rich foods as persons with a score ≥4 versus <4, with 4 being the median score in the study sample. The sum of partial scores (0–7) gave a diet diversity score that was divided in two categories (<4 and ≥4), respectively, for low and high diet diversity. We could believe that people often would be unable to tell whether the salt that they consume is iodized, hence information on salt (and related iodine) was omitted from the score as it was not obtained from participants.

Socioeconomic status

A socioeconomic status (SES) score was computed based on education, main occupation, and household amenities (as proxy for income) as previously reported [29]. Two levels were considered for education and occupation with respective partial scores of 0 and 1 (respectively: education below primary versus postprimary education; blue collar [semiskilled] versus white collar [skilled professionals and managers]). The household amenities partial score was the maximum of 10 [29], which was divided in two categories (0 and 1) if they were above or below the median score in the total sample. The SES total score ranged from 0 to 3.The SES score used in this study was then dichotomized as low (0–1) or high (2–3) based on the median score in the total sample.

Collection of 24-h urine

To optimize the collection of 24-h urine and given the constraints of complete collection, the following arrangements were made: avoidance of periods when food habits are subject to change (i.e., weekends, public and other

holidays); collection during a rest monitored by a nurse from the team in the nearest health center in the district where the participant lived; provision of medical justification for absence from work by employees. Each participant received a 5-L plastic container to collect urine for 24 h. The container was kept closed. The start and end collection were recorded. Participants reported whether they had missed any urine, particularly during a bowel movement. Once collection was complete, urine was homogenized and 2-mL samples were frozen at −20°C. The samples were transported to the Laboratory of Pharmacology and Toxicology at Limoges University Hospital in France, respecting the cold chain.

Analysis of urine samples

Iodine was measured by ICP-MS (Perkin Elmer Sciex Elan 6100 DRC ICP Mass Spectrometer, Courtaboeuf, France). The system was equipped with an AS-90 auto sampler, a Meinhard concentric nebulizer associated with a quartz cyclonic spray chamber, and a quartz bore injector [30]. The typical operating parameters were: radiofrequency power, 1350 W; plasma flow rate Ar 15-L/min; auxiliary gas flow, Ar 1.175-L/min. The dwell time was set to 100 ms. Because iodine has only one stable isotope, $m/z = 127$ was scanned for its determination. Tellurium (^{130}Te), used as internal standard, was selected as it possesses a similar mass and a comparable first ionization energy as iodine. The limit of detection was 0.1 μg/L and the linearity was good, up to 200 μg/L ($r = 0.9999$). The intra- and interassay inaccuracies, measured as the variation coefficient, were 1.8% and 13.5%, respectively. For internal quality control, we used Seronorm Trace Elements Urine Sero-AS (Billingstad, Norway) carried out after a passage of 10 urine samples to verify the instrument's adequate calibration. If there was a deviation, calibration was adjusted accordingly. External quality was successfully achieved by regular participation in the Intercomparison Program for Metals in Biological Matrices, organized by the Quebec Toxicology Center–National Institute of Public Health). The laboratory is accredited The French Accreditation Committee - International Organization for Standardization (COFRAC ISO) 15189 for this dosage.

For iodine measurements, 200 μL of urine were taken from each 24-h sample. The samples and their controls, composed of lyophilized human urine with enhanced iodine, were diluted 20-fold by adding an aqueous solution containing 0.1 mg/L NH_4 OH, 0.1 g/L EDTA, 5 mg/L *n*-butanol, and 0.1% Triton × 100. For each sample and control, five readings (replicates) were performed and the average was considered. The WHO and Iodine Global Network criteria were used to determine iodine intake status (Table 1). An appropriate level of consumption in a population was characterized by the combination of the following: a median urinary iodine concentration (UIC) ≥100 μg/L and <20% of the study population with UIC <50 μg/L [2].

