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Dietary iodine intake and urinary iodine excretion in a Danish population: effect of geography, supplements and food choice

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I deficiency diseases remain a health problem even in some developed countries. Therefore, measurement of I intake and knowledge about food choice related to I intake is important. We examined I intake in 4649 randomly selected participants from two cities in Denmark (Copenhagen and Aalborg) with an expected difference in I intake. I intake was assessed both by a food frequency questionnaire and by measuring I in casual urine samples. I excretion was expressed as a concentration and as estimated 24-h I excretion. Further, subgroups with low I intake were recognized. I intake was lower in Aalborg than in Copenhagen for all expressions, and lower than recommended in both cities if I intake from supplements was not included. Milk was the most important I source, accounting for about 44 % of the I intake, and milk ($P<0{\cdot}001$) and fish ($P=0{\cdot}009$) intake was related to I excretion in a multiple linear regression model. Thus, risk groups for low I intake were individuals with a low milk intake, those with a low intake of fish and milk, those not taking I supplements and those living in Aalborg where the I content in drinking water is lower. Even individuals who followed the advice regarding intake of 200–300 g fish/week and 0·5 litres milk/d had an intake below the recommended level if living in Aalborg.

Iodine intake: Iodine excretion: Risk for low iodine intake

I deficiency diseases continue to constitute a major health problem in many countries with about 656 million people suffering from goitre worldwide (Delange & Bürgi, 1989; World Health Organization, 1996), and I deficiency diseases remain a problem even in some developed countries (Delange & Bürgi, 1989; Delange, 1994). Denmark has a relatively low natural I supply and, correspondingly, national intake studies have shown that the I intake is lower than the recommended 150 μg/d (Laurberg *et al.* 1997). Enlarged thyroid gland has been found in 24 % of women over 40 years of age (Knudsen *et al.* 2000*a*).

I intake can be measured by assessing dietary intake or by measuring I excretion in the urine. Measurement of I in 24-h urine samples is the most precise estimation of I intake in a group but not practical in larger surveys. Instead, I excretion in casual urine samples is often measured, and expressed as either a concentration or as I:creatinine ratio.

In a Western society like the Danish, eating patterns are usually diverse. The habitual I intake (like the intake of other nutrients) may therefore vary considerably within the population, and thus, even if the median I intake is within an acceptable level, subpopulations with low I intake probably exist.

Until June 1998 sale of iodized salt and other iodized products was illegal in Denmark. In 1997 a working group under the Ministry of Health in Denmark concluded that the I intake in the general population should be increased and recommended an iodination programme (Rasmussen *et al.* 1996). The working group further concluded that the iodination programme should be monitored. Before the iodination of salt was started, a cross-sectional study, The Danish Investigation of Iodine Intake and Thyroid Diseases (DanThyr), was established. The aim of DanThyr was to investigate I intake, and the prevalence of goitre and other I-related thyroid abnormalities in two cities in Denmark with mild to moderate I deficiency.

Abbreviations: DanThyr, The Danish Investigation of Iodine Intake and Thyroid Diseases; FFQ, food frequency questionnaire.

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The aim of the part of DanThyr reported here was to assess I intake, determined by three methods (I concentration in casual urine, estimated 24-h I excretion and I intake measured by a food frequency questionnaire (FFQ)), in a Danish population and to attempt to recognize subgroups in this population with low I intake with regard to: (a) geography; (b) use of dietary supplements with I; (c) gender and age; (d) intake of I-rich food; (e) dietary habits. Furthermore, changes in I intake with season were investigated. Lastly, the three measures for I intake were evaluated in a subgroup of the participants who completed detailed dietary records and collected 24-h urine samples.

Subjects and methods

DanThyr took place at two centres located in the cities of Aalborg (situated in western Denmark) and Copenhagen (situated in eastern Denmark) (Knudsen *et al.* 2000*a*). A random sample was drawn from the Civil Registration System of all inhabitants in the two cities comprising the following groups: women aged 18–22, 25–30, 40–45 and 60–65 years, and men aged 60–65 years. Altogether 9274 subjects were invited and 4649 (50·1 %) participated. The number of participants in the five mentioned age and gender groups were for Copenhagen 497, 493, 490, 454 and 495, and for Aalborg 460, 451, 430, 435 and 444. An over-representation of young subjects was selected as the study was designed for follow-up. Since thyroid diseases are most common among women, most women were chosen. Only men in the age group 60–65 years were included to allow for comparison between genders. This age group was chosen because the number of cases with thyroid abnormalities was supposed to increase with age.

