J Food Sci Nutr
Vol 9, p 79~84 (2004)

J Food Science and Nutrition

Zinc Intake and Status of the Selected Korean Adults

Soo-Lim Lee, Eun-Hee Kwak, Jin-Sook Yoon[1], Chong-Suk Kwon, John H. Beattie[2] and In-Sook Kwun[†]

Department of Food Science and Nutrition, Andong National University, Kyungpook 760-749, Korea
[1]Department of Food Science and Nutrition, Keimyung University, Daegu 705-701, Korea
[2]Cellular Integrity Division, Rowett Research Institute, Aberdeen, Scotland, United Kingdom

Abstract

Zinc intake and status of South Koreans from rural, urban and metropolitan areas were investigated. The dietary habits of 760 healthy male and female adult subjects with a mean age of 54 were assessed using a food frequency questionnaire and were verified using 24 h dietary recall. Daily Zn intakes for men and women were 7.4±5.4 mg and 7.0±5.4 mg, respectively, which were 62% and 70% of the Korean RDA. The phytate : zinc and phytate×calcium : zinc molar ratios were 38 and 398, respectively. Both the low intake of zinc and the high extremely phytate and phytate×calcium ratios with zinc suggest that South Koreans may be at risk of zinc deficiency. Plasma zinc (86±61 μg/dL), urinary zinc (33±27 μg/dL) and plasma alkaline phosphatase (102±52 mU/mL) levels within the normal range did not however suggest marked zinc deficiency in these subjects. However, conventional zinc biomarkers are known to be unreliable for assessment of marginal zinc deficiency. Based on zinc intake alone, it is likely that at least a proportion of these subjects were marginally zinc deficient and the wider consumption of zinc rich, phytate deficient foods, particularly in rural areas, would be beneficial.

Key words: zinc intake, phytate : zinc, plasma zinc, urinary zinc, plasma alkaline phosphatase, South Koreans

INTRODUCTION

Marginal zinc deficiency adversely affects human health, particularly through suppression of growth and immune function (1). The Korean Recommended Daily Allowance (RDA) for dietary zinc is 15 and 12 mg/d for males and females, respectively (2). However, there is evidence that zinc intakes in the rural population in South Korea are significantly lower than the RDA levels (3). The Korean diet contains foods rich in phytate (inositol hexaphosphate), which inhibits zinc absorption and is likely to exacerbate deficiency caused by low zinc intake. There is therefore a very significant risk that a proportion of South Koreans are zinc deficient and that their health status is compromised.

The potential for zinc deficiency in Koreans has not been examined in detail, with only one study (3) estimating zinc intake based on selected foods from the 1995 National Nutrition Survey (4). Using the data obtained by trained dieticians over a 2-day period in 2000 households, the dietary zinc intakes from the 214 most consumed foods were calculated. The results of this study suggest that dietary zinc intake in large cities is around 80% the Korean RDA for zinc, but that in rural areas, the mean zinc intake is only around 60% of the RDA. What this study did not show was gender- and age-related differences in zinc intake, and since it was only possible to obtain data from foods included in the Survey, the estimation of zinc intake may have been incomplete. In addition, there was no assessment of zinc status using biochemical indicators.

The present study was designed to evaluate zinc intake from complete food intake data and conventional zinc biochemical indexes to assess zinc nutriture in South Koreans. In the same way, the zinc intake information for the previous study may have been incomplete, data for calcium and phytic acid, both of which inhibit zinc absorption, are also likely to have been incomplete. The aims of the present study therefore included a more complete estimation of these zinc absorption inhibitors.

SUBJECTS AND METHODS

Subjects

The subjects in this study were recruited from three different areas (Andong County, Andong City, and Daegu City) representing rural, city and metropolitan city populations, which were reported to be ca 2.6, 190, and 2,540 thousand people, respectively, at the time of the study. The subjects (total 760, men 341 and women 416)

[†]Corresponding author. E-mail: iskwun@andong.ac.kr
Phone: +82-54-820-5917, Fax: +82-54-823-1625

aged between 40 and 65 yrs were randomly selected from the register of the 2000~2001 Health Promotion Project in the Andong and Taegu Public Center, supported by Ministry of Health and Welfare. The study was conducted between September 2000 and May 2001. The study protocol was approved by the Ethical Committee of Andong National University and written consent was obtained from each subject after the aim of the study had been explained to them.

