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ORIGINAL ARTICLE

Iodine status of adolescent girls in a population changing from high to lower fish consumption

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Objectives: During the last decades, fish and milk consumption has decreased considerably in Iceland, especially among adolescents. As these food items are important dietary iodine (I) sources, the aim of the study was to assess the iodine status and dietary pattern of adolescent girls in a population changing from a high to lower consumption of milk and fish.
Subjects/Methods: Subjects were randomly selected adolescent girls (16–20 years old, $n=112$). A validated Food Frequency Questionnaire (FFQ) was used to evaluate food consumption and compare it with food-based dietary guidelines for milk and dairy products (2–3 portions/day) and fish ($\geqslant$2 times/week). Urine samples were collected for measuring urinary iodine (U-I) and creatinine (Cr) and blood samples for measuring serum thyroid-stimulating hormone (TSH).
Results: Milk and dairy products provided 43% and fish provided 24% of the total dietary I. More than 65% of the girls consumed fish less than twice a week, and 40% consumed less than two portions of milk and dairy products per day. The median U-I concentration was 200 μg/l and the U-I/Cr ratio 138 μg I/g Cr. High intake of milk was associated with higher urinary iodine concentration, but fish intake was not found to be directly associated with urinary iodine concentration.
Conclusions: Iodine status of Icelandic adolescent girls is within the optimal range defined by the World Health Organization. It is important to monitor both iodine status and the iodine concentration of important sources of iodine, as both dietary habits and composition of food might change with time.
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Introduction

Iodine is an essential component of the thyroid hormones, tetraodothyronine and triodothyronine, necessary for normal growth, development and metabolism during pregnancy, infancy and throughout life (Nordic Council of Ministers, 2004; Caldwell *et al*., 2005). Iodine deficiency is considered to be one of the most common nutrition disorders in the world and the world's largest single cause of preventable brain damage (Delange *et al*., 2001). When the physiological requirements for iodine are not met, a series of functional and developmental abnormalities occur as a result of thyroid dysfunction (Hetzel, 1983). All European countries except Iceland have experienced this health and socioeconomic threat to a greater or lesser extent (WHO/UNICEF, 2001).

The Icelandic population has in the past been known for its high iodine status, based on studies from 1939, 1988 and 1998 (Sigurjonsson, 1940a; Laurberg *et al*., 1998; Sigurdsson and Franzson, 1998). The excellent iodine status observed in these studies was suggested to be due to high fish consumption and abundant milk. Fish and seafood are the food items with the highest natural concentration of iodine in a normal diet. Another important dietary source of iodine is milk and dairy products (Reykdal *et al*., 2000; Dahl *et al*., 2004; Haldimann *et al*., 2005). Icelandic milk and dairy products are generally high in iodine (Reykdal *et al*., 2000). Dietary surveys in Iceland have shown that fish and seafood consumption has decreased considerably during the last decades and especially among adolescents (Steingrimsdottir *et al*., 2003; Thorsdottir and Gunnarsdottir, 2006) with

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possible consequences for the iodine status in the population. Furthermore, the iodine content of milk and dairy products has decreased during the last decades (Sigurdsson and Franzson, 1998; Reykdal *et al.*, 2007; ISGEM, 2008).

Iodized table salt is widely available in the Nordic countries but is not commonly used in Iceland (Nordic Council of Ministers, 2004).

Iodine status has not been assessed in Iceland in the past 10 years and never among adolescents. The aim of this study was to study the intake of iodine-containing food items and to assess the iodine status in Icelandic adolescent girls. Adolescent girls are future mothers and the most serious consequence of iodine deficiency is impaired fetal development (Dunn, 1998).

Subjects and methods

Sample
A random selection of 350 adolescent girls, born in the years 1987–1992, living in the capital Reykjavík and four neighboring towns in Iceland, was obtained from Statistics Iceland. The inclusion criteria were that subjects were able to understand Icelandic lived in the capital area and were healthy. Six percent of the original sample did not fulfill the participation criteria, and 13% could not be reached by phone, leaving 284 subjects. Of these, 145 girls (51% of the eligible sample) agreed to participate in the study. A total of 112 completed the study or 39% of the eligible sample, and 139 subjects or 49% declined participation. The main reasons for refusing to participate were lack of time because of part-time jobs, school work and leisure activities or lack of interest. The distribution of the participants' residence (subjects living in Reykjavik and the four neighbouring towns) was found to be very similar to that of the original sample. The study was approved by The National Bioethics Committee (VSNb2007040006) and The Icelandic Data Protection Commission (2007040320). Written consent was obtained from the participants and from legal guardians of subjects under 18 years of age. The study was conducted between June 2007 and May 2008.

