The Swiss Iodized Salt Program Provides Adequate Iodine for School Children and Pregnant Women, but Weaning Infants Not Receiving Iodine-Containing Complementary Foods as well as Their Mothers Are Iodine Deficient

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Background: If children and pregnant women in the population are iodine sufficient, it is generally assumed infants are also sufficient. But weaning infants may be at risk of iodine deficiency because iodized salt contributes little dietary iodine during this period. To fill this gap, iodine fortification of infant formula milk (IFM) and complementary foods (CF) is likely important.

Objectives: The objective of the study was to first confirm that Swiss school children and pregnant women remain iodine sufficient and then to assess iodine status in infancy and the relative contribution of breast milk and IFM/CF to their iodine intakes.

Methods: We measured urinary iodine concentrations (UIC) in national cross-sectional samples of: 1) pregnant women (n = 648); 2) school children (n = 916); 3) infants at three time points: at 3–4 d after birth and at 6 and 12 months (n = 875); and 4) breast-feeding mothers (n = 507). We measured breast milk iodine concentrations in the mothers, assessed iodine sources in infant diets, and analyzed iodine content of commercial IFM/CFs (n = 22) and salt samples from the school children’s households (n = 266).

Results: Median (m) UICs in pregnant women (162 μg/liter) and school children (120 μg/liter) were sufficient, and 80% of the household salt was adequately iodized (>15 ppm). However, mUICs in infants not receiving IFM/CF were not sufficient: 1) mUIC in breast-fed infants (82 μg/liter) was lower than in non-breast-fed infants (105 μg/liter) (P < 0.001), and 2) mUIC in breast-fed weaning infants not receiving IFM/CF (70 μg/liter) was lower than infants receiving IFM (109 μg/liter) (P < 0.01). mUIC was low in lactating mothers (67 μg/liter) and median breast milk iodine concentration was 49 μg/kg.

Conclusions: In countries in which iodized salt programs supply sufficient iodine to older children and pregnant women, weaning infants, particularly those not receiving iodine-containing IFM, may be at risk of inadequate iodine intakes. (J Clin Endocrinol Metab 95: 0000–0000, 2010)
Because iodine deficiency (ID) during infancy may irreversibly impair development and increase mortality (1, 2), control of ID in populations should emphasize this critical period. Infants are at high risk for ID because their requirements per kilogram body weight for iodine and thyroid hormone are much higher than at any other time in the life cycle. In areas of iodine sufficiency, thyroidal iodine content is only about 300 μg at birth (3), and T4 turnover is high, with estimated production rates of 5–6 μg/kg body weight/d in infancy (4).

Infants may be at particularly high risk for ID during the weaning period. Iodization of salt is the recommended strategy to control ID, and lactating mothers consuming iodized salt can transfer the iodine to the infant via breast milk. But experts recommend no extra salt (iodized or not) be given to infants during the first year, and mothers are encouraged to feed home-prepared complementary formula/foods (CF) without added salt after 6 months (5, 6).

So as infants wean from breast milk, iodized salt programs contribute little to their iodine intakes, and in industrialized countries, they depend nearly entirely on iodized commercial CF. However, European legislation does not stipulate minimum iodine levels for CF (7), and a U.S. study found iodine content of these foods is unpredictable (8).

There have been no national studies assessing infant iodine status in countries with established iodized salt programs in which the general population has adequate iodine intakes. Previous infant studies were limited by small nonrepresentative sampling, and, in many, the iodine intake of the population was too high or was inadequate (9).

The main indicator of iodine intake in populations is the median (m) urinary iodine concentration (UIC), and the World Health Organization (WHO) states a mUIC of 100 μg/liter or greater in infants indicates iodine sufficiency (10). A challenge to assessing UIC in this age group is sample collection, but we have recently developed and validated a simple pad collection method (11).

