

ORIGINAL ARTICLE

Adequate iodine nutrition in Sweden: a cross-sectional national study of urinary iodine concentration in school-age children

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Background/Objectives: Sweden has a long-standing salt iodization program; however, its effects on iodine intake have never been monitored on a national level. The objective of this study was to evaluate iodine nutrition in the Swedish population by measuring the urinary iodine concentration (UIC) in a national sample of Swedish school-age (6–12 years of age) children.

Subjects/Methods: A stratified probability proportionate to size cluster sampling method was used to obtain a representative national sample of school-age children from 30 clusters. Spot urine samples were collected for UIC analysis using a modified Sandell–Kolthoff method.

Results: The median UIC of the children ($n=857$) was 125 µg/l (range 11–757 µg/l). The proportion of children with a UIC <100 µg/l was 30.0% and the proportion of children with a UIC <50 and >300 µg/l was 5.5 and 3.0%, respectively.

Conclusions: The iodine nutritional status of the Swedish population is adequate. Iodized table salt remains the main dietary source of iodine in Swedish diet. Recommendations to reduce total salt intake in the population urge increased use of iodized salt in the production of processed foods. Pregnant and lactating women with high iodine requirements may still be at risk for low iodine intake. This study will serve as the basis for future monitoring of iodine nutritional status in Sweden.

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Introduction

Iodine deficiency remains a public health problem in 47 countries worldwide (de Benoist *et al.*, 2008). Adequate dietary iodine intake is essential for the production of thyroid hormones. Low iodine intake results in the development of hypothyroidism and goiter (Hetzl, 1983). Developing children are particularly vulnerable to iodine

deficiency. Impaired production of thyroid hormones during pregnancy affects growth and brain development in the progeny (Glinioer, 2007; Morreale de Escobar *et al.*, 2007; Zimmermann, 2007). Iodine deficiency in school-age children impairs somatic growth, cognitive performance and motor function (Zimmermann *et al.*, 2006; Zimmermann *et al.*, 2007).

In Sweden, iodine deficiency was first described in 1816 (Berggren, 1816). In the 1920s, an extensive nationwide survey reported several cases of cretinism and a goiter prevalence of up to 25% (Höjer, 1931). Regional and local studies around the same time documented isolated endemic areas with a goiter prevalence between 15 and 65% (Sjöberg and Sundlof, 1971). Nationwide iodine prophylaxis with iodized salt was established in 1936 with a level of

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10 mg iodine per kg of salt (Kungliga Medicinalstyrelsen, 1936). In response to persisting endemic areas, the level of iodine in salt was increased in 1966 to 50 mg/kg (Johnsson, 1965; Kungliga Medicinalstyrelsen, 1966; Sjöberg and Sundlof, 1971). A local evaluation of school-age children 3 years later reported a decreasing goiter prevalence in a previously endemic area (Sjöberg and Sundlof, 1971). The Swedish salt iodization program has been regulated by legislation since 1983, recommending voluntary addition of iodine as potassium iodate/iodide in the range of 40–70 mg/kg of salt (National Food Administration, 1983).

Although most countries worldwide have implemented universal salt iodization (UNICEF, 2008), countries like Australia, New Zealand and several European countries have been reporting reoccurring iodine deficiency (Skeaff *et al.*, 2002; Anonymous, 2003; Delange, 2003; Vitti *et al.*, 2003; Li *et al.*, 2006; World Health Organization, 2007a). Changes in food consumption patterns, legislation not covering processed food and decreased salt consumption impose new challenges in ensuring adequate iodine nutrition in the population. The World Health Organization recommends regular, population-based monitoring of iodine nutrition by measuring urinary iodine concentration (UIC) (World Health Organization *et al.*, 2007b). School-based multi-stage cluster sampling is the recommended survey method, and iodine intake in school-age children is assumed to provide an adequate assessment of iodine nutrition in the general population (World Health Organization *et al.*, 2007b). The use of dietary supplements in school-age children is low (Enghardt Barbieri *et al.*, 2006), and the assessment of iodine nutrition in this group is therefore likely to reflect the true dietary iodine intake. Few European countries have established such national monitoring programs of iodine intake (World Health Organization, 2007a). In Sweden, small local UIC studies performed during the 1970s and 1980s indicated levels of iodine intake in the population varying from low to adequate (Jarnerot and Karlberg, 1974; Gustavsson *et al.*, 1977; Sjöberg, 1978; Gutekunst *et al.*, 1986). A recent investigation of a community on the Swedish west coast measured adequate UIC in children, teenagers and adults (Milakovic *et al.*, 2004).

