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Household Salt Storage and Seasoning Consumption Are Predictors of Insufficient Iodine Status Among Pregnant Women in Southeastern Brazil

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Abstract

Iodine deficiency in pregnancy may lead to adverse maternal and fetal outcomes, including impaired child development. Sociodemographic factors and different dietary habits may be related to iodine status in pregnant women. The aim of this study was to evaluate the iodine status and its predictors among pregnant women in a city of Southeastern Brazil. This cross-sectional study was conducted with 266 pregnant women receiving prenatal care in 8 primary health care units. Sociodemographic, obstetric and health, habits of acquisition, storage and consumption of iodized salt, and dietary iodine intake data were collected through a questionnaire. The iodine content was evaluated in urinary iodine concentration (UIC), household salt and seasonings, and drinking water samples. Pregnant women were categorized into three groups according to the UIC, determined by iodine coupled plasma-mass spectrometry (ICP-MS): insufficient (< 150 μg/L), adequate (150–249 μg/L), and more than adequate iodine nutrition (≥ 250 μg/L). The median (p25–p75) UIC was 180.2 μg/L (112.8–262.7). It was found 38% and 27.8% of insufficient and more than adequate iodine nutrition, respectively. Number of gestations, KI content of supplement, alcohol consumption, salt storage, and frequency of using industrialized seasoning were associated to iodine status. Alcohol consumption (OR = 6.59; 95%CI 1.24–34.87), pack the salt in opened container (OR = 0.22; 95%CI 0.08–0.57), and use industrialized seasoning weekly (OR = 3.68; 95% CI 1.12–12.11) were predictors of iodine insufficiency. The pregnant women evaluated have adequate iodine nutrition. Household salt storage and seasoning consumption were risk factors for insufficient iodine status.

Keywords Iodine status · Pregnancy · Urinary iodine concentration · Iodized salt · Brazil

Introduction

Iodine deficiency in pregnancy has been one of the major public health problems affecting developed and developing countries [1], and the most important preventable cause of brain damage [2].

Maternal daily iodine requirement increased by approximately 50% due to the elevated production of thyroid hormone, the enhanced iodine renal clearance, the requirement of fetal iodine, and the transference of iodine from the mother to the fetus [3, 4].

Therefore, 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 a daily iodine intake of 250 μg

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to prevent iodine deficiency in pregnancy, in contrast to 100–150 µg for the general population [5].

The relevance of this issue concerns that iodine deficiency may lead to a wide spectrum of damage to maternal and child health, such as hypothyroidism, goiter, increased risk of miscarriage, perinatal and infant mortality, and neurocognitive and psychomotor deficits, collectively called iodine deficiency disorders (IDD) [1, 6].

The iodized salt is the main source of iodine in countries with fortification programs [7]. Universal salt iodization (USI) is a simple, effective and low cost method, and remains the primary strategy to achieve the goal of IDD elimination worldwide [8]. In Brazil, the USI is mandatory since 1956, and has been remarkably successful based on the relevant reduction in prevalence of goiter in school-age children, considered a proxy for the general population [9].

Currently, the country is considered a region of adequate iodine intake [10] not reflecting the iodine status in more vulnerable groups to the IDD, whereas studies conducted worldwide have been highlighting significant prevalences of iodine insufficiency in pregnant women [7, 10–12].

Sociodemographic factors and different dietary habits may be related to iodine status in pregnancy [13]. The urinary iodine concentration (UIC) is widely used in population surveys to assess the recent iodine status considering that more than 90% of the absorbed iodine is eliminated in the urine [6].

Regular monitoring of iodine status and the knowledge of its predictors in pregnant women are necessary to plan and execute specific actions against iodine deficiency. Furthermore, this evaluation should be carried out in different regions of Brazil, considering its large differences in socio-demographic, geographic, and climatic aspects.

We aimed to evaluate the iodine status and the predictors of insufficient and more than adequate iodine nutrition among pregnant women from primary health care units in a city of Southeastern Brazil.

