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The association of milk and dairy consumption with iodine status in pregnant women in Oporto region

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Abstract

The role of milk and dairy products in supplying iodine to pregnant women is unknown in Portugal. The aim of this study was to evaluate the association between milk and dairy product consumption and the iodine status of pregnant women in the IoMum cohort of the Oporto region. Pregnant women were recruited between 10 and 13 weeks of gestation, when they provided a spot urine sample and information on lifestyle and intake of iodine-rich foods. Urinary iodine concentration (UIC) was determined by inductively coupled plasma MS. A total of 468 pregnant women (269 iodine supplement users and 199 non-supplement users) were considered eligible for analysis. Milk (but not yogurt or cheese) intake was positively associated with UIC, in the whole population ($P = 0·02$) and in the non-supplement users ($P = 0·002$), but not in the supplement users ($P = 0·29$). In non-supplement users, adjusted multinomial logistic regression analysis showed that milk consumption <3 times/month was associated with a five times increased risk of having UIC < 50 µg/l when compared with milk consumption ≥2 times/d (OR 5·4; 95 % CI 1·55, 18·78; $P = 0·008$). The highest UIC was observed in supplement users who reported consuming milk once per d (160 µg/l). Milk, but not yogurt or cheese, was positively associated with iodine status of pregnant women. Despite the observed positive association, daily milk consumption may not be sufficient to ensure adequate iodine intake in this population.

Key words: Iodine status: Pregnancy: Dairy products: Milk

Abbreviation: UIC, urinary iodine concentration.

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Iodine, as a component of thyroid hormones thyroxine and triiodothyronine, is essential for maternal metabolism and fetal growth and neurological development[1–3]. During this period, iodine requirement increases mainly due to the higher thyroxine synthesis as well as to changes in urinary iodide excretion caused by increased renal clearance rate[4].

Insufficient iodine intake during pregnancy may negatively affect myelination and neuronal migration, compromising neurogenesis and thus the normal development of the brain[5]. In cases of severe iodine deficiency, the consequences include cretinism, goitre and developmental delay, conditions usually referred to as 'iodine deficiency disorders'[6]. More recent evidence has indicated associations between inadequate iodine intake during pregnancy and risk of increased child attention deficit hyperactivity disorder[7], while, in other studies, mild iodine deficiency was negatively associated with verbal intelligence quotient[8,9] or verbal skills of the offspring[10].

To address iodine deficiency, one of the most common nutritional deficiencies at global level, the WHO recommends the introduction of iodised salt programmes in both food industry and home meal preparation[11]. In addition, iodine supplement use is recommended by the WHO and UNICEF in countries with low household usage of iodised salt[12].

In Portugal, while there is no universal salt iodisation policy, the Directorate-General for Health (no. 011/2013) issued a guideline in 2013 for supplementation with potassium iodide in preconception, pregnancy and breast-feeding[13]. This guideline was implemented as a result of the first nationally representative study in this population between the years 2005 and 2007, which documented insufficient iodine status in pregnant women[14]. Currently, there is no data regarding the efficacy of this policy implementation in the country or regarding the association of food intake with iodine status.

Nevertheless, in other regions of the globe, milk consumption has shown a positive association with iodine status of pregnant women[15–18]. For example, in the UK, milk consumption has been linked to the eradication of iodine deficiency through not only increased consumption but also changes in agricultural practices which have led to a higher concentration of iodine in milk[19].

Importantly, cows' milk iodine content, and thus the association of milk intake with iodine status, is highly dependent on culture, livestock practices, seasons and weather conditions, which highlights the importance of data produced from different countries.

In Portugal, a country where iodine inadequacy was found in pregnant women more than 10 years ago[14] and where annual milk consumption has been showing a downward trend (decreasing from 925 tonnes in 2007 to 746 tonnes in 2017[20]), monitoring actions towards iodine status and iodine supplement use in pregnant women is still lacking. In addition, the consumption pattern of milk and dairy products and its association with iodine status in this specific population is also unknown.

