

Short Communication

Estimation of intakes of copper, zinc, and manganese in Japanese adults using 16-day semi-weighed diet records

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Data for the intake of copper, zinc, and manganese in Japanese populations obtained by detailed diet assessment methods and the most recent version of the food composition database in Japan are scarce. Moreover, data on food sources which contribute to the intake of these nutrients in Asian countries, including Japan, are not available. Here, we estimated copper, zinc, and manganese intake and elucidated major food sources of these nutrients in a Japanese population. We collected 16-day diet records from 225 adults aged 30 to 69 years living in 4 areas of Japan. Intakes of copper, zinc, and manganese were estimated using the 16-day diet records and the latest version of the Food Composition Tables in Japan. Mean intakes of copper, zinc, and manganese were 1.2 mg/day, 8.2 mg/day, and 4.9 mg/day for women and 1.4 mg/day, 10.1 mg/day, and 5.1 mg/day for men, respectively. White rice was the largest contributor to the intake of copper, zinc, and manganese, accounting for approximately 20%-30% of the total intake of each.

Key Words: copper, zinc, manganese, dietary intake, Japanese population

INTRODUCTION

Copper, zinc, and manganese are trace elements whose deficient or excess intake impairs cell functions and affects growth and development, immune system, and metabolism.¹ Copper is the primary constituent of cuproenzymes, which are involved in energy production, iron metabolism, and neurotransmitter synthesis and metabolism. Together with copper, zinc plays a role in antioxidant activity as superoxide dismutase (SOD). Zinc, vital for over 300 enzymes, has a critical structural role in proteins and cell membranes, and regulatory role in gene expression. Manganese is the primary constituent of superoxide dismutase (MnSOD), which catalyzes superoxide radicals, and several other enzymes depend on manganese for the metabolism of carbohydrates, amino acids, and cholesterol. Although findings are inconsistent, intake of these nutrients has been implicated in the etiology of several chronic diseases: copper with cardiovascular diseases and osteoporosis,² zinc with growth, immune response and macular degeneration,³ and manganese with osteoporosis.⁴

Any investigation into the effects of manganese, zinc, copper intake on the health status of specific populations should begin with an estimation of their intake in that population and an elucidation of their major food sources in that population. Since dietary habits and health status may change over different life stages of the individual, information based on demographic characteristics, such as sex and age groups, is important.

To date, few studies have investigated the intake of copper, zinc, or manganese by individuals using detailed diet assessment methods and the latest version of the food

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composition database in Japan.⁵ A few studies of copper and zinc intake used the old food composition tables published in 1982, which did not include a database for manganese.^{6,7} Moreover, data for food sources which contribute to the intake of these nutrients in Asian countries, including Japan, are not available, due in part to the lack of comprehensive food composition tables for these nutrients.⁸ Revision of the food composition tables in Japan from the previous 1982 version to the current 2010 version resulted in substantial differences in the intake estimates of several nutrients (eg, iron),⁹ and use of this latest and most comprehensive version of Standard Tables of Food Composition in Japan¹⁰ is therefore important to maximizing the accuracy of estimates.

Here, we estimated the intake of copper, zinc, and manganese and elucidated the major food sources of these nutrients in Japanese women and men with a specific demographic profile using 16-day diet records (DR) and the latest version of the Food Composition Tables in Japan.