Switzerland has a model iodized salt program that was initiated in 1922; in national surveys in 1999 and 2004, more than 90% of households were using iodized salt and school children were iodine sufficient (12, 13). However, according to national Swiss salt legislation, iodization of salt is not compulsory and all retail outlets must offer both iodized (at a level of 20 ppm) and noniodized salt (13). The first objective of the present study was to measure UIC in a national sample of pregnant women and school children to confirm that the Swiss population remains iodine sufficient in 2009. At the same time, we measured UIC in a national sample of infants during the first week and at 6 and 12 months of age. We also measured breast milk iodine concentrations (BMIC) in the mothers of the infants and assessed the relative contribution of BMIC, infant formula milk (IFM) and CF to iodine intakes during this vulnerable period.

Subjects and Methods

Subjects were recruited using a stratified probability-proportionate-to-size (PPS) cluster design. Based on current census data, the Swiss Federal Office of Statistics divided Switzerland into five geographic regions and divided each of these regions into three strata with communities of different population size. Then a two-stage PPS random cluster sampling (10) was used to obtain independent national samples of the population groups. Following WHO recommendations for cluster sampling in iodine surveys (10), for the pregnant women and school children, we aimed for 30 clusters including about 20 subjects, and for the newborns and the infant/mother pairs, we aimed for 20 clusters including about 20 subjects. For infants, PPS sampling was based on the birth rate of the seven greater Swiss regions. The collection periods were November 2005 to September 2007 (11) and August 2008 to November 2009. The ethical committee at the Swiss Federal Institute of Technology (ETH, Zürich, Switzerland) approved the study, and written informed consent was obtained from all participants and/or their parents; oral assent was obtained from the school children.

Newborns and infant/mother pairs

For the newborns, within each sampling cluster, a maternity clinic was randomly selected and newborns were sequentially enrolled at each clinic. Inclusion criteria were: 1) full-term, healthy pregnancy; 2) parental residence in Switzerland for 12 months or longer; 3) no history of thyroid disorders; 4) no ingestion of iodine-containing drugs or contrast media during gestation; 5) delivery without use of iodine-containing disinfectants; 6) age, 3 or 4 d after birth; and 7) exclusive breast-feeding. The centers collected spot urine samples using a pad collection method (11). Mothers filled out a registration form including birth data, infant feeding, and history of maternal use of iodized salt and/or iodine-containing supplements during pregnancy.

For the infant/mother pairs, within each sampling cluster, an outpatient pediatric clinic was randomly selected, and about 25 pairs were sequentially enrolled at each clinic at a routine check-up visit. The French-speaking part of Switzerland was not represented. Mother-infant-pairs were enrolled at the clinics according to the inclusion criteria above for the newborns but additionally the following criteria included: 1) infant age of 6 months ± 6 wk or 12 months ± 6 wk; 2) no health problems in the infant; and 3) residence in Switzerland since delivery. Spot urine samples were collected from the infant and the mother. A 10-ml breast milk sample was collected by manual expression. Weights and heights of the infants were measured. The mothers filled in a dietary questionnaire including current infant feeding practices and use of iodized salt in the home; the questionnaire also included information on height, weight, number of children, nutritional supplement use, cigarette smoking, professional activity, and education/profession of the mother.

Pregnant women

The proportion of Swiss pregnant women who receive prenatal care in private practices vs. hospitals is 4–5:1; this propor-
Comparison of labeled and measured iodine concentrations in different brands of formula milk and infant cereals

