

Iodine nutritional status of pregnant Brazilian women according to biochemical and dietary markers: EMDI-Brasil study

Estado nutricional de iodo de gestantes brasileiras segundo marcadores bioquímicos e alimentícios: estudo EMDI-Brasil

Estado nutricional de yodo en mujeres brasileñas embarazadas según marcadores bioquímicos y alimentarios: estudio EMDI-Brasil

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Abstract The scope of this study was to characterize the iodine nutritional status of pregnant Brazilian women according to biochemical and dietary markers. It involved a cross-sectional study of 2,376 pregnant women. A semi-structured questionnaire was used to characterize the population. Urine samples were collected to investigate iodine nutritional status, and a 24-hour recall was used to assess food consumption. For the statistical analysis, the Shapiro-Wilk test was applied to verify the normality pattern, and descriptive analyses were conducted. The median urinary iodine concentration (UIC) was 186.6 µg/L. There was a 36.7% prevalence of iodine deficiency, 28.7% of iodine excess and 3.6% of iodine deficiency. The median iodine concentration was 26.6 mg/kg in salt, 1.1 mg/100 g in seasonings, 2.9 µg/L in water and 19.4 µg/100 g in fresh food. The average iodine intake was 160.2 µg. When assessing dietary intake, 49.8% of the pregnant women had a habitual iodine intake below 160 µg and none had an excessive intake. The conclusion drawn is that the median UIC showed adequate iodine nutritional status, though a high prevalence of iodine deficiency and excess was observed. In addition, iodine nutritional status varied, which may reflect socioeconomic and health inequalities.

Key words Pregnant women, Iodine, Nutritional status, Brazil

Resumo O objetivo é caracterizar o estado nutricional de iodo das gestantes brasileiras de acordo com marcadores bioquímicos e dietéticos. Trata-se de um estudo transversal realizado com 2.376 gestantes. Para a caracterização da população, foi aplicado um questionário semiestruturado. Amostras de urina foram coletadas para investigar o estado nutricional de iodo e o recordatório de 24 horas foi aplicado para avaliar o consumo de alimentos. Para a análise estatística, foi aplicado o teste de Shapiro-Wilk para verificar o padrão de normalidade e foram realizadas análises descritivas. A concentração mediana de iodo urinário (CIU) foi de 186,6 µg/L. Houve uma prevalência de 36,7% de deficiência de iodo, 28,7% acima da necessidade e 3,6% de excesso de iodo. A concentração mediana de iodo no sal foi de 26,6 mg/kg, nos temperos foi de 1,1 mg/100 g, na água foi de 2,9 µg/L e nos alimentos in natura de 19,4 µg/100 g. A ingestão média de iodo foi de 160,2 µg. Avaliando o consumo alimentar, 49,8% das gestantes tinham ingestão habitual de iodo abaixo de 160 µg e nenhuma tinha ingestão excessiva. A mediana da CIU demonstrou estado nutricional de iodo adequado, mas foi observada alta prevalência de deficiência e de excesso de iodo. Além disso, o estado nutricional de iodo variou, o que pode refletir desigualdades socioeconômicas e de saúde.

Palavras-chave Gestante, Iodo, Estado Nutricional, Brasil

Resumen El objetivo es caracterizar el estado nutricional de yodo de embarazadas brasileñas según marcadores bioquímicos y dietéticos. Se trata de un estudio transversal realizado con 2.376 mujeres embarazadas. Para caracterizar la población se aplicó un cuestionario semiestructurado. Se recolectaron muestras de orina para investigar el estado nutricional del yodo y se aplicó un recordatorio dietético de 24 horas para evaluar el consumo de alimentos. Para el análisis estadístico se aplicó la prueba de Shapiro-Wilk para verificar el patrón de normalidad y se realizaron análisis descriptivos. La concentración urinaria mediana de yodo (CUI) fue de 186,6 µg/L. Se encontró una prevalencia de 36,7% de deficiencia de yodo, 28,7% de sobre requerimiento y 3,6% de exceso de yodo. La concentración mediana de yodo en la sal fue de 26,6 mg/kg, en los condimentos fue de 1,1 mg/100 g, en el agua fue de 2,9 µg/L y en los alimentos naturales fue de 19,4 µg/100 g. La ingesta media de yodo fue de 160,2 µg. Al evaluar el consumo de alimentos, el 49,8% de las embarazadas tenían una ingesta habitual de yodo inferior a 160 µg y ninguna tenía una ingesta excesiva. La CUI mediana demostró un estado nutricional de yodo adecuado, pero se observó una alta prevalencia de deficiencia y exceso de yodo. Además, el estado nutricional del yodo varió, lo que puede reflejar desigualdades socioeconómicas y de salud.

Palabras clave Mujer embarazada, Yodo, Estado nutricional, Brasil

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Introduction

Iodine is a micronutrient responsible for the synthesis of thyroid hormones that are important for fetal growth and neurocognitive development¹. The gestational period is critical in metabolic, energetic and nutritional terms and these changes result in a plasma deficit, making pregnant women susceptible to iodine deficiency².

Thus, to maintain maternal and fetal euthyroidism, iodine intake should increase from 150 µg/day, which is the recommendation for non-pregnant adult women, to 250 µg/day during pregnancy, representing an increase of 60%³. Thus, to ensure that the population has an adequate intake and prevent Iodine Deficiency Disorders (IDD), universal salt iodization has been implemented, which represents a low-cost and efficient intervention for controlling IDD and is sustainable in the long term⁴.