In this context, this study aims to evaluate the association of milk and dairy consumption with iodine status of a cohort of Portuguese pregnant women in the Oporto region.

Methods

Participants and study design

The sample used in this study is part of the IoMum cohort and is composed of women recruited at Centro Hospitalar Universitário São Joao, at the time of their first trimester fetal ultrasound scan. Participants were recruited between April 2018 and April 2019. All women who signed the informed consent statement, with gestational age between 10 and 13 weeks and whose first trimester ultrasound confirmed fetal vitality, were included in the study. The gestational age was determined by measuring the craniocaudal length of the fetus[21]. Women taking levothyroxine sodium (thyroid medication) were excluded from the study. For statistical analysis, we additionally excluded women with missing data on milk or dairy intake or on iodine-containing supplement use.

A total of 548 pregnant women were evaluated for eligibility to participate in the study (Fig. 1). Of these, sixty-three subjects did not meet the inclusion criteria (thirty-two women with gestational age out of range (<10 or ≥14 weeks) and thirty-one women taking thyroid medication), while seventeen provided incomplete data on variables of interest. The final sample comprised 468 pregnant women, of which 269 reported using iodine supplements and 199 reported no use of iodine-containing supplements. A characterisation of iodine supplements used showed that the mean iodine content was 169 (sd 40) µg, ranging from 75 to 200 µg iodine.

Ethical approval

This study (trial registration number NCT04010708) was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the Ethics Committee of Centro Hospitalar Universitário São Joao/Faculty of Medicine of University of Porto. Written informed consent was obtained from all subjects.

Data collection

Each participant collected a random spot urine sample and completed a lifestyle questionnaire to give information regarding consumption of iodine-rich foods, iodine supplement use, history of thyroid disease, as well as anthropometric and sociodemographic data.

Spot urine was collected directly into a urine collection container, immediately before or after the previously booked ultrasound scan. Urine samples were exclusively used for the scope of the study, and they were stored at 4°C until the end of each day when they were aliquoted and stored frozen at −80°C until analyses.

The frequency of milk or dairy intake was assessed using an eight-point scale (never, <3 times/month, 1–3 times/week, 4–6 times/week, once per d, twice per d, 3 times/d, 4 or more times/d), later combined into four categories for analysis. One cup or 250 ml of cows' milk, one yogurt (typically corresponding to 150 ml) and two slices of cheese (typically corresponding to 40 g) were defined as portion sizes. Iodine content was estimated to be 40, 27 and 16 µg iodine for each portion size of milk,

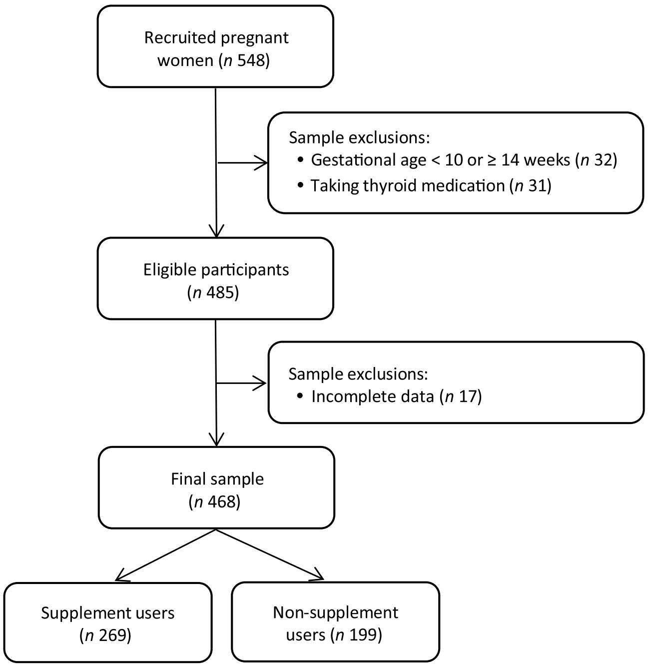

Fig. 1. Flow chart of recruitment and inclusion of participants in the study. Sample size (*n*) for each group is given.

yogurt and cheese, respectively, based on the latest update on iodine content of Portuguese foods[22]. Fish and egg intakes were also assessed using a similar eight-point scale which was converted into three categories for further analyses.

