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Daily Intake of Metals by Females in Osaka, Japan

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Recent remarkable progress in analytical chemistry has made it possible to quantitatively determine trace elements which could not be analyzed by conventional means (Maitani 1986). Under these circumstances, relationships between trace elements and living organisms have intensely attracted public attention. It is known that the incorporation of dietary metals in food for human consumption would be affected by the chemical form of each element, substances present together with them, and interactions among inorganic elements. It should be noted that a trace amount of selenium taken from foods would form an inactive complex together with a toxic heavy metal compound so as to suppress the expression of the toxicity of said heavy metal (Naganuma 1983).

To evaluate the safety and to compare recommended daily intake of food of humans, it is important to know the amounts of metals taken in from their daily diet. Thus, we examined the diets of 25 female adults living in Osaka, Japan thrice, namely, 75 samples in total, by the duplicate portion method, and determined daily dietary intake of 22 metal elements contained in these samples.

MATERIALS AND METHODS

Daily diets of 25 females 25-54 years of age from Osaka, Japan were measured on July 6, 1986, November 9, 1986 and August 9, 1987 for a total of 75 samples. The metals Hg, V, Co, Cd, Pb, Cr, Se, Mo, Ni, Ba, As, Cu, Sr, Al, Mn, Zn, Fe, Mg, Ca, P, K and Na were determined in these diets.

Standard solutions for analysis of Hg, V, Co, Cd, Pb, Cr, Se, Mo, Ni, Ba, Cu, Sr, Al, Mn, Zn, Fe, Mg, Ca, K and Na were obtained from Wako Pure Chemical Industries. Phosphorus standard was prepared from potassium dihydrogen phosphate; 43.9 g was weighed and dissolved in 0.5N nitric acid to make 1000 ml (P : 10000 ppm stock solution). Arsenic standard was prepared by dissolving 0.100 g anhydrous arsenous in 20 % sodium hydroxide solution (5 ml), then about 400 ml of water was added and the solution was

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neutralized with 10 % sulfuric acid. A further 10 ml of 10 % sulfuric acid was added, followed by water to make 1000 ml. This was used as stock solution of 100 ppm.

The total weight of breakfast, lunch, supper and snack eaten by each female was measured and blended thoroughly in a mixer so as to give a sample for analysis. When a sample contained less water, a calculated amount of water was added followed by mixing. A predetermined amount of a sample was freeze dried (Labconco, type FD 5) and then ashed in a low temperature asher (International Plasma Corporation, type 1101 B, USA). Ash was then dissolved in 0.5 N nitric acid so as to give a sample solution ; thus, 75 samples were prepared.

Mercury was measured by the reduction vaporizing method (Tanaka et al. 1974). Selenium was measured by wet-ashing with the use of nitric acid/perchloric acid followed by fluorophotometry (Japan Spectroscopic Co., Ltd.) with the use of 2,3-diaminonaphthalene (DAN). Arsenic was measured by wet-ashing with the use of sulfuric acid/nitric acid followed by Gutzeit method (Pharmaceutical Society of Japan 1990). Phosphorus was determined by subjecting some portion the sample solution thus obtained to the molybdenum blue method (Pharmaceutical Society of Japan 1990). Cadmium, Pb, Cr, Cu, Mn, Zn, Fe, Mg, Ca, K and Na were measured by flame or flameless atomic absorption spectrophotometry (Nippon Jarrell Ash AA-781, AA-855, FLA-100) and treated by the P method. Vanadium, Co, Mo, Ni, Ba, Sr and Al were measured by ICP-atomic emission spectrometry (SEIKO Plasma Spectrometer SPS 1200 A, Japan) and treated by the P method.

RESULTS AND DISCUSSION

Table 1 summarizes the average daily intake of 22 metal elements by females used in this study. The maximum daily intake (3110 g) was approximately 4 times greater than the minimum one (770 g). The daily intake of trace metals including V, Co, Cd, Pb, Cr, Mo and Ni varied widely and the maximum intake was approximately 20 to 80 times that of the minimum levels. The frequency distribution was a logarithmic normal distribution. On the other hand, the bulk elements Mn, Zn, Fe, Mg, Ca, P, K and Na showed relatively small changes and the maximum intakes corresponded to approximately 3 to 7 times those of the minimum ones. The frequency distribution was a normal one. Since these bulk elements contribute to the homeostatic mechanisms in living organisms, these results are highly interesting. Based on daily intake, elements are roughly classified into the following six groups : (1) up to 10 μg(Hg, V and Co) ; (2) from 10 to 100 μg(Cd, Pb, Cr and Se) ; (3) from 100 to 500 μg(Mo, Ni, Ba and As) ; (4) from 1 to 10 mg (Cu, Sr, Al, Mn, Zn and Fe) ; (5) from 100 to 1000 mg (Mg and Ca) ; and (6) from 1 to 10 g (P, K and Na).

