ORIGINAL ARTICLE

Iodine status of pregnant women in South Australia after mandatory iodine fortification of bread and the recommendation for iodine supplementation

Dominique Condo^{1,7,8} | Dao Huyhn² | Amanda J. Anderson^{1,3} | Sheila Skeaff⁴ | Philip Ryan⁵ | Maria Makrides^{1,3,6} | Beverly S. Mühlhäusler^{1,2} | Shao J. Zhou^{1,2}

¹Women's and Children's Health Research Institute, North Adelaide, South Australia, Australia

²FOOD plus Research Centre, School of Agriculture, Food & Wine, University of Adelaide, Waite Campus, Urrbrae, South Australia, Australia

³Healthy Mothers, Babies and Children, South Australian Health and Medical Research Institute, Adelaide, South Australia, Australia

⁴Department of Human Nutrition, University of Otago, Dunedin, New Zealand

⁵School of Population Health, University of Adelaide, Adelaide, South Australia, Australia

⁶School of Paediatrics & Reproductive Health, University of Adelaide, Adelaide, South Australia, Australia

⁷Deakin University, School of Exercise and Nutrition Sciences, Geelong, Australia

⁸Deakin University, Institute for Physical Activity and Nutrition (I-PAN), Geelong, Australia

Correspondence

Shao J. Zhou, FOOD plus Research Centre, School of Agriculture, Food & Wine, University of Adelaide, Waite Campus, Urrbrae, SA 5064, Australia.

Email: jo.zhou@adelaide.edu.au

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Abstract

Mandatory iodine fortification of bread was introduced in 2009 in Australia in response to the reemergence of iodine deficiency. The aim of this study was to assess iodine intake, urinary iodine concentration (UIC) and their correlation in pregnant women ($n = 783$) recruited from South Australia 2 years following mandatory iodine fortification. Total iodine intake (food and supplements) and UIC were assessed at study entry (<20 weeks') and at 28 weeks' gestation. Mean ($\pm$ SD) total iodine intake at study entry and 28 weeks' gestation was 307 ± 128 μ g/day and 300 ± 127 μ g/day, respectively. Overall, 85.9% of women met the estimated average intake (≥ 160 μ g/day) for iodine in pregnancy, but only 44.5% met the estimated average intake from food alone. The main food sources of iodine were dairy foods and iodine-fortified bread. Median (interquartile range) UIC at study entry and 28 weeks' gestation was 189 μ g/L and 172 μ g/L, respectively. At study entry, median UIC was higher in women taking supplements containing iodine ≥ 150 μ g/day compared with those containing iodine <150 μ g/day (221 μ g/L vs. 163 μ g/L, $p = .003$) and those not taking supplements containing iodine (221 μ g/L vs. 159 μ g/L, $p < .001$). At 28 weeks' gestation, the median UIC for the groups was 187, 152 and 141 μ g/L, respectively (each of the two comparisons yielded $p < .001$). Total iodine intake (food and supplements) from all women was positively, though weakly, correlated with UIC ($r = .23$, $p < .001$). In conclusion, pregnant women in South Australia are iodine sufficient postmandatory iodine fortification of bread. However, without iodine supplementation, it may be difficult to achieve a UIC >150 μ g/L.

KEYWORDS

iodine fortification, iodine status, pregnancy, supplements, UIC

1 | INTRODUCTION

Iodine is an essential trace element that is required for the production of thyroid hormones, which in turn play an important role in the regulation of metabolic processes, growth and optimal brain development (Zimmermann, 2009). Inadequate iodine intake can impair thyroid hormone production, resulting in hypothyroidism and

a spectrum of disorders collectively known as iodine deficiency disorders (Zimmermann, 2009). Iodine deficiency during pregnancy may impair growth and development in the child (Delange, 1994). In severe cases, iodine deficiency in pregnancy can result in cretinism, increased perinatal death and infant mortality (Delange, 1994). Thus, achieving an adequate iodine intake in pregnancy is important for ensuring optimal growth and cognitive development of the child.

