Yonsei Medical Journal
Vol. 39, No. 4, pp. 355~362, 1998

Dietary Iodine Intake and Urinary Iodine Excretion in Normal Korean Adults

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Korea is a region abundant in foods containing iodine such as seaweed and fish. An adequate amount of iodine consumption is extremely important as both a deficiency and excess of iodine can result in health problems. This study was undertaken to assess the iodine nutritional status of normal Korean adults who consume seaweed and fish, and to determine the relationship between the dietary iodine intake and the urinary excretion of iodine. The dietary assessment of iodine using a food frequency questionnaire and a urinary iodine excretion examination were carried out in 278 healthy adults. The iodide selective electrode (ISE) method was used to determine urinary iodine excretion. The average usual iodine intake of Korean adults was 479 μg per day (ranging from 61 μg to 4086 μg). There was no significant difference in sex or age. The major food sources of dietary iodine included seaweed (66%), milk and dairy products (11%), and fish (9%). The contribution of seaweed to the total iodine intake tended to increase with age while the contribution of milk decreased. The average urinary excretion of iodine was 674 μg/g creatinine and there was no significant difference in sex or age. The dietary iodine intake was positively correlated with the urinary excretion of iodine (γ=0.60, p<0.01). The study data indicated that the iodine intake and excretion of Koreans depends mostly on the amount of seaweed consumption like sea tangle and sea mustard. As well, the current iodine intake and urinary iodine excretion by Koreans seems to be higher than in other countries.

Key Words: Iodine intake, urinary iodine, Korean

Both an iodine deficiency and excess are well known health problems. Iodine deficiency is a cause of disorders such as endemic goiter and cretinism, along with a wide spectrum of psychoneurological developmental disorders (Delange and Burgi, 1989; Maberly, 1994; Vermiglio *et al.* 1995). By comparison, a number of studies have shown that iodine supplementation in areas with low iodine intake can result in complications, both in normal subjects in the absence of apparent thyroid disease and in patients with underlying thyroid disorders (Frederick *et al.* 1975; Laurberg, 1994; Delange, 1995; Elnagar *et al.* 1995; Todd *et al.* 1995). Also, an excess of iodine from food sources, dietary supplements, oral drugs and iodinated contrast media (ICM) can have adverse effects including thyroiditis, goiter, hypothyroidism and hyperthyroidism (Fradkin and Wolff, 1983; Phillips *et al.* 1988; Pennington, 1990; Konno *et al.* 1993; Martin *et al.* 1993; Takeda *et al.* 1993). Therefore, it seemed important to find an adequate intake level of iodine by assessing the iodine status of various age-sex groups in the population.

Korea is a peninsula bounded on three sides by water. Seaweed and fish, which are high in iodine,

Received May 13, 1998
Accepted June 20, 1998
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are abundant and easily available. However, there is a little information on iodine intake or its adequacy in Koreans.

This study was carried out to determine the dietary iodine intake and the urinary iodine excretion of healthy Korean adults and the relationship between the dietary iodine intake and the urinary iodine excretion.

MATERIALS AND METHODS

Subjects

The subjects of this study were 278 healthy male and female adults over 20 years of age who had volunteered to help medical examinations conducted by the Yonsei University Severance Hospital Health Promotion Center. They had no history of thyroid disease and were receiving no medication. They were 141 males (50.7%) and 137 females (49.3%), with the following age frequencies: 52 subjects in their 20s, 70 subjects in their 30s, 58 subjects in their 40s, 68 subjects in their 50s, and 30 subjects in their 60s.

Methods

Measurement of dietary iodine intake: A semi-quantitative food frequency method was used to investigate the usual iodine intake of the subjects. The questionnaire contained questions regarding the average food consumption frequency and 3 different levels of portion size. The food items included those with a relatively high iodine content and those which Koreans generally consume. The interview was conducted by trained nutritionists and food models, measuring tools, and photographs were provided to decrease the variation as much as possible between the interviewer and interviewee. The dietary iodine intake level was calculated as followings:

$$I = F \times Q \times N$$

(I: dietary iodine intake, F: frequency per day, Q: one-time consumption amount, N: iodine content in the food)

The data of iodine content in the food currently being analyzed were used (Moon *et al.* 1998).