Height as well as pre-pregnancy and current weight were self-reported by participants.

Determination of urinary iodine concentration and iodine: creatinine ratio

Median urinary iodine concentration (UIC) has been widely used as an indicator to assess iodine adequacy in the population. According to the WHO criteria, pregnant women are considered iodine insufficient when the median UIC is below 150 μg/l[23]. Furthermore, the proportion of participants with a UIC < 50 μg/l must not exceed 20 % of the population[23]. Given that WHO cut-offs for evaluation of iodine adequacy are given as group median UIC, this was the main outcome measure in the current study.

UIC was assessed by inductively coupled plasma MS according to the methodology developed by the Centres for Disease Control and Prevention[24], as previously described by us[25].

Creatinine was determined in a certified laboratory by Jaffe's reaction using an ADVIA 1800 instrument (Clinical Chemistry System, Siemens).

Iodine:creatinine ratio (μg/g) was calculated by dividing UIC in μg/l by the concentration of creatinine in g/l.

Statistical analysis

The descriptive statistics are presented in absolute (*n*) and relative (%) frequencies in categorical variables and, depending on the normality of the distribution of continuous variables, in means and standard deviations, or medians and 25th and 75th percentiles (interquartile range; IQR). When testing hypothesis about normally distributed variables (maternal age), the independent sample *t* test was used. When testing hypothesis about non-normally distributed variables (gestational age, negatively skewed and UIC, positively skewed), the non-parametric Mann–Whitney test or the χ^2 test was used as appropriate. To test for differences in median UIC according to food intake categories, the non-parametric Kruskal–Wallis test was applied. Differences in frequencies between groups of iodine status (UIC < 50 μg/l and UIC ≥ 150 μg/l) and food intake categories were assessed by the χ^2 test.

UIC was estimated for population subgroups, classified by frequency of intake of iodine-rich food sources. The consumption categories were established in order to achieve a balanced distribution in the four groups for milk and dairy intake (<3 times/month, 1–6 times/week, once per d, twice per d or more) and in the three groups for fish and eggs intake (<3 times/month, 1–3 times/week, 4 times/week or more). UIC results were expressed as median with 25th and 75th percentiles.

Additionally, a multinomial logistic regression model was used to assess factors associated with low UIC (dependent variable) defined with the WHO cut-off points: UIC < 50 μg/l and 50 μg/l ≤ UIC < 100 μg/l and UIC ≥ 100 μg/l, as reference. These cut-offs of 50 μg/l and 100 μg/l were used because the study population was particularly skewed to low UIC values with a small proportion achieving UIC ≥ 150 μg/l, and they serve as indicators of more severe iodine deficiency. Similar UIC categories were also used by Bath *et al.*[9].

The independent variable tested was consumption frequencies. The model fit was evaluated by the Hosmer–Lemeshow test. Potential confounding variables were considered for logistic regression: age, BMI, education level and smoking habits.

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Table 1. Population characteristics by urinary iodine concentration (UIC) categories in 468 pregnant women
(Mean values and standard deviations; numbers and percentages; medians and interquartile ranges (P25, P75))

	Total		UIC < 150 μg/l		UIC ≥ 150 μg/l		
	n	%	*n*	%	*n*	%	*P*
Mother's age (years)							0·17*
Mean	32		31		32		
SD	5		5		5		
Gestational age (weeks)							0·09†
Median	12		12		12		
P25, P75	12, 13		12, 13		12, 13		
Pre-pregnancy BMI§							
Underweight	10	2	7	2	3	2	
Normal weight	257	56	172	56	85	55	
Overweight	126	27	87	29	39	25	0·61‡
Obesity	67	15	40	13	27	18	
Smoking habits‖							
Non-smoker	333	71	223	72	110	70	
Smoker	55	12	36	12	19	12	0·78‡
Former smoker	78	17	49	16	29	18	
Education level¶							
High school or less	224	49	151	50	73	48	
Undergraduate level	164	36	112	37	52	34	0·30‡
Master's or higher	67	15	39	13	28	18	
Iodine supplementation							
No	199	43	170	55	29	18	<0·001‡
Yes	269	57	140	45	129	82	