Statistical analyses

Data were entered in Epi data 3.1 (EpiData Association, Odense, Denmark) and analyzed using Stat-view 5.0 software (SAS Institute, Cary, NC, USA). Quantitative variables were expressed as mean + standard deviation and medians. Differences in iodine levels were tested using the Student's *t* test when normality and homogeneity were verified, and otherwise using nonparametric tests (Mann-Whitney and Kruskal-Wallis tests). Logistic regression modes were performed to assess the associations between dichotomized categories of urinary iodine and selected variables (sex, survey area, age group, household size, SES, BMI classification, diet diversity score). Explanatory variables with $P < 0.20$ were included in the multivariate model, the dependent variables being UIC <100 μg/L on one hand and UIC <50 μg/L on the other. These limits were chosen to identify the factors associated with iodine status.

Table 1
Epidemiological criteria for assessing iodine nutrition based on median UIC of SAC and adults [2]

Urinary iodine (μg/L)	Iodine intake	Iodine status
<20	Insufficient	Severe iodine deficiency
20–49	Insufficient	Moderate iodine deficiency
50–99	Insufficient	Mild iodine deficiency
100–199	Adequate	Optimal
200–299	Above requirements	Likely to provide adequate intake for pregnant/lactating women, but may pose a slight risk for more than adequate intake in the overall population
≥300	Excessive	Risk for adverse health consequences

SAC, school-aged children; UIC, urinary iodine concentration

Results

Of 420 participants recruited for the study, 402 gave their consent (response rate, 95.7%).

The characteristics of the study population are summarized in Table 2. Potential food sources of iodine were consumed on average less than once a week, except for fresh milk, cheese in urban areas, and fruits in rural areas. Socioprofessional categories represented by subsistence farmers, women retailers, and housewives were in the majority (54.7%); 80% had no education beyond primary school.

We analyzed 401 urinary iodine results. One result deemed aberrantly high (1551.5 μg/L; >4 SD of the mean) was excluded. Three participants reported that they had missed a few drops of urine during bowel movements; their results were not excluded. 4.2% of the overall population had UIC <20 μg/L; 32.6% UIC: 20 to 49 μg/L; 39%: 50 to 99 μg/L; 19.6%:100 to 199 μg/L; 2%: 200 to 299 μg/L; and 2.5%: UIC ≥300 μg/L. The overall median UIC was 62.9 μg/L (IQR: 40–96.2 μg/L) with a mean of 81.3 ± 66.0 μg/L. The proportion of people with UIC <50 μg/L in the population was 36.8%. The distribution of UIC by area and sex is presented in Table 3. Urinary iodine was generally lower in rural than urban areas (median and mean of 54.7 μg/L, 66.8 ± 47.3 μg/L and

Table 2
General characteristics of study population (N = 401)