Table 2 compares data obtained in our study with the daily intake of metals (Fe and Ca) and recommended allowances (P, K and Na) reported by the Nutrition Division of the Public Health Council

Table 1. Daily total intake of metals by 25 females (sampled 3 times) estimated from dupulicate portion studies in Osaka, Japan

	Age	Total intake g/day	Hg μg/day	V μg/day	Co μg/day	Cd μg/day	Pb μg/day	Cr μg/day
Mean	38.8	1862.1	2.542	2.537	7.783	19.81	38.33	37.29
S D	7.6	403.2	1.231	5.203	7.727	11.02	39.50	31.44
Median	38.0	1940.0	2.080	0.05	9.40	17.50	28.80	31.50
Minimum	25	770	1.27	N D	N D	4.0	1.4	11.6
Maximum	54	3110	6.62	18.00	33.60	66.5	246.5	232.2

	Se μg/day	Mo μg/day	Ni μg/day	Ba μg/day	As μg/day	Cu mg/day	Sr mg/day	Al mg/day
Mean	79.11	146.8	246.0	424.8	345.0	1.054	2.337	3.141
S D	24.33	67.7	235.6	139.6	274.2	0.264	2.080	4.814
Median	76.90	137.0	177.0	414.0	275.0	1.040	1.890	1.550
Minimum	26.4	14	17	203	76	0.47	0.45	0.50
Maximum	135.0	352	1423	1075	1790	1.61	11.62	36.13

	Mn mg/day	Zn mg/day	Fe mg/day	Mg mg/day	Ca mg/day	P g/day	K g/day	Na g/day
Mean	3.319	7.610	7.531	275.0	609.3	1.189	2.221	4.612
S D	1.010	2.222	2.379	69.7	262.5	0.268	0.570	1.389
Median	3.290	7.300	7.290	271.0	556.0	1.162	2.180	4.490
Minimum	0.90	3.88	3.56	141	204	0.58	0.96	2.03
Maximum	5.90	15.11	16.20	456	1480	1.78	3.74	9.05

(the Ministry of Health and Welfare) in August, 1986. Regarding Fe, the intake examined by us was 7.53 mg, which amounted to approximately 63 % of the recommended value. According to Kunisaki et al.(1984) and Teraoka et al.(1981), the intake of Fe widely ranged from 8 to 17 mg. A well balanced intake of food groups rich in Fe, in particular fishes, meat and eggs, is necessary. The average intake of Ca examined was 609 mg, which was similar to the values reported by Teraoka et al.(1981) and Itokawa (1983). These results suggest that a sufficient amount of Ca is taken from daily foods. Regarding P, K and Na, K satisfied the recommended level by adult, while Na and P were taken in excess (1.2 to 2.0 times as much as the recommended levels by adult). These data also exceeded the levels recommended in the USA (Clinical Nutrition 1983,females 25-50 years). (Na : 1.1 to 3.3 g, P : 0.8 g).

Table 2. Recommended allowance and daily intake of 5 metals by 25 females (sampled 3 times)

Element	Fe	Ca	P	K	Na
Allowance 1)	12 mg	600 mg			
Daily desirable intake 2)			600 mg	2~4 g	3.9 g
Found	7.53±2.38	609±263	1189±268	2.22±0.57	4.61±1.39

1) Females 20 ~ 59 years
2) Adult

Table 3 compares our data with the allowances of Cr, Se, Mo, Cu, Mn, Zn and Mg recommended in the USA (Clinical Nutrition 1983). Although it is difficult to simply compare recommended allowances of metals in various countries based on different standards, these data are given for reference. Four elements (Se, Mo, Mn and Mg) almost satisfied the recommended levels, while the intake of Cu and Zn amounted to approximately 50 % of the recommended levels. According to my market basket study, foods contributing to the intake of Cu involved cereals, beans and fishes, while those contributing to the intake of Zn involved meats, eggs and cereals. The contribution ratios of these food groups to the whole of the diet were 55 % and 58 %, respectively. The intake of Cr was somewhat lower than the recommended level. Since this element contributes to the normal metabolism of sugars, it should be taken in sufficient amounts.

Table 3. Recommended daily dietary allowances and daily intake of 7 metals by 25 females (sampled 3 times)

Element	Cr	Se	Mo
Rec.allowance [1)]	50 ~ 200 μg	50 ~ 200 μg	150 ~ 500 μg
Found	37 ± 31	79 ± 24	147 ± 68

Element	Cu	Mn	Zn	Mg
Rec.allowance [1)]	2 ~ 3 mg	2.5 ~ 5 mg	15 mg	300 mg
Found	1.1 ± 0.3	3.3 ± 1.0	7.6 ± 2.2	275 ± 70

(Females 23 ~ 50 years)

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