Anthropometric assessment

Selected anthropometric measurements were made; height and body weight were measured with the subjects wearing light clothing and no shoes. Body fat was measured using a body composition analyzer (inBody 3.0 Body Composition Analyzer, Biospace, South Korea). Each measurement was taken by the same anthropometrist to avoid inter-examiner error.

Dietary assessment

A food frequency questionnaire (FFQ) was used for estimation of the intakes of zinc, calcium, phytate and other nutrients. The FFQ, which contained 38 food items, included the major food sources and major zinc-containing food items which are commonly consumed by Koreans during the four seasons of each year. In order to verify the reliability and reproducibility of the FFQ, a 24-h recall test was also used.

Nutrient intakes were calculated using Computer Aided Nutritional Analysis Program, version 2.0 (CAN Pro 2.0, Version 2.0) (2). Intake for zinc and phytate, which are not present in CAN Pro 2.0 program, were analyzed using food composition tables, databases, a cross-referenced index, and various values from the literature. The procedure for calculation of zinc, calcium, phytate and phytate : zinc molar ratio has been described previously (3,5,6). Nutrient intakes were compared with the Korean Recommended Dietary Allowance (2).

Zinc biochemical index assessment

Precautions were taken to avoid zinc contamination during the collection and analyses of the samples. Samples from 10~15 subjects were pooled for analysis. The accuracy and precision of all analytical methods were checked by analyzing a standard reference material (1577b, bovine liver, National Institute of Standards and Technology, Gaithersburg, USA).

Sample collection : Blood samples were obtained by venepuncture in the morning after overnight fasting and were collected into trace element-free heparinized tubes (Becton Dickinson, Rutherford, NJ, USA). Twenty four-hour urine collections were removed in the early morning. Hair samples (300 mg) were collected from close to the occipital portion of the scalp with stainless steel scissors. Only the proximal 2~3 cm of the hair strands were retained to avoid collection of contaminated hair. Nail clippings were also collected.

Sample analyses : Zinc and calcium level in plasma, red blood cells (RBCs) and urine were measured using inductively coupled plasma (ICP) emission spectroscopy (Boschstrasse 10 Spectro Analytical Instruments, Germany) after wet-digestion and appropriate dilution. In brief, RBCs were wet-digested with concentrated nitric acid and hydrogen peroxide. Plasma, urine and the wet-digested RBCs were diluted using trace element-free 0.125 M HCl (Fluka, Buchs, Switzerland). Protein level in RBCs was also measured using Lowry method (7). The collected hair and nail clippings were washed thoroughly and were wet-digested for element analyses. Plasma alkaline phosphatase was measured using a commercial kit (Sigma).

Statistical analyses

Statistical analyses were performed with the statistical package SPSS. The mean difference between men and women was analyzed using an unpaired Student's *t*-test at $p<0.05$.

RESULTS

Anthropometric assessment

The mean age of the subjects was 54.2±13.9 yrs which represents early aging people. The mean (±SD) heights were 165.3±6.8 and 153.4±7.4 cm, and weights were 63.9±10.4 and 54.3±8.4 kg for the men and women, respectively. Mean body fat values were 23.7±6.7 and 29.9±5.7% for the men and women, respectively, which are just above the normal range for men (10~20 %) and women (20~30%) using the body composition analyzer (Table 1).

Dietary assessment and diet pattern

Mean energy and macronutrient intakes are shown in Table 2. The nutrient intakes analyzed by FFQ were

Table 1. Age and anthropometric measurement of men and women Korean subjects

Factor	Subjects		
	Men (n=341)	Women (n=419)	Total (n=760)
Age (year)	56.8±11.9[1)]*	53.0±14.6*	54.2±13.9*
Height (cm)	165.3±6.8*	153.4±7.4*	157.2±9.1
Weight (kg)	63.9±10.4*	54.3±8.4*	57.4±10.1
Body fat (%)	23.2±5.7*	29.9±5.7*	28.2±6.4

[1)]Each value represents mean±SD.
*Values with asterisk in each row are significantly different between men and women at $p<0.05$ by *t*-test.