Anthropometric measures and lifestyle questioning
Subjects' weight was measured using a digital scale (SECA, model 708, Germany) to the nearest 100 g, with light clothing and without shoes. Standing height was measured using a SECA stadiometer (model 708, Germany) to the nearest 1 mm. Body mass index (BMI) was calculated. BMI is defined as weight in kilograms divided by square of height in meters (kg/m^2). Underweight is defined as BMI <18.5 kg/m^2, normal weight as BMI 18.5–24.99 kg/m^2, overweight as BMI $\geqslant 25$ kg/m^2 and obese as BMI $\geqslant 30$ kg/m^2 (Institute of Medicine, 2001). For girls who had not reached 18 years of age, recommendations by Cole *et al.* (2007) were used to define underweight, whereas Cole *et al.* (2000) was used to define overweight and obesity in this age group. Subjects were asked about their smoking habits, if they had ever smoked and if they smoked daily. They were also asked if they used an oral contraceptive. See Table 1 for overview.

Table 1 Subjects' characteristics

	Mean (s.d.)
Age (years)	17.7 (2.6)
Height (cm)	167.5 (6.2)
Weight (kg)	63.6 (12.2)
BMI (kg/m^2)	22.6 (4.0)
	n *(%)*
Currently smoke	16 (14.4)
Use oral contraceptive	43 (38.7)
Underweight	9 (8.1)
Normal weight	79 (70.5)
Overweight/obese	24 (21.4)

Food frequency questionnaire
Dietary intake was assessed by a validated Food Frequency Questionnaire (FFQ) (Thorsdottir *et al.*, 2004; Olafsdottir *et al.*, 2006). The FFQs were obtained from a personal interview by a trained research person. This semi-quantitative FFQ was developed at the Icelandic Nutrition Council. It provides information on the consumption of 130 different food items and is designed to reflect food intake over the previous 3 months. Portion sizes were estimated from pictures of three portion sizes of common food items and from general household measures. The National Nutrition Database (ISGEM, 2008) was used to calculate the intake of food items in grams per day and estimate the intake of iodine. The main sources of iodine in the diet are milk and dairy products and fish. In the Icelandic food-based dietary guidelines from 2006, two glasses, bowls or cans a day of milk or dairy products are recommended for children and adults, while adolescents are recommended to consume three portions. One portion of milk and dairy products is estimated to be equal to 250 g and one portion of cheese to be equal to 25 g. Fish is recommended at least twice a week as a main meal, in addition to fish used as a bread spread and in salads (Public Health Institute of Iceland, 2006).

Determination of iodine status
Urine spot samples were collected for iodine and creatinine measurements. Samples were collected in vials between 0900 and 1500 hours. The samples used for iodine measurements were kept frozen at $-80\,^{\circ}$C at Landspitali University Hospital in Reykjavik, Iceland, until all samples had been collected. The samples were sent by courier in dry ice packages to the National Institute of Nutrition and Seafood Research in Bergen, Norway. An Agilent quadrupole ICP-MS 7500c

(Yokogawa Analytical System Inc., Tokyo, Japan) was used as an iodine-specific detector for urinary determination. Optimization and operating conditions of the instrument are described elsewhere (Julshamn *et al*., 2001). The uncertainty in the method is based both on use of control chart (reproducability) and by participation in round robins (correctness).The uncertainty is by these means set at ±15%. Data were collected using the Agilent Chemstation ICP-MS chromatographic software (Julshamn *et al*., 2001; Dahl *et al*., 2003, 2004). Certified reference material (CRM) (Seronorm Trace Elements; Nycomed, Norway) of iodine in human urine was included in each analytical series of 25 samples to control the systematic errors of the analytical method.

Creatinine was measured with the VITROS CREA Slide method, using the VITROS CREA Slides and the VITROS Chemistry Products Calibrator Kit 1 (National Institute of Standards and Technology) on VITROS Chemistry Systems. The VITROS CREA Slide is a multi-layered analytical element, coated on a polyester support. Measurements were conducted the same day that urine samples were taken at Department of Clinical Biochemistry, Landspitali-University Hospital in Reykjavik, Iceland.