METHODS

Subjects

The study was conducted between November 2002 and September 2003 in four areas in Japan, Osaka (Osaka City), Okinawa (Ginowan City), Nagano (Matsumoto City) and Tottori (Kurayoshi City). In each area, we first recruited apparently healthy women aged 30-69 years who were living with and willing to participate with their husbands, without consideration to the husband's age. Our recruitment strategy was to obtain eight women for each 10-year age stratum (30-39 years, 40-49 years, 50-59 years and 60-69 years). Dietitians were excluded from participation. None of the subjects had recently received dietary counselling from a doctor or dietitian or had a history of educational hospitalization for diabetes or nutritional education from a dietitian. Group orientations were held to explain the study purpose and design before the study, and written informed consent was obtained from each subject. Body height was measured to the nearest 0.1 cm with the subject standing without shoes. Body weight in light indoor clothes was measured to the nearest 0.1 kg. BMI was calculated as body weight (kg) divided by the square of body height (m). The study did not undergo ethical approval because it was conducted before ethical guidelines for epidemiologic research were enforced in Japan. However, use of data from this study was approved by the Ethics Committee at the University of Tokyo Faculty of Medicine (No 3421). A total of 121 women and 121 men completed the study protocol. For analyses, one woman whose body weight was mistyped in the database and 11 men aged <30 or >69 years were excluded, leaving 120 women and 110 men aged 30-69 years in the analyses.

Diet records

Subjects completed a 4-day, semi-weighed DR. The DR was conducted four times on four non-consecutive days, once in each season, at intervals of approximately three months (DR1 in November and December 2002 (autumn), DR2 in February 2003 (winter), DR3 in May 2003 (spring) and DR4 in August and September 2003 (summer)). Each set of four recording days consisted of one

weekend day and three weekdays. Details of the diet record procedure are provided elsewhere.¹² Briefly, during the orientation session, registered dietitians gave the subjects both written and verbal instructions on how to keep the DR, provided recording sheets and a digital scale, and asked the subjects to record and weigh all beverages and foods consumed on each recording day. When weighing was difficult (eg, when eating out), they were instructed to record the size and quantity of foods they ate as precisely as possible using household measures. For each recording day, the subjects were asked to fax the completed forms to the local staff. The staff reviewed the submitted forms and, if necessary, asked the subject to augment and/or modify records by telephone or fax. The responses were faxed or, in some cases, handed directly to the staff. All collected records were checked by trained registered dietitians in the respective local centre and then again in the study centre. A total of 1299 beverage and food items appeared in the DR. Intakes of energy, iron, zinc, manganese, and copper were estimated based on the estimated intakes of all items and the Standard Tables of Food Composition in Japan.¹⁰

Statistical analyses

All statistical analyses were performed for women and men separately using the SAS statistical software package version 9.3 (SAS Institute Inc, Cary, NC, USA). We grouped subjects living in the four areas into two groups according to population density. Osaka (Osaka City, 11743 persons/km²) and Okinawa (Ginowan City, 4446 persons/km²) had much higher population densities and were classified as urban; and Nagano (Matsumoto City, 786 persons/km²) and Tottori (Kurayoshi City, 285 persons/km²) were classified as rural.¹³ We also categorized the subjects into four age groups (30-39 years, 40-49 years, 50-59 years and 60-69 years). The mean intake of nutrients in each age category was compared by ANOVA. Differences between the urban and rural areas in the intakes of copper, zinc, and manganese were examined using the non-paired t-test. All reported *p* values are two-tailed, and a *p* value of <0.05 was considered statistically significant.

RESULTS

Subject characteristics are shown in Table 1. Mean age was 49.7 years for women and 50.4 years for men. Mean BMI was 22.3 kg/m² for women and 23.8 kg/m² for men.

Mean copper intake was 1.2 mg/day for women and 1.4 mg/day for men, and below the RDA in 3.3% of women and 3.6% of men. Mean zinc intake was 8.2 mg/day for women and 10.1 mg/day for men, and below the RDA in 70.8% of women and 87.3% of men. Mean manganese intake was 4.9 mg/day for women and 5.1 mg/day for men, and below the AI in 37.5% of women and 34.6% of men. By gender, mean copper and zinc intake was significantly higher in men than women (*p*<0.001). In contrast, mean manganese intake did not differ between gender or residential area (Table 2).

By residential area, mean copper and zinc intake was significantly higher in rural women and men than in urban subjects (*p*<0.001) (Table 2).