<table>
<thead>
<tr>
<th>Brand/product specification</th>
<th>Labeled (µg/100 kcal)</th>
<th>Labeled (µg/100 ml)</th>
<th>Measured (µg/100 ml)</th>
<th>Difference (%)</th>
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</thead>
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<tr>
<td><strong>Infant formulas</strong>&lt;sup&gt;g&lt;/sup&gt;</td>
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<tr>
<td>Bimbosan&lt;sup&gt;f&lt;/sup&gt;</td>
<td>7.1</td>
<td>4.8</td>
<td>4.6</td>
<td>−3.3</td>
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<tr>
<td>Bimbosan Bio&lt;sup&gt;f&lt;/sup&gt;</td>
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<td>5.2</td>
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<td>Adapta 2&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>11.6</td>
<td>5.8</td>
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<tr>
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<td>7</td>
<td>9.4</td>
<td>34.3</td>
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<tr>
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<td>10</td>
<td>9.3</td>
<td>−6.9</td>
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<td><strong>Soy-based formula</strong>&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
<td>Bimbosan Bisoja&lt;sup&gt;f&lt;/sup&gt;</td>
<td>9.8</td>
<td>6.5</td>
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<tr>
<th>Brand/product specification</th>
<th>Labeled (µg/100 kcal)&lt;sup&gt;m&lt;/sup&gt;</th>
<th>Labeled (µg/portion)&lt;sup&gt;n&lt;/sup&gt;</th>
<th>Measured (µg/portion)&lt;sup&gt;n&lt;/sup&gt;</th>
<th>Difference (%)&lt;sup&gt;d&lt;/sup&gt;</th>
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<tr>
<td>Instant milk-cereals (to be prepared with water)</td>
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<tr>
<td>Milupa Miluvid plus&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>1.7</td>
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<td>Nestlé Baby Menu Milchgiess&lt;sup&gt;f&lt;/sup&gt;</td>
<td>21.4</td>
<td>45</td>
<td>46.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Instant cereals (to be prepared with milk and water)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Galactina Ceralino Milchzusatz Getreide und Ovomaltine&lt;sup&gt;e&lt;/sup&gt;</td>
<td>10.7</td>
<td>40&lt;sup&gt;o&lt;/sup&gt;</td>
<td>37.4&lt;sup&gt;o&lt;/sup&gt;</td>
<td>−6.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> Refers to product as prepared ready to eat; <sup>b</sup> calculated based on energy in ready-to-eat product; <sup>c</sup> measured by ICP-MS; <sup>d</sup> percentage of measured iodine concentrations compared with labeled iodine concentration based on micrograms per 100 ml ready-to-eat product; <sup>e</sup> cow milk-based; <sup>f</sup> product of Bimbosan Ltd. (Welschenrohr, Switzerland); <sup>g</sup> product of Adapta (Lenzburg, Switzerland); <sup>h</sup> product of Coop (Basel, Switzerland); <sup>i</sup> product of HiPP GmbH (Sachsen, Switzerland); <sup>j</sup> product of Holle Baby Food GmbH (Riehen, Switzerland); <sup>k</sup> product of Nestle Baby Food GmbH (Riehen, Switzerland); <sup>l</sup> product of MILUPA SA (Domdidier, Switzerland); <sup>m</sup> calculated based on energy in dry product; <sup>n</sup> standard portion as indicated on the package, varying from 175 to 200 g; <sup>o</sup> micrograms per 100 g instant powder; only water used for the preparation.

Content of iodine in commercial infant foods

The iodine concentration of commercial infant foods was directly analyzed and compared with the labeled concentration. These were: 1) IFM products (two infant formulas; nine follow-on formulas; one soy-based formula; all instant powders); and 2) commonly consumed baby cereal products (four instant powder) (Table 1). Selection of products was based on the brands most frequently used by the participating families as indicated in the dietary questionnaires, and the samples were purchased from retail outlets in the Zurich area. All infant foods were analyzed in dry form (0.25 g powder) and wet form, i.e., a ready-to-eat portion was prepared in Nanopure water, and 1.5–2.0 g of the food was sampled for the analyses.

Laboratory analysis

All urine, breast milk and salt samples were frozen and kept at −25 C until analysis. UIC and salt iodine content were measured in duplicate at the ETH Zürich by using a modification of the Sandell-Kolthoff reaction with spectrophotometric detection.