A blood sample was collected to measure serum thyroid-stimulating hormone. Thyroid-stimulating hormone was measured with electrochemiluminescence immunoasssy, using MODULAR ANALYTICS E170 from Roche (Tokyo, Japan). Measurements were conducted the same day as the blood samples were taken, at the Department of Clinical Biochemistry, Landspitali-University Hospital in Reykjavik, Iceland.

The World Health Organization (WHO) recommends that the median values of urinary iodine (U-I) concentration should be reported when evaluating the iodine status of a population (WHO/UNICEF/ICCIDD, 2008). According to the WHO guidelines, U-I concentration in a population is considered optimal if the median is between 100 and 200 μg/l, and no more than 20% of individuals have U-I concentration below 50 μg/l (WHO/UNICEF/ICCIDD, 2008). The use of μg iodine/g creatinine ratio is not recommended by WHO. However, it has been used in the past for adjusting dilution in spot samples. As urinary creatinine was analysed in this study we choose to present our data both as median U-I concentration (μg/l) as well as microgram iodine/g creatinine ratio.

Data analysis

Analysis was carried out using the statistical package SPSS 11.0 (SPSS Inc., Chicago, IL, USA). All variables were checked for normal distribution with one Kolmogorov–Smirnov test. The level of significance was taken as $P<0.05$. Assessing of relationships between two different variables was conducted with bivariate correlation, using Spearman's rho for non-normally distributed variables. Non-parametric Mann–Whitney *U*-tests were used to assess the difference between two groups, and non-parametric Kruskal–Wallis H tests were used to assess difference in means among three groups.

Results

The average consumption of milk and dairy products was three portions per day, equaling the recommended amount of milk and dairy products for adolescent girls (Public Health Institute of Iceland, 2006). See Table 2. However, the distribution of intake was skewed with a median intake of 2.2 portions per day. About 60% consumed less than three portions per day, and only 40% consumed at least two milk portions per day, the recommended intake for adults. The frequency of fish intake is shown in Table 3. Subjects consumed fish 1.4 times per week on average. The average consumption in grams was only 14.8 g/day, indicating that the estimated portion of fish was quite small. In general the average dinner portion of fish is about 150 g, and the recommended two meals per week should therefore correspond to more than 40 g/day of fish. Less than 65%

Table 3 Frequency of fish intake

Frequency of fish intake[a]	n	*Percentage*
Never	6	5.4
1–3 times per month	31	27.7
4–6 times per month	37	33.0
2 times per week	28	25.0
3 times per week	10	8.9

[a]Subjects were asked to mark the fish species most commonly consumed. Haddock was most commonly consumed by 83.2% of the subjects, Cod by 8.4%, Salmon by 6.5% and Halibut and other species by 1.9% of subjects.

Table 2 Distribution of fish, milk and iodine intake ($n=112$)

	Mean (s.d.)	*Percentiles*				
		50 (median)	*10*	*25*	*75*	*90*
Fish (g/day)	14.8 (13.3)	11	3.0	6.0	20.8	29.0
Milk (g/day)	540 (440)	422	145	225	765	1062
Cheese (g/day)	20 (25)	13	3	6	24	46
Milk and dairy products (portions/day)[a]	3.0 (2.3)	2.2	1.0	1.4	4.0	6.2
Iodine intake (μg/day)	170 (100)	148	66	90	218	312

[a]One portion of milk and dairy products corresponds to be equal to 250 g and one portion of cheese to 25 g.

consumed fish twice per week on average. The fish species most commonly consumed was haddock.

The average dietary iodine intake was calculated to be 170 μg/day, with a median intake of 148 μg/day (Table 2). The lower level of recommended intake is estimated to be 70 μg/day, and 10% of the subjects had iodine intake below this level. The safe upper limit for iodine intake is 600 μg/day (Nordic Council of Ministers, 2004), and none of the subjects had iodine intake above that value. Figure 1 shows the food sources of iodine in the diet. Milk and dairy products were the main contributors to dietary iodine, providing 43% of total iodine intake. Despite the low intake of fish and seafood, this food accounts for 24% of the total iodine intake.