	Total population	Urban area	Rural area	*P*-value
Quantitative variables mean (SD)				
Anthropometric and general information				
Age (y)	43.6 (11.3)	43.3 (10.9)	44.02 (11.8)	0.525
BMI (kg/m^2)	24.3 (5)	25.9 (5.1)	22.7 (4.3)	<0.001
Household size (number of people)	6.9 (3.5)	6.8 (3.2)	7.1 (3.7)	0.385
Dietary intake (frequency of consumption/wk)				
Fresh milk	0.7 (1)	1.2 (1.2)	0.19 (0.4)	<0.001
Fish	0.7 (0.6)	0.8 (0.4)	0.6 (0.7)	0.001
Egg	0.6 (0.6)	0.9 (0.5)	0.4 (0.7)	<0.001
Cheese	0.9 (0.9)	1.6 (0.8)	0.3 (0.6)	<0.001
Red meat	0.7 (0.6)	0.8 (0.5)	0.6 (0.6)	0.001
Vegetables (salads)	0.2 (0.4)	0.4 (0.5)	0.03 (0.2)	<0.001
Fruits	1.16 (1.23)	0.92 (0.92)	1.40 (1.44)	0.005
Qualitative variables (percentage)				
Sex				
Male	199 (49.5)	97 (48.5)	102 (50.5)	0.689
Female	203 (50.5)	103 (51.5)	100 (49.5)	
Zone	402 (100)	200 (49.7)	202 (50.2)	-
Socioeconomic category				
Farmer, salesman or woman, housewife	220 (54.7)	75 (37.5)	145 (71.7)	
Artisan, craftsman or woman	73 (18.6)	39 (19.5)	34 (16.8)	<0.001
Manager business person	106 (26.3)	85 (42.5)	21 (10.4)	
Education				
No schooling	260 (64.6)	95 (48)	165 (81.6)	
Primary	62 (15.4)	56 (28)	6 (2.9)	<0.001
Secondary	66 (16.4)	36 (18)	30 (14.8)	
Tertiary	14 (3.4)	13 (6.5)	1 (0.4)	
Age (y)				
25–34	103 (25.6)	54 (27)	49 (24.2)	
35–44	99 (24.6)	47 (23.5)	52 (25.7)	0.6118
45–54	107 (26.6)	57(28.5)	50 (24.7)	
55–64	93 (23.1)	42 (21)	51 (25.2)	
BMI category (kg/m^2)				
<18.5	32 (7.9)	3 (1.5)	29 (14.3)	
18.5–25	226 (56.2)	97 (48.5)	129 (63.8)	<0.001
25–30	84 (20.9)	58 (29)	26 (12.8)	
≥30	60 (14.9)	42 (21)	18 (8.9)	

BMI, body mass index

Table 3
Distribution of urinary Iodine by region and sex

Variable	Global distribution		Rural		Urban		*P*-value
	Urinary iodine*	(%)	Urinary iodine*	(%)	Urinary iodine*	(%)	
Iodine level (μg/L)							0.001
<100 μg/L							
Mean (SD)	54.4 (23.6)	305 (76)	50.2 (23.5)	167 (82.6)	59.5 (22.6)	138 (69.3)	
Median	51.0		46.4		57.5		
≥100 μg/L							
Mean (SD)	166.9 (82.7)	96 (23.9)	146.4 (51.4)	35 (17.3)	178.6 (94.5)	61 (30.6)	
Median	139.1		133.4		142.4		
Region							<0.001
Mean (SD)	81.3 (66)	401 (100)	66.8 (47.3)	202 (50.3)	96.0 (78.1)	199 (49.6)	
Median	62.9		54.7		77.8		
Sex							
Male							
Mean (SD)	90.5 (64.2)	199 (100)	78.8 (54.9)	102 (51.2)	102.8 (70.8)	97 (48.7)	0.005
Median	78.6		65.6		88.1		
Female							
Mean (SD)	72.3 (66.7)	202 (100)	54.6 (34.2)	100 (49.5)	89.5 (84.2)	102 (50.5)	<0.001
Median	56.5		46.7		67.9		

SD, standard deviation
* μg/L

77.8 μg/L, 96 ± 78.1 μg/L, respectively; $P < 0.001$). The comparison between rural and urban areas showed a lower median UIC among women than among men (46.7 vs 67.9 μg/L, respectively; $P < 0.001$ in rural and 65.6 μg/L versus 88.1 μg/L; $P = 0.005$ in urban areas). Mean and median of UIC were lower in women than in men globally and by area.

Multivariate results are presented in Tables 4 and 5. Insufficient UIC (<100 μg/L) was positively associated with women (odds ratio [OR], 2.48; 95% confidence interval [CI], 1.44–4.26; $P = 0.001$) and BMI <25 kg/m^2 (OR, 2.06; 95% CI, 1.20–3.54; $P = 0.008$). Variables positively associated with UIC <50 μg/L were women (OR, 2.7; 95% CI, 1.30–3.31; $P = 0.002$), and BMI <25 kg/m^2 (OR, 2.52; 95% CI, 1.51–4.19; $P < 0.001$).

