Dietary Habits and Selenium Intake of Residents in Mountain and Coastal Communities in Japan

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(Received July 14, 2003)

Summary We used a Simple Food Frequency Questionnaire (SFFQ) in combination with other dietary approaches to estimate the selenium intake from different food groups based on the average long-term diet, in two rural communities in Japan, one in a mountain area and the other in a coastal area. The intake frequencies of rice and wheat products were significantly different in the two districts. The intake frequencies of fish, meat, and eggs, which are rich in selenium, were not significantly different. The mean dietary selenium intake, estimated from the SFFQ and the 24-h recall method, was 82.7 $\mu\text{g}/\text{d}$ ($n=234$) (range 19.2–180.1 $\mu\text{g}/\text{d}$) in the mountain community. The mean dietary selenium intake estimated from the SFFQ and average value of the normal portion size was 118.0 $\mu\text{g}/\text{d}$ ($n=123$) (range 22.6–255.3 $\mu\text{g}/\text{d}$) in the coastal community. These estimated mean values exceeded the Japanese RDA, although the range of daily selenium intake was large. In the mountain community, fish made the largest contribution to dietary selenium intake (48.2% of daily total), followed by eggs (24.3%), and meat (17.0%). In the coastal community, fish accounted for 57.7% of daily total selenium intake, followed by meat (17.5%), and eggs (16.1%). In both districts, the total contribution of rice and wheat products was around 10%. It was found that the contribution of fish to dietary selenium intake was high and the contribution of cereals was low among Japanese.

Key Words selenium, food frequency questionnaire, dietary habit, nutrition surveys

Selenium is an essential trace element (1), and human selenium deficiency has been reported as the cause of endemic fatal cardiomyopathy in certain low selenium areas of China (2), and as the cause of muscular pain or discomfort in patients on long-term total parenteral nutrition (TPN) (3).

Selenium has many biological functions in humans. One of the most important effects of selenium is its antioxidant effect (4–6), which helps to prevent cardiovascular disease and cancer. Several epidemiological studies have reported that low selenium levels in serum are associated with the risk of vascular disease (7–11), and the risk of coronary heart disease (CHD) in Japanese subjects (12, 13). Low selenium intake has also been associated with the risk of cancer (14–18).

Marked selenium deficiency has not been reported in the Japanese general population. The mean daily selenium intake in Japan was estimated at 104.2 $\mu\text{g}/\text{d}$ by Suzuki et al. (19), and 154.7 $\mu\text{g}/\text{d}$ by Otsuka et al. (20). These studies are not based on the average long-term

diet of individuals. Koyama et al. (21) obtained values of the daily selenium intake in a mountain community by three different methods: the value was estimated at 137.3–199.1 $\mu\text{g}/\text{d}$ by the 24-h recall method, and 85.8–94.5 $\mu\text{g}/\text{d}$ by a food frequency questionnaire, while the measured value was 113.7 $\mu\text{g}/\text{d}$ by the duplicated meal method. Little is known about individual selenium intake and regional differences in selenium intake in Japan.

Selenium bioavailability has a high variability, principally due to the different chemical forms that exist in foods (4–6). It is important to know the contributions of various food groups to the overall dietary intake of selenium. The present Japanese recommended dietary allowances (RDA) take selenium bioavailability into consideration (22). However, data on selenium bioavailability to humans is sparse. Therefore, the selenium bioavailability of different food groups in the RDA is tentative.

Food frequency questionnaires (FFQ) are designed to measure average long-term diet (23), which is important for assessing the relationship between nutrition

and chronic disease. The reproducibility and validity of such questionnaires has been examined in a number of studies (24–27). The simple food frequency questionnaire (SFFQ) was developed to estimate dietary selenium intake for different food groups (21). By using the SFFQ to determine the frequency of consumption in combination with other methods to quantify portion sizes, it is possible to estimate average dietary selenium intake over the long-term.

In the present study, we conducted the SFFQ and some additional nutrition surveys by interview in two rural communities in Japan with different geographies, climates, and industries. One was Ohasama, which is a mountain community, and the other was Nishiizu, which is a coastal community. We estimated selenium intakes by food groups in the two districts with the SFFQ, and assessed the regional characteristics in the food consumption pattern, and dietary selenium intakes.

SUBJECTS AND METHODS

Survey site

Ohasama is a mountain community, situated in central Iwate Prefecture. It is about 80 km from the Sanriku-coast (Fig.1), and is situated on the road from the Sanriku-coast to Morioka city, the capital of Iwate prefecture. The area of this district is 246.61 km², 80% of

Fig. 1. Map of Japan showing where Ohasama town and the Nishiizu district are located.

which is forested mountains. The total population of Ohasama was 6,949, in 2000. About 28.4% of the adult population works in agriculture and forestry, 32.9% works in factories, and 38.7% works in offices. As of 2000, the major causes of death were cancer, cardiac disease, and cerebrovascular disease (CVD). Mortality due to cancer, cardiac disease, and CVD among the residents was 359.8, 244.6, 187.1 (per 100,000), respectively.