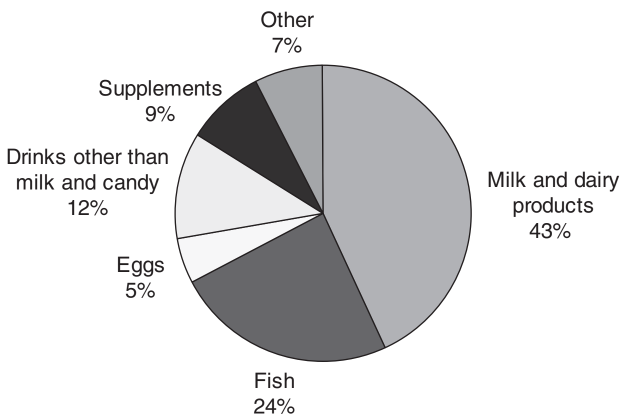

Figure 1 Dietary sources of iodine.

The distribution of U-I concentration can be seen in Table 4. The median U-I concentration was 200 μg/l. Only 6% of the population studied had U-I concentration below 50 μg/l. Serum thyroid-stimulating hormone concentration was within normal range. The μg iodine/g creatinine ratio was 138 μg iodine/g creatinine.

High intake of milk was associated with higher U-I concentration, but fish intake was not found to be directly associated with U-I concentration. Subjects were divided into tertiles depending on their milk consumption and U-I concentration (μg/l) and μg iodine/g creatinine ratio was assessed in each tertile (Table 5). The U-I concentration (μg/l) and μg iodine/g creatinine ratio was significantly higher in tertile 3 than in tertile 1 and 2 ($P<0.05$), and the μg iodine/g creatinine ratio was higher in tertile 2 than in tertile 1. Fish intake was was positively associated with intake of milk ($r=0.252$ and $P=0.007$), and as shown in Table 5 intake of fish in tertile 2 and 3 of milk consumption was significantly higher than in tertile 1.

Discussion

Until recently fish has been the most important source of iodine in the Icelandic diet, followed by milk and dairy

Table 4 Distribution of serum thyroid-stimulating hormone, urinary iodine and urinary creatinine concentration

	n	*Mean (s.d.)*	*Percentiles*		
			50 (median)	*20*	*80*
Urinary iodine (μg/l)[a]	111	235.9 (168.5)	200.0	90.0	320.0
Urinary creatinine (mg/dl)[a]	111	160.1 (87.5)	154.0	68.8	233.0
μg iodine/g creatinine ratio	111	167.2 (129.5)	138.1	71.9	237.7
Thyroid-stimulating hormone (mU/l)[a]	100	2.0 (1.2)	1.8	0.8	3.4

[a]Blood sample was missing from two participants, and urine sample from one participant.

Table 5 Urinary iodine concentration, μg iodine/g creatinine, ratio, thyroid-stimulating hormone and intake of milk, cheese and fish by tertiles of milk consumption

	Tertile 1		*Tertile 2*		*Tertile 3*	
	Median	*Mean (s.d.)*	*Median*	*Mean (s.d.)*	*Median*	*Mean (s.d.)*
Urinary iodine (μg/l)	170.0	185.1 (108.3)	140.0	199.4 (132.5)	265.0	327.0 (214.6)[a,b]
μg Iodine/g creatinine. ratio	99.7	112.1 (60.2)	135.8	155.8 (81.4)[a]	217.4	237.1 (183.3)[a,b]
Thyroid-stimulating hormone (mU/l)	1.9	2.2 (1.5)	1.7	1.8 (1.0)	1.9	2.1 (1.0)
Iodine intake (μg/day)	148.8	166.9 (91.7)	131.1	172.7 (119.3)[a]	163.0	170.8 (88.8)[a,b]
Milk intake (g/day)	195.0	182.5 (60.8)	427.0	429.1 (108.6)[a]	902.0	1017 (447.2)[a,b]
Cheese intake (g/day)	10.0	16.6 (30.8)	13.0	16.1 (13.6)	19.0	28.4 (26.2)[a]
Fish intake (g/day)	6.5	11.2 (11.7)	11.0	15.9 (14.7)[a]	18.0	17.4 (13.0)[a]

[a]Significantly different from Tertile 1 of milk intake (Mann-Whitney *U*-test).
[b]Significantly different from Tertile 2 of milk intake (Mann-Whitney *U*-test).

