



Improvement in iodine status of pregnant Australian women 3 years after introduction of a mandatory iodine fortification programme

Karen E. Charlton^{a,*}, Heather Yeatman^{a,1}, Erin Brock^a, Catherine Lucas^a, Luke Gemming^b, Alison Goodfellow^c, Gary Ma^{d,2}

^a School of Health Sciences, University of Wollongong, NSW 2500, Australia

^b National Institute for Health Innovation, University of Auckland, New Zealand

^c Illawarra Shoalhaven Local Health District, NSW Health, Australia

^d School of Medicine, College of Health and Sciences, University of Western Sydney, Campbelltown, NSW 2560, Australia

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ABSTRACT

Introduction: In order to address population-level mild iodine deficiency in Australia, a mandatory iodine fortification programme of salt used in bread was introduced in late 2009.

Methods: A before–after study was conducted to assess changes in median urinary iodine concentration (MUIC) measurements, according to supplement use, in convenience samples of pregnant women attending a public antenatal clinic in a regional area of New South Wales, Australia in 2008 ($n = 139$), 2011 ($n = 147$) and 2012 ($n = 114$). Knowledge and practices related to iodine nutrition were investigated in 2012, using self-administered questionnaires.

Results: The mild iodine deficiency confirmed pre-fortification (MUIC (IQR) = 87.5 (62–123.5; $n = 110$)) has steadily improved to 145.5 $\mu\text{g/L}$ (91–252) in 2011 ($n = 106$) and 166 (97–237) in 2012 ($n = 95$) (sufficiency $\geq 150 \mu\text{g/L}$). However, only women taking supplements containing iodine had MUIC indicative of sufficiency in both years surveyed post fortification (2011: 178 $\mu\text{g/L}$ vs. 109 $\mu\text{g/L}$, $P < 0.001$; 2012: 202 $\mu\text{g/L}$ vs. 124 $\mu\text{g/L}$, $P < 0.05$). Despite bread being the vehicle for iodine fortification, dairy foods remained major contributors to total iodine intake (58%). Overall knowledge regarding health implications of iodine deficiency was poor.

Conclusions: Iodine status of women has improved since the introduction of mandatory iodine fortification; however supplementation is indicated during pregnancy.

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1. Introduction

Iodine deficiency is a major public health issue (Zimmermann et al., 2008) that has been the focus of concerted international efforts on universal salt iodisation (Zimmermann and Andersson, 2012). Iodine is an essential trace element for human growth and development. Inadequate iodine intake during pregnancy is of particular concern as it can result in miscarriages, still births, cretinism, and other major impairments of the fetus (Glinioer, 2007; Simpson et al., 2011; Soriguer et al., 2000; Zimmermann et al., 2008).

Australia has been classified as mildly iodine deficient by the World Health Organization (WHO) (de Benoist et al., 2004) and children and

pregnant and breastfeeding women are most at risk (Burgess et al., 2007; Hamrosi et al., 2005; McDonnell et al., 2003; Nguyen et al., 2010). The main cause of iodine deficiency is low levels of iodine in foods grown in soils that are depleted of iodine, coupled with low intakes of iodine-rich fish and seafood (Charlton and Skeaff, 2011). Australia does not have a universal salt iodisation programme, and although iodised table salt is available its use is low (Li et al., 2008) and public health messages have encouraged reductions in salt intake (Eastman, 1999). The widespread replacement of iodophors with other cleansing agents in the dairy industry (Li et al., 2008) has reduced iodine in the diet. A general lack of awareness within the population about the importance of iodine in the diet has also been identified (Charlton et al., 2010a, 2010b; Eastman, 1999).

To address the re-emergence of population-level iodine deficiency, in 2009 it became mandatory for Australian bread manufacturers to use iodised salt in the baking process at levels of 25–65 mg per 1 kg of salt, so that 100 g of bread contained 48 μg of iodine (Food Standards Australia New Zealand, 2008). Additionally, the National Health and Medical Research Council (NHMRC) issued a public statement that recommended all pregnant and lactating women to take

* Corresponding author. Tel.: +61 2 4221 4754.

E-mail addresses: karenc@uow.edu.au (K.E. Charlton), hyeatman@uow.edu.au (H. Yeatman), eeb786@uowmail.edu.au (E. Brock), cjl623@uowmail.edu.au (C. Lucas), l.gemming@nihi.auckland.ac.nz (L. Gemming), Alison.Goodfellow@SESAHS.HEALTH.NSW.GOV.AU (A. Goodfellow), garyma@gmail.com (G. Ma).

¹ Tel.: +61 2 42213153.