By age group, mean copper and manganese intake was

Table 1. Characteristics of study subjects according to gender

	Women (n=120)			Men (n=110)		
	Mean	SD [†]	Range	Mean	SD [†]	Range
Age (years)	49.7	11.2	31-69	50.4	10.8	31-69
Body height (cm)	155	6.2	133-171	168	6.4	150-186
Body weight (kg)	53.4	7.1	41.5-74.0	67.3	10.1	45.0-97.5
BMI (kg/m ²)	22.3	2.8	17.8-31.3	23.8	2.9	17.4-30.9

[†]SD: standard deviation

highest in the 60-69 years group for both women and men (Table 2), while mean zinc intake was highest in the 60-69 years group for women and in the 50-59 age group for men.

Table 3 shows food sources contributing to the intakes of copper, zinc, and manganese. The largest contributors to copper intake were white rice (women, 23.1%; men, 29.7%), vegetables (women, 17.1%; men, 15.1%), and pulses and nuts (women, 15.1%; men, 12.4%). For zinc, the largest contributors were white rice (women, 19.8%; men, 25.0%), meat and meat products (women, 17.1%; men, 20.5%), and fish and seaweeds (women, 11.1%; men, 11.6%). For manganese, the largest contributors were white rice (women, 23.7%; men, 32.5%) and Japanese tea (women, 33.9%; men, 28.3%), followed by vegetables (women, 13.6%; men, 12.8%).

DISCUSSION

To our knowledge, this is the first study to estimate the intakes of copper, zinc, and manganese in a Japanese population by sex, residential area, and age group, and to show the food sources contributing to these intakes, using a detailed diet assessment method (ie diet records) and the latest version of the food composition tables in Japan (2010). We found that mean copper, zinc, and manganese intake among these Japanese subjects was 1.2 mg/day, 8.2 mg/day, and 4.9 mg/day for women and 1.4 mg/day, 10.1 mg/day, and 5.1 mg/day for men, respectively. Compared with the RDA or AI, zinc intake of the majority of subjects and manganese intake of a considerable number of subjects did not meet the recommendation. Regarding food sources, white rice was the largest contributor to the intake of all three nutrients. Since data for the intake and food source of copper, zinc, and manganese in Japanese populations using data obtained by detailed diet assessment methods and the most recent version of the food composition database in Japan are scarce, our results may provide important data.

Intakes of copper, zinc, and manganese in the present Japanese population were within the range of estimated mean intakes of residents of other countries. For copper, mean estimated intake was comparable to that assessed in several Western studies in similar age groups to our sample, which ranged from 0.6 to 1.7 mg/day for women¹⁴⁻²² and 0.9 to 2.3 mg/day for men.¹⁴⁻²¹ In a number of Asian studies, mean copper intake ranged from 0.7 to 2.3 mg/day for women^{6,7,23-29} and 1.0 to 3.8 mg/day for men.^{7,23-25,30} For zinc, mean intake in Western populations ranged from 6.2 to 12.9 mg/day for women^{14,16,17,31-38} and 8.6 to 16.6 mg/day for men.^{14,16,17,31-38} Thus, mean zinc intake of our subjects was relatively low. However, it was comparable to that assessed in a few previous Asian stud-

ies, which ranged from 3.4 to 11.2 mg/day for women^{6,7,23,25,27-29,39} and 5.1 to 13.7 mg/day for men.^{7,23,24,30,39}