The examinations took place from 10 March 1997 to 1 June 1998. All examinations were conducted independently in the two cities; however, all information gathered and procedures performed were standardized before the examination. The study was approved by the regional ethical committees. All participants provided written, informed consent.

All participants completed questionnaires which gave information about smoking habits and alcohol consumption. Participants were asked to bring with them all dietary supplements taken, and brand names, dose and frequency of usage were recorded. Less than about 5 % forgot to bring the supplements and these individuals were interviewed about present use. The daily I intake from dietary supplements was noted.

Food frequency questionnaire

The FFQ was given to all the participants when they arrived at the centre. The FFQ was filled in while waiting for a thyroid ultrasound examination and interview. The FFQ was semi-quantitative and included a list of fifty-three I-rich food items. The FFQ has been evaluated and is described in more detail by Rasmussen *et al.* (2001). The I intake was calculated for 4346 (93 %) participants who had filled out the questionnaire properly.

Diet records

Diet records were performed by a subgroup of participants in DanThyr to allow for comparison of I intake measured with the other methods. All women in the age groups 25–30 and 60–65 years who participated in DanThyr during the last 10 months of the survey were asked, when it was practically possible (time, availability of scales, etc.), to carry out dietary records. They weighed and recorded all food and drink consumed during 4 consecutive d comprising 3 week-days and 1 weekend-day. Of the 417 participants who agreed to carry out dietary records, 313 (75 %) completed useful records, and fourteen of these were excluded due to pregnancy. Thirty participants (10 %) with reported energy intake divided by estimated BMR below a cut-off value of 1·06 (Goldberg *et al.* 1991) were excluded due to high probability of under-reporting. Among the remaining 269 participants, 254 also completed useful FFQ.

Dietary I intake was calculated from values given in the Danish Food Database (Saxholt, 1996). I intake from the dietary records was calculated using a computer database based on the Danish Food Database (Dankost 2000, Danish Catering Centre, Copenhagen). However, both for the FFQ and the dietary records, more recent values for milk, water, wine and other beverages were used (Rasmussen *et al.* 2000).

Urine collections

All participants were asked to give a urine sample when they visited the centre. These casual urine samples were analysed for I and creatinine. I excretion was expressed in two ways: as a concentration (available for 4616 participants); as an estimated 24-h I excretion (available for 4594 participants). For the estimated 24-h I excretion, we multiplied I:creatinine ratio with the expected daily creatinine excretion for the given individual. The expected 24-h creatinine excretion was based on the data of Kesteloot & Joossens (1997), with combination of some groups due to negligible variation. The 24-h creatinine excretion used was 1·47 g for men (all aged 60–65 years), 1·23 g for women up to the age of 49 years and 1·07 for women 60–65 years of age. A satisfactory agreement between this estimated 24-h I excretion and observed 24-h I excretion has been found (Rasmussen *et al.* 1999; Knudsen *et al.* 2000*b*).

All participants who carried out dietary records in the last 6 months of the study were asked to collect one 24-h urine sample, and 156 agreed. Morning urine on the first day was not collected. The morning urine on day 2 was the last sample collected. Urine was stored cold and received at the laboratory within 2 d after collection, volumes were estimated by weight (specific gravity 1 g/ml) and 5 ml samples were stored at −20°C until analysis. Urine samples were validated for completeness with *para*-aminobenzoic acid (Jakobsen *et al.* 1997). Twenty-eight of the 24-h urine samples were rejected due to incomplete collection, which left 128 participants for whom the I content in urine was measured. Among these, 108 completed dietary records and useful FFQ. N was measured in complete 24-h urine samples to further validate the quality of the dietary records. N excretion in urine was converted to protein excretion by multiplying the figure for N excretion by 6·25 after adding

2 g N from extrarenal losses. Mean protein excretion (78·9 g) did not differ from mean protein intake (75·6 g) calculated from dietary records indicating no systematic under-reporting in these participants.