products (Reykdal *et al*., 2000). In this study milk and dairy products were the main sources of iodine, contributing 43% of the total iodine intake, whereas fish contributed only 24%, which is comparable to studies from other European countries, such as the UK, Denmark and Norway (Lightowler and Davies, 1998; Rasmussen *et al*., 2002; Brantsaeter *et al*., 2009). According to WHO guildelines U-I concentration in a population is considered optimal if the median is between 100 and 200 μg/l, and no more than 20% of individuals have U-I concentration below 50 μg/l. (WHO/UNICEF/ICCIDD, 2008). In this study the median U-I concentration was within the optimal range, and only 6% of the subjects had iodine concentration below 50 μg/l. Iceland has for many decades been known for its high iodine status (Sigurjonsson, 1940a, b; Sigurdsson and Franzson, 1998). With steep decrease both in milk and fish intake during the past decades, worries about iodine status in the population began to rise. In 1939 iodine status was assessed for the first time in the Icelandic population, and the results showed that the thyroid gland was very small compared to the accepted normal size in other countries (Sigurjonsson, 1940a). The first Icelandic dietary survey, which was carried out the same year, showed that fish and dairy products were the mainstay of the diet, consumed most commonly and in the greatest amounts of all food (Sigurjonsson, 1940b). Iodine status was measured for the second time in 1988, this time in subjects, aged 20–59 years. As before, the iodine status was considered to be good (Sigurdsson and Franzson, 1998). Finally, in 1998, iodine status was measured in 66- to 70-year-old Icelanders, and the results showed worsened iodine status, compared with previous studies. This was attributed to changes in eating habits (Laurberg *et al*., 1998), even though this age group (>65 years) consumes relatively high amounts of fish and dairy products even today (Steingrimsdottir *et al*., 2003). Since 1990 dietary habits have changed, and the intake of fish and dairy products has decreased considerably, especially among young women (Steingrimsdottir *et al*., 1990, 2003). This was the main trigger for this study. Furthermore, changes in the iodine content of milk and dairy products during the last decades, was believed to have resulted in poorer iodine status. The first measurements of iodine concentration in Icelandic milk were performed in 1962 (Sigurdsson and Franzson, 1998). The iodine concentration was found to be 21.6 μg/100 g, considerably higher than in the Scottish milk analysed for comparison. The iodine concentration of Icelandic milk was analysed again in 1997, with an average concentration of 11.2 μg/100 g (Reykdal *et al*., 2007; ISGEM, 2008). The reduction in the iodine content of milk since 1962 to present may be explained by changes in feed, especially less use of fishmeal in cattle fodder compared with earlier times.

The total iodine intake estimate (median intake of 148 μg/day and average intake of 170 μg/day) in this study might be somewhat underestimated. Given the average body weight of subjects in this study (63 kg), the iodine intake estimate based on the median U-I concentration of 138–200 μg/l would be close to 206–299 μg/day (Institute of Medicine, 2001). The underestimation of iodine intake might be due to underestimation of reported portion sizes or inaccuracy of the estimated iodine content of food. The portion sizes most frequently marked in the FFQ were 45 and 90 g, which might be an underestimation. The results show that worries about possible iodine deficiency in the population studied might have been partly based on poor estimates of iodine content of food and/or underestimated portion sizes in previous studies (Steingrimsdottir *et al*., 2003; Thorsdottir and Gunnarsdottir, 2006).

Nutrition composition databases need to be updated regularly if they are to be used to estimate risk of inadequate intake nutrients. However, it is cumbersome to reliably measure habitual iodine intake from foods and supplements and U-I measurements are therefore the most suitable methods for assessing dietary iodine intake (Vejbjerg *et al*., 2009). It is very important to monitor iodine status of vulnerable groups such as children and pregnant women. Adolescent girls are future mothers, and the most serious consequences of iodine deficiency are seen during pregnancy (Dunn, 1998).

In this study an association was found between U-I and the intake of milk. Similar findings have been reported in studies from other countries (Rasmussen *et al*., 2002; Girelli *et al*., 2004; Brantsaeter *et al*., 2009). The importance of milk and dairy products for iodine intake in these studies is primarily attributed to iodine fortification of industrially produced animal feed. In this study fish intake was not directly related to U-I. The iodine content of seafood is substantial, or up to 190 μg/100 g in haddock (ISGEM, 2008), which is the most commonly consumed fish species in Iceland. A plausible explanation for the lack of association is a large variation in U-I excretion (Rasmussen *et al*., 1999). In this study U-I concentration was measured in spot urine samples, which are a good marker of very recent dietary iodine intake (WHO/UNICEF/ICCIDD, 2008). Fish intake was estimated using an FFQ, which is designed to reflect intake over the previous 3 months. It is possible that had the subjects recorded their recent dietary intake before the urinary sample was collected, a correlation between fish consumption and U-I concentration could have been found. Day-to-day variation in milk and dairy intake are not as large as for fish.