* *t* test.
† Mann–Whitney.
‡ Pearson χ^2.
§ Missing data *n* 8.
‖ Missing data *n* 2.
¶ Missing data *n* 13.

Results are presented as adjusted OR and the 95 % CI. Statistical analyses were performed using SPSS Statistics version 25 software and statistical significance set to a *P* value < 0·05.

Results

Sample characterisation

The median UIC in the study population was 103 (IQR 61, 191) μg/l (median iodine:creatinine ratio: 123 (IQR 67, 222) μg/g), and 18·6 % had UIC < 50 μg/l. Table 1 presents the characterisation of the study population according to UIC stratified by the WHO recommended cut-off for adequacy in pregnant women (150 μg/l). No statistically significant differences between the two groups for age, gestational age, pre-pregnancy BMI, smoking and education level were found, whereas the iodine supplement use resulted in a significantly higher proportion of pregnant women achieving UIC above 150 μg/l. The mean age of the women was 31·6 (SD 5·4) years old, ranging from 16 to 46 years old. Regarding BMI, calculated from self-reported pre-pregnancy weight and height, 42 % of the women were overweight or obese and 56 % were normal weight. Most participants had educational attainment corresponding to high school or less (48 %) and 12 % reported smoking at the time of recruitment (Table 1).

Iodine status, milk and dairy consumption and iodine supplement use

Table 2 presents UIC by frequency of iodine-rich food sources, with UIC categorised as <50 μg/l, ≥150 μg/l, and iodine supplement use. Milk consumption was significantly associated with UIC (*P* = 0·02), but the same was not observed for yogurt or cheese consumption. In addition, fish or eggs intake was also not associated with UIC.

The majority of women (54 %) reported consuming milk less than once per d, and 26 % reported consuming milk <3 times/month. Women reporting one daily serving of milk had the highest median UIC (123 μg/l), and 40 % had UIC ≥ 150 μg/l. Women reporting milk intake <3 times/month had the lowest median UIC (83 μg/l), had the highest proportion with UIC < 50 μg/l (28 %) and only 27 % had UIC ≥ 150 μg/l.

When the sample was separated according to iodine supplement use, the association of milk consumption with iodine status was even more pronounced. Among non-supplement users, median UIC was higher in the groups with more frequent consumption of milk (from 52 μg/l in the group reporting milk intake <3 times/month to 91 μg/l in the group reporting milk intake ≥2 times/d; *P* = 0·002). On the contrary, in the iodine supplement user group, the association between milk intake and UIC was no longer observed (*P* = 0·29). In the non-supplement users, approximately 50 % consumed at least one cup of milk daily. In women who reported milk intake <3 times/month, median UIC was 52 μg/l which contrasts the median UIC of 123 μg/l in iodine supplement users with equally low milk intake.

Variation of urinary iodine adjusted to creatinine excretion with frequency of milk and dairy intake shows the same global trends and are presented in online Supplementary Table S1.