Assays. I in urine was measured in duplicate by the Ce–As method after alkaline ashing (Wilson & van Zyl, 1967) as described previously (Laurberg, 1987). The recovery of ^{127}I (corresponding to 32 μg/l) when added to fifteen urine samples with a median I content of 35 (range 15–80) μg/l was 95·9 (SEM 2·4)%. Final values were not corrected for percentage recovery. Serial dilutions of fifteen urine samples containing 15–80 μg I/l gave curves parallel to the standard curve. When a urine sample measured to contain 93·9 μg I/l was measured in triplicate in eighteen assays, the intra- and interassay CV for single determinations were 2·1 and 2·7 %, respectively. The lowest standard above the zero blank contained 10 μg I/l. With the set-up used, the analytical sensitivity varied between 2 and 3 μg/l. The standard was prepared from dried KI for analysis (Merck, Darmstad, Germany).

Twenty-four-hour urine samples were analysed for *para*-aminobenzoic acid by HPLC as described by Jakobsen *et al.* (1997). N in 24-h urine excretion was analysed by the Kjeldahl method (Tecator; Perstorp Analytical, Bristol). Urinary creatinine was determined by the kinetic modification of the Jaffe method (Bartels & Böhmer, 1971).

Statistics

Results are expressed as medians, with the 25th and 75th percentiles. The Wilcoxon signed ranks test was used to compare I intake with I excretion. The Mann–Whitney test was used to compare two independent variables. The Kruskal–Wallis test was used to analyse seasonal variations and differences between the age groups. Spearman's ρ was used for correlation analyses. Linear regression models were performed with log transformed I excretion expressed as estimated 24-h I excretion or as urinary I concentration as the dependent variable. As independent variables city, age and gender group, milk intake, water intake, fish intake and I intake from supplements were entered into the model. Predictors were eliminated according to the stepwise backwards elimination method. The final models were those which included all the statistically significant predictors. Geometric means of I excretion were estimated for milk intake groups with the covariates set to their respective sample means. *P* values below 0·05 were considered significant. Statistical analyses were performed with the Statistical Package for Social Sciences (SPSS version 10.0; Chicago, IL).

Results

Iodine intake and iodine excretion in the whole cohort

I excretion in casual urine samples in all participants and in the two cities expressed as a concentration and as estimated 24-h excretion can be seen in Table 1. Further, total I intake (I intake from diet plus I intake from supplements) is given in the table. With all three measures the I intake was significantly lower in Aalborg than in Copenhagen ($P<0·001$). Total I intake was higher than I excretion ($P<0·001$ for both expressions in both cities).

Estimated 24-h I excretion and I intake in participants who took a daily dietary supplement with 150 μg I (27·8 %), in participants who took dietary supplements with other amounts (mostly less) than 150 μg/d (6·6 %), and in participants who did not take any I-containing supplements (65·5 %) are shown in Table 2. Both the I excretion and the I intake from diet were significantly higher ($P<0·001$) in users of dietary supplements with 150 μg I/d than in non-users in both cities. Dietary supplements with I were mostly multivitamin–mineral tablets. Seventeen took an I supplement with 50 μg I/tablet and none took kelp.

Iodine excretion in participants not taking dietary supplements with iodine

The I excretion in participants who did not take I-containing supplements increased slightly with age in both cities ($P<0·001$ and $P<0·008$ in Copenhagen and Aalborg, respectively; Table 3). I intake from diet did not differ with age in Copenhagen ($P=0·167$), whereas in Aalborg I intake from diet differed between the age groups with highest intake in the age groups 25–30 and 60–65 years and lowest in the age groups 18–22 and 40–45 years ($P<0·001$ for difference between the age groups). Men had a higher I excretion ($P=0·05$) and a higher I intake ($P<0·001$) than

Table 1. Iodine excretion in casual urine samples expressed in two ways and total iodine intake in two Danish cities, located in the eastern (Copenhagen) and western (Aalborg) part of the country*

(Median values with 25th and 75th percentiles)

	All		Copenhagen		Aalborg	
	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles
I excretion (μg/l)	61	34, 101	68	38, 112	53†	30, 90
n	4616		2422		2194	
Estimated 24-h I excretion (μg/24 h)	93	59, 158	111	74, 180	74†	48, 126
n	4594		2419		2175	
Total I intake (diet + supplements)	152	93, 243	175	109, 263	131†	77, 218
n	4346		2205		2141	

* For details of participants and procedures, see p. 62.
† $P<0·001$ between the cities.