Determination of urinary iodine excretion: The urine samples were collected on the basis of a 24-hour sample and a random sample from 40 normal adults and urinary iodine was analyzed using the iodide selective electrode (ISE) method. The results indicated that there was no significant difference in the concentration between the 24-hour urine sample and the random urine sample. The correlation of coefficients was significantly high ($\gamma = 0.72$, $p < 0.001$)(Fig. 1). In this study, therefore, random urine samples were collected on the day the subjects were interviewed for the determination of urinary iodine excretion.

Urine samples were frozen at $-70°C$ and kept until analyzed. Urinary iodine was measured by ISE method. An Orion EA 940 ion meter (Orion Research, Boston, MA, USA), equipped with an Orion 94-53 iodide-specific ion electrode and an Orion 90-03 double-junction reference electrode, was used for determination of iodine. The standard solution was 0.1 M NaI and the ionic strength adjuster used was 5 M $NaNO_3$. The creatinine in the urine was analyzed by the Jaffe method using Kyobuto company's new creatinine test kit (Kyobuto, Tokyo, Japan).

Statistical analysis: All the materials were analyzed by the Statistical Analysis System (SAS) Package. Averages and standard deviations of all results were calculated, while ANOVA and t-tests according to gender, age and groups were also obtained. A probability level of < 0.05 was regarded as significant. When there were statistically signi-

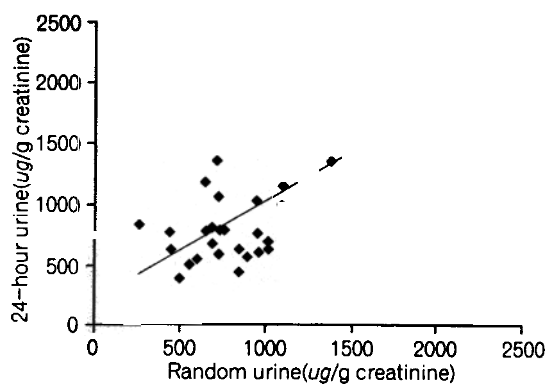

Fig. 1. Correlation of urinary iodine excretion between 24-hour and random urine samples ($\gamma = 0.72$, $p < 0.001$)

ficant differences, LSD and SNK tests were used. The association between the dietary iodine intake and urinary concentration was examined by using Pearson's correlation coefficient.

RESULTS

Among the 278 subjects, the main area of residence (this is not the current area of residence but the region the subjects spent most of their lives in) was classified according to inland and coastal regions. The results showed that 86.1% of the men were from inland and 13.9% from coastal regions, whereas 87.9% of the women were from inland and 12.1% were from coastal regions. Among the subjects, 84.9% were not taking any supplementation and two subjects were taking an iodine-containing health supplement called seaweed tablets (Table 1).

Table 1. Frequency of dietary supplementation in subjects*

	Men	Women	Total
No supplement	119 (42.8)	117 (42.1)	236 (84.9)
Iodine-containing health supplement	2 (0.7)	0 (0)	2 (0.7)
Vitamin/mineral tablet	9 (3.2)	11 (4.0)	20 (7.2)
Chinese herbal medicine	11 (4.0)	9 (3.2)	20 (7.2)
Total	141 (50.7)	137 (49.3)	278 (100)

Number of subjects(Percentage)

Table 2. Dietary iodine intakes of normal adults according to age groups

Age (years)	Iodine intake (μg/day)		
	Men	Women	Total
20~29	518.6±450.0	574.9±664.7	559.6±609.9
30~39	401.6±367.7	341.1±277.4	374.1±328.7
40~49	344.6±229.1	574.6±905.5	430.9±584.5
50~59	654.2±735.3	463.4±306.7	553.8±555.8
60≤	295.0±135.6	773.8±578.0	534.4±475.9
Total	450.9±465.5	504.6±563.1	478.6±517.7

Values are expressed as mean±SD.

Dietary iodine intake

The three subjects that were taking sea tangle tablets, a health supplemented food or iodized salt were removed from all statistical analyses to exclude theses influences.

The average usual iodine intake of normal Korean adults was 478.6±517.7 μg (Table 2). The average iodine intake according to gender was 450.9±465.5 μg for males and 504.6±563.1 μg for females and there was no significant difference between genders. The dietary iodine intake according to age showed that the intake was highest for subjects in their 20s and lowest for subjects in their 30s, but there was no significant difference among age groups. The range of iodine intake varied largely from 61 μg to 4086 μg. Four percent of subjects showed an iodine intake of less than 100 μg, 70% fell into the 100 to 500 μg range and 2% showed more than 2000 μg (Fig. 2).