The Nishiizu district includes two rural communities: Nishiizu town (65.88 km²) and Kamo village (39.64 km²). These neighboring communities are situated on the west coast of the Izu Peninsula in Shizuoka prefecture (Fig.1). Most (84%) of the Nishiizu district is forested. In 2000, the total populations of Nishiizu town and Kamo village were 7,747, and 3,521 respectively. About 9.0% of the adult population works in agriculture and fishing, 26.1% works in factories, construction, and the mining industry, and 64.8% works in service industries and businesses. Previously, the key industry was fishing, but more recently the tourist industry has become the major source of employment in this area. As of 2000, the major causes of death were cancer, cardiac disease, and CVD. Mortality due to cancer, cardiac disease, and CVD among the residents was 337.2, 275.1, 159.7 (per 100,000), respectively.

Subjects

In Ohasama, we interviewed 102 men and 140 women aged 40–69 y. These subjects were selected from participants in a health examination conducted by the government of Ohasama town in 1998, 1999, and 2000. The participants were stratified by sex and age group in each year, and the subjects were randomly selected from each stratum, respectively. The distribution of subjects was 88 (in 1998), 67 (in 1999), 87 (in 2000), and combined data for each year were used. In Nishiizu, we interviewed 55 men aged 44–76 y and 71 women aged 32–80 y. These subjects participated in a health examination conducted by the government of Nishiizu town and Kamo village in 2000 and volunteered for this study. All subjects gave their signed informed consent.

We excluded eight subjects from analysis for blank on the SFFQ. We also excluded two subjects under the age of 40 and 1 subject of over 80 years. A total of 357 subjects were included in the analysis.

Table 1. Frequency categories and their values converted to daily intake rate.

Major food groups		Vegetables	
Stated frequency	Value (times/d)	Stated frequency	Value (times/d)
Twice or more per day	2.00	Two or three times per day	3.00
Once per day	1.00	Twice a day	2.00
Once every two days	0.50	Once a day	1.00
Once or twice a week	0.14	Once every two days	0.50
Once or twice a month/almost never	0.04	Once or twice a week/almost never	0.14

Table 2. Cereal eating habits and the estimated equivalent daily intake rates.

Cereal eating habits		Value (times/day)	
Rice	Wheat products	Rice	Wheat products
Almost only rice	Less than once or twice a month	3.0	0.0
Almost only rice	Once or twice a week.	2.7	0.3
The rest is rice	Once every two days	2.5	0.5
The rest is rice	Once a day	2.0	1.0
The rest is rice	Twice or more a day	1.0	2.0

Dietary assessment

Subjects answered the SFFQ by interview. The questionnaire included twelve food group items, and subjects indicated their average frequency of consumption of each item over the past year. The food list consisted of cereals, fish, meat, eggs, soybean products, vegetables, seaweed, milk and dairy products, fruits, wheat products as snacks between meals, cakes and candies, juice and soft drinks with sugar. Questions relating to the intake frequency of major food group items (excluding cereals and vegetables) included five frequency categories from twice or more per day to once or twice a month/almost never (Table 1). The responses were converted into frequencies as daily intake rate (Table 1). For vegetables, the possible responses and frequencies were slightly different (Table 1). For cereals, the frequency of consumption of rice was asked separately from the consumption of wheat products, because the selenium contents in rice and wheat are considerably different. The possible responses and the corresponding frequencies are shown in Table 2.

In Ohasama and Nishiizu, at the same time of the SFFQ, the subjects were shown actual-sized pictures of food items and asked what they ate and the quantity of each food. The same photos were shown in each community. In Ohasama, the subjects were asked to base answers on what they ate the previous day (24-h dietary recall method), while later in Nishiizu, they were asked to base answers on what they usually ate. The averaged consumption of each food item in each community was used as the mean portion size. The daily consumption of each food item was calculated from the mean portion size and daily intake rate.

Daily selenium intake was the sum of the products of the selenium content, the mean portion size, and the daily intake rate of each food (i.e., $\sum(\text{selenium content} \times \text{mean portion size} \times \text{daily intake rate})$). The food groups of the major dietary selenium sources (21) were used for the estimation. The selenium content of each food group was obtained from the selenium content of food-stuffs measured by Koyama et al. (28). Selenium concentrations in the diet were determined fluorometrically by 2,3-diaminonaphthalene with a spectro-fluorometer (Type 821-FP; Japan Spectroscopic Co., Ltd., Tokyo) after digestion in nitric acid and perchloric acid as described by Watkinson (29). Bovine serum SRM1598 and bovine liver 1577a, produced by NIST (National

Table 3. The selenium content of main food groups.

Food item	Selenium content ($\mu\text{g/g}$)
Boiled rice	0.0090
Wheat products	0.0610
Fish	0.6287
Meat	0.6360
Egg	0.5640

Institute of Standards and Technology, Gaithersburg, MD), was used as a reference material to validate the selenium measurement (28). The selenium contents of main food items are shown in Table 3.

To determine the range of selenium intakes among different individuals, the individual portion size, which was not averaged, was also used for estimation in Nishiizu. For this estimation, the daily intake rate of cereals was modified when subjects took two servings per day.

Statistical analysis

The Mann-Whitney U test was used to determine the differences in the frequency of each food item on the SFFQ between the two districts. The significance level was set at $p < 0.05$. The analyses were performed using SPSS for Windows (version 11).