Mild-to-moderate iodine deficiency has reemerged in a number of industrialised countries worldwide (de Benoist, McLean, Andersson & Rogers, 2008), including Australia (Li et al., 2006). In response to this, mandatory iodine fortification of salt used in the bread-making process was introduced in Australia in October 2009 (FSANZ, 2009). Shortly thereafter, the National Health and Medical Research Council (NHMRC) introduced recommendations that all pregnant women should take an iodine supplement providing 150 µg iodine per day (NHMRC, 2010), due to concerns that the increased iodine intake as a result of iodine fortification may be inadequate to meet the higher iodine requirements of pregnant women (FSANZ, 2009).

Data relating to the iodine status or iodine intake of pregnant women in Australia since the introduction of mandatory iodine fortification of bread are limited. Two studies, undertaken postfortification in Victoria and South Australia (Clifton et al., 2013; Rahman, Savige, Deacon, Chesters, & Panther, 2011), reported mild iodine insufficiency as indicated by a urinary iodine concentration (UIC) <150 µg/L, whereas a study in New South Wales (NSW) showed that only women taking iodine supplements were iodine-sufficient postfortification (Charlton et al., 2013). However, women in these studies were opportunistically sampled, and the sample sizes were all relatively small ($n = 86$ – 196), well below the $n = 300$ recommended by the World Health Organization (WHO) for the reliable assessment of population status (WHO, UNICEF, & ICCIDD, 2007). As a tool for monitoring iodine status, UIC is reflective of recent iodine intake but can vary significantly from day to day in the same individual (König, Andersson, Hotz, Aeberli, & Zimmermann, 2011). Assessing dietary iodine intake may provide a better indication of iodine adequacy in an individual, but only one study to date (Charlton et al., 2013) has assessed iodine intake in a smaller number ($n = 147$ in 2011 and $n = 114$ in 2012) of pregnant women in NSW, Australia, and the iodine food frequency questionnaire (I-FFQ) used in that study was validated for use in the elderly (Tan, Charlton, Tan, Ma, & Batterham, 2013), and not in pregnant women.

The aims of this study were to assess iodine intake using an I-FFQ validated in pregnancy (Condo, Makrides, Skeaff, & Zhou, 2015) and iodine status, as determined by UIC, in a large cohort of pregnant women in South Australia and to investigate the correlation between iodine intake and UIC in pregnancy.

2 | PARTICIPANTS AND METHODS

This study involved pregnant women who were participating in a prospective cohort study of Pregnancy Iodine and Neurodevelopment

in Kids (Condo et al., 2015). Eligible women, less than 20 weeks' gestation, were recruited between August 2011 and December 2012 from the Women's and Children's Hospital and Flinders Medical Centre, Adelaide. Exclusion criteria included a history of thyroid disease, known fetal abnormality, known history of drug or alcohol abuse and families in which English was not the primary language spoken at home. Written informed consent was obtained from all participants, and all study procedures were performed in accordance with the approval of the relevant Human Research Ethics Committee at each site.

2.1 | Assessment of iodine intake

Iodine intake from food was assessed at study entry (<20 weeks' gestation) and at 28 weeks' gestation using a validated I-FFQ administered as previously described (Condo et al., 2015). Information regarding the use of nutritional supplements, in particular, supplements that contained iodine, was obtained at the same time points via a structured interview. Briefly, for each food item, the frequency of intake was recorded as the number of serves per day, per week or per month. If the food was not consumed on a monthly basis, the frequency of intake was marked as rarely/<1 per month. Additional three semiquantitative questions were included, which related to salt use, including whether salt was added in cooking or at the table, if the salt added was iodised salt and the estimated daily portion used in categories ranging from less than one fourth of a teaspoon to more than one teaspoon.