Iodine deficiency affects 53% of pregnant women worldwide and can cause miscarriage, goiter, thyroid nodules and hypothyroidism in the pregnant woman and fetus, cretinism, delayed neuropsychomotor development and hypothyroidism^{5,6}. On the other hand, excess iodine in pregnancy has become a reality due to the ingestion of water, food, supplements and topical medications with a high iodine content, which can cause miscarriage, gestational hypertension, irritability, palpitations, fatigue, weight loss, premature birth and fetal death^{7,8}.

In Brazil, mandatory iodization of salt intended for human consumption was established in 1974⁹. In 2008-2009, the Family Budget Survey found that the Brazilian population was consuming around 12 g/day of salt, which would represent an average iodine intake of 420 µg/day¹⁰. For this reason, the iodization range was changed to 15 to 45 mg/kg of salt, and is still in force today¹¹. Currently, based on data from the National Survey to Assess the Impact of Salt Iodization, Brazilians are classified as having an adequate iodine nutritional status¹²⁻¹⁴. To maintain adequate iodine levels during pregnancy, one should consume 5 grams of salt a day, drink 3 liters of water daily and have an adequate diet¹⁵.

Iodine nutritional status is influenced by socioeconomic status, which determines access to food, food and nutritional security and adequate consumption⁵. In addition, food and water with adequate iodine content can be a protective factor against deficiency¹⁶.

In Brazil, there have been no studies characterizing the nutritional status of iodine among

pregnant women. The aim of this study was to characterize the iodine nutritional status of Brazilian pregnant women according to biochemical and dietary markers.

Methods

Design and population of the study

This research is part of the Multicenter Study of Iodine Deficiency (EMDI-Brazil), which aimed to assess the nutritional profile of iodine, sodium and potassium in the maternal-infant group through a cross-sectional study during pregnancy and lactation.

EMDI-Brazil was carried out in research centers in 11 municipalities in nine states and the Federal District. The municipalities investigated were: Palmas-TO, Aracaju-SE, São Luís-MA, Macaé-RJ, Belo Horizonte-MG, Viçosa-MG, Vitória-ES, Ribeirão Preto-SP, Rondonópolis-MT, Brasília-DF and Pinhais-PR. The research centers were invited on the basis of the local institution's infrastructure, researchers with recognized training in the field and the availability of staff to take part in the study. In this way, Brazil's macro-regions were represented, as well as coastal and inland regions.

This is an epidemiological, observational and cross-sectional study of Brazilian pregnant women.

Ethical aspects

This study was approved by the Human Research Ethics Committee of the Federal University of Viçosa under protocol number 2.496.986.

Data collection was carried out after signing the Informed Consent Form (ICF). The pregnant women received guidance on the importance of iodine for their health and that of their child, including how to store salt properly.

Sample calculation

To determine the sample size, the simple random sample was defined, with a minimum proportion of 8%, an estimated prevalence of 50% (range of 4% to 12%), and a 95% confidence level, resulting in 177 individuals. After including 10% for possible losses, the sample size was 195 pregnant women. This design was the same for all study centers, totaling a final sample of 2,145 pregnant women.

Criteria for inclusion and non-inclusion

Pregnant users of the public health system and residents in urban and rural areas of each municipality studied were considered eligible for evaluation. Pregnant women under the age of 18, history of disease and/or thyroid surgery, reported diagnosis of hypothyroidism, previous hypertension or hypertensive pregnancy syndrome were not included.

Data collection and laboratory analysis

Data collection took place between October 2018 and April 2021. The first contact with pregnant women was made at the Basic Health Units in each municipality, where doubts about the project were clarified and signatures were collected. Each municipality had an average of 10 Basic Health Units, and all pregnant women who were present in the units and met the inclusion criteria were invited to participate in the study. A semi-structured questionnaire was administered using the Research Electronic Data Capture (Redcap) online platform.

The questionnaire was subdivided into five parts, the first consisting of questions related to eligibility. The second part was related to the health profile assessment. The third part corresponded to information about salt and seasonings. The fourth part comprises questions about alcohol and cigarette consumption. And the fifth part was related to questions about sociodemographic condition. After collection, the data processing, validation and analysis steps were carried out.

To characterize the nutritional status of iodine in pregnant women, the Urinary Iodine Concentration was determined. This concentration is recommended as a biochemical indicator of greater sensitivity to iodine deficiency and a nutritional marker of recent dietary intake.

As a standardized procedure, the women were instructed at home to discard the first stream of urine and to collect 10 mL of casual urine in a sterile, hermetically sealed and previously identified container. The collected samples were separated into 5 mL aliquots and stored at -20°C in the respective centers until they were sent by SEDEX to the Clinical and Toxicological Analysis Laboratory of the Faculty of Pharmaceutical Sciences of the University of São Paulo in Ribeirão Preto.

An inductively coupled plasma mass spectrometer was used for the analyses model Elan DRC II (Perkin-Elmer, Norwalk, CT) operating

with high purity argon (99.999%, White Martins, Brazil). For the preparation of the samples and analysis in the ICP-MS, the method proposed by Macours¹⁷ was used with some modifications, being 500 µL of each urine sample diluted with 9 mL of solution containing TMAH 1% (v/v) + 0.01% Triton X-100. The calibration curves were prepared in base urine of bovine origin under the same conditions as the samples¹⁷. The quality control of the results was performed with analysis of certified reference material of urine from the National Institute of Standards and Technology (NIST), SRM 2670a - Toxic Elements in Freeze-Dried Urine.