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Table 2. Estimated 24-h iodine excretion and dietary iodine intake in users and non-users of iodine-containing supplements*

(Median values with 25th and 75th percentiles)

	Non-users of I-containing supplements		Users of I-containing supplements of 150 μg/d		Users of I-containing supplements, other than 150 μg/d	
	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles
Estimated 24-h I excretion (μg/24 h)						
Copenhagen	93	65, 133	193†	120, 296	132	87, 227
n	1569		658		192	
Aalborg	62	43, 90	137†	78, 239	88	52, 180
n	1441		622		112	
I intake (μg/d)						
Copenhagen	126	92, 182	139††	101, 183	121	93, 163
n	1427		595		183	
Aalborg	92	65, 135	100†††	69, 140	86	68, 122
n	1424		602		115	

* For details of participants and procedures, see p. 62.
†$P<0{\cdot}001$, ††$P=0{\cdot}007$, †††$P=0{\cdot}032$ between users of I-containing supplements of 150 μg/d and non-users.

women in the same age group (60–65 years) in Copenhagen. In Aalborg men had a higher I excretion than women ($P=0{\cdot}008$), but there was no difference in I intake ($P=0{\cdot}235$).

Dietary sources of iodine

Milk and other beverages (including water, tea, coffee, juice, soft drinks, beer and wine) were the main sources of I according to the FFQ contributing about 68 % of I intake. Milk and milk products alone contributed about 44 % of I intake. Fish gave about 15 % and other sources about 14 % of I intake.

I excretion increased with increased milk intake in both cities ($P<0{\cdot}001$; Table 4). I excretion increased with increased intake of fish in Aalborg ($P<0{\cdot}001$) but not in Copenhagen ($P=0{\cdot}142$; Table 4). Milk and fish intake was combined in an I index; participants with a weekly fish intake below 100 g/week and a milk intake lower than 0·5 glasses of milk/d had a low I index, and participants who consumed more than 200 g fish/week and at least 0·5 litres milk/d had a high I intake. All other participants were said to have a median I index. The I excretion increased with higher I index ($P<0{\cdot}001$ in both cities).

In multiple linear regression models which included city, age- and gender-group, and I intake from supplements, the intakes of milk ($P<0{\cdot}001$) and fish ($P=0{\cdot}009$) were positively associated with the log-transformed I excretion expressed as estimated 24-h I excretion. Fig. 1 shows geometric mean of estimated 24-h I excretion with increased intake of milk. Likewise, the I index was positively associated ($P<0{\cdot}001$) to the log-transformed I excretion when included in a similar model.

Iodine excretion in participants with special dietary patterns

I excretion did not differ between vegetarians and non-vegetarians (median 73 and 70 μg I/24 h in vegetarians (*n* 77) and non-vegetarians (*n* 4492), respectively). Only two of the vegetarians abstained from milk or milk products. Participants with an alcohol consumption of eight or more drinks/week (*n* 1349) had a higher I excretion ($P<0{\cdot}001$) than participants with a lower alcohol consumption (*n* 3237). No difference in I excretion or intake was found in participants who were on a slimming diet (*n* 505) or who had been on a slimming diet more than three times (*n* 1541) compared with the other participants, and, likewise, I excretion or intake in participants with food allergy (*n* 711) did not differ from the other participants.

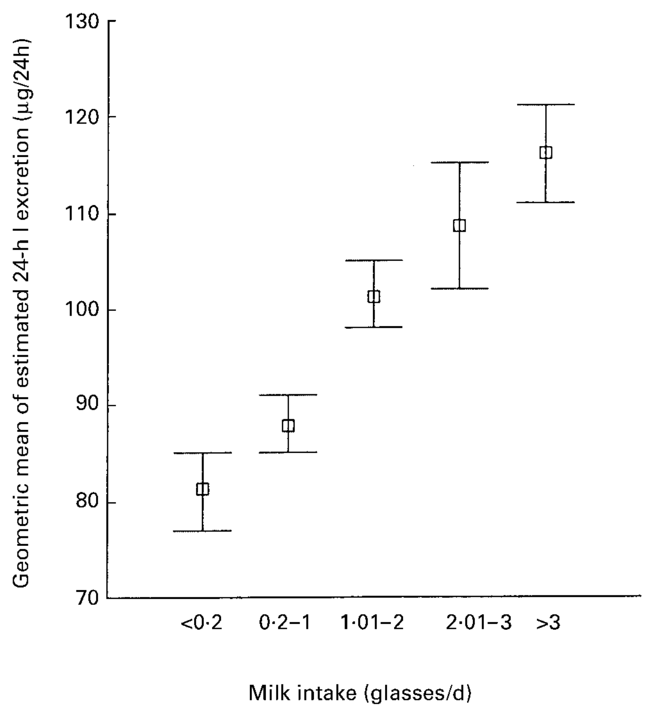

Fig. 1. Geometric mean of estimated 24-h iodine excretion as a function of milk intake. The vertical bars represent the 95 % confidence intervals.