As previously described (Condo et al., 2015), all frequencies of consumption (per week and per month) were converted to per day assuming that there were 7 days in a week and 30 days in a month. The frequency of consumption per day was multiplied by the average iodine content of the specific food derived from the most up-to-date Australian composition database (NUTTAB 2010 (NUTTAB 2010 – Australian Food Composition Tables, 2011) or AUSNUT 2007 (Australian Food, Supplement, & Nutrient Database, 2007 for estimation of population nutrient intakes: explanatory notes 2008)). This was completed for each individual food item and was added together to give the mean daily iodine intake from food. Due to the difficulty in estimating iodine intake from salt, the daily portion of iodised salt recorded on the I-FFQ was not quantified.

2.2 | Assessment of iodine status

Spot urine samples were collected from women at study entry (<20 weeks' gestation) and at 28 weeks' gestation, stored at -20°C

Key messages

- Pregnant women in South Australia are iodine sufficient since mandatory iodine fortification of bread and the recommendation for routine iodine supplementation during pregnancy.
- Iodine supplementation during pregnancy is required to meet the estimated average requirement for iodine of ≥ 160 µg/L and to achieve a urinary iodine concentration of ≥ 150 µg/L.
- Ongoing research to monitor the impact of routine iodine supplementation in pregnancy on clinical and developmental outcomes of children in iodine-sufficient populations is warranted.

and batch-analysed by a laboratory at the University of Adelaide, which is accredited by the Centre for Disease Control and Prevention ensuring the quality of urinary iodine procedures programme (Caldwell, Makhmudov, Jones, & Hollowell, 2005). UIC was determined using a modified WHO "method A" procedure using ammonium persulfate digestion and read on a microplate. The detection limit and reporting limit of this method were 5.5 and 18.3 µg/L, respectively. Intra-assay coefficient of variation and interassay coefficient of variation were both less than 5%. Iodine sufficiency was defined as a median UIC ≥ 150 µg/day in accordance with the WHO criteria (WHO et al., 2007).

2.3 | Sample size and statistics

Previous reports of correlations between maternal total iodine intake and UIC in pregnant women ranged from 0.15–0.42 (Brantsæter, Haugen, Julshamn, Alexander, & Meltzer, 2009; Rebagliato et al., 2010). Based on these previous findings, a correlation of 0.2 with 90% power was used to calculate sample size. It was estimated that 270 women would be required to detect this correlation between maternal total iodine intake and UIC. With a sample size of 783, the study has the power to detect a minimum correlation of 0.13 with 90% power and 5% precision. This sample size also exceeds the WHO recommended sample size ($n = 300$) for reliable assessment of iodine status of populations.

Women were classified into groups based on whether or not the iodine supplements they were taking at study entry met the NHMRC recommendation of 150 µg/day (NHMRC, 2010): women not using iodine supplements, women taking supplements containing iodine ≥ 150 µg/day and women taking supplements containing iodine < 150 µg/day. Independent of supplement use, the women who used iodised salt at 28 weeks' gestation were categorised as iodised salt users, whereas those who used no salt or used noniodised salt were classified as noniodised salt users. The percentage of women with a UIC below the WHO cut-offs for iodine insufficiency in pregnancy (< 150 µg/L) and below the WHO cut-offs for moderate iodine insufficiency in the general population (< 50 µg/L; WHO et al., 2007) as well as those women with iodine intake below the estimated average requirement (EAR; 160 µg/day; NHMRC, 2006) in pregnancy was determined.

Results were reported as mean $\pm$ SD for normally distributed variables or median (interquartile range) for non-normally distributed variables. For categorical variables, results were reported as number and percentage. One-way analysis of variance using Bonferroni post hoc tests was used to compare continuous baseline characteristics of the women between categories of iodine supplement intake (women not using iodine supplements, women taking supplements containing iodine ≥ 150 µg/day and women taking supplements containing iodine < 150 µg/day), whereas chi square or Fisher's exact tests were used to compare categorical baseline characteristics of the women between categories of iodine supplement intake.