The concentration of urinary iodine was classified according to the epidemiological criteria defined by the World Health Organization, where a urinary excretion of less than 150 µg/L is considered iodine deficiency, from 150 to 249 µg/L is adequate, from 250 to 499 µg/L above the need, and greater or equal to 500 µg/L excess³.

The concentration of iodine in foods, water, salt for household consumption and in industrialized or homemade spices was evaluated in the Chemistry and Food Analysis Laboratory of the Department of Food Technology of the Federal University of Viçosa (UFV).

The foods analyzed were selected by identifying foods consumed more than 80% of the time by pregnant women, including: *cario-quinha* beans, red beans, black beans, polished rice, cassava flour, cornmeal, whole milk powder and tapioca starch. Fifty grams of each uncooked food item were collected from farmers and local businesses in each center studied.

To prepare the food for analysis, all the rice and bean samples were ground in a knife mill. The other food samples were not ground, but were standardized to a similar particle size by passing them through a sieve. The crushed samples were stored in closed containers, duly identified and kept in the freezer at -18°C until analysis. The analyses were carried out in duplicate, by spectrophotometry, using the method proposed by Sveikina (1975), modified by Moxon and Dixon (1980), recognized and widely validated for iodine analysis in food samples, adapted by Perring *et al.* (2001) and modified^{18,19}.

Water samples were collected in the Basic Health Units (UBS) of all centers, in two bottles of polyethylene of 200 mL each (proof and proof), in the four seasons of the year: spring, summer, autumn, and winter. The quantification of iodine concentration in water was performed using the method described in the Stan-

dard Methods for the Examination of Water and Wastewater, 4500-I B, spectrophotometric method “Leuco Cristal Violeta” which determines aqueous iodine in the form of elemental iodine and hypoiodine acid²⁰.

And for the analysis of home-consumption salt and industrialized or homemade seasonings, 50 grams of home-consumption salt and 20 grams of seasonings were collected in hermetically sealed plastic containers and previously identified, in a sub-sample of 20% of the population studied. However, the evaluation of consumption salt and spices by pregnant women was not performed in the centers of Brasília, Macaé, and Palmas due to the interruption of collection caused by the COVID-19 pandemic.

It was also analyzed 52 commercial brands of salt available and acquired in the municipalities participating in EDMI-Brazil in order to verify the percentage of adequacy of salt brands available in retail for iodine content. For the evaluation of iodine content in the consumption salt, it was used the titration method recommended by the Ministry of Health and analyzed according to the manual of the Adolfo Lutz Institute²¹. Samples with iodine content between 15 and 45 mg/kg of salt were considered adequate as recommended by RDC nº 23, of 24 April 2013 of the National Health Surveillance Agency⁷. For the evaluation of iodine in seasonings was initially used the method of Moxon and Dixon that was later adapted by Perring *et al.* in triplicate, blindly, and randomly^{18,19}.

Finally, to estimate the dietary intake of the pregnant women, a 24-hour recall (R24h) was applied by trained assessors to the entire sample on the same day as the sociodemographic questionnaire and urine collection, followed by a second 24-hour recall in a sub-sample (18.3%) one week apart. To carry out the interview, the Automated Multiple-Pass Method was used, in which the pregnant women were instructed to report the food consumed, then this list was taken up again in search of any forgotten food, then information was collected on the time and place of meals, then a detailed description of the preparations was made, followed by the quantity. The Brazilian Food Quantification Manual was used to quantify the food portions in the 24hR^{22,23}.

For the estimation of iodine consumption, the Table of Composition of Iodine in Food (TCIA) was used²⁴. Iodine composition data from other tables were consulted when not available in TCIA²⁵.

The tool University of California, Davis (UCD)/National Cancer Institute (NCI) Sim-

ulating Intake of micronutrients for Policy Learning and Engagement (SIMPLE) was used to quantify the usual intake of iodine and the prevalence of inadequate intake, minimizing the effect of intraindividual variability on these estimates²⁶.

The adequacy of dietary iodine intake was based on the harmonized intake reference values proposed for populations, in order to allow the comparison of results between different epidemiological contexts. Thus, the values of Average Requirement (H-AR<160 µg) and Upper Level Intake (H-UL>600 µg) were considered to estimate the percentage of pregnant women with insufficient and excessive intake, respectively²⁷.

The analyzes were made for the total sample and stratified by Research Center, considering the parameters obtained in the analysis of the total sample. The usual intake of iodine in pregnant women was described by the median, percentiles of intake (P25 and P75), the average with their respective confidence intervals (95%CI), and the prevalence of inadequate intake and 95%CI.

Significant statistical differences were assumed when 95%CI did not overlap. The software SAS OnDemand for academics version (SAS Institute Inc.: Cary, NC, USA) was used in the estimates of habitual iodine intake²⁸.

Categorization of variables

Age was classified according to the risk factor. According to the Ministry of Health, women aged 35 or over are considered pregnant women at high risk for hypertension and gestational diabetes. Thus, age was classified as up to 34 years old, and 35 years old or more²⁹.

Per capita income was categorized considering the minimum wage of R\$ 1,045.00 or U\$ 216.33, defined for 2020, the year in which most of the data collection took place²⁴.

To assess nutritional status, the Pre-gestational Body Mass Index was calculated and classified according to the criteria of the Institute of Medicine (2009).

According to the Ministry of Health, pregnant women should preferably start prenatal care in the first trimester and have at least six consultations, one in the first trimester, two in the second and three in the third²⁹.

Thus, the week in which prenatal care began was categorized as before the 13th week, that is, in the first trimester, and after the 13th week.