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Table 3. Iodine excretion and iodine intake in participants not taking dietary supplements containing iodine*
(Median values with 25th and 75th percentiles)

	Women								Men	
Age (years) …	18–22		25–30		40–45		60–65		60–65	
	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles
Estimated 24-h I excretion (μg/24 h)										
Cogenhagen	86	57, 129	81	57, 116	95	71, 136	97	68, 136	105	73, 157
n	354		318		313		255		336	
Aalborg	55	38, 85	56	39, 81	63	45, 88	63	42, 96	71	49, 101
n	303		276		306		276		310	
I intake (μg/d)										
Cogenhagen	116	82, 167	126	94, 180	122	93, 177	123	85, 171	149	107, 207
n	354		318		313		255		336	
Aalborg	85	62, 140	98	69, 144	85	59, 118	97	71, 131	103	69, 145
n	303		276		306		276		310	

* For details of participants and procedures, see p. 62.

Table 4. Estimated 24-h iodine excretion (μg/24 h) in participants who did not take iodine-containing supplements for different intakes of milk and fish, and iodine intake index*
(Median values with 25th and 75th percentiles)

	Milk intake (glasses/d)					Fish intake (g/d)					I intake index†		
	≤0·2	>0·2–1	>1–2	>2–3	>3	<15	15–25	>25–45	>45–75	>75	1	2	3
Copenhagen: median	79	86	99	116	118	91	90	92	96	94	75	93	114
25th, 75th percentiles	(55–112)	(58–120)	(70–140)	(75–151)	(78–165)	(60–127)	(59–137)	(66–128)	(67–139)	(70–137)	(53–115)	(67–133)	(85–165)
n	310	476	395	83	164	352	191	363	290	276	37	1157	172
Aalborg: median	54	51	63	71	71	52	57	62	65	71	48	63	70
25th, 75th percentiles	(42–75)	(35–74)	(41–90)	(50–106)	(51–102)	(37–78)	(39–93)	(43–84)	(46–94)	(50–100)	(32–62)	(43–91)	(54–101)
n	151	257	441	183	353	322	202	324	285	303	98	1160	114

* For details of participants and procedures, see p. 62.
† 1, less than 100 g fish/week and less than 0·5 glasses (100 ml) milk/d; 3, more than 200 g fish/week and at least 0·5 litres milk/d; 2, all other intakes.

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Table 5. Iodine excretion and iodine intake in the subgroup (n 108) which collected 24-h urine*

I excretion, 24-h urine (µg/d)		I excretion (µg/l)		Estimated 24-h I excretion (µg/24 h)		Total I intake FFQ (µg/d)		Dietary records (µg/d)	
Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles	Median	25th, 75th percentiles
118	81, 197	63†	32, 108	89††	57, 160	162†	92, 279	168†	96, 268

FFQ, food frequency questionnaire.
* For details of participants and procedures, see p. 62.
†$P<0{\cdot}001$, ††$P=0{\cdot}007$ compared with 24-h I excretion.

Iodine intake and iodine excretion in the subgroup

Table 5 shows I excretion and I intake in the subgroup, which collected 24-h urine samples and carried out dietary records. I excretion in 24-h urine samples was higher than the excretion determined in the casual samples with both methods. I intake determined by the FFQ and by dietary records was similar and higher than the I excretion in 24-h urine samples ($P<0{\cdot}001$). All measures correlated significantly with 24-h I excretion and with the other expressions ($P<0{\cdot}001$ for all correlations). The highest correlation with 24-h I excretion was I intake determined by dietary records ($\rho = 0{\cdot}79$) and the lowest correlation was with I excretion expressed as a concentration ($\rho = 0{\cdot}35$). In the subgroup more participants took supplements containing 150 µg I than in the whole cohort (39·5 *v.* 27·8 %) and less took no I-containing supplements at all (51·8 *v.* 65·5 %).

Seasonal variation in iodine intake

Fig. 2 shows the seasonal variation in I excretion. I excretion changed during the year with highest values in the winter and spring and lowest values in the summer and autumn ($P<0{\cdot}001$ for change during the year). This pattern was seen in both cities. Further, the same pattern was seen in participants who did not take dietary supplements with I (results not shown).