The multinomial logistic regression model confirmed the association between the frequency of milk intake and iodine status of pregnant women not taking iodine supplements (Table 3). In this group, the risk of having UIC below 50 μg/l was five times

Table 2. Urinary iodine concentration (UIC) by intake frequency of milk, dairy products, fish and eggs in 468 pregnant women*
(Numbers and percentages; medians and interquartile ranges (P25, P75))

			UIC (µg/l)			UIC < 50 µg/l		UIC ≥ 150 µg/l			UIC (µg/l) non-supplement users					UIC (µg/l) supplement users				
Food intake	*n*	%	Median	P25, P75	*P*	*n*	%	*n*	%	*P*	*n*	%	Median	P25, P75	*P*	*n*	%	Median	P25, P75	*P*
Milk																				
< 3 times/month	121	26	83	48, 161		34	28	33	27		48	24	52	35, 78		73	27	123	72, 224	
1–6 times/week	132	28	94	57, 205	0·02†	28	21	45	34	0·003‡	53	27	69	42, 97	0·002†	79	29	141	78, 274	0·29†
1 time/d	151	32	123	71, 196		16	10	60	40		62	31	85	61, 129		89	33	160	84, 268	
≥2 times/d	64	14	106	74, 197		9	14	20	31		36	18	91	58, 130		28	11	147	98, 327	
Yogurt																				
<3 times/month	71	15	100	57, 198		14	20	24	34		31	16	69	43, 148		40	15	108	67, 223	
1–6 times/week	192	41	103	63, 195	0·95†	35	18	68	35	0·98‡	76	38	78	47, 107	0·81†	116	43	142	82, 258	0·46†
1 time/d	143	31	107	58, 188		27	19	48	34		63	32	72	36, 107		80	30	156	88, 283	
≥ 2 times/d	62	13	93	63, 185		11	18	18	29		29	14	76	54, 124		33	12	135	79, 325	
Cheese																				
<3 times/month	71	15	94	56, 189		16	23	24	34		30	15	69	43, 105		41	15	132	74, 218	
1–6 times/week	247	53	107	63, 188	0·74†	47	19	83	34	0·74‡	103	52	76	43, 122	0·85†	144	53	145	88, 259	0·74†
1 time/d	105	22	105	66, 216		15	14	36	34		44	22	75	48, 122		61	23	140	81, 268	
≥2 times/d	45	10	92	58, 193		9	20	15	33		22	11	58	40, 107		23	9	183	69, 295	
Fish																				
<3 times/month	71	16	129	67, 203		9	13	30	42		28	15	83	54, 138		43	17	170	80, 300	
1–3 times/week	310	69	102	63, 187	0·31†	61	20	101	33	0·22‡	135	71	74	42, 112	0·60†	175	67	138	81, 244	0·40†
≥4 times/week	68	15	106	66, 223		12	18	25	46		27	14	85	42, 113		41	16	156	85, 344	
Eggs																				
<3 times/month	106	23	97	57, 184		21	20	37	35		51	26	69	43, 97		55	20	162	91, 294	
1–3 times/week	314	67	106	63, 193	0·81†	59	19	108	34	0·99‡	132	66	75	40, 118	0·43†	182	68	140	81, 260	0·08†
≥4 times/week	48	10	89	63, 172		7	15	13	27		16	8	82	58, 128		32	12	90	70, 185	

P25, 25th percentile; P75, 75th percentile.
* Non-milk consumers (*n* 49); non-yogurt consumers (*n* 16); non-cheese consumers (*n* 25); non-fish consumers (*n* 3); non-egg consumers (*n* 10). Missing data for fish intake (*n* 19).
† Kruskal–Wallis.
‡ Pearson's χ^2 for comparisons between the food intake categories and the two UIC categories indicating severe iodine deficiency and iodine adequacy (<50 µg/l and ≥150 µg/l, respectively).

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Table 3. Multinomial regression model for the association between milk intake and urinary iodine concentration (UIC) < 50 µg/l (*n* 58), and 50 ≤ UIC < 100 µg/l (*n* 73) and UIC ≥ 100 (*n* 61, reference) in the non-supplement users*
(Odds ratios and 95 % confidence intervals)

	UIC < 50 µg/l				50 ≤ UIC < 100 µg/l			
Milk intake	*n*	Adjusted OR	95 % CI	*P*	*n*	Adjusted OR	95 % CI	*P*
<3 times/month	23	5·38	1·55, 18·78	0·008	18	3·18	0·95, 10·58	0·06
1–6 times/week	19	2·83	0·89, 8·95	0·08	22	2·40	0·83, 6·95	0·11
1 time/d	11	0·67	0·21, 2·13	0·50	23	1·19	0·45, 3·14	0·72
≥2 times/d	8	1·00			12	1·00		

* Model adjusted for potential confounders (age, BMI, education level and smoking habits).