Materials and Methods

Study Design

This is a cross-sectional study conducted with 266 pregnant women receiving prenatal care from May, 2019, to February, 2020, in 8 randomly selected primary health care units covering almost all regions of a city from Southeastern Brazil. The study is part of the Multicenter Study of Iodine Deficiency (EMDI-Brazil) aimed at assessing the status of iodine, sodium and potassium among pregnant women, mothers and infants groups in Brazilian macro-regions.

Participants

Pregnant women aged ≥ 18 years old, at any gestational age, with no history of previous or current diagnosed thyroid disease and/or surgery were included in the study.

The sample size was determined from a minimum proportion of 8%, with a relative error of 4% (range 4 to 12%) and a 95% confidence level, which led to a simple random sample of 177 pregnant women. As the sample was selected by primary health care unit, a design effect of 1.5 was included, which increased the sample size to 266 pregnant women.

Informed consent was provided by all participants. Ethical approval was granted by the Ethics Committee of Hospital das Clinicas of Medical School of Ribeirão Preto – University of São Paulo (no. 3.252.310).

Data Collection

Sociodemographic; obstetric and health; and habits of acquisition, storage, and consumption of iodized salt data were collected through the application of a semi-structured and face-to-face interview questionnaire, with the support of Research Electronic Data Capture (REDCap®)—version 8.10.1.

The estimation of the dietary iodine intake was carried out by previously trained nutritionists through 24-h dietary recalls (24hR) following the "multiple-pass" methodology into five stages [14].

The first 24hR was obtained from all sample, and the second, from a subsample (16.6%) to control the intrapersonal variability.

Urine, Household Salt and Seasoning, and Drinking Water Samples

The collection of a random urine samples (20 mL) was taken. Samples were separated into 10 mL aliquots and stored at − 20 °C. The pregnant women were categorized into three groups according to the UIC cut-off points defined by WHO: insufficient (< 150 µg/L), adequate (150–249 µg/L), and more than adequate iodine nutrition (≥ 250 µg/L) [5].

Approximately 50 g of household salt and 20 g of homemade[1] or industrialized[2] seasoning (when used by the participants) were collected from pregnant women. EMDI-Brazil determined the collection of 20% ($n = 54$) of a subsample. However, due to the pandemic of COVID-19, only 39 (15%) and 28 (10.5%) samples were collected for salt and seasoning, respectively.

[1] Prepared by hand in the home by adding fresh ingredients such as onions, garlic and herbs to table salt.

[2] Ready-to-use seasoning, industrially prepared and purchased in commercial establishments, such as meat and vegetable bouillons.

Approximately 200 mL of drinking water were collected in two climatic seasons of the year, winter and spring, in the drinking fountains[3] of the 8 primary health care units included in the study, for a total of 16 samples.

Treatment of Food Intake Data

Dietary iodine intake was assessed based on a dietary iodine table compiled from international databases [15] with the support of GloboDiet® Program version *Data Entry*.

The 24-h recall was adapted for paper application and subsequent data entry into the GloboDiet software, Brazilian version. The adaptations were made to reflect the data entry in GloboDiet, in which they are structured in the form of facets and descriptors systematically applied to describe the foods.

Inconsistency notes automatically generated by the software or included by the typist were treated in a standardized way. Data quality control was also performed to check for extreme values in daily intake of nutrients and food groups, number of recollections collected, days of the week assessed, and number of items reported.

Data were linked to the table of composition of iodine in foods [15]. Multiple Source Method (MSM) software was used to estimate the usual dietary intake of iodine and energy [16]. The usual dietary iodine intake was adjusted for total energy intake by linear regression by SPSS software version 22.0.

Usual iodine intake was classified into: < 150 µg/day, 150–249 µg/day, and ≥ 250 µg/day, referring to the WHO recommendations for the adult population and pregnant women, respectively.

Laboratory Analysis

The determination of ioduria was performed using an inductively coupled plasma mass spectrometer (ICP-MS) (NexIon 2000, PerkinElmer, USA) operating with high purity argon (99.999%, Maxiair, Brazil). The method proposed by Macours et al. [17] with some modifications was used for the analysis.