Total iodine intake in pregnancy was calculated as the average iodine intake at study entry and at 28 weeks' gestation. UIC was not normally distributed and therefore was log transformed for statistical analysis. One-way analysis of variance using Bonferroni post hoc test was used to compare total iodine intake and Kruskal–Wallis H test

using Dunn's procedure (Dunn, 1964) with a Bonferroni adjustment was used to compare UIC between categories of iodine supplement intake at study entry and 28 weeks' gestation. Independent t tests were used to compare total iodine intake in pregnancy by EAR category (< 160 µg/day vs. ≥ 160 µg/day) and use of iodised salt in pregnancy (iodised salt users vs. noniodised salt users). Pearson's correlation coefficient was used to determine the correlation between total iodine intake in pregnancy and UIC at 28 weeks' gestation, and between intake of food groups that are major sources of iodine (presented as a percent of total iodine intake from food) and UIC at 28 weeks' gestation. Statistical significance was set at $p < .05$.

3 | RESULTS

There were 783 pregnant women who participated in the study. Of these women, the number of women that completed each phase of the study is shown in Figure 1. Characteristics of the participants are shown in Table 1. The mean age of the women was 30.5 years, and the mean gestational age at enrolment was 16.3 weeks (range 5.6–19.6 weeks). Eighty-one percent (635/783) of women reported taking supplements containing iodine during their pregnancy, with 62.4% of all women (489/783) meeting the NHMRC recommendation of supplements providing at least 150 µg of iodine per day (NHMRC, 2010). A higher proportion of women taking supplements containing iodine ≥ 150 µg/day completed secondary education and were currently employed compared with women taking supplements containing iodine < 150 µg/day or women not using iodine supplements, whereas fewer women taking supplements containing iodine ≥ 150 µg/day were multiparous (Table 1).

3.1 | Iodine intake

Iodine intake from food and supplements at study entry and at 28 weeks' gestation is shown in Table 2. Total iodine intake did not vary between study entry (< 20 weeks' gestation) and 28 weeks' gestation ($p = .29$, Table 2). Total iodine intake was significantly different between all categories of iodine supplement intake ($p < .001$, Table 2). The average dose of iodine supplement use over pregnancy in all women was 154 ± 126 µg/day. In women taking supplements containing iodine ≥ 150 µg/day, the average dose of iodine supplement use over pregnancy was 220 ± 112 µg/day, and in women taking supplements containing iodine < 150 µg/day, the average dose of iodine supplement use over pregnancy was 90 ± 34 µg/day. Of the women taking supplements containing iodine ≥ 150 µg/day at study entry, 88% were adhering to this supplement use at 28 weeks' gestation, whereas 4% of women were using supplements < 150 µg/day, and 8% of these women were not using iodine supplements at 28 weeks' gestation. In addition, 3% of women who were not using iodine supplements at study entry were using iodine supplements at levels > 150 µg/day at 28 weeks' gestation.

A total of 667/773 (85.9%) women met the EAR (≥ 160 µg/day) for iodine intake from food and supplements. When iodine from supplements was excluded, 344/773 (44.5%) of women met the EAR for iodine during pregnancy. Dairy foods were the major contributor

FIGURE 1 Women that completed each stage of the study. I-FFQ, iodine food frequency questionnaire

TABLE 1 Characteristics of pregnant women at study entry

	All (n = 783)	Women taking supplements containing iodine ≥150 µg/day ^a (n = 489)	Women taking supplements containing iodine <150 µg/day ^a (n = 146)	Women not taking supplements containing iodine ^a (n = 148)
Age (years)	30.5 ± 5	30.7 ± 5	30 ± 5	29 ± 5
Gestational age (weeks)	16.3 ± 2	16.3 ± 2	16 ± 2	16.4 ± 2
Body mass index (kg/m ²)	26 ± 6	26 ± 6	25 ± 5	27 ± 5.8
Parity (≥1)	361 (46.1%)	189 (38.6%)**	83 (56.8%)	89 (60.1%)
Mother's education				
Completed secondary	648 (82.8%)	428 (87.8%)*††	115 (79.3%)	105 (71.9%)
Degree or higher degree	404 (51.6%)	269 (55.2%) [§]	76 (52%)††	59 (40.6%)
Mothers' employment				
Currently employed	650 (83.0%)	434 (88.7%)††	115 (78.7%)††	101 (68.2%)
Smoking	45 (5.7%)	22 (4.4%)	11 (7.5%)	12 (8.1%)
Drinking alcohol (any)	40 (5.1%)	25 (5.1%)	7 (4.7%)	8 (5.4%)

Note. Data are presented as mean ± SD for continuous variables and as n (%) for categorical variables.