Regarding manganese, mean manganese intake in our subjects was relatively high compared with that of the few available Western populations, which ranged from 0.9 to 5.0 mg/day for women^{14,16,21,22,40} and 1.0 to 5.2 mg/day for men.^{14,16,21,40} However, the mean manganese intake of our subjects was comparable to that in the very few available Asian studies; mean intake of 200 Chinese women aged 40-70 years was 5.0 mg/day²⁶ while that of 205 Korean women aged 35-60 years and 149 men aged 20-65 years was 4.1 mg/day and 5.2 mg/day, respectively.⁸ The only previous study conducted in Japan among women aged 21-51 years estimated a mean manganese intake of 2.4 mg/day.²⁷ The lower estimates may be partly explained by diet habits indigenous to the restricted research area (Shimane prefecture); however, comparison with this study is hampered by the difference in sample size (n=10) and assessment method (i.e., 2-day duplicate diet method). As shown, the estimated intakes of copper, zinc, and manganese widely vary among studies. These discrepant estimates might be explained by differences in populations and dietary habits. In Japan, consumption of white rice and Japanese tea is high,⁴¹⁻⁴³ and these were shown to be the largest contributors to the intake of copper, zinc, and manganese in our present subjects. In contrast, bread is the largest source in Western countries, as discussed below.^{17,22,35,40} Another reason may be the different databases used, with a different number of items and analytical values.⁸ The estimates might also have been influenced by different diet assessment methods (eg, duplicate diet method, 24-hour recall, or multiple-day diet records).

Regarding food sources, we found that these differed considerably to those in Western countries (ie, white rice and Japanese tea vs breads) for all three nutrients but that the major contribution came from staple foods in both. For copper, the largest contributors were legumes, potatoes, and nuts and seeds (percentages not given) for older adults in the US;¹⁹ breads (19%), potatoes (16%), and meats (15%) in Irish adults;¹⁷ and breads (22%), fats and sugars (21%), and vegetables (21%) in Canadian women.²² For zinc, meats, legumes, and cereals were the main sources among older adults in the US,¹⁹ whereas meats, breads, and dairy were the largest contributors among Irish adults,¹⁷ Canadian women,²² and Spanish adults.³⁵ For manganese, the largest sources were breads (47%) and fats and sugars (25%) in Canadian women²² and breads (49%) and vegetables (18%) in the other Canadian subjects.⁴⁰ In our subjects, the contribution of Japanese tea to manganese intake (men, 28.3%; women, 33.9%) was also high. These findings suggest the importance of

Table 2. Intakes of energy, copper, zinc, and manganese of 120 women and 110 men according to residential area and age group

	Total			Rural		Urban		<i>p</i> value*	30-39 years		40-49 years		50-59 years		60-69 years		<i>p</i> value [§]
	Mean	SD [†]	Median	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Women	(n=120)			(n=62)		(n=58)			(n = 28)		(n = 29)		(n = 32)		(n = 31)		
Energy (kcal/day)	1848	289	1844	1893	270.4	1801	303	<0.0001	1877	376	1812	288	1851	217	1854	276	<0.0001
Copper (mg/day)	1.17	0.25	1.16	1.24	0.24	1.10	0.24	<0.0001	1.09	0.27	1.06	0.24	1.22	0.20	1.31	0.22	0.002
Zinc (mg/day)	8.2	1.5	8.1	8.2	1.4	8.1	1.5	<0.0001	7.9	1.7	7.8	1.4	8.2	1.1	8.7	1.5	<0.0001
Manganese (mg/day)	4.9	3.7	3.9	4.9	2.8	4.9	4.5	0.59	3.7	1.7	4.1	2.5	4.8	2.2	6.7	6.0	0.14
Men	(n=110)			(n=56)		(n=54)			(n = 21)		(n = 32)		(n = 28)		(n = 29)		
Energy (kcal/day)	2397	428	2368	2463	457	2328	387	<0.0001	2271	369	2512	521	2454	387	2304	361	<0.0001
Copper (mg/day)	1.40	0.32	1.37	1.46	0.34	1.34	0.29	<0.0001	1.21	0.21	1.39	0.43	1.46	0.25	1.50	0.26	<0.0001
Zinc (mg/day)	10.1	2.0	10.0	10.1	2.1	10.0	1.8	<0.0001	9.3	1.8	10.3	2.5	10.6	1.8	9.8	1.4	<0.0001
Manganese (mg/day)	5.1	2.6	4.5	5.3	2.5	5.0	2.7	0.79	3.7	1.0	4.8	1.8	5.6	3.8	6.0	2.5	0.08

[†]SD: standard deviation.