² Tel.: +61 409 072 175.

daily supplements containing at least 150 µg of iodine (National Health and Medical Research Council, 2009).

Before–after surveys were conducted to assess whether the iodine status of pregnant Australian women had improved since commencement of mandatory fortification.

2. Methods

Convenient samples of pregnant women were recruited in a single public antenatal clinic in the Illawarra region of Australia (about 80 km south of Sydney) in August–October 2008 ($n = 139$) (Charlton et al., 2010a), 2011 ($n = 147$) and 2012 ($n = 114$). Approximately 2300 births a year occur at the clinic, with a total number of occasions of antenatal service in September 2012 being 2762.

Pregnant women across all three trimesters were invited to participate in the study. In all surveys, non-English speaking women and those receiving treatment for thyroid dysfunction were excluded.

Consenting women provided a spot urine sample (to determine UIC) and socio-demographic information. In the 2012 study, data were also collected on participants' perceived dietary adequacy, good food sources of iodine, changes to diet, supplement use, adequacy of dietary education received and awareness of the mandatory iodine fortification programme. A validated iodine-specific food frequency questionnaire (FFQ) (Tan et al., 2013) was administered in 2011 and 2012, which assessed food intake over the previous month (including dairy, eggs, cereal products, fish and seafood, meat, vegetables, fruit and mixed dishes), as well as tap water consumption and use of iodised salt.

Urine samples were stored at -80°C and batch analysed for each survey using the Sandell–Kolthoff method with ammonium persulfate digestion and microplate reading (Ohashi et al., 2000) by the accredited laboratory of the Institute of Clinical Pathology and Medical Research, Westmead Hospital, Sydney. The sensitivity of the urinary iodine assay was 10 µg/L. At 25 µg/L the coefficient of variation is 8.2%, at 120 µg/L the coefficient of variation is 9.8% and at 350 µg/L the coefficient of variation is 11.3%. Sufficiency was determined using World Health Organization criteria of $\text{MUIC} \geq 150 \mu\text{g/L}$ in pregnancy (Andersson et al., 2007b; World Health Organization, 2007).

This study was conducted according to the guidelines in the Declaration of Helsinki and approval was granted by the University of Wollongong Human Research Ethics Committee. Written informed consent was obtained from all participants.

2.1. Statistical analysis

All statistical analyses were conducted using SPSS 17.0 (SPSS Inc. Chicago, IL, USA). MUIC was compared between the three surveys using the Kruskal Wallis test, and between individual years using the Mann–Whitney U test. Within surveys, Mann–Whitney tests were performed to assess differences in MUIC according to supplement use, use of iodised salt, reported changes to dietary intake, age, previous pregnancies and education level.

Iodine intake was determined using FoodWorks (version 7, Xyris Software, Pty Ltd, Highgate Hill, QLD, Australia). Iodine intake from bread was calculated as 48 µg/100 g. It was assumed that reported salt use greater than or equal to one teaspoon of added salt had not taken into account the amounts lost in cooking and meals eaten by more than one person, therefore an amount of 1 g per day was used based on discretionary salt use estimated from dietary modelling by FSANZ (Andersson et al., 2007a). Iodine intake was compared to EAR for pregnant women (160 µg/day) (National Health and Medical Research Council, 2006) and contribution of each food source was calculated as a percentage and compared to the 2011 study.

3. Results

Women across the surveys were similar in age (mean = 28.4 (5.6) years, range = 15–45 years) and highest level of education attained, with the majority having a post-school qualification (Table 1). More women in the 2008 survey were in their third trimester ($P < 0.001$), but the majority in all surveys were similarly having their first child. More women in 2012 had experienced a previous miscarriage than those from 2008 or 2011 ($P < 0.001$). Different response rates were obtained for the different data areas (2008

Table 1

Sample characteristics including age, education level, pregnancy trimester, first pregnancy, intention to breastfeed and previous miscarriage.

	2008 (Pre-fortification) $n = 139$	2011 (Post-fortification) $n = 146^a$	2012 (Post-fortification) $n = 109^b$
Age			
Mean (SD)	28.4 ± 5.7	28 ± 5.0	29.6 ± 5.8
Range	16–45	16–40	19–45
Highest level of education attained			
Some high school	17%	23%	19%
Completed high school (year 12)	30%	19%	18%
TAFE (technical and further education or apprenticeship)	31%	32%	36%
University Degree (Undergraduate level)	13%	21%	19%
University degree (Postgraduate level)	9%	6%	7%
Trimester ^c			
1 (0–12 weeks)	2%	2%	0.9%
2 (13–24 weeks)	13%	37%	29%
3 (25+ weeks)	85%	61%	71%
First pregnancy/birth	41%	46%	35%
Intention to breastfeed	84%	88%	85%
Previous miscarriage ^c	29%	25%	35%

^a $n = 146$ of 147 participants completed the questionnaire.