It might be considered a limitation to this study, that is, U-I concentration was measured in a spot sample but not by 24-h urine collection. The reason for choosing spot samples was mainly related to participation rate, as the greater burden of collecting urine samples might result in lower participation. Spot samples cannot give a precise measure of iodine excretion in a single individual due to the large inter individual variations in 24-h urinary volume (Knudsen *et al*., 2000; Vejbjerg *et al*., 2009). However, spot samples have successfully been used to assess iodine status in large population studies like the National Health and Nutrition Examination Survey (Hollowell *et al*., 1998) and the method is recommended by the WHO (WHO/UNICEF/ICCIDD, 2008). It has been suggested that the use of μg iodine/g creatinine ratio could minimize the variations caused by variations in the urinary volume (Frey *et al*., 1973). However, the use of creatinine to express results could lead to an underestimation of iodine excretion compared with the 24-h iodine excretion in industrialized countries (Vejbjerg *et al*., 2009), especially when age and sex distribution is large. The subjects in this study were adolescent girls (age 16–20 years) and the sex and age-related variability in creatinine excretion is therefore reduced. Whether the μg iodine/g creatinine ratio or the urinary creatinine concentration (μg/l) gives a better estimate of the iodine status in the population studied is a challenging question, but from public health point of view the most important message is that in both cases the estimates are within the optimal range defined by WHO (WHO/UNICEF/ICCIDD, 2008).

Another limitation of the study requiring consideration is the rather low participation rate from the original selection. It is possible that individuals with a healthier lifestyle, and thus consuming more dairy products and fish, are more willing to participate in a health-oriented study, thereby biasing the results. One variable that is related to healthy lifestyle is smoking habits. In this study, 14.4% of the subjects were current smokers, a somewhat lower percentage than found in a study performed on college students, aged 15–19 years, where 15.1–17.6% smoked (Sigfusdottir *et al*., 2008). Therefore, participants in this study may have a slightly healthier lifestyle than the average population, and it cannot be precluded that the iodine status of Icelandic adolescent girls is somewhat worse than shown in this study.

Despite the lack of direct association between fish consumption and iodine status in this study, fish intake among adolescent girls should be emphasized. The intake of fish in this study was below the recommendation of two main meals per week, in addition to using fish as a bread spread and in salads (Public Health Institute of Iceland, 2006). Fish contributes significantly to total iodine intake, but the recommendations from the Public Health Institute of Iceland are also based on fish being a good source of other essential nutrients, such as selenium, vitamin D and long-chain n-3 fatty acids (Nordic Council of Ministers, 2004). Fish intake has been shown to reduce the risk of cardiovascular disease (Whelton *et al*., 2004), stroke, hypertension (Mozaffarian, 2007), rheumatoid arthritis (Pattison *et al*., 2004) and non-insulin-dependent diabetes mellitus (Ukropec *et al*., 2003). Furthermore, fish consumption has also been shown to have positive effects on weight loss in overweight men (Thorsdottir *et al*., 2007).

Iodized salt is not commonly used in Iceland and the results of this study suggest that iodization of salt might have more disadvantages than advantages at the population level in Iceland. A recent study from Denmark showed that iodine fortification was associated with increase in the incidence of hyperthyroidism as measured by use of anti-thyroid medication (Cerqueira *et al*., 2009). Adolescent girls in Iceland are to be encouraged to consume milk, dairy products and fish in line with public recommendations but the use of iodized salt is not recommended on a population basis.

In conclusion, iodine status of adolescent girls in Iceland is within the optimal range defined by the World Health Organization. It is important to monitor both iodine status and the iodine concentration of important sources of iodine, as both dietary habits and composition of food might change with time.

Conflict of interest

The authors declare no conflict of interest.

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References

Brantsaeter AL, Haugen M, Julshamn K, Alexander J, Meltzer HM (2009). Evaluation of urinary iodine excretion as a biomarker for intake of milk and dairy products in pregnant women in the Norwegian Mother and Child Chort Study (MoBa). *Eur J Clin Nutr* **63**, 347–354.