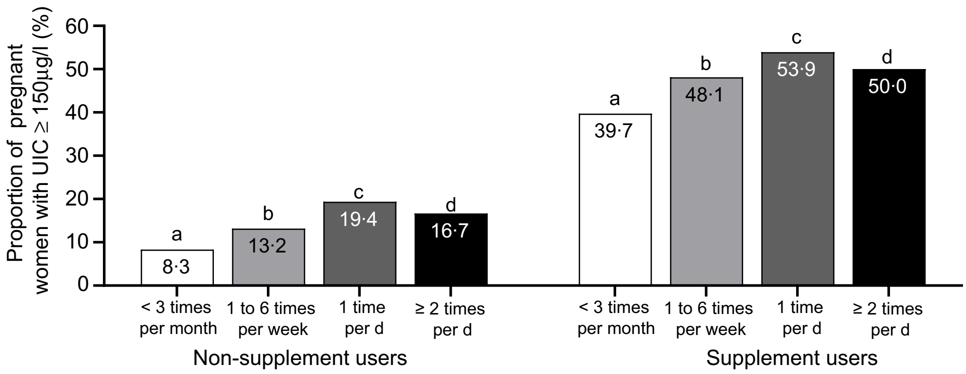

Fig. 2 Proportion of participants with urinary iodine concentration (UIC) ≥ 150 µg/l by frequency of milk intake in non-iodine and in iodine supplement users. Numbers inside the bars indicate the proportion values (%). Equal letters over the bars indicate statistically significant differences between the respective proportions, assessed by the Pearson's χ^2 test: (a) *P* < 0·001; (b) *P* < 0·001; (c) *P* < 0·001; (d) *P* = 0·004.

higher with a milk intake of less than three portions per month compared with ingestion of two or more portions per d (OR 5·38; 95 % CI 1·55, 18·78; *P* = 0·008). Additionally, the risk of having a UIC between 50 and 100 µ/l tended to increase three times, compared with the same reference group, but this odds did not reach statistical significance (OR 3·18; 95 % CI 0·95, 10·58; *P* = 0·06).

Also, among non-supplement users, in the group consuming milk 1–6 times/week, there was a trend for increased risk of having UIC < 50 µg/l (OR 2·83; 95 % CI 0·89, 8·95; *P* = 0·08), but this odds also lacked statistical significance. For the remaining intake frequencies, there were no significant differences.

Finally, the proportion of women with UIC at least 150 µg/l was low in the non-supplement group, ranging from 8·3 % in those with the lowest intake of milk to 19·4 % in those with intake once per d (Fig. 2). At all levels of milk consumption, the percentage of women with UIC above 150 µg/l was higher in iodine supplement users when compared with non-supplement users (*P* < 0·001 for intake <3 times/month, 1–6 times/week and once per d; *P* = 0·004 for intake of two or more portions per d). Differences in proportions of women with UIC at least 150 µg/l between different frequencies of milk intake, in the same group according to supplement use, were not statistically significant (*P* = 0·42 among non-supplement users; *P* = 0·35 among supplement users).

Discussion

The present study evaluated the association of milk and dairy consumption with iodine status in pregnant women in the Oporto region, Portugal. Our results show that milk, but not yogurt and cheese, is an important determinant of iodine status in this population. This association was observed for the whole population and for the group of women who did not take iodine supplements. On the contrary, among supplement users, association between milk intake and iodine status was no longer observed suggesting that iodine supplementation may mask the contribution of milk intake on iodine status.