The determination of iodine content in salt samples was performed using the techniques recommended by the Ministry of Health and the Adolfo Lutz Institute manual [18]. Samples with iodine levels between 15 and 45 mg/kg of salt were considered adequate according to the ANVISA criteria (available in https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2013/res0023_23_04_2013.html).

[3] The water in the drinking fountains reflects the water consumed by pregnant women, since drinking water in Ribeirão Preto, São Paulo, comes from a single source, the Guarani aquifer.

The determination of iodine content in seasonings samples was performed by the methodology adapted for colorimetric determination [19]. The determination of iodine content in drinking water samples was performed by the "Leuco Crystal Violet" Spectrophotometry method [20–22].

Statistical Analysis

Normally distributed data are presented as mean ± standard deviation; non-normally distributed data are presented as median and interquartile range. Categorical data are presented as frequency and percentage.

Normality assumption was assessed by the Kolmogorov–Smirnov test. To compare the means of different groups, one-way analysis of variance (ANOVA) was performed, followed by Tukey post hoc test. To verify possible associations between different groups and categorical variables, the chi-square test or Fisher's exact test was performed.

The variables known to influence iodine status in pregnancy reported from previous studies were included in the multinomial logistic regression model: age, education, paid work, pregnancy planning, number of gestations, gestational trimester, gestational BMI, smoking habit, alcohol consumption, type of salt, salt storage, habit of adding salt to food, frequency of industrialized seasoning use, and usual dietary iodine intake. The iodine content in salt, seasoning, drinking water, and supplement was not included because its small sample size. The absence of multicollinearity was checked.

The variables that remained in the final model resulted in $p \leq 0.05$ by backward stepwise method. Results are presented as odds ratio (OR) and 95% confidence intervals (95% CI). Analysis was performed using SPSS software version 22.0.

Results

A total of 266 pregnant women were evaluated. Sociodemographic data, obstetric and health data, habits of acquisition, storage and consumption of iodized salt, and dietary iodine intake are described in Tables 1, 2 and 3, respectively.

The median (p25–p75) UIC was 180.2 µg/L (112.8–262.7), classified as adequate iodine nutrition according to WHO epidemiological criteria (Table 2). The prevalence of insufficient, adequate and more than adequate iodine nutrition was 38.0% ($n = 101$), 34.2% ($n = 91$), and 27.8% ($n = 74$), respectively.

The mean ± SD of the iodine content in household salt samples was 31.4 ± 15.7 mg/kg, compatible with current governmental recommendation (Table 3). The iodine content was below 15 mg/kg in 5 (12.8%), above 45 mg/kg in 6 (15.4%), and within the recommended range in 28 (71.8%) samples. The iodine content varied from 0 to 79.4 mg/kg.

Table 1 Sociodemographic data according to iodine nutritional status in pregnant women from primary health care units in a city of Southeastern Brazil

		All participants	Iodine nutritional status (UIC)						*P* value*
			Insufficient		Adequate		More than adequate		
		n (%)	*n*	%	*n*	%	*n*	%	
Geographic region	North	59 (2.2)	23	22.8	16	17.6	20	27.0	0.48
	South	139 (52.3)	54	53.5	54	59.3	31	41.9	
	East	40 (15.0)	15	14.9	12	13.2	13	17.6	
	West	28 (10.5)	9	8.9	9	9.9	10	13.5	
Age (years old)		26.7 ± 5.8	26.7 ± 5.8		27.1 ± 6.0		26.2 ± 5.6		0.65
Age (years old)	< 20	28 (10.5)	10	9.9	8	8.8	10	13.5	0.41
	20–29	150 (56.4)	59	58.4	53	58.2	38	51.4	
	30–34	56 (21.1)	21	20.8	15	16.5	20	27.0	
	≥ 35	32 (12.0)	11	10.9	15	16.5	6	8.1	
Skin color	White	94 (35.5)	32	31.7	34	37.8	28	37.8	0.26
	Black	27 (10.2)	7	6.9	13	14.4	7	9.5	
	Brown	143 (54.0)	62	61.4	43	47.8	38	51.4	
	Other	1 (0.4)	0	0.0	0	0.0	1	1.4	
Education (years of study)	≤ 4	6 (2.3)	3	3.0	1	1.1	2	2.7	0.67
	5–8	70 (26.3)	28	27.7	19	20.9	23	31.1	
	9–11	167 (62.8)	63	62.4	61	67.0	43	58.1	
	> 11	23 (8.6)	7	6.9	10	11.0	6	8.1	
Paid work	Yes	139 (52.3)	59	58.4	48	52.7	32	43.2	0.13
	No	127 (47.7)	42	41.6	43	47.3	42	56.8	
Household income (MW)	-	2.8 ± 1.8	2.6 ± 1.5		2.9 ± 1.9		2.9 ± 2.1		0.65