RESULTS

The intake frequencies of rice and wheat products as staple foods in Ohasama and Nishiizu are shown in Table 4. Mean of daily intake rate of rice in Ohasama and Nishiizu was 2.77 and 2.46, respectively. Mean of daily intake rate of wheat products in Ohasama and Nishiizu was 0.24 and 0.54, respectively. There was a significant difference in the intake frequencies of rice and wheat products between the two districts by the Mann-Whitney U test ($p = 0.000$). Rice was more frequently consumed in Ohasama, and wheat products were more frequently consumed in Nishiizu.

The intake frequencies of other food items are shown in Tables 5 (a)–(c). When the data for all subjects in a community were combined, the frequencies of consumption of soybean products, vegetables, seaweed, cakes and candies, juice and soft drinks with sugar were significantly greater in Ohasama, and the frequency of consumption of fruits was greater in Nishiizu. The intake frequencies for fish, meat, eggs, milk and dairy

Table 4. Comparison of food frequency of cereals as staple foods between two districts, Ohasama and Nishiizu (all subjects).

	District	n	Mean of daily intake rate		Frequency categories ^a					p value ^b
			Rice	Wheat products	1	2	3	4	5	
All subjects	Ohasama	234	2.77	0.24	117 (50.0%)	75 (32.1%)	21 (9.0%)	20 (8.5%)	1 (0.4%)	0.000
	Nishiizu	123	2.46	0.54	35 (28.5%)	35 (28.5%)	9 (7.3%)	36 (29.3%)	8 (6.5%)	
Males	Ohasama	98	2.81	0.19	55 (56.1%)	28 (28.6%)	9 (9.2%)	6 (6.1%)	0 (0.0%)	0.002
	Nishiizu	55	2.52	0.48	20 (36.4%)	16 (29.1%)	3 (5.5%)	12 (21.8%)	4 (7.3%)	
Females	Ohasama	136	2.73	0.27	62 (45.6%)	47 (34.6%)	12 (8.8%)	14 (10.3%)	1 (0.7%)	0.000
	Nishiizu	68	2.40	0.60	15 (22.1%)	19 (27.9%)	6 (8.8%)	24 (35.3%)	4 (5.9%)	

^a Frequency categories were as follows (cf. Table 2). 1: Almost only rice, and wheat products are less than once or twice a month. 2: Almost rice, and wheat products are once or twice a week. 3: Wheat products are once every two days and the rest is rice. 4: Wheat products are once a day and the rest is rice. 5: Wheat products are twice or more a day and the rest is rice.

^b The Mann-Whitney U test was used.

Table 5. Comparison of food frequency between two districts, Ohasama and Nishiizu.

(a) All subjects

Food group item	District	n	Mean of daily intake rate	Food frequency categories					p value ^b
				1	2	3	4	5	
				Twice or more per day	Once per day	Once every two days	Once or twice a week	Once or twice a month/almost never	
Fish	Ohasama	234	1.01	43 (18.4%)	123 (52.6%)	52 (22.2%)	15 (6.4%)	1 (0.4%)	0.144
	Nishiizu	123	0.97	31 (25.2%)	39 (31.7%)	31 (25.2%)	21 (17.1%)	1 (0.8%)	
Meat	Ohasama	234	0.36	1 (0.4%)	30 (12.8%)	71 (30.3%)	106 (45.3%)	26 (11.1%)	0.575
	Nishiizu	123	0.36	3 (2.4%)	11 (8.9%)	36 (29.3%)	58 (47.2%)	15 (12.2%)	
Eggs	Ohasama	234	0.59	6 (2.6%)	75 (32.1%)	88 (37.6%)	52 (22.2%)	13 (5.6%)	0.246
	Nishiizu	123	0.56	5 (4.1%)	36 (29.3%)	34 (27.6%)	41 (33.3%)	7 (5.7%)	
Soybean products	Ohasama	234	1.27	87 (37.2%)	105 (44.9%)	31 (13.2%)	11 (4.7%)	0 (0%)	0.000
	Nishiizu	123	0.71	13 (10.6%)	38 (30.9%)	39 (31.7%)	28 (22.8%)	5 (4.1%)	
Vegetables ^a	Ohasama	234	2.58	151 (64.5%)	69 (29.5%)	11 (4.7%)	2 (0.9%)	1 (0.4%)	0.001
	Nishiizu	123	2.24	62 (50.4%)	33 (26.8%)	20 (16.3%)	7 (5.7%)	1 (0.8%)	
Seaweed	Ohasama	234	0.70	13 (5.6%)	82 (35.0%)	98 (41.9%)	41 (17.5%)	0 (0%)	0.003
	Nishiizu	123	0.58	6 (4.9%)	32 (26.0%)	44 (35.8%)	36 (29.3%)	5 (4.1%)	
Milk & dairy products	Ohasama	234	0.90	42 (17.9%)	106 (45.3%)	31 (13.2%)	38 (16.2%)	17 (7.3%)	0.528
	Nishiizu	123	0.87	23 (18.7%)	51 (41.5%)	12 (9.8%)	25 (20.3%)	12 (9.8%)	
Fruits	Ohasama	234	0.71	24 (10.3%)	81 (34.6%)	53 (22.6%)	65 (27.8%)	11 (4.7%)	0.001
	Nishiizu	123	0.89	18 (14.6%)	56 (45.5%)	29 (23.6%)	18 (14.6%)	2 (1.6%)	
Wheat products as snacks between meals	Ohasama	234	0.24	3 (1.3%)	26 (11.1%)	21 (9.0%)	55 (23.5%)	129 (55.1%)	0.660
	Nishiizu	123	0.22	0 (0%)	12 (9.8%)	15 (12.2%)	33 (26.8%)	63 (51.2%)	
Cakes & candies	Ohasama	234	0.75	34 (14.5%)	85 (36.3%)	30 (12.8%)	42 (17.9%)	43 (18.4%)	0.002
	Nishiizu	123	0.55	10 (8.1%)	35 (28.5%)	15 (12.2%)	24 (19.5%)	39 (31.7%)	
Juice & soft drinks with sugar	Ohasama	234	0.78	56 (23.9%)	52 (22.2%)	21 (9.0%)	44 (18.8%)	61 (26.1%)	0.000
	Nishiizu	123	0.52	18 (14.6%)	18 (14.6%)	10 (8.1%)	21 (17.1%)	56 (45.5%)	