Statistical analysis

The databases were exported from Redcap software to the exploratory analysis, in order to evaluate the consistency of the data. After these actions, the database was exported to Statistical Package for Social Sciences (SPSS) version 21.0 to perform the descriptive statistical analysis.

The Shapiro-Wilk test was applied to verify the pattern of distribution of quantitative variables, followed by visual analysis by histogram and box chart (Box Plot). The average with standard deviation or confidence interval (95%CI) was presented for parametric variables and the median with minimum and maximum or percentile 25 and 75 for non-parametric variables.

Results

Sociodemographic characteristics

Information was collected from 2,376 Brazilian pregnant women, being evaluated in Aracaju 273 (11.5%) pregnant women, in Brasília 202 (8.5%), Belo Horizonte 162 (6.8%), Macaé 220 (9.3%), Palmas 93 (3.9%), Pinhais 282 (11.9%), Ribeirão Preto (11.9%) (12.6%), Viçosa 272 (11.4%) and Vitória 60 (2.5%). In some centers more than 195 pregnant women were evaluated, because concomitant to this study, other studies were being developed with different objectives that would use this same sample. On the other hand, some centers did not reach the defined sample size, due to the interruption of data collection caused by the COVID-19 pandemic.

The median age of the pregnant women was 26 years, ranging from 18 to 47 years. Most of the pregnant women lived in the urban area (94.6%), lived with their partner (78.2%), self-declared brown (53.8%), had completed high school (46.0%), and had an income of half to one minimum wage per capita (31.3%) (Table 1).

Obstetric characterization

Regarding the health profile and obstetric history, most of the pregnant women were evaluated in the second trimester (40.2%), with a median gestational age of 24 weeks, ranging from 2 to 42 weeks. Most were primiparous (57.5%) and began prenatal care before the 13th gestational week (85.1%). Among multiparous pregnant women, 85.7% had the first pregnancy between 10 and 19 years, that is, still in adolescence (Table 2).

Table 1. Demographic and socioeconomic characteristics of Brazilian pregnant women. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Characteristics	Absolute and relative frequencies	
	n	%
Place of residence (n=2,239)		
Rural	122	5.4
Urban	2,117	94.6
Home agglomeration (n=2,218)		
Up to 2 two people at home	649	29.3
3 or more people at home	1,569	70.7
Live with a partner (n=2,225)		
No	486	21.8
Yes	1,739	78.2
Level of education (n=2,225)		
Incomplete elementary school	368	16.5
Complete elementary school	119	5.3
Incomplete high school	360	16.2
Complete high school	1,023	46.0
Incomplete higher education	148	6.7
Complete higher education	167	7.5
Postgraduate	40	1.8
Race (n=2,236)		
White	519	23.2
Brown	1,204	53.8
Black	420	18.8
Indigenous	12	0.6
Yellow	81	3.6
Income <i>per capita</i> (n=1,425)		
Up to ¼ of the minimum wage	278	19.5
Between ¼ to ½ of the minimum wage	394	27.6
Between ½ to 1 minimum wage	445	31.3
Higher than 1 minimum wage	251	17.6
2 or more minimum wages	57	4.0
Receives benefit of income transfer (n=2,251)		
No	1,804	80.2
Yes	447	19.8

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Evaluating supplementation, 82.5% made use in pregnancy. The most used supplements were ferrous sulfate (60.2%, n=1,363) and folic acid (47.5%, n=1,075). Only 6.7% (n=122) ingested a supplement that had iodine in its composition. According to the evaluation of the pre-pregnancy nutritional status, 48.4% were in the eutrophy range. Regarding lifestyle, most did not report smoking and alcohol consumption during pregnancy (Table 2).

Table 1. Demographic and socioeconomic characteristics of Brazilian pregnant women. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Characteristics	Absolute and relative frequencies	
	n	%
Receives Family Grant (n=2,248)		
No	1,815	80.7
Yes	433	19.3
Exercises paid work (n=2,235)		
No	1,274	57.0
Yes	961	43.0
Type of paid work (n=956)		
Employed in private sector with formal contract	557	58.1
Employed in private sector without formal contract	85	9.2
Domestic worker with formal contract	34	3.5
Domestic worker without formal contract	33	3.4
Public servant	62	6.5
Formal autonomous	62	6.5
Informal autonomous	123	12.8
Head of household (n=2,236)		
The pregnant woman herself	594	26.6
Partner	1,083	48.4
Others	559	25.0

*For some variables, the n is less than 2,376, either because it was information that some pregnant women did not answer or did not know.

Source: Authors.

Characterization of the nutritional status of iodine

Of the 2,376 pregnant women evaluated, only 1,891 delivered urine samples. Therefore, there was a loss of 485 urines, either because the pregnant woman answered only the questionnaire or because she gave up collecting urine later. Thus, the universe for analysis of the nutritional status of iodine was lower.

The median urinary iodine concentration among Brazilian pregnant women was 186.6 µg/L, ranging from 1.9 µg/L to 975.6 µg/L. The median urine concentration of each study center is described in Table 3.