The aim of this study was to evaluate iodine nutrition in the Swedish population by measuring the UIC in a national sample of Swedish school-age children. The data will serve as the basis for future national monitoring of iodine nutrition in Sweden.

Subjects and methods

Study population

A three-stage probability proportionate to population size cluster sampling method was used to obtain a representative national sample of 857 school-age children from 30 clusters (World Health Organization *et al.*, 2007b). Stratified random sampling was applied using the common grouping of the

Swedish population into six regions (H regions) based on regional population size (Statistics Sweden, 2003). National school register data from 2006, listing all schools and the total number of students in each school, was used to provide a systematic sampling of urban and rural communities in each stratum on the basis of the cumulative population (Statistics Sweden, SCB Örebro, Sweden). In the first stage of selection, 30 primary schools were recruited. For each stratum, the same proportion of individuals, relative to the total population of each stratum, was selected. If a selected school declined participation, an alternate school was randomly selected with replacement sampling from the same stratum. In the second stage, one to two classes were randomly selected from each school depending on the number of students per class. If a class rejected participation, an alternate class above or below was selected from the same school. Finally, all children in the class whose parents provided written consent were invited to participate. Data were collected between October 2006 and May 2007. The study was approved by the Ethics Committee of the University of Gothenburg, Sweden. The study protocol complied with the principles enunciated in the Helsinki Declaration (World Medical Association, 2001).

Sample collection

Height and weight were measured using standard anthropometric techniques (World Health Organization, 1995). For the measurements, subjects removed their shoes, emptied their pockets and wore light indoor clothing. Height was recorded to the nearest 0.5 cm and weight to the nearest 500 g. Spot urine samples were collected from subjects in the morning between 0800 and 1200 hours. Samples were sent to the laboratory on the day of sampling and were frozen upon arrival. Samples were stored at -20°C until analysis.

Laboratory analysis

Urinary iodine concentration was measured in duplicate by a modified Sandell–Kolthoff method (Pino *et al.*, 1996) using the Pyrex test tube (12×100 mm) format and a spectrophotometer (Milton Roy Spectronic 301; Milton Roy Company, Rochester, NY, USA). The interassay coefficient of variation of this method in our laboratory was 3.9% at $61.0 \pm 2.4 \mu\text{g/l}$. Satisfactory agreement in UIC was obtained on urine samples at four different concentrations measured by our laboratory and the EQUIP-Network (Ensuring the Quality of Urinary Iodine Procedures, Centers for Disease Control and Prevention, Atlanta, GA, USA). A median UIC of 100–200 $\mu\text{g/l}$ indicates adequate iodine nutrition in the population (World Health Organization *et al.*, 2007b).

Statistical analysis

Data processing and statistical analysis were done using SPSS (version 15.0, 2006; SPSS Inc., Chicago, IL, USA) and

with Microsoft EXCEL (2003; Microsoft Corporation, Redmond, WA, USA). The sample-size calculation was based on an estimated 50% prevalence of UIC $<100\mu\text{g/l}$, a 95% confidence interval (CI) for the true prevalence of UIC $<100\mu\text{g/l}$, a design effect of 2 (Kaiser *et al.*, 2006) and a relative precision of 5%. The normality of the data was checked before analysis with the Kolmogoroff–Smirnov test and graphically by evaluating Q-Q plots. Normally distributed data were expressed as mean (\pm s.d.); non-normally distributed data were expressed as median (range) with 95% CI. The spread of UIC was described as the frequency of distribution. UIC concentrations were not normally distributed and were log transformed for comparison. Comparisons were made using non-parametric tests, the Mann–Whitney test for gender differences and the Kruskal–Wallis test for differences between age groups. Significance was set at $P<0.05$.