products, and wheat products as snacks were not significantly different. Among males, significant differences in intake frequency were found for soybean products, vegetables, seaweed, cakes and candies, juice and soft drinks with sugar. These food items were consumed more frequently in Ohasama. Among females, significant differences in intake frequency were found for soybean products, vegetables, fruits, cakes and candies, juice and soft drinks with sugar. These food items,

except fruits, were consumed more frequently in Ohasama.

Estimations of daily consumption of the main food items and selenium intakes in Ohasama and in Nishiizu are shown in Tables 6 (a), (b). In Ohasama, the mean daily total selenium intake in males and in females was 96.3 $\mu\text{g}/\text{d}$ and 72.9 $\mu\text{g}/\text{d}$, respectively. In Nishiizu, the mean daily total selenium intake in males and in females was 125.1 $\mu\text{g}/\text{d}$ and 112.3 $\mu\text{g}/\text{d}$, respectively.

(b) Males

Food group item	District	n	Mean of daily intake rate	Food frequency categories					p value ^b
				1	2	3	4	5	
				Twice or more per day	Once per day	Once every two days	Once or twice a week	Once or twice a month/almost never	
Fish	Ohasama	98	1.09	26 (26.5%)	45 (45.9%)	17 (17.3%)	9 (9.2%)	1 (1.0%)	0.365
	Nishiizu	55	1.01	15 (27.3%)	19 (34.5%)	11 (20.0%)	9 (16.4%)	1 (1.8%)	
Meat	Ohasama	98	0.36	1 (1.0%)	11 (11.2%)	31 (31.6%)	48 (49.0%)	7 (7.1%)	0.077
	Nishiizu	55	0.30	1 (1.8%)	4 (7.3%)	12 (21.8%)	30 (54.5%)	8 (14.5%)	
Eggs	Ohasama	98	0.63	5 (5.1%)	32 (32.7%)	32 (32.7%)	24 (24.5%)	5 (5.1%)	0.100
	Nishiizu	55	0.52	2 (3.6%)	14 (25.5%)	15 (27.3%)	19 (34.5%)	5 (9.1%)	
Soybean products	Ohasama	98	1.27	40 (40.8%)	35 (35.7%)	16 (16.3%)	7 (7.1%)	0 (0%)	0.000
	Nishiizu	55	0.62	4 (7.3%)	16 (29.1%)	15 (27.3%)	17 (30.9%)	3 (5.5%)	
Vegetables ^a	Ohasama	98	2.55	65 (66.3%)	24 (24.5%)	6 (6.1%)	2 (2.0%)	1 (1.0%)	0.009
	Nishiizu	55	2.14	27 (49.1%)	12 (21.8%)	10 (18.2%)	5 (9.1%)	1 (1.8%)	
Seaweed	Ohasama	98	0.74	9 (9.2%)	35 (35.7%)	34 (34.7%)	20 (20.4%)	0 (0%)	0.021
	Nishiizu	55	0.56	2 (3.6%)	14 (25.5%)	21 (38.2%)	15 (27.3%)	3 (5.5%)	
Milk & dairy products	Ohasama	98	0.84	19 (19.4%)	34 (34.7%)	14 (14.3%)	19 (19.4%)	12 (12.2%)	0.507
	Nishiizu	55	0.75	8 (14.5%)	21 (38.2%)	4 (7.3%)	15 (27.3%)	7 (12.7%)	
Fruits	Ohasama	98	0.67	10 (10.2%)	33 (33.7%)	16 (16.3%)	32 (32.7%)	7 (7.1%)	0.063
	Nishiizu	55	0.79	5 (9.1%)	24 (43.6%)	16 (29.1%)	10 (18.2%)	0 (0%)	
Wheat products as snacks between meals	Ohasama	98	0.23	0 (0%)	13 (13.3%)	8 (8.2%)	26 (26.5%)	51 (52.0%)	0.706
	Nishiizu	55	0.20	0 (0%)	5 (9.1%)	6 (10.9%)	14 (25.5%)	30 (54.5%)	
Cakes & candies	Ohasama	98	0.58	10 (10.2%)	24 (24.5%)	18 (18.4%)	19 (19.4%)	27 (27.6%)	0.032
	Nishiizu	55	0.42	4 (7.3%)	11 (20.0%)	3 (5.5%)	12 (21.8%)	25 (45.5%)	
Juice & soft drinks with sugar	Ohasama	98	1.01	35 (35.7%)	24 (24.5%)	5 (5.1%)	16 (16.3%)	18 (18.4%)	0.010
	Nishiizu	55	0.68	13 (23.6%)	7 (12.7%)	3 (5.5%)	14 (25.5%)	18 (32.7%)	