Discussion

In the present study I intakes were assessed: (1) by a FFQ; (2) from casual urinary samples based on concentration and by estimated 24-h I excretion in populations living in two cities in Denmark. With all three expressions I intake was significantly higher in Copenhagen (eastern part of Denmark) than in Aalborg (western part of Denmark), but in both cities all estimates of I intake in subjects not taking I-containing supplements were lower than the recommended intake of 150 µg I/d (Sandström *et al.* 1996).

The geographical difference reflects the difference in I content in drinking water and to some degree milk (Pedersen *et al.* 1999; Rasmussen *et al.* 2000). In Copenhagen I concentration in tap water is about 19 µg/l and in Aalborg about 5 µg/l (Rasmussen *et al.* 2000). In general, the western part of Denmark has a lower water I content than the eastern part.

I excretion determined from the casual urine samples in the present study is at the same level as the figures found in earlier studies in Denmark but with a tendency to be about 10 µg higher in median-estimated 24-h I excretion (Munkner, 1969; Pedersen *et al.* 1995, 1997; Knudsen *et al.* 1999). An increase in I excretion can be explained by a higher I content in milk which seems to have increased since 1995 (Rasmussen *et al.* 2000). No clear age and gender difference in I intake was found although it tended to be higher in males than in females and to increase slightly with age.

It is often recommended to measure I status in a population by determining I concentration in casual urine samples (Bourdoux *et al.* 1985). According to this measure both cities would be classified as mildly I-deficient

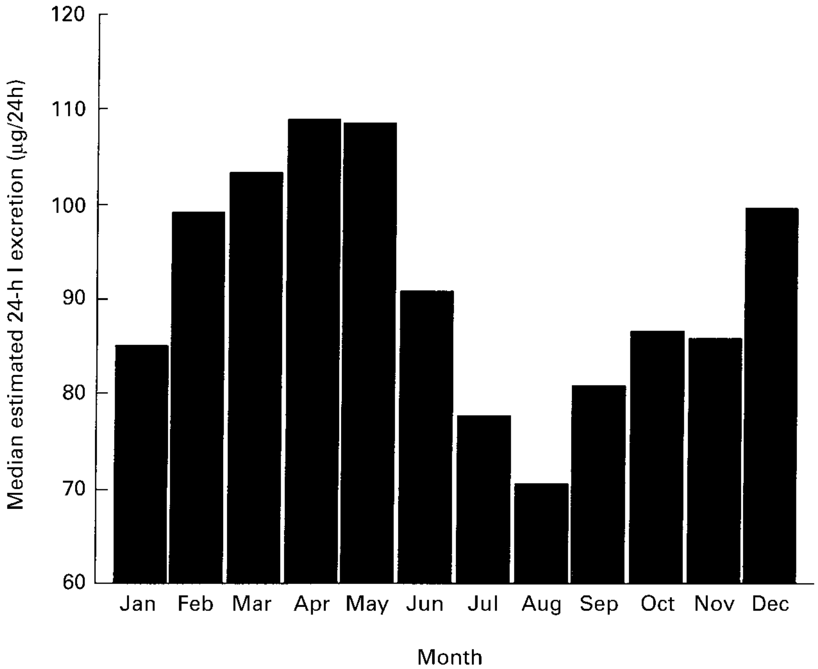

Fig. 2. Seasonal variation in estimated 24-h iodine excretion.

(Delange, 1994) if all participants are evaluated, and mildly and moderately I-deficient if based on subgroups not taking I-containing supplements. However, in two Danish studies it was found that age-and gender-adjusted I:creatinine ratio (estimated 24-h I excretion) better reflects 24-h I excretion in this population (Rasmussen *et al.* 1999; Knudsen *et al.* 2000*b*). Therefore, the estimated 24-h I excretion is used in the analysis of subgroups of the population, although this measure seems to underestimate I excretion in the present study. The reason for this is probably a systematically higher measure of creatinine in the present study.

I intake found in the present study was higher than the urinary I excretion. Urinary I excretion should reflect I intake closely if the subjects are in I balance although I intake should be 10–20 µg higher because of I excretion in primarily faeces and sweat (Vought *et al.* 1963). There are more sources of errors when assessing I intake by a FFQ, e.g. choice of food portion sizes, frequency of intake and, particularly, the values used for I content in food, than by measuring I excretion.