The levels of dietary iodine intake according to main area of residence showed that the intake was higher for those living in coastal regions rather than inland. However, 87% of the subjects lived inland, therefore, the statistical difference was not verified.

The food sources of dietary iodine were sea mustard, sea tangle, laver, fish, milk, yogurt, beef, eggs, sea lettuce, and chicken in decreasing order

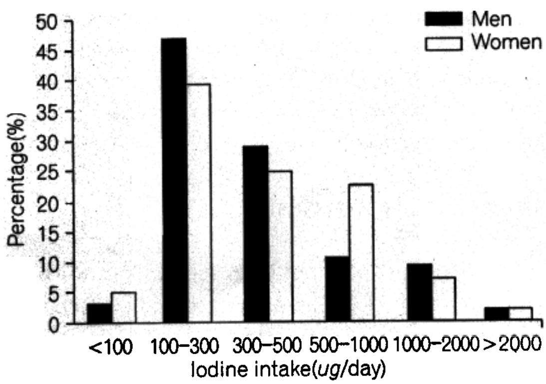

Fig. 2. Frequency distribution of iodine intake in subjects

Table 3. Contribution of food sources to the total iodine intakes of adults

	Men		Women		Total	
	Food item	(%)*	Food item	(%)	Food item	(%)
	Sea mustard	(26.4)	Sea mustard	(28.1)	Sea mustard	(27.3)
	Sea tangle	(21.1)	Sea tangle	(27.8)	Sea tangle	(24.5)
	Laver	(19.3)	Laver	(14.8)	Laver	(14.6)
	Fish	(10.7)	Milk	(8.2)	Fish	(9.0)
	Milk	(7.1)	Fish	(7.5)	Milk	(7.7)
6	Dairy products	(3.2)	Dairy products	(3.6)	Dairy products	(3.4)
7	Beef	(2.7)	Sea lettuce	(2.2)	Beef	(2.4)
	Egg	(2.2)	Beef	(2.2)	Egg	(2.0)
	Sea lettuce	(1.6)	Egg	(1.7)	Sea lettuce	(1.9)
10	Chicken	(1.2)	Chicken	(0.7)	Chicken	(1.0)

*: percentage of total iodine intake

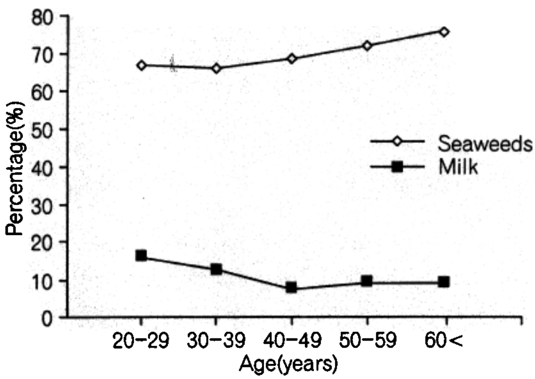

Fig. 3. Contribution of seaweed and milk to the total iodine intake in different age groups

Table 4. Average urinary iodine excretion according to age groups

Age (years)	Urinary iodine excretion (μg/g creatinine)		
	Men	Women	Total
20~29	713.3±304.6	666.7±328.1	695.5±326.3
30~39	633.3±351.0	614.5±382.5	625.9±366.8
40~49	606.7±333.1	718.8±412.2	662.8±395.6
50~59	707.0±439.7	688.2±467.9	700.1±433.8
60≤	600.8±312.7	764.7±451.8	683.7±395.2
Total	653.8±350.2	691.6±408.5	673.6±385.5

Values are expressed as mean±SD.

(Table 3). The different kinds of seaweed, sea mustard, sea tangle and laver took up 66% of the dietary iodine intake and fish, milk and dairy products took up 20%. The contribution of seaweed to the total iodine intake tended to increase with age while the contribution of milk decreased (Fig. 3).

Urinary iodine excretion

The iodine concentration in the random urine is shown in Table 4. The average iodine concentration in the urine was 673.6±385.5 μg/g creatinine and there was no significant difference between genders. The iodine concentration according to age indicated that it was highest for subjects in their 50s, but there was no significant difference among the age groups.