Based on the epidemiological criteria adopted by the WHO, it was observed in the national scenario a prevalence of 36.7% (n=694) of iodine deficiency, 31% (n=586) of adequacy,

Table 2. Obstetric and health characteristics of Brazilian pregnant women. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Obstetric and health profile	Absolute and relative frequencies	
	n*	%
Gestational trimester (n=2,376)		
1 st	493	20.7
2 nd	954	40.2
3 rd	929	39.1
Age of the pregnant woman (n=2,376)		
Up to 34 years old	2,092	88.0
Higher or equal to 35 years old	284	12.0
Pregestational nutritional status (n=1,607)		
Underweight	96	6.0
Eutrophic	778	48.4
Overweight	457	28.4
Obesity	276	17.2
Parity (n=1,299)		
Primiparous	747	57.5
Multiparous	552	42.5
Week of the 1 st prenatal consultation (n=2,022)		
Prior to the 13 th week	1,720	85.1
After the 13 th week	302	14.9
Dietary supplement (n=2,280)		
Yes	1,881	82.5
No	399	17.5
Planned Pregnancy (n=2,370)		
Yes	819	34.6
No	1,551	65.4
Miscarriage (n=2,376)		
None	1,920	80.8
1	374	15.8
2	62	2.6
3 or more	20	0.8
Smoking during pregnancy (n=2,239)		
No	2,135	95.4
Yes	104	4.6

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28.7% (n=543) above the need and 3.6% (n=68) of the pregnant women presented excessive iodine intake. According to the research center, iodine deficiency presented a higher prevalence in Palmas-TO (62.2%), followed by Vitória-ES (51.4%), Brasília-DF (48.1%) and São Luís-MA (41.3%). The city of Viçosa-MG had the highest proportion of pregnant women with iodine intake above the recommendations (36.9%), followed by Pinhais-PR, with 33.3%. Regarding excess, there was no prevalence (0%) in Vitória-ES and Brasília-DF presented only 0.7% (Figure 1).

Table 2. Obstetric and health characteristics of Brazilian pregnant women. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Obstetric and health profile	Absolute and relative frequencies	
	n*	%
Frequency of smoking (n=103)		
Daily	84	81.6
Weekly	10	9.6
Fortnightly	3	2.9
Monthly	1	1.0
Rarely	5	4.9
Alcoholism in pregnancy (n=2,239)		
No	2,070	92.5
Yes	169	7.5
Frequency of alcohol consumption (n=169)		
Daily	2	1.2
Weekly	54	32.0
Fortnightly	29	17.2
Monthly	31	18.3
Rarely	53	31.3
Use of pure salt (n=2,243)		
No	478	21.3
Yes	1,765	78.7
Use of homemade seasoning (n=2,240)		
No	1,442	64.5
Yes	793	35.5
Use of industrialized seasoning (n=2,240)		
No	900	40.2
Yes	1,340	59.8
Frequency of eating out in days (n=2,242)		
None	934	41.7
Between 1 to 3 days	786	35.0
Between 4 to 7 days	522	23.3

*For some variables, the n is less than 2,376, either because it was information that some pregnant women did not answer or did not know.

Source: Authors.

Concentration of iodine in food, water, salt, and seasonings

The median concentration of iodine in uncooked food, in its fresh form, was 19.4 µg/100 g, ranging from 0.0 µg/100 g to 341.5 µg/100 g, depending on the food and the center analyzed (Table 4). Regarding drinking water, the median concentration of iodine was 2.9 µg/L (P25: 1.0 µg/L - P75: 3.6 µg/L), according to Table 4.

In the salt samples analyzed, the median iodine concentration was 26.6 mg/Kg (P25: 18.7 mg/Kg - P75: 34.2 mg/Kg). It was observed ad-

equate iodine concentration in 100.0% (n=14) of the salt samples of Belo Horizonte, in 90.5% (n=19) of the samples of Vitória, 85.7% (n=30) of the samples of Aracajú, 76.9% (n=30) of Ribeirão Preto, 72.2% (n=52) of Viçosa, 69.7% (n=23) of Rondonópolis, and 52.2% (n=24) of São Luís. In the available retail salt brands, the iodine concentration in 13.5% (n=7) was below 15 mg/kg and 13.5% (n=7) was above 45 mg/kg.

In seasonings, the median concentration of iodine was 1.1 mg/100g ranging from 0.0 to 7.0 mg/100g according to the research center. Seasoning samples from pregnant women from Belo Horizonte-MG were analyzed, where the median was 1.26 mg/100 g, ranging from 0.9 to 4.3 mg/100 g; Pinhais-PR presented a median of 0.9 mg/100 g, ranging from 0.00 to 1.8 mg/100 g; Ribeirão Preto-SP the median was 0.8 mg/100 g, ranging from 0.0 to 2.1 mg/100 g; in Viçosa-MG the median was 1.2 mg/100 g ranging from 0.00 to 4.1 mg/100 g; in the samples of Vitória-ES the median was 1.2 mg/100 g ranging from 0.1 to 7.0 mg/100 g and in Rondonópolis-MT where the median was 1.3 mg/100 g ranging from 0.0 to 3.9 mg/100 g.

Consumption of iodine

The median iodine intake was 160.2 µg (P25: 135.8 µg - P75: 187.2 µg). About 49.8% (95%CI: 49.6-50.0) of the pregnant women had habitual iodine intake below 160 µg and none had excessive intake. The median habitual iodine intake of pregnant women according to the research center is shown in Table 4.

Discussion

According to the characterization of the nutritional status of iodine in Brazilian pregnant women, about 49.8% had habitual iodine intake below 160 µg, that is, insufficient intake and none had excessive intake. In addition, the median concentration of urinary iodine was 186.6 µg/L, with a prevalence of 36.7% of deficiency, 28.7% above the need, and 3.6% of excess.