School children

Within each sampling cluster, two to three classes in a primary school were randomly selected, and all children in the classes who consented were enrolled. Height and weight were measured using standard anthropometric techniques (14). A spot urine sample was collected. At all schools except one, urine samples were collected before noon. In each school, 10 children were randomly selected and given plastic bags for collection of a household salt sample.
By this method, the coefficient of variation for UIC (±sd) in our laboratory is 11.5% at 31 ± 4 μg/liter and 3.6% at 212 ± 8 μg/liter. External control was provided by inductively coupled plasma mass spectrometry (ICP-MS) (Element 2; Thermo Fisher Scientific, Bremen, Germany) measurements of 10% of UIC samples (school children, pregnant women) at the Swiss Federal Office of Public Health (Liebefeld, Switzerland). The agreement between the Sandell-Kolthoff and ICP-MS methods was high (r = 0.97, P < 0.001). The ETH iodine laboratory participates successfully in the Program to Ensure the Quality of Urinary Iodine Procedures (16).

Statistical analysis

EXCEL (XP 2003; Microsoft, Seattle, WA), SPSS 16.0, and PASW 18.0 (SPSS, Inc., Evanston, IL) were used for data processing and statistics. Normally distributed data were expressed as means ± sds; nonnormally distributed data (UIC) were expressed as medians [ranges, and/or 95% confidence interval (CI) obtained by 1000 bootstrap samples]. Group differences for continuous variables were tested by using Wilcoxon or Mann-Whitney U tests with Bonferroni correction when indicated. To look for correlations, Spearman or Pearson correlations were done. A multiple linear regression analysis was done with log infant UIC as the dependent variable and including sex, current breast milk and IFM consumption, log BMIC, and log UIC of mothers as covariates. P < 0.05 was considered significant.

Results

Newborns

Twenty-four participating clinics provided samples from exclusively breast-fed infants on d 3 or 4 after birth that matched the inclusion criteria (n = 368: d 3, n = 248; d 4, n = 120). Ninety percent were delivered vaginally, and all were term infants, with normal birth weights and Apgar scores. Median UIC was 91 μg/liter (Table 2); at d 3, mUIC was 87 μg/liter and at d 4, it was 100 μg/liter. Among the mothers, 65% (n = 241) were taking supplements, but only 0.8% (n = 3) were consuming iodine-containing supplements (during pregnancy or currently), and 12% (n = 42) were using noniodized salt.

Infants and their mothers

Eighteen participating clinics provided 507 infant/mother pairs. The ratio of vaginal to cesarean deliveries was 208:70 and 174:54 in the 6 and 12 month olds, respectively. The UICs in the 6- and 12-month-old infants are shown in Table 2 and were not significantly different.

### Table 2. UIC by age/population group in Switzerland

<table>
<thead>
<tr>
<th>Age group</th>
<th>n</th>
<th>Male/female</th>
<th>Mean (±SD)</th>
<th>Range</th>
<th>Median (95% CI)</th>
<th>% &lt; 50 (SE)</th>
<th>% 50 – 99 (SE)</th>
<th>% &gt; 150 (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 4 d</td>
<td>368</td>
<td>171/197</td>
<td>3.4 ± 0.4</td>
<td>Not measured</td>
<td>91 (82, 99)</td>
<td>20 (0.021)</td>
<td>36 (0.026)</td>
<td>6 (0.011)</td>
</tr>
<tr>
<td>6-month</td>
<td>142/36</td>
<td>63 ± 0.9</td>
<td>9.6 ± 1.7y</td>
<td>4.7–921</td>
<td>120 (144, 177)</td>
<td>36 (0.003)</td>
<td>47 (0.017)</td>
<td>4 (0.013)</td>
</tr>
<tr>
<td>12-month</td>
<td>106/22</td>
<td>6.3 ± 0.7</td>
<td>9.6 ± 1.7y</td>
<td>4.7–921</td>
<td>120 (144, 177)</td>
<td>36 (0.003)</td>
<td>47 (0.017)</td>
<td>4 (0.013)</td>
</tr>
</tbody>
</table>