The relationship between dietary iodine intake and urinary iodine excretion

There was a significant correlation between usual iodine intake and urinary excretion at the day the subjects were interviewed (γ =0.60, $p<0.01$) (Fig. 4). The subjects were divided into 5 groups according to dietary iodine intake level (Table 5). As the iodine intake increased, the urinary excretion showed a trend of gradual increase as well. There was a significant difference in the urinary iodine excretion between all groups except for the group with an iodine intake level between 500~1000 μg and the

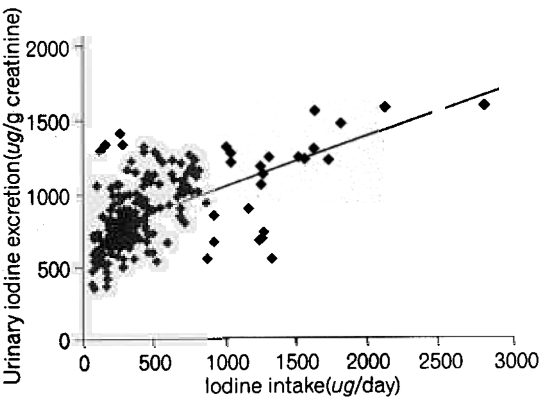

Fig. 4. Relationship between iodine intake and urinary iodine excretion in normal adults (γ =0.60, p<0.01)

Table 5. Urinary iodine excretion by quintiles according to dietary iodine intakes

	Iodine intake (μg/day)		Urinary iodine excretion* (μg/g creatinine)
Group I	<100	4.3%	595.9±296.8[a]
II	100≤~<300	43.1%	786.4±333.8[b]
III	300≤~<500	26.7%	924.2±314.1[c]
IV	500≤~<1000	16.4%	1124.9±416.5[d]
V	≥1000	9.5%	1243.0±412.5[d]

*: Mean±SD. a, b, c, d: Values with different alphabet within the column are significantly different ($p<0.001$).

Table 6. Comparison of iodine intake among various countries

Country	Year	Iodine intake (μg/day) Mean	Range	Major iodine source
Canada	1987	1,046		iodized salt, dairy products
Finland	1982	340		dairy products, iodized salt, eggs
Japan	1986	544	361~1,023	seaweed, erythrosine
Netherlands	1989	402	253~875	bread, sugar & sweets
UK	1994	166		milk & dairy products
United States	1989	195	150~250	milk & dairy products, cereals
Korea (this study)	1998	479	61~4,086	seaweed

group with an intake above 1000 μg ($p<0.001$).

DISCUSSION

The usual iodine intake of Korean adults was assessed using a food frequency questionnaire that has been tested for validity and reliability.

The major iodine food source was seaweed. The consumption frequency of the different seaweeds was 1~2 times a month for sea tangle and less than once a week for sea mustard. Therefore, for Koreans, the food frequency method is more suitable than the 24-hour recall or diet record method in determining the usual iodine intake level.

Table 6 shows the dietary iodine intake level and major food sources compared to other countries (Varo *et al.* 1982; Katamine *et al.* 1986; van Dokkum *et al.* 1989; Pennington and Young, 1991; Lee *et al.* 1994). This study shows that the dietary iodine intake level is higher in Korea than other countries except for Canada and Japan.

The daily dietary iodine intake for Canadians was over six times greater than the recommended iodine intake of 160 μg and the main food sources were iodized salt and dairy products (Lee *et al.* 1994). The major iodine source in Japanese meals was also seaweed, the same as in Korea, while erythrosine, a red food coloring with low iodine bioavailability, also contributed to increasing the iodine level (Katamine *et al.* 1986). The primary iodine food sources in U.S. diets were dairy products and cereals. The level of Americans' dietary iodine intake was reported as showing a downward trend. The decline in the iodine level may have been mainly due to the decreased use of the red dye erythrosine in cereals (Allegrini *et al.* 1983; Pennington *et al.* 1984; Pennington *et al.* 1989; Pennington and Young, 1991). The iodine intake of British adults as estimated by the Total Diet Study, was also showing a downward trend (166 μg/d in 1991, 277 μg/d in 1985, 323 μg in 1982) and the major iodine sources were milk and dairy products, which contributed approximately one-third of the iodine intake (Wenlock and Buss, 1982; Lee *et al.* 1994). Lee *et al.* reported that current iodine intakes for British adults was above the UK reference nutrient intake (RNI) of 140 μg/d, but was not excessive (Lee *et al.* 1994). The average iodine intake level for adults in Finland was 340 μg/d, although an extensive seasonal variation was found in the estimate for the summer season (280 μg) and for the winter season (400 μg). The most significant food source was dairy products, which also caused the seasonal variation in iodine content. Iodized table salt and eggs were also important food sources in Finnish diets (Varo *et al.* 1982). In the Netherlands, the mean of iodine intake in total diets was 402 μg/d in 1989 and 210 μg/d in 1982. The main food groups that contributed to the dietary iodine intake level were breads (41%), sugar and sweets (27%), and milk and dairy products (5%)(van Dokkum *et al.* 1982; van Dokkum *et al.* 1989).