In addition, consumption of one milk serving daily among the whole population or among the non-supplement users was not sufficient to ensure adequate iodine status. This result is similar to that observed by Alvarez-Pedrerol *et al.* in Spanish pregnant women, which reports that 74 % of the non-supplement users consuming milk one or two times/d had UIC below 150 µg/l[18]. In fact, cows' milk iodine content in Portugal has been estimated to reach a maximum of 230 µg/l[26] and this value is not very different from that observed in Spain, which has been reported to be 259 µg/l[27]. Contrary to ours and Alvarez-Pedrerol's study, a UK study had shown that milk intake of at least 280 ml (a portion comparable to one milk serving daily used in our study) was sufficient to ensure iodine adequacy in pregnancy[17]. This is consistent with an almost two times higher iodine content (427 µg/l) found in UK cows' milk samples[28], which is justified by a long history of iodine supplementation of dairy herds[19]. This evidences the importance and differential influences of farming practices from different countries on iodine status of pregnant women.

In addition, among non-supplement users, consuming milk <3 times/month was shown to be associated with a five times increased risk of having UIC below 50 µg/l. The fact that approximately 25 % of the pregnant women reported ingesting milk

<3 times/month reveals that dietary choices can severely affect iodine intake during pregnancy when not properly complemented with other strategies, such as supplementation and use of iodised salt. Thus, it would be important to understand the impact of these different factors on overall iodine status of women in the women of childbearing age and especially during pregnancy.

The importance of milk consumption for iodine status adequacy has already been observed in other studies in pregnant women in Europe and also in school-age children in Portugal[17,18,25,29,30]. These results have contributed to reinforce the interest in school milk programmes in our country[25,31]. Despite this, milk consumption per capita in Portugal has suffered a downward trend in the last two decades, changing from 89 kg per capita in 2001 to 71 kg in 2015, at a time when consumption values had stabilised[32]. Additionally, numbers regarding total consumption show a decrease from 925 tonnes in 2007 to 746 tonnes in 2017[20]. This decrease may result from a perceived negative impact of milk on health, environmental and animal welfare concerns and the emergence of plant-based milk substitutes on the market[33]. Plant-based milk substitutes have a lower iodine content, and the transition from cows' milk to these substitutes has been shown to be associated with lower iodine status in British women[26,34]. While yogurt has an iodine content comparable to milk, white cheese is low in iodine as iodine is water soluble and follows the whey when milk is separated into whey and curd[22]. Despite being dairy products, yogurt and cheese contribute little to iodine intake as also shown in populations of pregnant women of other regions of the globe[30]. The fact that yogurt, as well as cheese, fish or eggs are typically consumed in smaller portions than milk may also underlie the observed lack of association between the consumption of these iodine-rich foods and iodine status. Specifically regarding dairy products, an intake unit of yogurt (typically 150 ml, equivalent to 27 μg iodine) or cheese (typically two slices or 40 g, equivalent to 16 μg iodine) is estimated to be poorer sources of iodine when compared with an intake unit of milk (typically 250 ml, equivalent to 40 μg iodine)[22]. With respect to fish consumption, it would be interesting to explore further the association between iodine richer fish types and UIC. Although this has not been addressed in the current study, lean fish consumption, which is reported to be richer in iodine when compared with fatty fish, could present a positive association with UIC[35]. The lack of detail on the type of fish consumed may also have contributed to the observed lack of association between fish consumption and UIC.

The latest available data on iodine status of pregnant women in Portugal indicated that median UIC in continental Portugal was 84·9 μg/l, with only 16·8 % of women with UIC within the WHO recommended range. This motivated the Directorate-General of Health to recommend supplementation with potassium iodide in this population[13,14]. At the European level, consensus was reached at the 1992 World Health Assembly on the need to eliminate this iodine deficiency disorder and, in 2005, the importance of regular monitoring of iodine status in all countries was reinforced[36,37]. Nevertheless, in 2015, the pregnant population of twenty-one countries in this region had insufficient iodine intake[38].

The results of this study add to the current knowledge and corroborate the need to consider iodine-rich food intake in pregnant women and also to reflect on the advantages of iodine fortification of cows' feed.