(c) Females

Food group item	District	n	Mean of daily intake rate	Food frequency categories					p value ^b
				1	2	3	4	5	
				Twice or more per day	Once per day	Once every two days	Once or twice a week	Once or twice a month/almost never	
Fish	Ohasama	136	0.96	17 (12.5%)	78 (57.4%)	35 (25.7%)	6 (4.4%)	0 (0%)	0.196
	Nishiizu	68	0.94	16 (23.5%)	20 (29.4%)	20 (29.4%)	12 (17.6%)	0 (0%)	
Meat	Ohasama	136	0.35	0 (0%)	19 (14.0%)	40 (29.4%)	58 (42.6%)	19 (14.0%)	0.468
	Nishiizu	68	0.40	2 (2.9%)	7 (10.3%)	24 (35.3%)	28 (41.2%)	7 (10.3%)	
Eggs	Ohasama	136	0.57	1 (0.7%)	43 (31.6%)	56 (41.2%)	28 (20.6%)	8 (5.9%)	0.974
	Nishiizu	68	0.60	3 (4.4%)	22 (32.4%)	19 (27.9%)	22 (32.4%)	2 (2.9%)	
Soybean products	Ohasama	136	1.27	47 (34.6%)	70 (51.5%)	15 (11.0%)	4 (2.9%)	0 (0%)	0.000
	Nishiizu	68	0.79	9 (13.2%)	22 (32.4%)	24 (35.3%)	11 (16.2%)	2 (2.9%)	
Vegetables ^a	Ohasama	136	2.60	86 (63.2%)	45 (33.1%)	5 (3.7%)	0 (0%)	0 (0%)	0.027
	Nishiizu	68	2.32	35 (51.5%)	21 (30.9%)	10 (14.7%)	2 (2.9%)	0 (0%)	
Seaweed	Ohasama	136	0.66	4 (2.9%)	47 (34.6%)	64 (47.1%)	21 (15.4%)	0 (0%)	0.062
	Nishiizu	68	0.60	4 (5.9%)	18 (26.5%)	23 (33.8%)	21 (30.9%)	2 (2.9%)	
Milk & dairy products	Ohasama	136	0.95	23 (16.9%)	72 (52.9%)	17 (12.5%)	19 (14.0%)	5 (3.7%)	0.937
	Nishiizu	68	0.96	15 (22.1%)	30 (44.1%)	8 (11.8%)	10 (14.7%)	5 (7.4%)	
Fruits	Ohasama	136	0.73	14 (10.3%)	48 (35.3%)	37 (27.2%)	33 (24.3%)	4 (2.9%)	0.005
	Nishiizu	68	0.97	13 (19.1%)	32 (47.1%)	13 (19.1%)	8 (11.8%)	2 (2.9%)	
Wheat products as snacks between meals	Ohasama	136	0.24	3 (2.2%)	13 (9.6%)	13 (9.6%)	29 (21.3%)	78 (57.4%)	0.364
	Nishiizu	68	0.23	0 (0%)	7 (10.3%)	9 (13.2%)	19 (27.9%)	33 (48.5%)	
Cakes & candies	Ohasama	136	0.87	24 (17.6%)	61 (44.9%)	12 (8.8%)	23 (16.9%)	16 (11.8%)	0.013
	Nishiizu	68	0.65	6 (8.8%)	24 (35.3%)	12 (17.6%)	12 (17.6%)	14 (20.6%)	
Juice & soft drinks with sugar	Ohasama	136	0.62	21 (15.4%)	28 (20.6%)	16 (11.8%)	28 (20.6%)	43 (31.6%)	0.003
	Nishiizu	68	0.40	5 (7.4%)	11 (16.2%)	7 (10.3%)	7 (10.3%)	38 (55.9%)	

^a Frequency categories of vegetables are as follows; 1: two or three times per day, 2: twice a day, 3: once a day, 4: once every two days, 5: once or twice a week/almost never (cf. Table1).

^b The Mann-Whitney U test was used.

Table 6. (a) Estimation of daily consumption of the main food item and selenium intakes in Ohasama.