Results

In total, 857 school-age children (445 boys and 412 girls) participated in the study. An average of 29 children (range 10–44) was sampled at each of the 30 schools. The sample represents 71% (range 27–100) of all children in selected classes, with an overall 18% of subjects actively declining participation, 8% not responding to the invitation and 2% of samples lost in sample handling. Nine subjects older than

12 years of age were excluded. Ten schools rejected participation in the first stage and were replaced with an alternate school from the same stratum. One of the selected classes from the original selection was replaced with a randomly selected class above the selected class. The baseline characteristics of the children were a mean (\pm s.d.) age of 9.0 ± 2.0 years, weight of 36.2 ± 11.4 kg and height of 140.2 ± 13.2 cm.

The median UIC concentration in the population of school-age children was $125\mu\text{g/l}$ (range 11–757) with 95% CI of 120 – $130\mu\text{g/l}$. Figure 1 shows the frequency distribution of UIC. The distribution was slightly skewed toward elevated values. The proportions of children with a UIC <100 , <50 and $<20\mu\text{g/l}$ were 30.0, 5.5 and 0.5%, respectively. The proportion of children with a UIC $>200\mu\text{g/l}$ was 13.3% and $>300\mu\text{g/l}$ was 3.0%. The median UIC varied from 99 to $149\mu\text{g/l}$ among the 30 clusters. There were no significant gender differences in median UIC; 28.3% of the boys and 31.8% of the girls had UIC $<100\mu\text{g/l}$. There were no differences in the median UIC by age.

Discussion

This is the first national study of iodine nutrition in Sweden. The obtained median UIC of $125\mu\text{g/l}$ in school-age (6–12 years of age) children indicates adequate iodine intake in the Swedish population. The iodine nutrition in the school-age

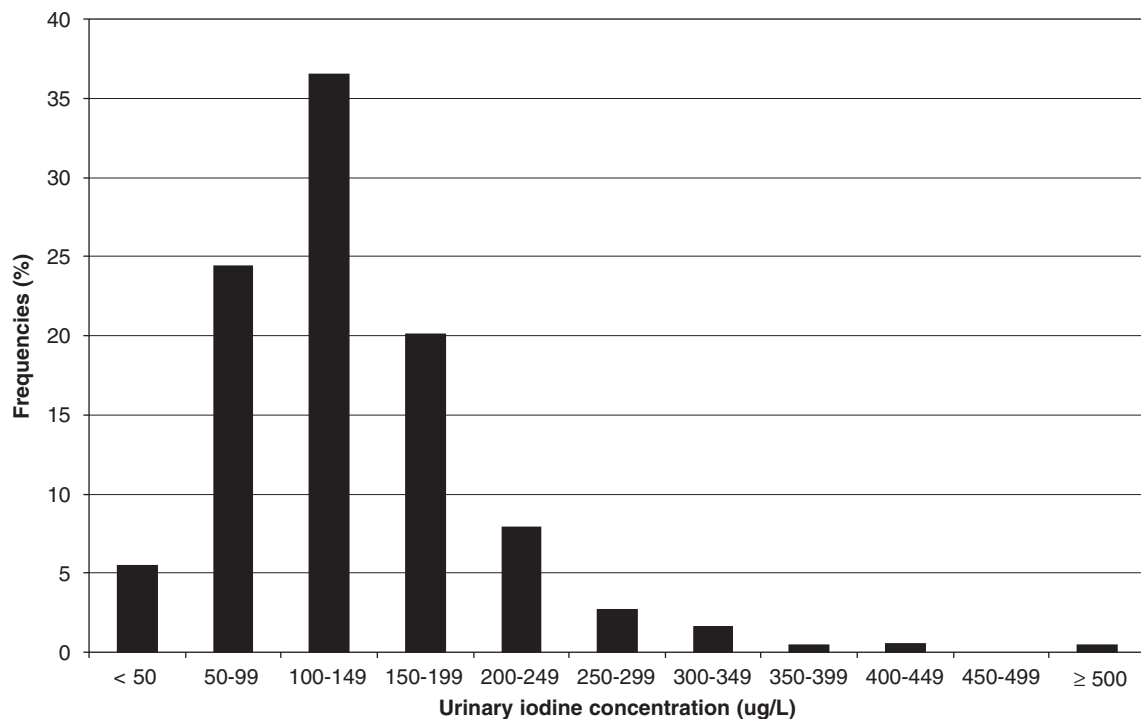


Figure 1 Distribution of spot urinary iodine concentration in a national sample of 857 school-age children (6–12 years of age) in Sweden.

children population is optimal with a low proportion of children having UIC <100 and >200 µg/l. Only 3% of the children had UIC >300 µg/l, indicating a low risk of iodine-induced thyroid disease in the population. The stratified cluster sampling methodology applied ensures a representative national sample, but does not allow for analysis of variations in iodine intake among different regions. Dietary intake data from earlier studies show relatively small variations in overall food consumption patterns among different regions in Sweden (National Food Administration, 1998) and, a study design permitting estimates of regional iodine intake was therefore not regarded as necessary.