Ten participants with UIC >300 μg/L were recontacted to investigate the use of iodinated contrast agents. Three participants had used dermal Betadine (povidone iodine) solution 3 mo before the study. One woman had used gynecologic Betadine after giving birth. The other individuals had used a traditional medication proposed by healers, of unknown composition to them. These results were not excluded because of insufficient evidence and a relatively long period between use of the products and the investigation.

Discussion

The results showed a mild deficiency in the general population with a median UIC of 62.9 μg/L and with 36.8% of participants with UIC <50 μg/L. Significant differences between urban and rural areas and between men and women were found. The frequency of consumption of foods rich in iodine was low in the

Table 4
Determinants of insufficient iodine intake (UIC <100 μg/L) in Beninese adults

Variables	Univariate			Multivariate		
	OR	CI	*P*-value	OR	CI	*P*-value
Sex						
Men	1			1		
Women	2.17	[1.35–3.48]	**0.001**	2.48	[1.44–4.26]	**0.001**
Zone						
Urban	1			1		
Rural	2.14	[1.33–3.43]	**0.002**	1.60	[0.91–2.80]	0.101
Age group (y)						
<44	1			1		
≥44	1.08	[0.68–1.70]	0.739	1.07	[0.66–1.73]	0.770
Household size						
≤7	1					
>7	0.96	[0.60–1.55]	0.898			
Socioeconomic status						
High	1			1		
Low	2.58	[1.60–4.14]	**<0.001**	1.34	[0.74–2.42]	0.327
BMI category						
≥25	1			1		
<25	2.01	[1.26–3.21]	**0.003**	2.06	[1.20–3.54]	**0.008**
Diet diversity						
High	1					
Low	0.92	[0.56–1.52]	0.77			

BMI, body mass index; CI, confidence interval; OR, odds ratio; UIC, urinary iodine concentration
Bold indicates statistically significant values in univariate and multivariate analysis

Table 5
Determinants of moderate and severe iodine deficiencies (<50 μg/L) in Beninese adults

Variables	Univariate			Multivariate		
	OR	CI	*P*-value	OR	CI	*P*-value
Sex						
Men	1			1		
Women	1.70	[1.12–2.55]	**0.011**	2.07	[1.30–3.31]	**0.002**
Zone						
Urban	1			1		
Rural	2.05	[1.36–3.11]	**0.001**	1.60	[0.98–2.62]	0.057
Age group (y)						
<44	1			1		
≥44	1.35	[0.90–2.03]	**0.145**	1.38	[0.90–2.12]	0.136
Household size						
≤ 7	1					
>7	0.99	[0.65–1.51]	0.98			
Socioeconomic status						
High	1			1		
Low	2.21	[1.38–3.55]	**0.001**	1.11	[0.62–1.97]	0.723
BMI category						
≥25	1			1		
<25	2.42	[1.54–3.81]	**<0.001**	2.52	[1.51–4.19]	**<0.001**
Diet diversity						
High	1					
Low	1.28	[0.82–2.01]	0.263			

BMI, body mass index; CI, confidence interval; OR, odds ratio
Bold indicates statistically significant values in univariate and multivariate analysis

study population (in general less than once a week). This low frequency might partly explain ID observed if salt added to food was not properly iodized (15–40 ppm). More generally, it is estimated that ~90% of all salt in households in Benin is iodized, including in the area of the study according to the national survey on IDD performed in 2011 [14]. However, another more recent survey, the MICS-2014 (Multiple Indicators Cluster Survey), showed 39% coverage of adequately iodized salt nationwide [31]. Our results and those from the MICS-2014 suggest insufficient enforcement of the salt iodization program in Benin.

Investigation into the association between the variables showed women, and nutritional status (BMI <25 kg/m^2) to be associated with inadequate iodine intake in the present study. Association between UIC and diet diversity not significant may be due to the less sensitivity of the score. This suggests that special attention should be given to women and overall nutritional status to improve the iodine status in study population.