According to the region of location, Brazil has differences in climate, geographical, socio-demographic, cultural, and food characteristics. All these factors, directly and indirectly, affect the nutritional status of iodine³⁰. This can also be influenced by socioeconomic factors related to social class, occupation in the labor market, number of family members, schooling, family income, and culture, which determine the pref-

Table 3. Iodine concentration in foods consumed by Brazilian pregnant women according to the research center. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Center	Region of Brazil	Uncooked food	Iodine concentration (µg/100g)
Aracajú	Northeast	White rice (<i>Oryza sativa</i>)	16.8
		Cassava flour (<i>Manihot esculenta</i>)	3.9
		Carioca beans (<i>Phaseolus vulgaris</i> L)	9.2
		Black beans (<i>Phaseolus vulgaris</i> L)	0.0
		Red beans (<i>Phaseolus vulgaris</i> L)	16.9
		Cornflakes (<i>Zea mays</i> L)	62.5
		Milk powder (<i>Bos taurus</i>)	4.6
Brasília	Midwest	White rice (<i>Oryza sativa</i>)	20.2
		Cassava flour (<i>Manihot esculenta</i>)	19.4
		Carioca beans (<i>Phaseolus vulgaris</i> L)	14.6
Macaé	Southeast	White rice (<i>Oryza sativa</i>)	18.2
		Cassava flour (<i>Manihot esculenta</i>)	7.6
		Carioca beans (<i>Phaseolus vulgaris</i> L)	21.2
		Black beans (<i>Phaseolus vulgaris</i> L)	0.0
		Red beans (<i>Phaseolus vulgaris</i> L)	9.0
		Maize bran (<i>Zea mays</i> L)	12.2
		Milk powder (<i>Bos taurus</i>)	6.0
Palmas	North	White rice (<i>Oryza sativa</i>)	19.4
		Carioca beans (<i>Phaseolus vulgaris</i> L)	24.2
		Cassava flour (<i>Manihot esculenta</i>)	34.7
		Red beans (<i>Phaseolus vulgaris</i> L)	43.6
		Sprinkles (<i>Manihot utilissima</i>)	46.0
Pinhais	South	White rice (<i>Oryza sativa</i>)	21.8
		Cassava flour (<i>Manihot esculenta</i>)	15.3
		Carioca beans (<i>Phaseolus vulgaris</i> L)	5.4
		Black beans (<i>Phaseolus vulgaris</i> L)	2.9
		Red beans (<i>Phaseolus vulgaris</i> L)	15.7
		Maize bran (<i>Zea mays</i> L)	13.5
		Milk powder (<i>Bos taurus</i>)	19.8
Ribeirão Preto	Southeast	White rice (<i>Oryza sativa</i>)	14.9
		Cassava flour (<i>Manihot esculenta</i>)	0.3
		Carioca beans (<i>Phaseolus vulgaris</i> L)	19.7
		Black beans (<i>Phaseolus vulgaris</i> L)	9.7
		Maize bran (<i>Zea mays</i> L)	7.7
São Luís	Northeast	White rice (<i>Oryza sativa</i>)	31.9
		Cassava flour (<i>Manihot esculenta</i>)	8.2
		Carioca beans (<i>Phaseolus vulgaris</i> L)	29.1
		Black beans (<i>Phaseolus vulgaris</i> L)	25.6
Viçosa	Southeast	Brown rice (<i>Oryza sativa</i>)	48.0
		White rice (<i>Oryza sativa</i>)	50.4
		Cassava flour (<i>Manihot esculenta</i>)	48.3
		Carioca beans (<i>Phaseolus vulgaris</i> L)	53.7
		Black beans (<i>Phaseolus vulgaris</i> L)	42.7
		Red beans (<i>Phaseolus vulgaris</i> L)	40.3
		Maize bran (<i>Zea mays</i> L)	57.0
Vitória	Southeast	Milk powder (<i>Bos taurus</i>)	93.2
		White rice (<i>Oryza sativa</i>)	4.5
		Cassava flour (<i>Manihot esculenta</i>)	59.2
		Carioca beans (<i>Phaseolus vulgaris</i> L)	9.5
		Black beans (<i>Phaseolus vulgaris</i> L)	13.1
		Red beans (<i>Phaseolus vulgaris</i> L)	1.4
		Maize bran (<i>Zea mays</i> L)	14.7
		Milk powder (<i>Bos taurus</i>)	0.0

Source: Authors.

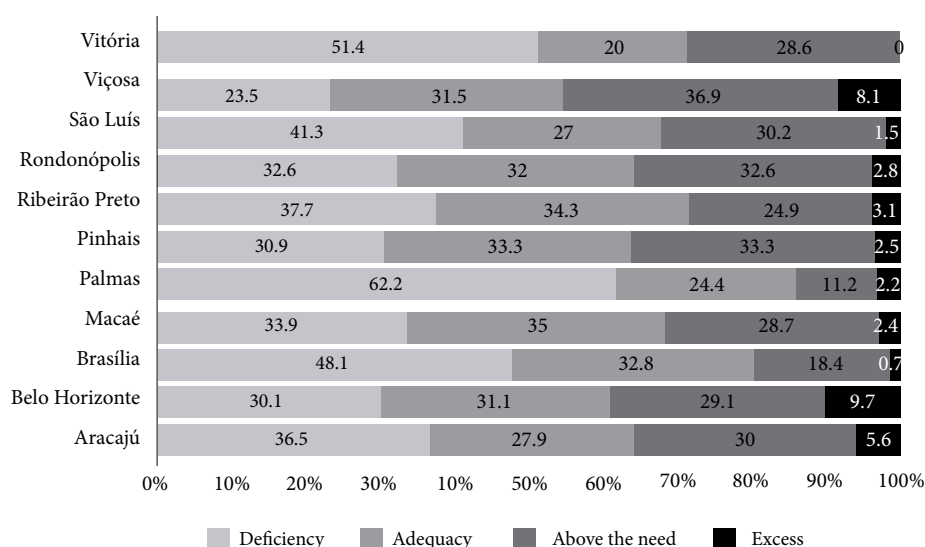


Figure 1. Prevalence of deficiency, adequacy, above the need and excess of iodine in Brazilian pregnant women according to the research center. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2023.