There were a few limitations for the study. First, the response rate was only 71%, but is still comparable with other similar studies (Zimmermann *et al.*, 2005; Li *et al.*, 2006). The main reason for no response was the inability to return parental consent forms on time for urine sampling. The iodine intake is not expected to differ among participating children and non-responding children. Second, we did not investigate the use of iodized salt in the school mid-day meal. Most schools serve food prepared in centralized canteens. Both iodized and non-iodized salt are used by such canteens (personal communication, Akzo Nobel Salt and Falk Salt, 2008). Third, sampling was performed during the academic school year (autumn, winter and spring seasons). The iodine intake from dairy products is expected to be slightly higher during these seasons compared with the summer season, as livestock are fed with iodine-enriched fodder during indoor seasons.

The recommended daily intake for iodine is 120 µg in children 6–9 years of age and 150 µg in children ≥10 years of age and in adults (Becker *et al.*, 2004). The main source of iodine in the Swedish diet is iodized salt. The salt intake of children (4, 8 and 11 years of age) is 5–7 g salt per day and in adults it is 8–12 g salt per day (National Food Administration, 1998; Becker and Pearson, 2002; Larsson and Johansson, 2002; Bruce, 2007). Only 20% of the total salt intake is from table salt (Bruce, 2007). The remaining 80% of salt intake is from ready-made foods and dishes: 30% from meat and meat products; 25% from bread and cereal products; 15% from dairy products; and 10% from margarine and cooking fat (Becker, 2000; Becker, 2003; Bruce, 2007). Seventy-five percent of all households use iodized table salt (Becker and Pearson, 2002; Enghardt Barbieri *et al.*, 2006). Sales figures from the Swedish salt manufacturers indicate that iodized salt comprises >90% of total table salt sales (personal communication, Akzo Nobel Salt and Falk Salt, 2008). The level of iodine in table salt at the household level is assumed to be adequate (>15 mg/kg) considering the added level of 40–70 mg/kg and proper packaging (World Health Organization *et al.*, 1996). The iodine levels are being monitored by the Swedish salt manufacturers at the factory. For adults, table salt provides an average iodine intake of 80–120 µg iodine per day (>50% of the recommended daily intake for adults).

Other dietary sources of iodine in the Swedish diet are dairy products, fish and seafood. Reanalysis of dietary data from the most recent national dietary survey indicates a mean daily iodine intake of 70 µg (~50% of the recommended daily intake for adults) from a typical Swedish diet (iodized table salt excluded); 44–53 µg from milk and 17 µg from fish and seafood (National Food Administration, 1998). The average iodine content in milk is 14 µg/100 g, with seasonal variations ranging from 12 µg/100 g in July to 17 µg/100 g in March (Lindmark-Månsson *et al.*, 2003; National Food Administration, 2007). The high iodine content in dairy products is mainly due to supplementation of iodine in cow fodder at a maximum level of 10 mg/kg fodder (European Community, 1970). The earlier praxis of using iodophores for tending the teats of cows in the Swedish dairy industry is now limited and is not expected to contribute much to the total iodine content in milk (Iwarsson *et al.*, 1972) (personal communication, Lantmännen and The Swedish Dairy Association, 2007). Iodine from drinking water is considered insignificant (Jarnerot and Karlberg, 1974) (unpublished water analysis, E Gramatkovski, 2007).