Food item	Mean of daily intake rate	Mean portion size (g)	Mean daily consumption (g)	Mean selenium intakes (μg)
Males ($n=98$)				
Boiled rice	2.81	260.7	731.9	6.6
Wheat products as staple foods	0.19	224.0	43.2	2.6
Wheat products as snacks between meals	0.23	71.9	16.6	1.0
Fish	1.09	68.8	75.0	47.2
Meat	0.36	76.5	27.7	17.6
Eggs ^b	0.63	60.0	37.7	21.3
Daily total				96.3
Females ($n=136$)				
Boiled rice	2.73	172.1	470.6	4.2
Wheat products as staple foods	0.27	141.7	37.6	2.3
Wheat products as snacks between meals	0.24	55.4	13.3	0.8
Fish	0.96	57.6	55.2	34.7
Meat	0.35	51.9	18.3	11.6
Eggs ^b	0.57	60.0	34.1	19.2
Daily total				72.9

^a Mean portion size was derived from the 24 h recall method. ^b One egg was estimated as 60 g.

(b) Estimation of daily consumption of the main food item and selenium intakes in Nishiizu.

Food item	Mean of daily intake rate	Mean portion size (g)	Mean daily consumption (g)	Mean selenium intakes (μg)
Males ($n=55$)				
Boiled rice	2.52	161.6	407.6	3.7
Wheat products as staple foods	0.48	190.9	91.3	5.6
Wheat products as snacks between meals	0.20	114.8	23.3	1.4
Fish	1.01	122.4	124.1	78.0
Meat	0.30	98.9	29.7	18.9
Eggs ^b	0.52	60.0	30.9	17.4
Daily total				125.1
Females ($n=68$)				
Boiled rice	2.40	112.1	269.1	2.4
Wheat products as staple foods	0.60	164.4	98.4	6.0
Wheat products as snacks between meals	0.23	104.2	23.7	1.4
Fish	0.94	101.9	95.4	60.0
Meat	0.40	87.4	35.0	22.2
Eggs ^b	0.60	60.0	35.9	20.2
Daily total				112.3

^a Mean portion size was estimated from the usual average portion size. ^b One egg was estimated as 60 g.

Dietary selenium intakes estimated using the SFFQ and the mean portion size in Ohasama are shown in Table 7 (a). When the data for all subjects in a community were combined, the mean daily total selenium intake was $82.7 \mu\text{g/d}$ (range 19.2 – $180.1 \mu\text{g/d}$). The major selenium source was fish, which accounted for 48.2% of the daily total, followed by eggs (24.3%) and meat (17.0%). The contributions of rice and wheat products to daily total selenium intake were 6.3% and 4.0%, respectively.

Dietary selenium intakes estimated using the SFFQ and the mean portion size in Nishiizu is shown in Table 7 (b). When the data for all subjects in a community were combined, the mean daily total selenium intake

was $118.0 \mu\text{g/d}$ (range 22.6 – $255.3 \mu\text{g/d}$). The major selenium source was fish, which accounted for 57.7% of the daily total, followed by meat (17.5%), eggs (16.1%). The contributions of rice and wheat products to daily total selenium intake were 2.5% and 6.1%, respectively.

Dietary selenium intakes estimated using the SFFQ and the individual portion sizes in Nishiizu are shown in Table 7 (c). When the data for all subjects in a community were combined, the mean daily total selenium intake was $123.5 \mu\text{g/d}$ (range 22.4 – $422.2 \mu\text{g/d}$). The major selenium source was fish, which accounted for 58.1% of the daily total, followed by meat (19.1%), eggs (15.2%). The contributions of rice and wheat products

Table 7.

(a) Dietary selenium intakes estimated using the Simple Food Frequency Questionnaire and mean portion size in Ohasama ($\mu\text{g}/\text{d}$).

	<i>n</i>	Mean	SD	Min.–Max.	Median	Percent of daily total
All subjects	234					
Fish		39.9	22.5	1.7–86.6	36.2	48.2%
Eggs		20.1	14.0	1.4–67.7	16.9	24.3%
Meat		14.1	13.5	1.3–97.3	6.8	17.0%
Rice		5.2	1.3	1.6–7.0	4.6	6.3%
Wheat products		3.3	3.4	0.1–20.7	2.7	4.0%
Daily total		82.7	32.9	19.2–180.1	79.5	100.0%
Males	98					
Fish		47.2	26.7	1.7–86.6	43.3	49.0%
Eggs		21.3	16.0	1.4–67.7	16.9	22.1%
Meat		17.6	16.3	2.0–97.3	6.8	18.3%
Rice		6.6	0.6	4.7–7.0	7.0	6.9%
Wheat products		3.7	3.9	0.2–15.9	4.3	3.8%
Daily total		96.3	36.2	20.0–180.1	95.5	100.0%
Females	136					
Fish		34.7	17.1	5.1–72.5	36.2	47.6%
Eggs		19.2	12.3	1.4–67.7	16.9	26.3%
Meat		11.6	10.4	1.3–33.0	4.6	15.9%
Rice		4.2	0.5	1.6–4.7	4.2	5.8%
Wheat products		3.1	3.1	0.1–20.7	2.7	4.3%
Daily total		72.9	26.3	19.2–149.5	65.8	100.0%

(b) Dietary selenium intakes estimated using the Simple Food Frequency Questionnaire and mean portion size in Nishiizu ($\mu\text{g}/\text{d}$).