Values are presented as absolute and relative frequency – *n* (%) or mean ± standard deviation

*According to ANOVA or Chi-square tests. *UIC* urinary iodine concentration; *MW* minimum wage

The mean ± SD of the usual dietary iodine intake was 122.8 ± 29.2 µg (Table 3), below the daily iodine requirement recommended by WHO (250 µg) and the recommended dietary allowance (RDA) (220 µg) during pregnancy. Most of the sample (72.3%) presented usual dietary iodine intake below 150 µg, the daily intake for adult population.

Sociodemographic data (geographic region, age, skin color, education, paid work, and household income) were not associated ($p > 0.05$) to iodine nutritional status (Table 1). There was association of number of gestations ($p = 0.04$) and alcohol consumption ($p = 0.03$) to iodine nutritional status. Furthermore, there was a difference in the KI content of the supplement between the insufficient and more than adequate iodine nutritional status ($p = 0.02$) (Table 2).

Regarding the habits of acquisition, storage and consumption of iodized salt, there was association of salt storage ($p = 0.04$) and the frequency of industrialized seasoning use ($p = 0.05$) to iodine nutritional status. There was no difference ($p > 0.05$) in the iodine content in salt, seasoning and drinking water samples. Likewise, the usual dietary iodine intake was not different ($p > 0.05$) among the groups (Table 3).

The multinomial logistic regression model showed that alcohol consumption (OR = 6.59; 95% CI 1.24–34.87; $p = 0.02$), and weekly use of industrialized seasoning (OR = 3.68; 95% CI 1.12–12.11; $p = 0.03$) were positively related to UIC < 150 µg/L. Stored salt in a opened container (OR = 0.22; 95% CI 0.08–0.57; $p = 0.002$) was negatively related to UIC < 150 µg/L. No variable was predictor of more than adequate iodine nutrition (Table 4).

Discussion

In this study, pregnant women have adequate iodine nutrition based on median UIC. Nonetheless, 38% and 27.8% presented insufficient and more than adequate iodine nutrition, respectively. This finding highlights the evidence of a higher prevalence of iodine deficiency in pregnant women even in iodine-sufficient regions [12, 23].

Considering the WHO epidemiological criteria, the studied population does not present an iodine status that characterizes a public health problem, since less than 50% of the sample (15.8%) presented a UIC < 100 µg/L and less than 20% (3%), a UIC < 50 µg/L [5]. However, there is not a defined criteria for pregnant women, making this interpretation challenging.

Table 2 Obstetric and health data according to iodine nutritional status in pregnant women from primary health care units in a city of Southeastern Brazil