*All such values.*

*Percentage less than 150 μg/liter (10).
The overall infant mUIC was 98 μg/liter (95% CI 89, 105). The UICs did not differ significantly among geographic regions or pediatric clinics, but girls had higher UICs than boys (mUIC, 103 vs. 88 μg/liter) (P < 0.05). The mean (±SD) parity of the mothers was 1.7 ± 0.8. Their mUIC was 75 μg/liter (95% CI 69, 81) (Table 2), and their mBMIC was 48.9 μg/kg (n = 179). The mUIC of lactating women did not significantly differ from nonlactating women (67 μg/liter, n = 196 vs. 81 μg/liter, n = 311). The mBMIC of mothers in the 6-month group (50.6 μg/kg, n = 149) did not significantly differ from the BMIC of the 12-month group (42.3 μg/kg, n = 32). The BMIC of the mothers was positively correlated with the UIC of their infants (r² = 0.32, P < 0.001).

Fifty-seven percent of the 6-month-old infants and 18% of the 12-month-old infants were being breast-fed fully or partly at the time of sampling. Breast-fed infants with or without IFM had a lower mUIC than infants not currently breast-fed (82 μg/liter, n = 196 vs. 105 μg/liter, n = 311) (P < 0.001). About 60% of all infants were receiving IFM, and their mUIC was higher than those not receiving IFM (109 μg/liter, n = 304 vs. 73 μg/liter, n = 203) (P < 0.001). Infants (breast fed and/or CF) receiving IFM had higher mUIC than breast-fed weaning infants who did not receive IFM (109 μg/liter, n = 304 vs. 70 μg/liter, n = 131) (P < 0.01) (Fig. 1). Weaned infants not receiving breast milk or IFM did not differ in UIC (89 μg/liter, n = 72) from the other two groups. Eighty-four percent of mothers were using iodized salt at home, 8% of mothers were not using iodized salt, and 8% were unsure; there were no significant differences in UIC of the mothers or infants among these three groups. Among the 6-month-old infants, nearly four of five were already receiving complementary foods, and at 6 and 12 months, 7 and 95% of infants were receiving some foods from the family table. The mUIC of infants receiving some iodized salt in complementary foods (103 μg/liter, n = 287) was higher but not significantly different from the mUIC of infants not receiving iodized salt (89 μg/liter, n = 189).

Thirty-two percent of the mothers were taking nutritional supplements (n = 158), but only 3% of women were consuming iodine-containing supplements. There were no significant monthly differences in the UICs of infants or mothers, or the BMICs, suggesting no major seasonal fluctuations in iodine supply to these groups. Ten percent of the mothers were current smokers, but the UIC of the smoking mothers and their infants was not significantly different from those not smoking. Predictors of infant UIC are shown in Table 3.

### Iodine content of infant foods

The agreement between the labeled and analyzed iodine content of the IFMs and infant cereals was high (Table 1); the mean (±SD) difference (percent) between labeled and measured values was 13.5 ± 9.1% for the formulas and 4.5 ± 2.6% for the cereals. None of the formula milks or cereals exceeded the recommended maxima of 50 and 35 μg per 100 kcal (18). The agreement between the iodine content of the wet vs. dry form of the infant foods was high (data not shown for the dry form).

### TABLE 3. Predictors of UIC in Swiss 6- and 12-month-old infants

<table>
<thead>
<tr>
<th>Predictor</th>
<th>β</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>BMIC a</td>
<td>0.320</td>
<td>0.000</td>
</tr>
<tr>
<td>Currently consuming IFM (yes/no)</td>
<td>0.201</td>
<td>0.010</td>
</tr>
<tr>
<td>UIC of mothers a</td>
<td>0.107</td>
<td>0.130</td>
</tr>
<tr>
<td>Gender of infant (female/male)</td>
<td>-0.074</td>
<td>0.291</td>
</tr>
<tr>
<td>Currently consuming breast milk (yes/no)</td>
<td>-0.046</td>
<td>0.552</td>
</tr>
<tr>
<td>R² adjusted</td>
<td>0.153</td>
<td></td>
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</tbody>
</table>