Large variations in I content in food have been found, and I in some foods, e.g. milk and drinking water, changes with season and/or geographical area. However, such errors could result in both higher and lower values. The I content in milk used in the present study is an average value based on samples taken in March, June and October, and that could have overestimated the average intake of I in milk because we had no samples from July and August where the content seems to be lowest (Larsen *et al.* 1999; Rasmussen *et al.* 2000). The intake of fish was probably overestimated due to the many questions on specific fish. However, this can only explain a minor part of the high I intake. Another explanation for the high total I intake compared with the excretion could be that intake of dietary supplements with I is over-reported or that I from dietary supplements is not absorbed completely. I intake from diet only was not significantly higher than I excretion indicating that dietary I intake was not seriously overestimated.

In the present study milk and milk products (apart from supplements) were the main sources of I accounting for about 44 % I intake. Fish contributed with about 15 % I intake. Because of the uncertainty of the I content in milk, a model was made to show how important the food groups were for I excretion. Milk intake was the food most closely related to I excretion, and, therefore, it is concluded that milk is an important I source in Denmark. Fish intake was also related to I excretion. In the UK milk and milk products were also found to be the main sources accounting for 35 % I intake whereas fish provided less than 10 % I intake (Lightowler & Davies, 1998). In contrast, neither milk and milk products nor fish were found to be associated with I excretion in the Netherlands (Brug *et al.* 1992) where iodinated bread is the main source.

Although there was a relationship between milk and I intake, and between fish and I intake, even the participants who consumed at least 200 g fish/week and 0·5 litres milk/d did not get enough I, especially when living in the western part of the country. The I-deficiency problem cannot be overcome by dietary changes. Thus, it is important to implement a iodization programme in Denmark. Except for a low intake of milk and fish we could not identify any eating patterns or any behaviour with relation to diet which causes an increased risk for I deficiency. Vegans may have an increased risk for I deficiency (Appleby *et al.* 1999; Remer *et al.* 1999), but this must mainly be due to the lack of milk in the diet rather than the lack of fish or other foods; vegetarians in our study population did not have a lower I intake than non-vegetarians.

A seasonal variation in I excretion was found in the present study with the highest excretion during winter and spring. As the same pattern was observed in participants who did not take dietary supplements with I the main explanation must be the higher I content in winter milk than in summer milk (Larsen *et al.* 1999; Rasmussen *et al.* 2000). In a British study, a seasonal variation in I intake was also found concurrent with a seasonal variation in I content in milk (Nelson & Philips, 1985). In contrast, in a study from New Zealand, clear seasonal variation in I excretion was not found (Ford *et al.* 1991).

Excretion of I in 24-h urine, considered to be the 'gold standard' for validating I intake, was higher than the values determined from the casual urine samples in the subgroup, suggesting that the casual urine underestimated I intake. However, the 24-h urine samples were not taken the same day as the casual urine samples, thus theoretically the difference could be due to a higher I intake on the day that the 24-h urine collections were carried out. Collections took place during the dietary registration period (usually on day four of the registration period), normally within 1 week after the FFQ was fulfilled, and it cannot be excluded that the participants changed their diet to a more I-rich diet due to the focus on I-rich food items in the FFQ. However, I intake determined by the dietary registration was quite similar to I intake determined by the FFQ in the subgroup contradicting that the participants changed their eating habits with regard to I during the registration period. Furthermore, the intake of dietary supplements with I was not higher on the day that the 24-h urine was collected than their normal intake as stated by the participants. Due to the high demands of performing dietary records and sample 24-h urine, the subgroup was not representative, though I intake in the subgroup did not differ from I intake in the whole group. Thus, although there are some limitations in this part of the study, the optimal way to measure the level of I intake is to measure I in 24-h urine samples controlled for complete collection.

In conclusion, a seasonal and geographical variation in I intake was found in Denmark. The methods used to evaluate I intake gave different results and an accurate level of I intake cannot be determined with the measures used. However, in the studied population the intake is lower than recommended especially in the western part of Denmark. Thus, introduction of an I fortification programme is important. Further, I intake varied appreciably and subgroups not taking I-containing dietary supplements should be investigated separately. Milk and, to a minor degree, fish are the most important I sources in Denmark, but even individuals who followed the advice regarding intake of fish and milk had an I intake below the recommended level.

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