		Iodine Nutritional Status (UIC)							
		All participants	Insufficient		Adequate		More than adequate		
		n (%)	*n*	%	*n*	%	*n*	%	*P* value*
UIC (µg/L)	-	180.2 (112.8;262.7)	100.0^{a} (80.9; 125.1)		192.2^{b} (166.9; 212.9)		322.6^{c} (289.5; 390.8)		< 0.001
Number of gestations	Primigravida	91 (34.2)	38	37.6	33	36.3	20	27	0.04
	Secundigravida	99 (37.2)	27	26.7^{a}	38	41.8$^{a.b}$	34	45.9^{b}	
	Multigravida	76 (28.6)	36	35.6^{a}	20	22.0^{b}	20	27$^{a.b}$	
Gestational age (weeks)		21.9 ± 8.8	21.86 ± 8.73		21.77 ± 8.35		22.07 ± 9.5		0.97
Pre-gestational BMI	Underweight	15 (5.7)	7	7.0	5	5.5	3	4.1	0.93
	Normal weight	110 (41.5)	38	38.0	38	41.8	34	45.9	
	Overweight	75 (28.3)	30	30.0	24	26.4	21	28.4	
	Obese	65 (24.5)	25	25.0	24	26.4	16	21.6	
Gestational BMI	Underweight	33 (12.5)	12	11.9	13	14.6	8	11.0	0.48
	Normal weight	87 (33.1)	32	31.7	30	33.7	25	34.2	
	Overweight	78 (29.7)	35	34.7	19	21.3	24	32.9	
	Obese	65 (24.7)	22	21.8	27	30.3	16	21.9	
KI supplement use	Yes	9 (3.4)	3	3.0	3	3.3	3	4.1	0.93
	No	257 (96.6)	98	97.0	88	96.7	71	95.9	
KI content of the supplement (µg)	-		143.3 ± 11.5^{a}		166.7 ± 28.9$^{a.b}$		200.0 ± NA^{b}		0.02
Smoking habit	Never	239 (89.8)	89	88.1	82	90.1	68	91.9	0.38
	Stopped	7 (2.6)	5	5.0	2	2.2	0	0.0	
	Continue	20 (7.5)	7	6.9	7	0.7	6	8.1	
Alcohol consumption	Yes	18 (6.8)	12	11.9	4	4.4	2	2.7	0.03
	No	248 (93.2)	89	88.1	87	95.6	72	97.3	

Values are presented as absolute and relative frequency – *n* (%) or mean ± standard deviation

*According to ANOVA or Chi-square tests. Different subscribed letters indicate statistical difference. *BMI* body mass index; *KI* potassium iodide. *NA* not applicable; *UIC* urinary iodine concentration

Table 3 Household salt data, iodine content in salt, seasoning and drinking water samples, and usual dietary iodine intake according to iodine nutritional status in pregnant women from primary health care units in a city of Southeastern Brazil

		All participants	Iodine Nutritional Status (UIC)						*P* value*
			Insufficient		Adequate		More than adequate		
		n (%)	*n*	%	*n*	%	*n*	%	
Salt type	Sea	3 (1.1)	2	2.0	0	0.9	1	1.4	0.37
	Iodized refined	254 (95.8)	95	94.1	86	95.6	73	98.6	
	Light	1 (0.4)	1	1.0	0	0.0	0	0.0	
	Pink Himalayan	7 (2.6)	3	3.0	4	4.4	0	0.0	
Salt storage	Opened container	55 (20.7)	14	13.9[a]	27	29.7[b]	14	18.9[a.b]	0.04
	Closed container	208 (78.2)	85	84.2[a]	63	69.2[b]	60	81.1[a.b]	
	Original packing	3 (1.2)	2	2.0	1	1.1	0	0.0	
Salt duration (months)	$n=219$	2.4 ± 2.0	2.4 ± 2.3		2.7 ± 2.2		2.1 ± 1.1		0.20
Homemade seasoning use	Daily	22 (78.6)	9	75.0	6	75.0	7	87.5	0.58
	Weekly	4 (14.3)	2	16.7	2	25.0	0	0.0	
	Rarely	2 (7.1)	1	8.3	0	0.0	1	12.5	
Industrialized seasoning use	Daily	81 (40.1)	29	38.7	33	47.1	19	33.3	0.05
	Weekly	90 (44.3)	40	53.3	26	37.1	24	42.1	
	Rarely	31 (15.3)	6	8.0[a]	11	15.7[a.b]	14	24.6[b]	
Iodine content in salt	Below	5 (12.8)	2	13.3	3	20.0	0	0.0	0.43
	Adequate	28 (71.8)	10	66.7	10	66.7	8	88.9	
	Above	6 (15.4)	3	20.0	2	13.3	1	11.1	
Iodine content in salt (mg/kg)	$n=39$	31.4 ± 15.7	33.4 ± 16.5		27.4 ± 15.6		34.8 ± 14.8		0.45
Iodine content in seasoning (mg/100 g)	$n=28$	0.9 ± 0.5	0.7 ± 0.3		0.9 ± 0.6		1.1 ± 0.7		0.41
Iodine content in drinking water (μg/L)	$n=16$	1.1 ± 0.4	1.0 ± 0.5		0.9 ± 0.4		1.0 ± 0.5		0.34
Dietary iodine intake (μg/day)	$n=252$	122.79 ± 29.22	122.9 ± 31.1		119.4 ± 28.2		126.8 ± 26.5		0.28