* UIC and BMIC values log transformed.
Pregnancy

A total sample of 648 women from 27 practices (six hospitals and 21 private practices) participated in the pregnancy study. The mUIC was 162 µg/liter (95% CI 144, 177) and 47% of pregnant women had a UIC less than 150 µg/liter (Table 2). The percentage of pregnant women who reported using iodized salt was 74% (n = 480). The mUIC of the subjects using iodized salt was 162 µg/liter. The mUIC of the 17% (n = 108) reported not knowing what type of salt they were using was 187 µg/liter and the mUIC in the subjects (9%) (n = 60) who reported using noniodized salt was 176 µg/liter. The UIC did not significantly differ among the three groups.

Seventy-nine percent of the pregnant women were taking nutritional supplements, but only 15% (n = 100) were taking supplements containing iodine. The amount of iodine in the iodine-containing supplements ranged from 45 to 200 µg/dose, mainly as potassium iodide. The mUIC in the women taking/not taking iodized supplements was 198 vs. 155 µg/liter (P = NS). The mUIC of women in the first trimester of pregnancy (n = 20) was 116 µg/liter, in the second trimester (n = 317), it was 166 µg/liter, and for women in the third trimester (n = 309), it was 156 µg/liter (P = NS). Parity was not a significant predictor of UIC. The mUIC of women attending the private practices (n = 499) and hospital (n = 149) was 179 and 113 µg/liter (P = 0.001), respectively.

School children

Twenty-eight schools participated in the study; the average participation per school was 33 children (range 22–50). The final sample included 916 children, representing approximately one in 700 children in the age group from 6 to 13 yr in Switzerland. The mUIC was 120 µg/liter (95% CI 120, 128), and the proportion of children with UIC less than 100 µg/liter was 36% (Table 2). The mUIC of the girls was 113 (95% CI 105, 121) µg/liter and was significantly lower than the mUIC of the boys, which was 124 (95% CI 119, 130) µg/liter (P < 0.001). All five of the geographic regions in Switzerland had a mUIC greater than 100 µg/liter, with a range from 108 to 132 µg/liter. No significant differences in UIC were found between different ages.

Household salt iodine content

In total, 266 salt samples were analyzed from the households of the participating children. Eighty percent (n = 213) of samples had iodine concentrations greater than 15 ppm and the median (range) iodine concentration of those samples was 19.8 (15.1–33.0) ppm.

Discussion

Our data indicate iodine sufficiency in the general Swiss population as assessed by the two indicators recommended by WHO: mUICs in school children and pregnant women are adequate (10). WHO also states a mUIC of 100 or greater µg/liter indicates iodine sufficiency in infancy (10), and the mUIC in our infants at 3–4 d and at 6 months was below this cutoff. Infants who were not receiving iodine-fortified IFM during the weaning period were clearly deficient, with a mUIC of 74 µg/liter. Several reports of mUIC in infants (<2 yr old) in countries with more-than-adequate or excess iodine intakes have found higher values than in our study (19–22). However, studies in European infants have generally reported mUIC similar to ours (19, 23–26).

Our findings emphasize the importance of iodine-containing infant foods/formula as dietary iodine sources during weaning. The mBMIC of the mothers in our study was 49 µg/kg, somewhat lower than expected because a previous Swiss study reported BMICs of 60–80 µg/liter (23). A review of BMIC among the iodine-sufficient countries reported a wide range of mean or median concentrations, from 50 µg/liter in Finland to 270 µg/liter in the United States, but sample sizes were small and not representative, and the potential contribution of iodine supplements was generally not assessed, making it difficult to draw conclusions (9).