Despite variations in urine output, the concentration of urinary iodine is a valuable and useful index for assessing current iodine status in a population (Furnee *et al.* 1994). However, the urinary iodine values do not reflect iodine intake exactly. Therefore, more elaborate studies than a simple estimation of average urinary iodine levels may be necessary to evaluate whether certain groups are at risk (Laurberg, 1994; Pedersen, *et al.* 1995).

This study's data indicates that the urinary iodine excretion of Koreans depends on the amount of seaweed consumption, as it is with iodine intake.

A study conducted on male university students in Japan also indicated that there was a large difference in urinary iodine excretion according to seaweed consumption (it was 1106 μg when seaweed was consumed and 153 μg when it was not) (Suzuki and Tamura, 1985). Konno *et al.* reported that the iodine concentration in urine was significantly higher in coastal regions than in non-coastal regions in Japan (Konno *et al.* 1994). In this study, most of the subjects lived inland, but the subjects who lived in coastal regions tended to show higher urinary iodine excretion. In China, iodine deficiency occurs in the mountainous regions, whereas the iodine-excess areas are in the low-lying lands between the mountains. There was a difference of iodine status according to geographical region. Furthermore, the urinary iodine concentration of children who drank water from wells with high iodine content was greater than those who drank water from wells with low iodine content (1237 μg/g creatinine and 428 μg/g creatinine, respectively)(Mu *et al.* 1987). The urinary iodine excretion was also higher for infants in East Berlin where iodine supplementation of all household salt and cattle food was mandated than in West Berlin where iodized salt was used voluntarily (Grüters *et al.* 1995). Students who engage in regular exercise had lower urinary iodine excretion than sedentary students, probably due to iodine loss in sweat during exercise. Therefore, in the evaluation of the iodine nutrition for physically active persons working in hot and humid environments, iodine loss due to sweat must be taken into consideration (Suzuki and Tamura, 1985). Ali *et al.*'s study found that the urinary iodine concentrations for Malays was significantly higher than for aborigines (43 μg for Malays and 24 μg for aborigines). And it was lower for rural areas compared with urban areas. Therefore, the study showed that there was an ethnic and geographical influence on iodine concentration in urine (Ali *et al.* 1994). Nelson *et al.* reported the marked seasonal and geographical variation in urinary iodine excretion in British towns correlated strongly with the iodine content of milk (Nelson *et al.* 1987). In Denmark, urinary iodine excretion was different according to individual iodine supplementation (Nohr *et al.* 1994; Pedersen *et al.* 1995). Iodine excretion was 36 μg/g creatinine in the part of the population that did not take iodine supplementation, while it was 81 μg/g creatinine in the part of the population taking daily iodine supplementation (Pedersen *et al.* 1995).

In this study, the two subjects who consumed sea tangle tablets as a health supplement had a considerably high iodine excretion of 2868 μg/g creatinine and 3661 μg/g creatinine, respectively. Korea currently has a variety of health supplement foods available, but the iodine contents are not adequately labeled. There is also lack of research regarding the maximum safe iodine intake level. Therefore, there is some concern that there will be a negative effect regarding the consumption of iodine-containing food supplements and there is a great need for setting an allowable standard regarding the iodine content in those supplements.

In England, kelp-based dietary supplements had the highest content level of 1240 μg/ daily dose (range 210~3840 μg/daily dose) which was much higher than the level that was indicated by the manufacturing company (Lee *et al.* 1994).

According to the results of this study, there is a high correlation between iodine intake and excretion. However, a more accurate and sensitive method of analyzing the iodine concentration in urine is needed to estimate the iodine intake. Though the ISE method is a fast and simple method of determining the iodine concentration in urine, it is influenced by other elements and its repeatability is low. In addition, detailed research is necessary on the factors other than foods which influence iodine intake and excretion.

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