Values are presented as absolute and relative frequency – *n* (%) or mean ± standard deviation

*According to ANOVA or Chi-square tests. Dietary iodine intake was adjusted for total energy intake. *UIC* urinary iodine concentration

Table 4 Multinomial logistic regression models for predictors of iodine nutritional status in pregnant women from primary health care units in a city of Southeastern Brazil

Predictors	Insufficient		More than adequate	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
(Intercept)	-	0.29	-	0.63
Alcohol consumption (yes)	6.59 (1.24–34.87)	0.02	1.50 (0.19–11.54)	0.69
Alcohol consumption (no)	Reference	-	Reference	-
Salt storage (opened container)	0.22 (0.08–0.57)	0.002	0.51 (0.20–1.24)	0.13
Salt storage (closed container)	Reference	-	Reference	-
Industrialized seasoning use (daily)	1.74 (0.53–5.67)	0.35	0.60 (0.21–1.71)	0.34
Industrialized seasoning use (weekly)	3.68 (1.12–12.11)	0.03	0.97 (0.33–2.82)	0.96
Industrialized seasoning use (rarely)	Reference	-	Reference	-

OR Odds ratio; *CI* confidence interval. Reference group: adequate iodine status

In a study conducted by Ferreira et al. [12] in Ribeirão Preto, São Paulo, a non-coastal city of Brazil, 57% of iodine insufficiency was found among 191 pregnant women in the first trimester, while 9.9% had more than adequate iodine nutrition (median UIC: 137.7 μg/L). Mioto et al. [23] detected 52.2% and 4.4% of UIC below 150 μg/L and above 250 μg/L, respectively, in 273 pregnant women from São Paulo (median UIC: 146 μg/L). Saraiva et al. [4] concluded that 48.7% of pregnant women in the first trimester from Rio de Janeiro, a coastal city of Brazil, showed insufficient and 4.5%, excessive UIC (median UIC: 221 μg/L). Machamba (2021) found 22.3% of iodine insufficiency and 8.2% of excessive iodine nutrition in 184 pregnant women from Viçosa (median UIC: 244 μg/L).

It is noted that the prevalence of more than adequate iodine nutrition is low among Brazilian pregnant women, which differs from our finding. Nonetheless, we highlight the methodological and study design differences of the previous studies, such as the method used to evaluate UIC (modified Sandell-Kolthoff reaction versus ICP-MS) and the stage of pregnancy, associated to the fact that Brazil is a heterogeneous country with sociodemographic, geographic and climatic differences, possibly explaining the coexistence of areas with insufficient and adequate median UIC in pregnant women.

The mean of iodine content in household salt samples was 31.4 mg/kg, within the range recommended by ANVISA. It was observed that 71.8% of the samples were in compliance with the legislation, while 12.8% were below and 15.4%, above recommended. One of the sustainability indicators of salt iodization is the proportion of families using properly iodized salt (at least 15 mg/kg) that must be greater than 90% according to the National Program for the Prevention and Control of IDD (pro-iodine) [9]. In our study, 87.2% of the samples met these criteria. Nonetheless, due to the small sample size, it was not possible to determine the effectiveness of salt iodization policy in the studied city.

In a study conducted by Alves et al. [24], all household salt samples from the schoolchildren in Ribeirão Preto had iodine content within the range recommended by the legislation. In contrast, a previous study conducted in 2010 detected irregular iodine content in salt samples, either less than half or up to three times more than recommended [25].

In accordance with our finding, Saraiva et al. [4] concluded that the most table salt samples contained adequate iodine content, with iodine excess in 18.7% of them. Here, the iodine content in salt could be a predictor of adequate median UIC in pregnant women, although an association has not been detected, corroborating with Azevedo (2019) and de Oliveira Campos et al. [26], probably due to the small sample size.