Source: Authors.

erences and eating habits that interfere in the selection, use and, intra-family distribution of food and, consequently, the adequacy of iodine intake^{8,31}.

Furthermore, studies show that pregnant women with low income, lower education, and self-declared black and brown, are more likely not to use iodized salt, which is associated with deficiency, due to insufficient intake of salt which is the main food source of iodine³²⁻³⁴.

In our study, we observed according to the Pre-gestational Body Mass Index that 45.6% of pregnant women were overweight. This result is close to that found by the Food and Nutrition Surveillance System (SISVAN) in 2020, where 1,087,538 pregnant women in Primary Health Care were evaluated, and of these, 564,136 (51.8%) were overweight³⁵. In pregnancy, excessive weight gain can increase maternal and perinatal morbidity, as well as fetal mortality, because it is a risk factor for Hypertensive Syndrome in Pregnancy, gestational diabetes, macrosomia, and prematurity^{36,37}.

Regarding the nutritional status of iodine, the median concentration of urinary iodine was 186.6 µg/L, indicating that Brazilian pregnant women had adequate nutritional status. However, it was observed that 36.7% had deficiency and 32.3% excess (considering intake above

need and excess), demonstrating a coexistence of significant prevalence in both extremes in our study. The high prevalence of disability shows the social vulnerability that affects Brazilian pregnant women.

In a study conducted in Rio Grande do Sul with 147 pregnant women, the average iodine was 226.8 µg/L, demonstrating adequate iodine nutritional status, which corroborates our study³⁸. However, in a study conducted with pregnant women living in Ribeirão Preto, São Paulo, median iodine was 137.7 µg/L, indicative of iodine deficiency³⁹. And, in a study conducted in Diamantina, Minas Gerais, median iodine was 94.6 µg/L, and 74% of the 214 pregnant women investigated presented deficiency⁴⁰.

Evaluating urinary iodine among the centers participating in this study, the highest prevalence of iodine deficiency was in Palmas-TO, followed by Vitória-ES, Brasília-DF and São Luís-MA. In Brazil, iodine deficiency, considering school data, is more prevalent in the states of the North region, in some of the Midwest and Northeast regions, and in some states of this area such as Amazonas, Acre, Maranhão and Piauí, the prevalence of deficiency is higher, due to the lower consumption of iodine in consequence of the long distance and poor quality of roads, which make it difficult to access urban ar-

Table 4. Median iodine concentration in urine, water, salt and usual iodine intake samples according to research centers. Multicenter Study of Iodine Deficiency (EMDI - Brazil), 2019-2021.

Research Center	Urine (µg/L)			Usual daily intake of iodine (µg)			Water (µg/L)			Consumption Salt (mg/Kg)		
	P25	Median	P75	Average (CI95%)	Prevalence of inadequate intake % (CI95%)	P25	Median	P75	P25	Median	P75	P75
Aracajú	119.1	199.8	315.9	163.4 (162.9-163.9)	49.4 (48.8-50.0)	135.8	160.6	188.0	2.3	3.0	4.2	22.1 29.1 34.8
Belo Horizonte	136.5	210.0	299.2	162.9 (162.4-163.5)	49.7 (49.0-50.5)	135.8	160.2	186.5	2.8	3.6	4.3	25.0 33.1 37.6
Brasília	101.7	153.4	216.2	163.4 (162.7-164.0)	49.3 (48.5-50.1)	136.8	160.7	187.8	3.1	3.2	3.2	- - -
Macaé	135.0	186.1	283.1	162.9 (162.4-163.5)	50.2 (49.5-50.8)	135.7	159.9	187.3	1.7	3.9	18.4	- - -
Palmas	72.5	124.2	184.3	163.1 (162.3-163.9)	50.1 (49.1-51.2)	135.3	159.7	187.8	0.0	0.2	0.4	- - -
Pinhais	132.2	198.6	285.6	163.0 (162.6-163.5)	49.7 (49.1-50.3)	135.8	160.3	187.2	6.7	7.8	8.8	26.5 29.4 39.0
Ribeirão Preto	112.8	180.9	263.6	163.3 (162.9-163.8)	49.4 (48.8-50.0)	136.2	160.6	187.2	0.5	1.0	1.6	21.1 30.0 42.2
Rondonópolis	134.3	204.0	287.2	163.2 (162.7-163.7)	49.8 (49.1-50.5)	135.6	160.2	187.3	1.5	2.8	5.4	17.0 28.7 34.9
São Luís	110.5	179.8	272.3	162.6 (162.2-163.1)	50.5 (49.9-51.0)	135.4	159.6	186.8	0.0	0.0	0.9	10.5 16.1 21.9
Viçosa	152.5	238.4	342.0	162.7 (162.2-163.2)	50.2 (49.6-50.8)	135.5	159.8	186.7	2.5	2.9	3.8	21.7 28.0 34.6
Vitória	101.9	135.0	251.0	163.9 (162.8-165.1)	47.9 (46.5-49.4)	135.8	161.8	188.4	1.0	1.1	1.2	18.7 24.8 29.4
National	118.0	186.6	280.9	163.1 (162.9-163.2)	49.8 (49.6-50.0)	135.8	160.2	187.2	1.0	2.9	3.6	18.7 26.6 34.2

P25 = Percentile 25; P75 = Percentile 75; CI95% = Confidence Interval 95%.