^{*}Differences between subjects in the 2 areas were tested by the unpaired t-test.

[§]The mean intake of nutrients in each age category was compared by ANOVA.

The mean age of subjects living in rural and urban area was 50.2 and 49.8, respectively.

Table 3. Contribution (%) of selected food groups to copper, zinc, and manganese intake of 120 women and 110 men[†]

Food group	Copper		Zinc		Manganese	
	Women	Men	Women	Men	Women	Men
Foods						
White rice	23.1	29.7	19.8	25.0	23.7	32.5
Bread	3.9	3.1	3.8	3.0	2.8	2.4
Noodles	3.8	3.9	2.2	2.2	3.2	3.8
Other grain products	2.0	2.1	1.5	1.6	2.5	2.7
Vegetables	17.1	15.1	3.3	2.9	13.6	12.8
Fruits	4.7	3.2	1.4	0.9	3.5	2.3
Pulses and nuts	15.1	12.4	8.7	7.1	6.5	6.2
Fish and seaweeds	9.5	10.9	11.1	11.6	1.7	1.9
Meat and meat products	4.2	5.3	17.1	20.5	0.3	0.3
Eggs	2.6	2.6	5.9	5.8	0.2	0.2
Dairy	1.4	1.0	8.1	5.3	0.1	0.1
Fats and oils	0.1	0.1	0.3	0.3	0.1	0.1
Sugars and confectionaries	4.8	3.5	3.8	2.6	2.2	1.8
Seasonings and other foods	1.7	1.9	2.6	2.5	0.7	0.8
Beverages						
Japanese tea	2.9	2.4	2.2	1.4	33.9	28.3
Soft drinks	0.6	0.7	0.4	0.6	0.2	0.2
Fruits and vegetable juice	0.5	0.6	0.1	0.1	0.2	0.2
Coffee and tea	0.4	0.2	0.1	0.1	3.4	2.5
Alcohol	0.1	0.2	0.1	0.3	0.6	1.7

[†]Definition of foods and beverages included in each group is described in elsewhere.⁴³

considering major food sources in a population when conducting interventions for individuals within it.

By residential area, mean zinc and copper intake were higher in women and men living in rural areas (Table 2). Mean manganese intake did not differ by residential area, which may be explained by the wide intake range. To our knowledge, the only available observational evidence for copper, zinc, or manganese intake of individuals by residential area comes from a study in Chinese adults, which assessed the copper and zinc intake of subjects using 3-day dietary records.²⁴ Consistent with our results, copper and zinc intake which significantly higher in those Chinese subjects living in rural areas than urban areas. These findings may be partly explained by the higher energy intake of the subjects living in urban areas, although additional studies are needed.

Few previous studies in other countries have provided data on copper or zinc intake according to age group, and the results differed among populations. To our knowledge, data for manganese is not available. In a US population aged over nine years, copper intake was highest in the 31-50 and 51-70 years group for women and in the 31-50 years group for men, while zinc intake was highest in the 19-30 years group for women and in the 14-18 and 31-50 years groups for men.²⁰ In an Irish population aged 18-64 years, copper intake was highest in the 36-50 years group for women and in the 35-50 and 51-64 years groups for men, whereas zinc intake was highest in the 51-64 years group for women and 35-50 years group for men.¹⁷ In a Chinese population aged 4-89 years, copper and zinc intake of women and men was highest in those aged 18-49 years.²⁴ In a Navajo population aged 12-91 years, zinc intake was highest in the 20-39 years group for women and the 40-59 years group for men.³⁷ Our data showed that the copper and zinc intake of older age groups was higher (Table 2), which may be explained by their high intake of white rice (Table 3). White rice is the largest

food source for copper and zinc intake in our subjects and the principal staple food traditionally consumed in Japan, and consistency with traditional habits may be more pronounced among older populations.