	<i>n</i>	Mean	SD	Min.–Max.	Median	Percent of daily total
All subjects	123					
Fish		68.1	48.0	3.1–153.9	64.0	57.7%
Eggs		19.0	15.8	1.4–67.7	16.9	16.1%
Meat		20.7	22.1	2.2–125.9	8.8	17.5%
Rice		3.0	0.9	1.0–4.4	2.9	2.5%
Wheat products		7.2	6.2	0.3–26.4	5.3	6.1%
Daily total		118.0	57.8	22.6–255.3	110.4	100.0%
Males	55					
Fish		78.0	52.7	3.1–153.9	76.9	62.4%
Eggs		17.4	15.6	1.4–67.7	16.9	13.9%
Meat		18.9	22.1	2.5–125.9	8.8	15.1%
Rice		3.7	0.8	1.5–4.4	3.9	2.9%
Wheat products		7.0	6.7	0.3–24.3	4.5	5.6%
Daily total		125.1	60.0	29.7–255.3	121.5	100.0%
Females	68					
Fish		60.0	42.6	9.0–128.1	64.0	53.4%
Eggs		20.2	15.9	1.4–67.7	16.9	18.0%
Meat		22.2	22.2	2.2–111.2	7.8	19.8%
Rice		2.4	0.5	1.0–3.0	2.6	2.1%
Wheat products		7.4	5.8	0.3–26.4	6.2	6.6%
Daily total		112.3	55.7	22.6–230.4	105.0	100.0%

were 2.3% and 5.2%, respectively.

DISCUSSION

The mean dietary intake of selenium estimated in this study was similar to the values reported by Otsuka (20), and Koyama (21). It was two or three times higher than the normative requirement (the lower limits of the safe

range) estimated by the WHO (4). According to the WHO, the normative requirement is 40 $\mu\text{g}/\text{d}$ for males and 30 $\mu\text{g}/\text{d}$ for females (aged 18 y and over). Our estimates of dietary intake of selenium also exceeded the Japanese RDA (22), which is 45–55 $\mu\text{g}/\text{d}$ for males and 40–45 $\mu\text{g}/\text{d}$ for females (aged 30 y and over). However, the range of daily selenium intakes estimated by the

(c) Dietary selenium intakes estimated using the Simple Food Frequency Questionnaire and the individual portion size in Nishiizu ($\mu\text{g/d}$).

	<i>n</i>	Mean	SD	Min.–Max.	Median	Percent of daily total
All subjects	123					
Fish		71.8	69.9	2.2–330.7	55.0	58.1%
Eggs		18.8	15.8	1.4–67.7	16.9	15.2%
Meat		23.6	35.8	0.0–232.8	8.1	19.1%
Rice		2.9	1.5	0.5–8.1	2.7	2.3%
Wheat products		6.4	6.2	0.0–28.1	4.6	5.2%
Daily total		123.5	80.1	22.4–422.2	100.0	100.0%
Males	55					
Fish		84.8	82.7	2.2–330.7	55.0	63.4%
Eggs		16.9	15.5	1.4–67.7	16.9	12.6%
Meat		22.3	37.7	0.0–232.8	8.1	16.7%
Rice		3.7	1.8	0.9–8.1	3.6	2.8%
Wheat products		6.1	6.6	0.0–24.9	3.7	4.6%
Daily total		133.7	90.0	22.7–337.1	109.1	100.0%
Females	68					
Fish		61.3	56.1	4.0–264.1	47.2	53.2%
Eggs		20.2	15.9	1.4–67.7	16.9	17.5%
Meat		24.6	34.5	0.0–190.8	12.0	21.4%
Rice		2.4	0.8	0.5–4.1	2.4	2.1%
Wheat products		6.7	5.9	0.0–28.1	6.3	5.8%
Daily total		115.2	71.8	22.4–422.2	98.2	100.0%

SFFQ was large, and selenium intake was low in some subjects.

As shown in Tables 6 (a) and (b), the mean portion size of food items, except eggs, was different between the two districts. It is not clear whether these differences were related to the different method of obtaining portion size or the dietary habit in the two districts. In Ohasama, the 24-h dietary recall method was used to obtain mean portion size. This method can accommodate any level of food description detail, and serves important functions in describing mean values for groups (23). In Nishiizu, subjects were asked the usual portion size. This change in protocol, for portion size information in this study, was made because it was thought to estimate not only portion size as the group mean value, but also individual portion size in Nishiizu. To consider the individual average long-term diet, the usual portion size may be better, because the 24-h dietary recall method depends on the previous day's diet. However, it is possible with both methods to assess group averages.

When individual portion size was used as the amount in Nishiizu, the range of selenium intakes was large. However, the mean of the selenium intakes was not different so much in the use of the mean or individual portion size. This result shows that the food consumption pattern varies among individuals. Selenium intake would probably be low in people who consumed very little fish, meat and eggs. It is not sufficient to estimate the mean value, but it is important to know the dispersion of selenium intakes.

By comparing of the intake frequencies of food items on the SFFQ between Ohasama and Nishiizu, the intake frequencies of fish, meat, and eggs, which are rich in

selenium, were not seen to be significantly different. However, the intake frequencies of rice and wheat products were significantly different. The intake frequency of boiled rice was higher in Ohasama than in Nishiizu and the intake frequency of wheat products was lower in Ohasama than in Nishiizu. These differences may be related to regional dietary habits.