Source: Authors.

eas to buy iodized salt. In addition, as livestock is very widespread in this region, families end up consuming the coarse salt used for animal feed, which is usually not iodized¹⁴.

In contrast, we observed a highest proportion of pregnant women with intake above the recommendations was in Viçosa-MG, followed by Pinhais-PR; and excess was in Belo Horizonte, followed by Viçosa. In the southeastern and southern regions of Brazil, the population ingests a large amount of ultra-processed foods that have high caloric density and are rich in sugars, fats, and sodium¹⁴. In addition, it is necessary to consider that, especially during pregnancy, the high consumption of ultra-processed foods increases the risk for nutritional inadequacies, such as micronutrient deficiency, which can bring complications to the health of the mother and child, considered a global public health problem⁴¹.

Ultra-processed foods are produced with iodized salt, so they can increase the risk of excess⁴². In developed countries, processed foods such as meat, cheese, and bread already constitute the largest portion of salt intake and in developing countries, the consumption of processed foods and condiments has increased in recent decades, influenced by income growth, urbanization, greater female participation in the labor market and lifestyle changes⁴³. However, the Brazilian legislation is flexible and allows salt to be used without iodine in the formulation of food products, if it changes the organoleptic properties, so it is necessary to periodically monitor the use of iodized salt by food industries, in order to achieve adequate iodine nutrition in the population^{7,44}.

Regarding the concentration of iodine in water and food, it is necessary to consider that it is variable according to the proximity of the region to the sea, climatic conditions, and the use of fertilizers containing iodine for food production. These factors may affect the environmental availability of iodine and, consequently, condition the contribution of this micronutrient to the population⁴⁵. Thus, the low concentration of iodine in water, as evidenced in our study, may be associated with deficiency. The place that presented the highest concentration of iodine in the water was Pinhais-PR, different from what was expected, since it is a rainy region and the higher volume of precipitation causes increased water levels in the reservoirs, resulting in dilution and lower concentration of the mineral in the water⁴⁶.

According to the evaluation of the salt consumption of Brazilian pregnant women, the median iodine in the samples was 26.6 mg/kg, a value that is within the recommended range of 15 to 45 ppm⁴⁴. Corroborating with our study, although superior, in the National Survey for Assessment of the Impact of Salt Iodation of school-children, the same methodology and range of iodization was used to evaluate the salt. Thus, the authors observed that the mean iodine in the samples was 40.14 ± 2.72 µg/g, and was also considered adequate¹². Regarding the evaluation of the seasonings, most were homemade, without indications of ingredients or the presence of salt, which justifies the presence of iodine in different concentrations in most of the samples analyzed.

Considering food consumption, about 49.8% of pregnant women studied did not meet the estimated average need for iodine, considering the EAR⁴⁷. Stratifying by evaluated center, the place with the lowest usual consumption of iodine was São Luís with 159.6 µg and, consequently, with the highest percentage of inadequacy (50.5%). However, it is necessary to consider that the food consumption of pregnant women can be influenced by family, cultural beliefs, desires for specific foods, and physiological changes, such as nausea and vomiting⁴⁸.

Limitations of this study include the loss of 20.4% of urine samples from pregnant women, either because they only answered the questionnaire or because they gave up collecting urine afterwards. In addition, the use and random application of the 24-hour recall during the validity period of the study in different centers, which may have reduced the ability of this instrument to capture sporadic consumption of important dietary sources of iodine, such as fish. In addition, the concentration of iodine in food was influenced by the high variability of this nutrient in food and the use of nutritional composition information from composition tables of other nationalities. Finally, this is a cross-sectional study, which does not allow us to assess cause and effect. However, it does give us an overview of the situation of pregnant women in Brazil.

The strengths of this study include the national scope of the sample, which is essential for investigating the current iodine status of Brazilian pregnant women. In addition, through this study, it was possible to know the situation of Brazilian pregnant women regarding the nutritional status and food availability of iodine, allowing the development of strategies and effective public policy actions.

Final considerations

The median urinary iodine concentration indicated adequate iodine nutritional status among Brazilian pregnant women. However, considering the extremes, a high prevalence of iodine deficiency and excess was observed, which may be

a reflection of the social, economic and health inequalities among Brazilian women.

In addition, it was observed that the concentration of iodine in water, food, salt and condiments varied according to geographical region, so iodine deficiency can also be caused by ecological factors.

Collaborations

AC Candido was responsible for analyzing and interpreting the data, writing the article and is responsible for all aspects of the work to ensure the accuracy and integrity of any part of the work. SAV Ribeiro assisted in the interpretation of the data, carried out a relevant critical review of the intellectual content and approved the final version to be published. PCA Fonseca carried out a relevant critical review of the intellectual content and approved the final version to be published. AM Navarro carried out a relevant critical review of the intellectual content and approved the final version to be published. FCC Oliveira carried out a relevant critical review of the intellectual content and approved the final version to be published. DLF Silva assisted in

the interpretation of the data, carried out a relevant critical review of the intellectual content and approved the final version to be published. EAF Fontes carried out a relevant critical review of the intellectual content and approved the final version to be published. SP Crispim carried out a relevant critical review of the intellectual content and approved the final version to be published. MS Macedo carried out a relevant critical review of the intellectual content and approved the final version to be published. SCC Franceschini was responsible for the conception and interpretation of the data, is responsible for all aspects of the work in guaranteeing the accuracy and integrity of any part of the work, carried out a relevant critical review of the intellectual content and approved the final version to be published.

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