Several limitations of the present study should be mentioned. Although the use of diet records allows detailed assessment of the dietary intake of individuals, the self-reported dietary assessment method is subject to measurement error. In addition, although we estimated the intake of copper, zinc, and manganese using the latest and most comprehensive version of the food composition tables available in Japan, there are some missing values and the tables do not represent the total number of food products on the market. Moreover, since the DR was not designed solely for the estimation of copper, zinc, and manganese intake and does not enquire about brand names, we were unable to differentiate types and forms of beverages and foods, such as brewed coffee made at home from that made at coffee outlets. Furthermore, since energy intake (a surrogate measure of overall dietary intake) in the older age groups did not tend to be lower than that in the younger groups, our results for intake of the three nutrients by age group should be interpreted with caution: given that total energy expenditure should be lower in older than younger age groups⁴⁴ and that under-reporting is a common problem even with self-reported semi-weighted DR,⁴⁵ the present study may be biased by under-reporting among younger age groups, which would in turn mean the underestimation of intake among these groups. Also, the diet data in the present study was obtained in 2003, which was about 10 years ago. According to the only available latest report from the National Health and Nutrition Survey⁴⁶ in Japan, energy intake (per capita per day) in 2011 was 4.2% lower than that in 2003. However, proportion of intake of food groups to energy intake did not show the substantial difference; white rice, vegetables, pulses and nuts, fish, and meats,

the main contributors to the intake of copper, zinc, and manganese in the present study, decreased by 2.4%, 0%, 0.1%, and 0.6%, and increased by 2.2%, respectively. Thus, the major source of each trace element may not be largely changed. Finally, the generalizability of our results is hampered by the fact that the present subjects were not randomly sampled from the general Japanese population but were instead volunteers and possibly health-conscious. As we lacked information on subject characteristics, including education and occupation, we were unable to determine how such characteristics might have influenced our findings.

In conclusion, we found that mean copper, zinc, and manganese intake among the Japanese subjects in the present study was 1.2 mg/day, 8.2 mg/day and 4.9 mg/day for women and 1.4 mg/day, 10.1 mg/day and 5.1 mg/day for men, respectively. White rice was the largest contributor to the intakes of copper, zinc, and manganese. To our knowledge, this is the first study to estimate the intakes of copper, zinc, and manganese in a Japanese population by sex, residential area, and age group, and to show the food sources contributing to these intakes, using a detailed diet assessment method (i.e. diet records) and the latest version of the food composition tables in Japan (2010).

AUTHOR DISCLOSURES

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Short Communication

Estimation of intakes of copper, zinc, and manganese in Japanese adults using 16-day semi-weighed diet records

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用 16 天半定量膳食记录估计日本成年人铜、锌和锰的摄入量

通过详细的饮食评估方法和日本最新版的食物成分数据库获得铜、锌和锰摄入量的数据在日本很罕见。另外，亚洲国家（包括日本）也没有这些营养素食物来源的资料。在这里，我们估计了日本人铜、锌和锰的摄入量，并阐明了这些营养素的主要食物来源。我们收集了 225 名居住在日本 4 个区域，年龄在 30-69 岁的成年人 16 天的饮食记录。用 16 天的饮食记录和日本最新版的食物成分表估计铜、锌和锰的摄入量。铜、锌和锰的平均摄入量分别为：女性 1.2 毫克/天、8.2 毫克/天和 4.9 毫克/天，男性 1.4 毫克/天、10.1 毫克/天和 5.1 毫克/天。白米饭是铜、锌和锰摄入量最大的贡献者，约占每个营养素总摄入量的 20%~30%。

关键词：铜、锌、锰、饮食摄入、日本人