Caldwell KL, Jones R, Hollowell JG (2005). Urinary iodine concentration: United States national health and nutrition examination survey 2001–2002. *Thyroid* **15**, 692–699.

Cerqueira C, Knudsen N, Ovesen L, Perrild H, Rasmussen LB, Laurberg P *et al*. (2009). Association of iodine fortification with incident use of anti-thyroid medication - A Danish nationwide study. *J Clin Endocrinol Metab* **94**, 2400–2405.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ* **320**, 1240–1243.

Cole TJ, Flegal KM, Nicholls D, Jackson AA (2007). Body mass index cut offs to define thinness in children and adolescents: International survey. *BMJ* **335**, 194.

Dahl L, Johansson L, Julshamn K, Meltzer HM (2004). The iodine content of Norwegian foods and diets. *Public Health Nutr* **7**, 569–576.

Dahl L, Opsahl JA, Meltzer HM, Julshamn K (2003). Iodine concentration in Norwegian milk and dairy products. *Br J Nutr* **90**, 679–685.

Delange F, Benoist B, Pretell E, Dunn JT (2001). Iodine deficiency in the World: where do we stand at the turn of the century? *Thyroid* **11**, 437–447.

Dunn JT (1998). What's happening to our iodine? *J Clin Endocrinol Metab* **83**, 3398–3400.

Frey HM, Rosenlund B, Torgersen JP (1973). Value of single urine specimens in estimation of 24 h urine iodine excretion. *Acta Endocrinol* **72**, 287–292.

Girelli ME, Coin P, Mian C, Nacamulli D, Zambonin L, Piccolo M *et al.* (2004). Milk represents an important source of iodine in schoolchildren of the Veneto region, Italy. *J Endocrinol Invest* **27**, 709–713.

Haldimann M, Alt A, Blanc A, Blondeau K (2005). Iodine content of food groups. *J Food Compost Anal* **18**, 461–471.

Hetzel BS (1983). Iodine deficiency disorders (IDD) and their eradication. *Lancet* **2**, 1126–1127.

Hollowell JG, Staehling NW, Hannon WH, Flanders DW, Gunter EW, Maberly GF *et al.* (1998). Iodine nutrition in the United States. trends and public health implications: iodine excretion data from national health and nutrition examination surveys I and III (1971–1974 and 1988–1994). *J Clin Endocrinol Metab* **83**, 3401–3408.

Institute of Medicine (2001). Food and Nutrition Board (FNB). Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.http://www.nap.edu/openbook.php?record_id = 10026&page = 264.

ISGEM (2008). *Icelandic Database on Food Composition*. MATIS – Icelandic food research: Reykjavik.

Julshamn K, Dahl L, Eckhoff K (2001). Determination of iodine in seafood by inductively coupled plasma/mass spectrometry. *J AOAC Int* **84**, 1976–1983.

Knudsen N, Christiansen E, Brandt-Christensen M, Nygaard B, Perrild H (2000). Age- and sex-adjusted iodine/creatinine ratio. A new standard in epidemiological surveys? Evaluation of three different estimates of iodine excretion based on casual urine samples and comparison to 24 h values. *Eur J of Clin Nutr* **54**, 361–363.

Laurberg P, Pedersen KM, Hreidarsson A, Sigfusson N, Iversen E, Knudsen PR (1998). Iodine intake and the pattern of thyroid disorders: a comparative epidemiological study of thyroid abnormalities in the elderly in Iceland and in Jutland, Denmark. *J Clin Endocrinol Metab* **83**, 765–769.

Lightowler HJ, Davies GJ (1998). Iodine intake and iodine deficiency in vegans as assessed by the duplicate-portion technique and urinary iodine excretion. *Br J Nutr* **80**, 529–535.

Mozaffarian D (2007). Fish, n-3 fatty acids, and cardiovascular haemodynamics. *J Cardiovasc Med* **8**, S23–S26.

Nordic Council of Ministers (2004). Iodine. In *Nordic Nutrition Recommendations 2004*: Integrating nutrition and physical activity (4th edn). Nordic Council of Ministers: Copenhagen.

Olafsdottir AS, Thorsdottir I, Gunnarsdottir I, Thorgeirsdottir H, Steingrimsdottir L (2006). Comparison of women's diet assessed by FFQs and 24-h recalls with and without underreporters: associations with biomarkers. *Ann Nutr Metab* **50**, 450–460.