This is, to our knowledge, the first study conducted in Africa using ICP-MS to measure urinary iodine. ICP-MS is considered the most accurate method of analysis for urinary iodine and is often used as the "gold standard." It is a technically advanced method and is costly to implement and operate. This method is usually used in settings where high accuracy and precision are required and when the instrument can also be used for other applications in governmental, university, and hospital laboratories [16]. Despite the high cost for instrumentation, ICP-MS may soon become a routine procedure in clinical chemistry because of it high accuracy and its ability to measure several trace elements simultaneously [32]. When assessing iodine intake from 24-h urine, the WHO recommends a minimum sample size of 40 to 50 individuals for a precise estimate of the median [2,15] because of daily variation in iodine intake and excretion in individuals [33]. We used a large representative sample of the areas in this study (N = 402).

ID remains a public health problem in Benin. The fight against IDD began in Benin in 1994 and may have reduced the incidence of related diseases in the general population. A national study on iodine intake conducted in 2011 reported satisfactory results: median UIC among 798 SAC of 317.8 μg/L, with 4.5% who had a urinary iodine level <50 μg/L, and 12.5% with a level <100 μg/L [14]. The study analyzed spots urine samples by spectrophotometry at 420 nm using the Sandell-Kolthoff reaction, and results suggested a high iodine intake and were consistent with the absence of a substantial prevalence of IDD. Results on iodine intake in this study in children were higher than results among adults in the present study. However, the spot urine technique used in the study in children may not have adequately reflected 24-h iodine intake [18].

Studies in the West African region, specifically in Ivory Coast [34] and Nigeria [35], among adult populations free of goiter, revealed a median UIC of 443 μg/d in Abidjan, 166 μg/d in the north rural areas of Ivory Coast; and a mean of 138 μg/L in Ogun State (Nigeria), suggesting that iodine intake was adequate in these populations and possibly excessive in Abidjan. Iodine intake was determined using 24-h urine collections in Ivory Coast; whereas in Nigeria, the spot urine method was used, the sample size was extremely small (N = 6), and the validity may be questionable.

Results reported among children and pregnant women in other African regions were consistent with those found in the present study [36,37]. Moreover, the resurgence of ID remains a public health problem in some industrialized countries. Among the WHO regions, Europe has the highest prevalence of ID (>40% of children have low iodine intakes) and the lowest household coverage with iodized salt [38]. This is due, in some countries, to the fact that iodization of salt is not or no longer mandatory and that non-iodized salt may be imported from regions/countries where iodization is not mandatory.

Study limitations

The present study has several limitations. The first is that use of a single collection of 24-h urine to indicate iodine status may not necessarily represent the usual diet of a person. This potential source of variation could be minimized by doing repeat measures over several days a week with the same individuals. The second limitation is that the assessment of food consumption was focused only on major categories of foods due to field constraints, which may be specified in qualitative terms as the quantitatively in the FFQ. Although the FFQ may not assess absolute amounts accurately, it is likely that ranking (e.g., high versus low intake) is valid. Third, we did not assess conditions that affect the thyroid function because of lack of resources. Furthermore, the prevalence of medical diseases is expected to be low when participants come from a sample of the general population, which limits the possibility of true outliers. Finally, the study covered only two regions of Benin and may not necessarily reflect the situation in other areas in the country.

Conclusion

Iodine intakes in two regions of Benin were slightly below the usual recommendations. This population may therefore be mildly deficient in terms of iodine status. Despite continued public health efforts, optimal intake of iodine recommended for IDD elimination has not yet been achieved in the study population. The results obtained in this study were compared with the 2011 national data, in which iodine intake was assessed in SAC. Satisfactory results in the study in children, which contrasts with results from the adults in the present study, suggest significant regional disparities. The national salt iodization program should be strengthened to eliminate IDD permanently, and designed to take into account sex, social variables, and nutritional status.

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