^b $n = 109$ of 114 participants completed the questionnaire.

^c χ^2 test for difference between surveys: $P < 0.001$.

total $n = 139$, 139 questionnaires, 110 urine samples; 2011 total $n = 147$, 146 questionnaires, 106 urine samples, 130 FFQs; 2012 total $n = 114$, 95 urine samples, 109 questionnaires and 83 FFQs).

3.1. Urinary iodine concentration

Pre-fortification (2008), women had MUIC values within the mildly deficient range (87.5 (IQR 62–123) (Table 2). The MUIC of women improved to 145.5 µg/L (91–252) ($P < 0.001$) in 2011 which indicates borderline insufficiency, while in 2012 MUIC had increased 166 µg/L (97–237) ($P < 0.001$), indicating insufficiency. Post fortification, a greater proportion of women, (19–22%) had UIC values $> 250 \mu\text{g/L}$ (pre-fortification: 3.6%; $P < 0.05$), and 3.2–3.8% of women had an UIC $> 500 \mu\text{g/L}$ (none pre-fortification). Within surveys, no difference in MUIC was found for age, education or number of previous pregnancies.

Table 2

Urinary iodine concentrations of pregnant women attending public antenatal clinic.

	2008 (Pre-fortification) $n = 110^a$	2011 (Post-fortification) $n = 106^b$	2012 (Post-fortification) $n = 95^c$
Median (IQR) (µg/L) ^d	87.5 (62–123.5) ^e	145.5 (91–252) ^f	166 (97–237)
Minimum–maximum (µg/L)	18–325	26–850	10–640

^a $n = 110$ of 139 participants provided a urine sample.

^b $n = 106$ of 147 participants provided a urine sample.

^c $n = 95$ of 114 participants provided a urine sample.

^d $P < 0.05$ for differences between samples (Kruskal Wallis);

^e $P < 0.05$ for 2008 vs. 2012 (Mann–Whitney U);

^f $P < 0.05$ for 2008 vs. 2011 (Mann–Whitney U).

Pre-fortification, 59% of women indicated supplement use during pregnancy, but only 20% was taking supplements containing iodine. The most common dosage was 250 µg/day (23/28; 82%). Supplement use was higher among women in their first pregnancy (72% vs. 49%; $P < 0.005$) and among women who had a tertiary education (73.5% vs. 54%; $P = 0.049$) (reported elsewhere, Charlton et al., 2010a). Most supplement users had been taking them for over 3 months (3–6 months, 36.5%; 6+ months, 41%); as the majority of participants (61–85%) were mainly in their third trimester, this implies supplement use from the end of their first trimester. No difference in MUIC was observed between those that reported using iodine supplements and those that did not.

Post-fortification, reported nutritional supplement use was 71% and 77% in 2011 and 2012, respectively. Iodine-containing supplements were being taken by 60% and 66% of women in the two surveys, respectively, with the most common dosage being 250 µg/day (45% of iodine supplement users), followed by 150 µg/day (30%). Women taking iodine-containing supplements had an adequate MUIC (2011: 178 (118–313) µg/L; 2012: 202 (115–289) µg/L) but in non-supplement users, MUIC remained insufficient (2011: 109 (72–155) µg/L; 2012: 124 (58–196) µg/L; $P < 0.05$ for differences between supplement and non-supplement users by year).

3.2. Dietary intake

Mean dietary iodine intake in 2012 was 160 ± 80 µg/day (median (IQR) = 154 (95–195) µg/day) which was similar to the 2011 sample (mean = 176 ± 92 µg/day; median = 152 (106–233) µg/day). Once iodine contributed from iodised salt in bread was accounted for, mean intake increased in both years, to 193 ± 86 µg/day (median = 190 (137–243) µg/day) and 211 ± 98 µg/day (median = 193 (133–264) µg/day) in 2012 and 2011, respectively.

Reported dietary intakes from both years exceeded the EAR for pregnancy (160 µg/day). In 2012 most dietary iodine was provided from milk and dairy sources (58%), followed by breads and cereals (20%), tap water (8%), iodised salt (4.5%), seafood (3%), and eggs (3%). Dietary iodine sources were similar in 2011 (Fig. 2).