Pattison DJ, Symmons DP, Young A (2004). Does diet have a role in the aetiology of rheumatoid arthritis? *Proc Nutr Soc* **63**, 137–143.

Public Health Institute of Iceland (2006). *Nutrition Recommendations and Food Based Recommendations for Adults and Children above 2-years*. Public Health Institute of Iceland: Reykjavik (In Icelandic).

Rasmussen LB, Ovesen L, Bulow I, Jorgensen T, Knudsen N, Laurberg P *et al.* (2002). Dietary iodine intake and urinary iodine excretion in a Danish population: Effect of geography, supplements and food choice. *Br J Nutr* **87**, 61–69.

Rasmussen LB, Ovesen L, Christiansen E (1999). Day-to-day and within-day variation in urinary iodine excretion. *Eur J Clin Nutr* **53**, 401–407.

Reykdal O, Hilmarsson OTh, Auðunsson GA (2007). Iodine in agricultural produce. *Agriculture conference* **4**, 516–518 (In Icelandic).

Reykdal O, Thorlacius A, Audunsson GA, Steingrimsdottir L (2000). Selenium, iodine, fluorine, iron, copper, zink, manganese, kadmin, mercury and lead in agricultural produce. *Agricultural Mimeograph* **204**, 7–36 (In Icelandic).

Sigfusdottir ID, Kristjansson AL, Thorlindsson T, Allegrante JP (2008). Trends in prevalence of substance use among Icelandic adolescents, 1995–2006. *Subst Abuse Treat Prev Policy* **3**, 12.

Sigurdsson G, Franzson L (1998). Urine excretion of iodine in an Icelandic population. *Icelandic Med J* **74**, 179–181 (In Icelandic).

Sigurjonsson J (1940a). *Studies on the Human Thyroid in Iceland. Doctorial Dissertation*. University of Iceland, Faculty of medicine, Iceland.

Sigurjonsson J (1940b). *Survey of Diet and Health in Iceland. Doctorial Dissertation*. University of Iceland, Faculty of medicine.

Steingrimsdottir L, Thorgeirsdottir H, Aegisdottir S (1990). *The Diet of Icelanders*. Dietary Survey of the Icelandic Nutrition Council 1990: Reykjavik (In Icelandic).

Steingrimsdottir L, Thorgeirsdottir H, Olafsdottir AS (2003). *The Icelandic National Nutrition Survey 2002*. Public Health Institute of Iceland: Reykjavik (In Icelandic).

Thorsdottir I, Gunnarsdottir I (2006). *The Diet of Icelandic 9- and 15-year-old Children and Adolescents 2002–2003*. Unit for Nutrition Research: Reykjavik (In Icelandic).

Thorsdottir I, Gunnarsdottir I, Steingrimsdottir L (2004). Validity of a food frequency questionnaire to assess dietary intake of adults. *Icelandic Med J* **90**, 37–41 (In Icelandic).

Thorsdottir I, Tomasson H, Gunnarsdottir I, Gisladottir E, Kiely M, Parra MD *et al.* (2007). Randomized trial of weight-loss-diets for young adults varying in fish and fish oil content. *Int J Obes* **31**, 1560–1566.

Ukropec J, Reseland JE, Gasperikova D, Demcakova E, Madsen L, Berge RK *et al.* (2003). The hypotriglyceridemic effect of dietary n-3 FA is associated with increased beta-oxidation and reduced leptin expression. *Lipids* **38**, 1023–1029.

Vejbjerg P, Knudsen N, Perrild H, Laurberg P, Andersen S, Rasmussen LB *et al.* (2009). Estimation of iodine intake from various urinary iodine measurements in population studies. *Thyroid* **19**, 1281–1286.

Whelton SP, He J, Whelton PK, Muntner P (2004). Meta-analysis of observational studies on fish intake and coronary heart disease. *Am J Cardiol* **93**, 1119–1123.

WHO/UNICEF (2001). *Iodine Deficiency in Europe: A Continuing Public Health Problem*. World Health Organization WHO: Geneva.

WHO/UNICEF/ICCIDD (2008). *Assessment of the Iodine Deficiency Disorders and Monitoring their Elimination. A Guide for Programme Managers*. World Health Organization WHO: Geneva.