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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