3.3. Knowledge and practices

Fifty four percent of women in the 2012 survey correctly identified seafood as a good food source of iodine, but many incorrectly identified vegetables (62%) and meat (55%) as being good sources (Table 3). Most participants did not know if their diet provided enough iodine for their own (74%) or their baby's (80%) needs. Only 10% of women correctly

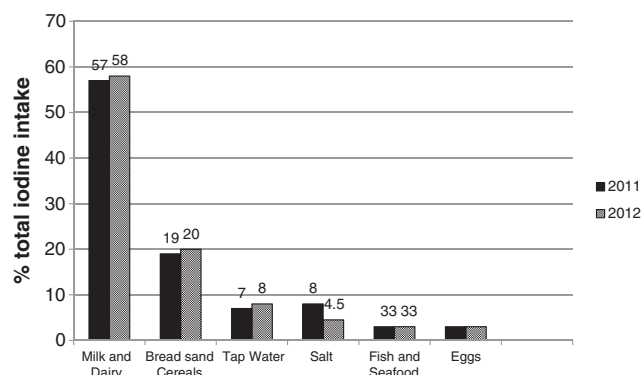


Fig. 2. Contribution of food sources to total iodine intake in pregnant Australian women, as assessed from a food frequency questionnaire: 2011 and 2012.

identified mental retardation and 14% identified goitre as being related to iodine deficiency in pregnancy. However 63% and 40% of women were able to identify that pregnant and breastfeeding women, respectively, were at risk of iodine deficiency.

A third (32%) of women reported receiving adequate information about iodine, which was similar to 2011 (34%) and up from 2008 (17%; $P = 0.007$), but lower than for other nutrition-related topics (Fig. 1). The most commonly reported source of information regarding iodine during pregnancy was verbal advice from a health care professional ($n = 30/109$; 27.5%).

Across surveys, most women (78%) did not know whether iodine deficiency was a public health problem in Australia. Only 3.7% of participants identified that bread was required by Australian law to have iodine added. Reported iodised salt use in cooking and/or at the table did not differ significantly across surveys (39–49%).

4. Discussion

This study provides evidence that the mandatory iodine fortification programme has resulted in improvements in the iodine status of pregnant women from one geographical area in Australia. Despite being small, non-representative samples, the same methodology and recruitment location were used in each of the three cross-sectional surveys, and all urinary iodine analyses were performed using standard methodology by a single accredited laboratory.

There have been a few publications examining the impact of the iodine fortification programme on the UIC of Australian and New Zealander communities (Depaoli et al., 2012; Skeaff and Lonsdale-Cooper, 2012;

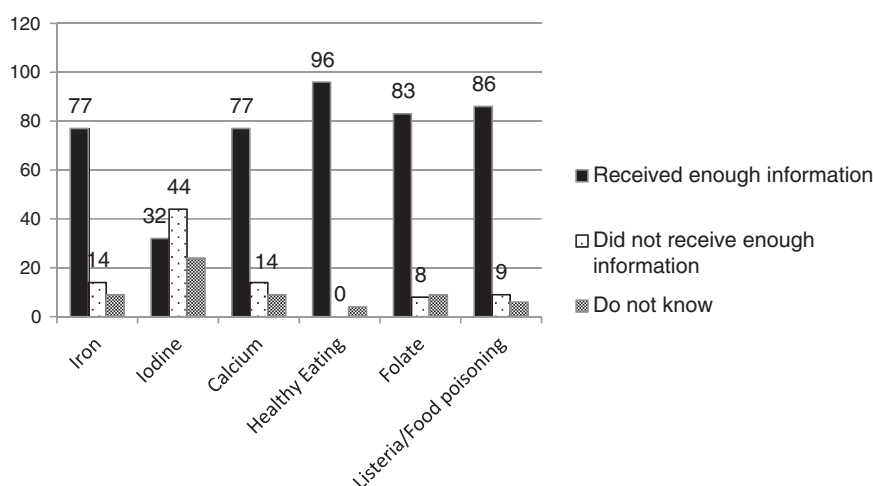


Fig. 1. Participant responses (%) regarding adequacy of dietary information received regarding different dietary issues (2012 survey; $n = 109$).

Table 3

Percentage (%) of participants who believed that the food sources were a good source of iodine, not a good source or did not know ((2012 survey; n = 109).

Food source	Good source	Not a good source	Do not know
Milk ^a	26	10	64
Bread ^{a, b}	24	12	64
Vegetables	62	3	35
Fruit	39	4	57
Eggs ^a	37	6	57
Fish and seafood ^a	54	9	37
Meat	55	4	41
Salt ^{a, c}	51	17	32

^a Good sources of iodine.

^b Fortified only after 2009.

^c Good source if iodised.