The main source of iodine in Brazil is the iodized salt, essential to estimate the iodine intake [27]. We concluded that there is an important heterogeneity in the distribution of the iodine content in household salt samples in Brazil, which highlights the need for strengthening the existing salt iodization policy to make a homogenous and adequate iodized salt for all population groups.

Recently, Milagres et al. [15], researchers of EMDI-Brazil, constructed a table of iodine content in foods using a compilation of international databases from 14 countries. Fish, eggs, sea food, and dairy products are potential sources of iodine worldwide. Nonetheless, the median daily intake of fish, milk and dairy products is low, according to IBGE [28].

On the other hand, ultra-processed foods contributed to 22.7% of the total energy intake in adult population [29, 30]. A study of EMDI-Brazil showed that in natural and minimally processed foods (59.2%) are still the basis of the pregnant women's diet in Ribeirão Preto, São Paulo. However, ultra-processed foods contributed with 28.4% of the total energy intake (Silva, 2021).

Data from family budget survey estimated that the total salt intake is ~ 12 g/day per capita due to the high consumption of processed foods [31]. If we consider this amount of salt, the iodine intake in pregnant women from primary health care units in Ribeirão Preto is ~ 376.8 µg/day (mean iodine content: 31.4 mg/kg). However, a salt intake of 5 g/day, based on the Ministry of Health recommendation, results in an iodine intake of ~ 157 µg/day [32], below the recommendation for pregnant women (250 or 220 µg/day). Actions should be focused on reducing the daily amount of salt and adjusting the content of iodine in salt, considering the possible losses from production to the household level. Strengthening monitoring of the existing policy is critical.

Studies evaluating the source of salt consumption are scarce. This data is relevant because the consumption of seasonings is very common in Brazil, and it may potentially interfere with the amount of iodine intake especially in those individuals who use seasonings as a substitute for iodized salt.

In our study, a low consumption of salt in its pure form was observed (20.3%) while there was a high consumption of industrialized seasonings (74.3%). According to Machamba (2021), seasonings were associated to lower UIC. Macedo [33] observed that industrialized seasonings were protective factors while homemade seasonings, risk factors for lower UIC.

Converging with Machamba (2021) and diverging from Macedo [33], we observed that use industrialized seasoning weekly was a predictor of iodine insufficiency regarding to a rare consumption, probably due to the low iodine content compared to salt in its pure form (43 µg/5 g of seasoning versus 157 µg/5 g of salt). It suggests that iodized salt in manufacturing of processed foods is compromised. Furthermore, WHO recommends in natural foodstuffs and salt in its pure form in the amount up to 5 g/day for preparing and cooking food [5].

All salt intended for human consumption in Brazil must be iodized, including the salt used in processed/ultra-processed foods, except in cases where it is verified that iodine causes interference in the product. However, it was estimated that ~ 25% of processed foods are iodized [26]. A nationwide monitoring of iodine content in this type of product should be included in existing public policy.

Personal and environmental factors such as storage, handling practices, and knowledge of iodized salt and IDD may interfere with the iodine stability in salt. Moreover, iodine content in salt may be reduced from its production site to the consumer level [34–36].

The loss of iodine in the salt is more noticeable when packaging is done outside the original container. Salt stored in a covered container was more likely to have adequately iodized salt than in opened containers, since covered containers prevent the salt from being exposed to light and humidity [34, 35]. Here, we found an inverse association that may be explained by other factors not evaluated, such as storage salt area and handling practices which if inadequate the salt may attract moisture and become wet carrying the iodine to the bottom of the container [35]. This may occurs even in covered containers.

We found an association between number of gestations and iodine status. Corroborating our finding, de Zoysa et al. [37] reported that parity was negatively correlated with UIC, but only in the third trimester. Fereja et al. [38] found higher rates of goiter in parous as compared to nulliparous women, suggested that repeated pregnancies could deplete iodine status.

Other variable that must be taken into account is the time interval between the last two pregnancies, which was not evaluated here. Gargari et al. [1] observed that every year added to the time interval between the two most recent pregnancies led to a 20% reduction in low UIC. Possibly, this interval was adequate among secundigravida regarding to multigravida women interfering in UIC in our study.