Although Portugal has a recommendation for a daily consumption of 2–3 portions of dairy products during pregnancy[39], the values found in this study as well as those observed for Portuguese women in the last National Food, Nutrition and Physical Activity Survey are in general lower[40]. In fact, the pattern of milk consumption in this segment of the population has proven to be lower than in other population groups (e.g. children and elderly), and also the one presented by men[40]. Actually, in the IoMum cohort, we could also observe that a very small proportion of the population was aware of the importance of milk as a good source of iodine[41] and, also due to literacy issues, iodised salt consumption was not used as a co-variable as we were not able to confirm those that were actually consuming iodised salt. On public health grounds, the need to raise awareness and inform women of childbearing age regarding the association between milk intake and iodine status should be a subject of reflection.

The importance of milk as a source of iodine was evidenced in this study. Importantly, the studied cohort was homogenously divided between iodine supplement and non-supplement users, giving the opportunity to evidence that iodine supplementation masks the association between milk intake and iodine status.

As referred above, the concentration of iodine in milk varies throughout the year and it is recognised that its content is higher in winter, probably due to the fortification of dairy cows' feed, while, in summer, cows may consume more fresh grass, poorer in iodine than mineral-enriched feed[28,42]. Considering the distribution of participant recruitment, which took place throughout the year, it is not presumed that this factor was determinant for the obtained results. However, it would be interesting to explore the possible differences in UIC between seasons.

UIC is not a good marker of iodine status at the individual level, and it is strongly influenced by recent food intake and hydration status. Therefore, the use of a single urine sample is a poor marker of regular iodine intake. A study in Norway showed that dairy consumption on the day before the urine sample collection was significantly associated with higher UIC[43,44]. Even so, spot urine is the recommended method for evaluating iodine status of populations[45]. The subsequent adjustment of these values for urinary creatinine concentration may reduce the intra-individual variation in the daily volume of urine produced, thus providing a more real approximation of the iodine state, helping to understand the results obtained[43,46]. Nevertheless, in this study, adjustment to creatinine did not substantially change the observed trends of milk intake effect. Importantly, creatinine adjustment may also bias the results as creatinine excretion varies with age and muscle mass[47,48].

In several studies, the place of residence and proximity to the coastal zone were associated with the iodine status of the population. However, the limited geographical dispersion of the sample and results from previous studies conducted in Portugal suggest that these variables are unlikely to have affected the results[14,25].

In conclusion, milk is an important source of iodine for pregnant women in Portugal, particularly for those who do not use iodine supplements. Nevertheless, daily intake of one portion is not enough to ensure the adequate iodine intake. The obtained results therefore reinforce the need to implement a coherent public health policy that considers aspects such as the use of iodised salt and adherence to the Portuguese Directorate-General of Health recommendation for supplementation with potassium iodide, in addition to eating habits. In a public health perspective, it is important to secure adequate iodine intake in all Portuguese women of childbearing age so that women have adequate iodine status and sufficient thyroidal stores to meet the increased needs of a future pregnancy. This requires regular monitoring and the implementation of appropriate measures for control of inadequate iodine status.

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P. F. participated in population recruitment and also in writing the article. C. P., C. M. C., A. C., C. P., C. A. R., C. M., I. M., G. P., I. B., J. G., N. X. M. and E. P. carried the study in tasks such as population recruitment, sample management and storage and sample analyses. V. C. F. coordinated sample analyses and participated in the interpretation of the findings. A. A., C. D.-M., D. P. and N. M. participated in interpretation of the findings. C. R., C. C. and L. F. A. were in charge of study design and participated in writing the article. A. M.-R. and C. C. D. were in charge of analysing the data. A. L. B. had responsibilities in designing the study and writing the article. E. K. and J. C. L. coordinated the work and were mainly responsible for formulating the research question, designing the study and writing the article.

The authors declare that there are no conflicts of interest.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S000711452100009X

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