Baxter et al., 2011). One small study has been conducted in pregnant women (n = 86) during the period of introduction of the fortification programme and reported an insufficient MUIC (96 µg/L) (Rahman et al., 2011). Our group has previously reported that a year after fortification, urinary iodine status was adequate in breastfeeding women (Axford et al., 2011a, 2011b) but was higher for iodine supplement users compared to non-users, respectively (206 µg/L (86–262) vs. 97 µg/L (56–190); P = 0.029).

Prior to mandatory fortification in Australia, a voluntary iodine fortification programme trialled with bread manufacturers in Tasmania found no improvement in MUIC in pregnant women despite an uptake of the programme by 80% of bakeries (Burgess et al., 2007). The discrepancy between the improvement in MUIC results reported here and those of the Tasmanian experience may reflect a change in supplement formulation that occurred simultaneously to the mandatory fortification programme.

Previously most major multivitamin/mineral supplements for pregnant and lactating women available in Australia did not contain iodine. In 2009, 65% of these supplements contained iodine (as potassium iodide), with the recommended dose varying from 38.3 to 250 µg/L (Gallego et al., 2010). Reported use of iodine containing supplements in pregnancy more than doubled between 2008 and 2011/12 (35–60% respectively), however this change could be attributed to an increased availability of iodine-containing multivitamin brands targeted to pregnant and lactating women in Australia, rather than behaviour change per se.

Poor knowledge related to iodine nutrition during pregnancy has not improved following mandatory iodine fortification (Charlton et al., 2012). Most women were unaware that neurocognitive impairment of the fetus is associated with iodine deficiency. There was also confusion between the role of iodine and folic acid in pregnancy, with a quarter of participants incorrectly attributing neural tube defects to iodine deficiency. This may be related to simultaneous mandatory fortification of both folic acid and iodine (both added to bread) that occurred in Australia in late 2009 (Food Standards Australia and New Zealand, 2009).

Women were also unclear about food sources of iodine. Despite identification of fish and seafood as a good source of iodine, seafood contributed minimally (3%) to overall iodine intake in this population, with the majority being provided from dairy sources, followed by breads and cereals. Limited fish and seafood consumption during pregnancy may be related to concerns about mercury levels in seafood (Lando et al., 2012).

Opinion is divided (Zhou et al., 2010) regarding whether iodine supplementation is premature prior to formal evaluation of the mandatory iodine fortification programme on a nationally representative level, as will be conducted in the current (2011/12) National Health Survey (ABS, 2012). Well-designed randomised controlled trials (RCTs) would ideally evaluate the impact of iodine supplementation on both maternal and child health outcomes, but these trials are

ethically complex and unlikely to be performed. Thus weaker study designs such as ours are necessary to inform whether biomarkers of iodine status (urinary iodine excretion, thyroid volume, etc.) have changed with changes in the food supply.

It is well documented that the introduction of iodine into areas with a history of iodine deficiency results in a temporary increase in the incidence of thyrotoxicosis (Bürgi, 2010; Pedersen et al., 2011), which gradually resolves after 2–5 years (Zimmermann, 2008). Regular and ongoing monitoring is required to ensure that population iodine intakes achieve recommended ranges without excessive intakes in some sectors of the population (Australian Institute of Health and Welfare, 2011). In 27 countries with universal salt iodisation, MUIC values are considered to be more than adequate (>200 µg/L, 158 µmol/L) and in seven countries, excessive (MUIC >300 µg/L, 237 µmol/L) (de Benoist et al., 2008). Our data show that since fortification, a fifth of women had UIC values above 250 µg/day, and of particular concern is the emergence of individuals with concentrations >500 µg/day. However the clinical significance of applying reference ranges developed for group MUIC values to individual women is unknown.

The main limitation of the study is the non-representativeness of the sample and the possibility that participants may have been better informed about health and nutrition than the general population. Dietary modelling by Mackerras et al. (2011) using the data from pregnant women who were similarly above average education identified an increased intake of milk and bread compared to non-pregnant women. The exclusion of non-English speaking women also limits generalizability, since this group has been reported to be at a higher risk of iodine deficiency (Hamrosi et al., 2005).

5. Conclusion

Encouraging improvements in MUIC levels have been shown in Australian women two to three years following introduction of the mandatory iodine fortification of bread. A need for public health education has been identified, given the lack of knowledge regarding iodine nutrition among the pregnant women surveyed. Ongoing monitoring and surveillance of the iodine status of pregnant women are essential to ensure that fortification and supplementation strategies achieve optimal iodine intakes, without the risk of excess.

Conflict of interest statement

There are no competing interests.

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