Regarding iodine supplementation, Murillo-Llorente et al. [39] found that iodized supplements was an important predictor of iodine status in pregnant women. Vongchana et al. [40] found that universal supplementation reduced the prevalence of iodine insufficiency, but it has been associated with excessive iodine nutrition in this group. A randomized controlled trial compared the effectiveness of universal and individualized iodine supplementation in pregnant women. Both strategies reduced the prevalence of iodine insufficiency, however, individualized supplementation prevented more than adequate/excessive UIC, although studies with larger sample sizes are needed [40].

Here, a supplementation with higher content of KI (mean: 200 µg) was associated to more than adequate iodine nutrition. Likewise, Rebagliato et al. [41] found that women who consumed 200 µg/day or more of KI supplement had a higher risk of thyroid dysfunction. These findings deserves attention because iodine excess may lead to an increased risk of subclinical hypothyroidism and isolated hypothyroxinemia in susceptible individuals, besides iodine-induced fetal hypothyroidism (Wolff-Chaikoff effect) [40].

Although KI supplement may be useful to ensure adequate iodine status, care should be taken in countries where salt iodization is mandatory. Moreover, in regions where the UIC is between 150 and 249 µg/L, KI supplementation is not necessary, according to OMS, UNICEF and ICCIDD consensus [42]. Further research is needed to confirm the efficacy and safety of iodine supplementation during pregnancy in areas with adequate iodine intake.

The association between alcohol consumption and iodine status in pregnancy are controversial. A population-based study in Denmark indicated protective effects of moderate alcohol consumption against the development of autoimmune thyroid diseases, which has higher prevalence among women than in men, in part related to pregnancy. On the other hand, alcohol may exert toxic effects on the thyroid gland [43].

Donald et al. [44] found that moderate-to-severe alcohol consumption in pregnancy was associated with alterations in maternal thyroid function, particularly increased serum TSH, decreased serum free T4, and increased serum free T3, a novel and unexpected finding. A possible suggestion is a greater proportion of T4 converted to T3 by increased expression of deiodinase 2 (Dio2) after alcohol exposure. Alcohol is the most important factor that have been documented as having some effects on thyroid size and function, then the control of its consumption is one of the measures of primary prevention of thyroid disorders [45].

As strengths of this study, we highlight the assessment of predictors of insufficient and more than adequate iodine nutrition in pregnant women, and the iodine content in other sources of iodine besides salt. To our knowledge, this is the first study that assessed these factors among pregnant women in the city of Ribeirão Preto. As limitations, we mention the small sample size regarding to household salt samples making it impossible to assess the effectiveness of salt iodization policy in the studied city, and some important data regarding the salt that could interfere on iodine status.

Conclusions

Despite the significant prevalence of insufficient and more than adequate iodine nutrition in pregnant women, this population group has iodine sufficiency according to the median UIC. Alcohol consumption, pack the salt in closed container, and use industrialized seasoning weekly were risk factors for iodine insufficiency.

Our findings highlight a critical need for regular monitoring of iodine status in pregnant women. Current public policy must be revised and expanded to other more vulnerable groups from different regions are covered as well as to promote more homogeneous salt samples. Public awareness regarding the importance of iodized salt, IDD, appropriate salt storage/handlings practices at household level is crucial.

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Author Contribution Ana Carolina Momentti, Mariana de Souza Macedo, Sylvia do Carmos Castro Franceschini, and Anderson Marliere Navarro contributed to the study conception and design. Ana Carolina Momentti and Ana Flávia de Sousa Silva contributed to data collection. Ana Carolina Momentti, Fernando Barbosa Júnior, and Vanessa Cristina de Oliveira Souza contributed to data analysis. The first draft of the manuscript was written by Ana Carolina Momentti. All authors read and approved the final manuscript.

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Data Availability The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics Approval Approval was granted by the Ethics Committee of Hospital das Clínicas at Ribeirão Preto Medical School, University of São Paulo (no. 3.252.310).

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Competing Interests The authors declare no competing interests.

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