^aBased on intake of iodine supplements across pregnancy (study entry and 28 weeks' gestation).

**p < .001 compared to women taking supplements containing iodine <150 µg/day and women not taking supplements containing iodine.

*p = .008.

†p = .002 compared to women taking supplements containing iodine <150 µg/day.

‡p < .001.

§p = .01.

††p = .04 compared to women not taking supplements containing iodine.

to iodine intake in pregnancy (50%), with 34.3% from milk. Iodine-fortified bread made up 23.0%, whereas eggs and total seafood contributed to 8% and 5% of total iodine intake from food in pregnancy, respectively.

3.2 | Urine iodine concentration

The median UICs at study entry (189 µg/L) and 28 weeks' gestation (172 µg/L) are shown in Table 2. Median UIC changed significantly during pregnancy (between study entry and 28 weeks' gestation), and measurements at study entry were higher than at 28 weeks' gestation (Table 2). The median UIC at study entry and at 28 weeks' gestation was higher in women taking supplements containing iodine

≥150 µg/day compared with women taking supplements containing iodine <150 µg/day and women not using iodine supplements (Table 2), but there were no differences in UIC between women taking supplements containing iodine <150 µg/day and women not using iodine supplements (Table 2).

Women whose average iodine intake in pregnancy met or was above the EAR (160 µg/day) had a higher median UIC at study entry (206 [130–324] µg/L) and 28 weeks' gestation (179 [104–300] µg/L) compared to those who were below the EAR at study entry (148 [79–193] µg/L) and 28 weeks' gestation (144 [95–205] µg/L; p ≤ .001). There was no difference in UIC between iodised salt and noniodised salt users at study entry or at 28 weeks' gestation. The average percentage of women over pregnancy (study entry and

TABLE 2 Total iodine intake (food and supplements) and UIC of pregnant women

	Study entry (<20 weeks' gestation)	28 weeks' gestation
Total iodine intake ($\mu\text{g}/\text{day}$)		
<i>n</i>	773	719
All women	307 $\pm$ 128	300 $\pm$ 127
Women taking supplements containing iodine $\geq 150 \mu\text{g}/\text{day}^a$	377 $\pm$ 133*	367 $\pm$ 133*
Women taking supplements containing iodine $< 150 \mu\text{g}/\text{day}^a$	251 $\pm$ 98*	237 $\pm$ 98*
Women not taking supplements containing iodine ^a	142 $\pm$ 69*	152 $\pm$ 67*
UIC ($\mu\text{g}/\text{L}$)		
<i>n</i>	781	730
All women	189 (112–308)**	172 (103–281)
Women taking supplements containing iodine $\geq 150 \mu\text{g}/\text{day}^a$	221 (129–347) ^{†,‡}	187 (114–325) ^{†,§}
Women taking supplements containing iodine $< 150 \mu\text{g}/\text{day}^a$	163 (103–283)	152 (88–260)
Women not taking supplements containing iodine ^a	159 (91–214)	141 (92–216)

Note. Iodine intake presented as mean $\pm$ SD; UIC presented as median (interquartile range).

n = number; UIC = urine iodine concentration.

^aBased on intake of iodine supplements across pregnancy (study entry and 28 weeks' gestation).

**p* < .001 between categories of iodine supplement intake,

***p* = .04 at study entry versus 28 weeks' gestation in all women,

[†]*p* < .001 compared to women not taking supplements containing iodine,

[‡]*p* = .004,

[§]*p* = .007 compared to women taking supplements containing iodine $< 150 \mu\text{g}/\text{day}$.

28 weeks' gestation) with UIC $< 150 \mu\text{g}/\text{L}$ was 34% and with UIC $< 50 \mu\text{g}/\text{L}$ was 2% (Figure 2).