The estimated total dietary iodine intake ranges from 150 to 190 µg/l in Swedish adults and meets the recommended daily intake. Currently, more than 50% of the iodine intake is provided by iodized table salt. However, new Swedish Nutrition Recommendations urge a reduced total salt intake from the current 8–12 to 5–6 g/day (National Food Administration, 2005). A national hypertension program has been initiated by the National Food Administration in collaboration with the food industries aiming at reducing salt intake in the population to the recommended level by 2011 (Bruce, 2007). At present, the main proportion of the total salt intake (~80%), that is from ready-made foods and dishes, does not provide iodine. Less than 10% of salt sold to canteens, institutional kitchens and the Swedish food industries is iodized (personal communication, Akzo Nobel Salt and Falk Salt, 2008). The cost of iodized and non-iodized salt is the same and lack of awareness of the importance of iodine seems to be the main reason for not choosing iodized salt in food production. Several new alternative table salts without iodine have been launched in the market (flake salt, gourmet salt, sea salt and so on.). These new table salts are increasingly popular as a result of promotion in cooking magazines and cooking shows on national television, and may compete with the iodized table salt. Unless iodine is added to all salt used at the table and to a higher proportion of salt used in food production, a reduced salt intake may result in a decreased iodine intake that falls below the recommended level.

In July 2007, the Swedish legislation from 1983 recommending iodine to be added to salt at a level of 40–70 mg/kg was replaced with a common European regulation on the addition of vitamins and minerals to foods (The European Parliament and the Council of the European Union, 2006). The European regulation lists iodine as a permitted food

additive, but does not specify the level of fortification. The nature of the legislation and the recommended salt iodine levels vary considerably among countries within the European Union, as does the actual iodine intake (World Health Organization, 2007a). Concern for low iodine intakes in Europe and following the risk of iodine deficiency has been raised by several expert forums (Anonymous, 2003; Delange, 2003; Vitti *et al.*, 2003, World Health Organization, 2007a). The policies and iodine intakes vary even between the neighboring Scandinavian countries. In Denmark, salt iodization has been mandatory since 2000 for salt used in bread (Rasmussen *et al.*, 2008). Norway has no universal salt iodization, but does have mandatory iodization of cow fodder, which contributes to high milk iodine concentrations (Dahl *et al.*, 2004). In Finland, both table salt and animal fodder are iodine-fortified (Valsta, 2003). Although iodine intakes may vary between different population groups, all Scandinavian countries have adequate iodine intake in the general population.

The results of this study indicate adequate iodine intake in the school-aged population. However, extrapolation of the national median UIC from school-aged children to the general population may mask inadequate iodine intake in vulnerable population groups. Several countries with overall adequate iodine nutrition still have persisting insufficient iodine intake in women of childbearing age, and in pregnant and lactating women with higher iodine requirements (Pearce, 2007; de Benoist *et al.*, 2008; Rasmussen *et al.*, 2008). The World Health Organization recommends an iodine intake of 250 µg/day during pregnancy and lactation (WHO Secretariat on behalf of the participants to the Consultation *et al.*, 2007). The corresponding median UIC for adequate dietary iodine intake is 150–249 µg/l in a representative sample of pregnant women and ≥100 µg/l in lactating women (lower than the iodine requirements because of the iodine excreted in breast milk) (WHO Secretariat on behalf of the participants to the Consultation *et al.*, 2007). Data on iodine intake in pregnant and lactating women in Sweden are scarce. Two small local studies report low iodine intake in pregnant women based on UIC of 145–178 µg/day (Elnagar *et al.*, 1998) and 89 µg/l (Eltom *et al.*, 2000). Further investigation of the iodine intake in pregnant and lactating women in Sweden is needed.

Dietary habits are dynamic, and awareness of iodine deficiency among the younger Swedish population is generally low. Consumer behaviors are influenced by recent trends, one of them being a reluctance to consume 'food additives.' Continuous education and increased awareness of the importance of adequate iodine intake, the early history of iodine deficiency in Sweden and the presence of the existing salt iodization program are important components in a national iodine program. As shown from an example in Australia, even brief reports in the media about iodine deficiency and the benefits of using iodized salt can influence health-related decisions (Li *et al.*, 2008).

Our findings provide evidence that current voluntary addition of iodine to salt at a level of 40–70 mg/kg is sufficient to ensure adequate iodine nutrition in the Swedish population. However, vulnerable subgroups may still exist. New recommendations to lower salt intakes may require adjustment of current salt iodization praxis to comprise all salt, including salt used in processed foods. This study is the first on iodine nutrition in Swedish school-age children and will serve as reference for future studies. Public education together with periodic monitoring of iodine nutrition in school-age children, pregnant and lactating women should be established to ensure that iodine intakes continue to be adequate in all population groups.

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Disclosure statement

The authors have nothing to disclose.

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