The mean selenium intakes were not comparable because of the different methods used to obtain mean portion size, however, the difference in frequency and portion size is reflected in the contribution of rice and wheat products to dietary selenium intake. That is, the contribution of rice to daily selenium intake was greater than the contribution of wheat products to daily selenium intake in Ohasama, and the reverse tendency was observed in Nishiizu.

The mean selenium intake from rice was almost the same in spite of the use of the mean or individual portion size in Nishiizu, and the range of selenium intake from rice was smaller than the range of selenium intake from wheat products. This suggests that rice consumption is less variable than wheat consumption among individual Japanese.

Rice and wheat products made small contributions to dietary selenium intake in both districts, and the values estimated in this study were similar to the values obtained by Otsuka (7.7%) (20) and Koyama (5–11%) (21). The proportion of selenium intake that is derived from cereals varies considerably among countries (4, 5, 30–33), and depends on the content of selenium in the soil, which affects the selenium contents in plants. The mean of selenium content in Japanese rice is 43 ng/g (range 11–182 ng/g) (34). For comparison, wheat, which is processed into bread and noodles in Japan, and

which is imported almost entirely from North America, contains 0.30–0.82 $\mu\text{g/g}$ of selenium (35). The low value in rice in Japan is probably due to the soil chemistry.

Even though Ohasama is situated far from the coast, the intake frequency of fish was not significantly different from that at Nishiizu. The contributions of fish to dietary selenium were high in both districts, and were similar to the values reported by Otsuka (55.5%) (20) and Koyama (50–60%) (21).

Levels of selenium in fish are comparatively higher than in other foodstuffs. Though measured values of selenium content in fish demonstrate some range by species, these values do not remarkably differ. Suzuki et al. showed values used for the estimation of selenium intake as 0.875 $\mu\text{g/g}$ (tuna); 0.4 $\mu\text{g/g}$ (flounder); 0.3 $\mu\text{g/g}$ (sardine); 0.163 $\mu\text{g/g}$ (salmon); 0.3 $\mu\text{g/g}$ (others) (19). The value of selenium content in fish used for the estimation of selenium intake in this study is within the previously reported range, and is nearly the medium value for the selenium content of fish.

Levels of selenium in other foodstuffs shown by Suzuki et al. are as 0.104–0.273 $\mu\text{g/g}$ (meat); 0.447 $\mu\text{g/g}$ (eggs); 0.0148 $\mu\text{g/g}$ (rice); 0.15 $\mu\text{g/g}$ (bread); 0.30 $\mu\text{g/g}$ (noodles) (19). Levels of selenium in meat cereals used in the estimation of selenium intake in this study are slightly lower than these values, eggs and meat are slightly higher. Such variation in the reported values would be due to some reason, for example, the district producing the foodstuffs.

One limitation of this study is that the estimated selenium intake value depends upon the food frequency, portion size, and selenium contents in food groups. It should be carefully considered that the estimated selenium intakes were affected by these values. Further studies, for example, duplicating meal analysis in each district, would be informative for selenium contents and estimation of selenium intakes.

Because fish is a major selenium source in the Japanese diet, the bioavailability of fish selenium is important. Studies have shown marked differences in the ability of selenium from fish to increase selenium status. Some animal studies have shown that the bioavailability of selenium in fish is less than that in wheat (36–39). However, selenium from flounder and tuna was found to be more efficient than selenium from other meats at restoring liver glutathione peroxidase activity (40).

Very few selenium bioavailability studies have been conducted with humans. An increased consumption of fish increases plasma selenium concentration, but not the plasma level of glutathione peroxidase or Selenoprotein-P (41). The glutathione peroxidase activities in plasma and erythrocytes were not influenced by shrimp intake (42). In Norwegians, serum and platelet selenium levels were consistently raised by consumption of wheat, but only slightly raised by consumption of fish (43). These findings indicate that the bioavailability of selenium from fish is relatively low in humans. However, selenium from fish intake has been reported to

have a marked impact on selenium status in humans (44). The chemical form of selenium in fish is not known, and the reason for the low selenium bioavailability in certain fish is not clear. A possible explanation for low selenium bioavailability in certain fish is that the selenium might combine with other heavy metals, especially mercury, in these fish (5, 45).

Wheat selenium is reported to have a high bioavailability, and cereals are an important selenium source in humans (43, 46). A greater intake of selenium from cereals may be important for optimal selenium status among the Japanese.

The Japanese RDA assumes that 30% of dietary selenium is derived from cereals, and that the bioavailability of selenium is 90% in cereals and 50% in all other foods, resulting in an overall nutritional availability of dietary selenium of 60% (90% of 30% + 50% of 70%) (22). However, because of the low contribution of cereals and the high contribution of fish to selenium intake in the Japanese diet, the nutritional availability of dietary selenium might be lower than the above estimate. Further studies of selenium intake that consider the dietary habits of the Japanese population are needed to estimate the optimal selenium intake.

Acknowledgments

We thank Ayano Kariya, Nao Kondo, Aiko Morizono, Yuki Kaneko, Naoko Hosokawa, Yuko Miyairi (Gunma University) for their assistance with the dietary survey. We are also grateful to the subjects for their willing cooperation.

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