3.3 | Relationship between iodine intake and UIC

A positive but weak association was found between total iodine intake in pregnancy and UIC at 28 weeks' gestation ($r = .23$, $p < .001$).

Total dairy intake also had a weak positive association with UIC at 28 weeks gestation ($r = .11$, $p < .001$). Other food groups were not correlated with UIC.

4 | DISCUSSION

Our study is the largest prospective cohort study, and the only study with adequate sample size, that has assessed dietary iodine intake and UIC in pregnancy since the introduction of the mandatory iodine

fortification programme and iodine supplement recommendations in Australia. Based on a median UIC of $189 \mu\text{g}/\text{L}$ at study entry, our cohort of South Australian pregnant women could be considered iodine sufficient. This finding is comparable to that reported by Charlton et al. (2013) in a smaller cohort of pregnant women in NSW in 2012 (median UIC $166 \mu\text{g}/\text{L}$). It is also in line with the results of the Australian Health Survey conducted in 2011 (ABS, 2013), which reported iodine sufficiency in Australian women of child-bearing age postmandatory iodine fortification of bread (median UIC $121 \mu\text{g}/\text{L}$). In contrast, Clifton et al. (2013) reported mild iodine insufficiency (median UIC $82 \mu\text{g}/\text{L}$) in a small cohort ($n = 196$) of South Australian pregnant women. However, this study was conducted between January 2009 and July 2010, meaning that some samples were collected premandatory iodine fortification of bread and unlike our study, only 47% of women were using iodine-containing supplements. Furthermore, the sample size in the Clifton study was less than the WHO recommendation of a minimum of 300 to reliably determine

FIGURE 2 Urine iodine concentration (UIC) of women according to the average intake of iodine supplements over pregnancy (<20 weeks' gestation and 28 weeks' gestation)

the iodine status of a population (WHO et al., 2007), and the women were recruited from one hospital (Lyell McEwin Hospital) in a low socioeconomic area providing antenatal care for 16.5% of pregnant women in South Australia (Scheil et al., 2015), whereas women in our study were recruited from two of the major hospitals that provide antenatal care for 41% of pregnant women in South Australia (Scheil et al., 2015).

To the best of our knowledge, ours is the only study that has used validated dietary assessment tools to estimate dietary iodine intake during pregnancy. Although the vast majority of pregnant women had an adequate iodine intake when iodine from supplements was included, with 86% meeting the EAR (160 µg/day) for total iodine intake in pregnancy, less than 50% of women met the EAR from food alone. The median UIC over pregnancy (study entry and 28 weeks' gestation) of women who were not taking iodine supplements was just below the WHO criteria for iodine sufficiency (UIC <150 µg/L). These findings suggest that even after the iodine fortification of bread, it may be difficult for women to meet the EAR for iodine in pregnancy from food alone and that without iodine supplementation, women may be at risk of iodine deficiency based on the current WHO criteria (WHO et al., 2007).

Our finding that dairy products were the main source of dietary iodine is consistent with other studies (Alvarez-Pedrerol et al., 2010; Charlton et al., 2013; Combet & Lean, 2014). Although fish and seafood are high in iodine content, these foods are not a major contributor to iodine intake in this population, which is similar to findings from a recent national survey of pregnant women in Australia showing that women reported eating less fish and seafood in pregnancy (Malek, Umberger, Makrides, & Zhou, 2006). Concern around mercury levels in fish and confusion around recommendation to limit intake of high-mercury fish in pregnancy may contribute to the lower intake of fish in pregnant women. Lack of knowledge about good sources of dietary iodine may also contribute to this finding as less than 40% of healthcare providers involved in the care of pregnant women in Australia discussed dietary sources of iodine with women in their care (Guess, Malek, Anderson, Makrides, & Zhou, 2016).