In our infants, only 58% of the 6-month-olds and 18% of the 12-month-olds were being breast-fed, whereas nearly two thirds of all infants were receiving IFM, and their UIC was significantly higher than those breast fed (Fig. 1). Breast-fed infants who were also receiving IFM had significantly higher UIC than those who were being breast fed without additional IFM. Infants who were breast fed and given home-prepared CF (that contain little or no added salt) were at highest risk of low iodine intakes. In Germany, using a dietary model, it was estimated that the iodine intake of an 8-month-old breast-fed infant who receives home-prepared CF would be only about 45 µg/d compared with 125 µg/d or greater in a formula-fed infant who receives commercial CF (27).

Previous dietary intake studies have highlighted the importance of iodized CF for weaning infants. In the New Zealand Total Diet study, which simulated typical diets, iodine-containing formula and foods provided 60% of iodine intakes for infants older than 6 months (28). In the U.S. Total Diet Study, 90% of iodine intake in infants older than 6 months was provided by infant formula/foods and dairy products (29). In Europe, the required level of iodization for infant formula milks is 10–50 µg per 100 kcal (2.5 µg per 100 kJ), but for cereal-based and other
there are no requirements for minimum iodization, whereas the allowed upper level is 35 μg per 100 kcal (7). In the United States, iodine fortification of infant formula is mandatory at a minimum level of 5 μg per 100 kcal (maximum level is 75 μg per 100 kcal) (30). In Germany, it is estimated only about 50% of CFs are fortified with iodine (27).

The mUIC of pregnant women attending private practices was significantly higher than those attending a hospital. This may be due to different dietary habits between these two groups, but it was not explained by increased use of iodized salt in the former group. Although we might have expected mUIC to be higher in the pregnant women who said they were using iodized salt than in those claiming to use noniodized salt, there was no significant difference between the mUIC between these two groups. Because it is estimated that in Western Europe, the majority of salt intake comes from processed foods rather than salt added in the home (31), one possible explanation is that iodized salt intakes from processed foods were similar between groups because 60–70% of the food industry in Switzerland is using iodized salt (13). Another potential explanation is the relatively small number of women (n = 60) who reported using noniodized salt, making the estimate of the mUIC in this group less robust.

The mothers of the 6- and 12-month-old infants were iodine deficient; their overall mUIC was 75 μg/liter (Table 2), less than half of the median UIC in the pregnant women. Because of iodine secretion into breast milk, the median UIC of the lactating women would be expected to be less than that of pregnant women. However, not all women in the postpartum period were still breast-feeding, and the mUIC of currently breast-feeding women, although lower than that of nonlactating women (67 μg/liter, n = 196 vs. 81 μg/liter, n = 311), was not significantly lower, so losses into breast milk are likely not to be the only explanation for the lower median UIC in the postpartum period. The higher use of iodine containing supplements by pregnant women (15%) compared with women in the postpartum (<5%) may contribute to this difference. It is also possible a proportion of the urinary iodine samples collected from pregnant women may have been exposed to iodine contamination from routine clinical use of glucose dipsticks (32). But the most likely explanation for the low mUIC in postpartum women who have finished breast-feeding compared with pregnant women is that their thyroidal iodine stores have been depleted by the very high iodine demands of pregnancy and lactation. Thus, the low mUIC in the postpartum, postlactation women could reflect greater fractional clearance of circulating iodide by the thyroid to rebuild depleted thyroidal iodine stores.

In our study, supplements containing iodine were consumed by less than 5% of lactating women. Although iodine supplements (either to lactating mothers or their infants) could supply additional iodine during infancy, most European pediatric societies do not recommend supplements for infants on well-balanced diets or their lactating mothers (33). Similarly, in countries such as Switzerland with an effective iodized salt program, WHO does not recommend iodine supplementation for infants or lactating women (34). Our findings need confirmation in other countries but suggest these recommendations may need to be reconsidered. In countries in which commercial infant foods are available, the fortification of iodine in IFM and CF should be strongly encouraged to ensure adequate iodine intakes in infancy (35).

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