The observed association between maternal total iodine intake in pregnancy and UIC was expected, as it is well known that UIC is indicative of recent iodine intake (Zimmermann, 2008). The magnitude of the association was small, but comparable with previous observational studies, which also reported weak associations between total iodine intake and UIC from spot urine samples (Jaruratanasirikul et al., 2009) or UIE from 24-hr urine samples (Brantsæter et al., 2009). This is not surprising as both spot and 24-h urine samples are subject to large intra-individual variation. Furthermore, unlike spot UIC, the I-FFQ used in this study assessed iodine intake over the last month, accounting for the day-to-day variability in iodine intake, thus, possibly explaining the weak correlation shown between the two variables.

This study has a number of strengths, including large sample size from two major antenatal hospitals in South Australia. Intake and UIC were assessed at two time points in pregnancy, with over 90% of the women assessed at both of these time points. A validated I-FFQ was used to assess dietary iodine intake in pregnancy. Weaknesses include the fact that the I-FFQ did not quantify salt use. However,

we observed that UIC did not differ between iodised salt and nonsalt users, possibly indicating a minimal effect of iodised salt use on iodine status in this population. Furthermore, Food Frequency Questionnaires (FFQs) have some limitations as a dietary assessment tool that require consideration including the over or under estimation of intake and memory bias (Meltzer et al., 2008). However, although diet records are often considered the "gold standard" as they are less subject to memory bias (Meltzer et al., 2008), FFQs may be more appropriate to assess iodine intake as they are able to estimate usual intake over a longer period of time (Mouratidou, Ford, & Fraser, 2006), which is beneficial as for nutrients such as iodine that are not overly common in the food supply. Furthermore, FFQs have low participant burden and are more practical to use in a large cohort study.

Further limitations include the single-spot urine samples that were collected, as only two samples were collected in pregnancy, which may not adequately reflect the day-to-day variability in iodine intake. It has been suggested that 24-hr urine collections may be a better indication of iodine intake. However, single 24-hr collections are still subject to variability as it has been shown that at least 10 repeated spot urine samples are needed to assess individual iodine status with 20% precision (König et al., 2011), which is impractical in a large cohort such as this one. Due to these limitations of UIC as a marker of individuals' iodine intake and status, a simple I-FFQ may be a more practical tool to assess iodine intake in pregnant women.

In conclusion, the results from this study showed that pregnant women in South Australia are iodine sufficient after mandatory iodine fortification of bread and the NHMRC's iodine supplement recommendation. It also showed that it may be difficult to meet the EAR for iodine in pregnancy or to achieve a UIC ≥150 µg/L without the use of iodine supplementation. Although iodine supplementation is now a common practice among pregnant women in Australia, further research among pregnant women who are not taking iodine supplements is recommended to determine the reasons for noncompliance with the NHMRC's recommendation. In addition, a recent randomised controlled trial (RCT) (Zhou et al., 2015) and a systematic review of RCTs of iodine supplementation in pregnancy highlighted a lack of data on efficacy (beyond UIC) or safety of iodine supplementation in pregnancy in areas of mild iodine deficiency or sufficiency (Zhou, Anderson, Gibson, & Makrides, 2013). Ongoing research to monitor the impact of mandatory iodine fortification of bread and routine iodine supplementation in pregnancy on clinical outcomes including thyroid function and developmental outcomes of the children in Australia is warranted.

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CONFLICTS OF INTEREST

Maria Makrides has received honoraria for scientific advisory board contributions to Fonterra and Nestle Nutrition Institute. All honoraria are paid to the Women's and Children's Health Research Institute to support continuing education activities for students and postgraduates. No other authors declare a conflict of interest.

CONTRIBUTIONS

The specific contributions made by each author are outlined below: Conception and design of the study: SS, MM, SJZ, and PR. Acquisition of data: DC and DH under the supervision of SJZ and MM. Analysis of data: DC and DH. Interpretation of data: DC, SS, MM, SJZ, PR, AJA, BSM, and DH. Drafting the manuscript: DC and AJA. Revising it critically for important intellectual content: DC, SS, MM, SJZ, PR, AJA, BSM and DH. Final approval of the version to be published: DC, SS, MM, SJZ, PR, AJA, BSM and DH.

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