Table 2. Energy and macronutrient intakes in subjects by food frequency record (intake/day)

Nutrient	Subjects		
	Men (n=262)	Women (n=363)	Total (n=625)
Energy (kcal)	1458.8±486.3[1)]	1485.2±680.6	1478.4±635.7
Protein (g)	51.9±26.6	51.9±34.2	51.9±32.5
Animal protein (g)	20.1±14.1	19.2±18.0	19.5±16.1
Plant protein (g)	31.8±11.8	32.7±15.8	32.5±14.9
Lipid (g)	24.9±17.5	26.5±23.4	26.1±22.0
Animal fat (g)	12.0±11.7	11.8±14.6	11.9±13.9
Plant oil (g)	12.9±9.2	13.7±11.8	14.2±11.2
Carbohydrate (g)	252.2±70.4	257.0±99.6	255.8±92.8
Dietary fiber (g)	5.0±2.5	5.0±3.1	5.0±2.9
Cholesterol (mg)	141.6±114.8	128.0±101.7	131.5±108.2

[1)]Each value represents mean±SD.

verified for reliability and reproducibility using 24-hr dietary recall. Most of the analyzed nutrient intakes using FFQ and 24-hr dietary recall were similar, except for Na, vitamin A, and vitamin C, and this confirms the reliability of using FFQ for dietary assessment in this study for Zn and Zn-related nutrients intakes.

No significant difference was found between nutrient intakes in men and women. Energy intake was 1478.4± 635.7 kcal which constitutes around 75% of the Korean RDA (7th ed. 2000). Protein intake (51.9±32.5 g) was about 74% (men) and 94% (women) of the Korean RDA and animal protein intake (19.5±16.1 g) was 38% of total protein intake. Cholesterol intake (131.5±108.2 g) was the less than half the suggested intake level for Koreans (300 mg/d) (2). Dietary fiber intake was 5.0± 2.9 g which is much lower than the suggested dietary intake per day (2). The general pattern of macronutrient intake indicated that the subjects consumed low amounts of animal products.

Mean mineral and vitamin intakes are shown in Table 3. Calcium and iron intakes are 476.2±384.3 mg and 8.5±5.9 mg which comprised 68% and 71% of the Korean RDA. Approximately half of the calcium intake was derived from animal foods. Most water-soluble vitamin intakes were 60~90% of the Korean RDA.

Zinc intake and molar ratio of phytate : Zn and phytate × Ca : Zn

The calculated daily Zn, Ca, phytate intake and their molar/millimolar ratios are shown in Fig. 1 and 2. Daily Zn intakes for men and women were 7.4±5.4 mg and 7.0±5.4 mg, respectively, which were 62% and 70% for men (12 mg) and women (10 mg) of the Korean RDA. Ca intake was 485.5±369.4 mg, which was 69% for both men and women (700 mg) of the Korean RDA. The estimated daily phytate intake was 2332.6±976.0

Table 3. Mineral and vitamin intakes in subjects by food frequency record (intake/day)

Mineral	Subjects		
	Men (n=262)	Women (n=363)	Total (n=625)
Ca (mg)	430.5±325.8[1)]	492.2±401.9	476.2±384.3
Animal Ca (mg)	187.3±214.5*	228.3±266.2*	217.7±254.3
Plant Ca (mg)	243.2±176.0	263.9±211.2	258.5±202.7
P (mg)	874.8±441.7*	947.5±604.6*	928.6±567.4
Fe (mg)	8.2±5.1	8.6±6.1	8.5±5.9
Animal Fe (mg)	1.8±2.0	1.7±2.5	1.7±2.3
Plant Fe (mg)	6.5±3.8	7.0±4.6	6.9±4.4
Na (mg)	2875.1±1415.7	2770.7±1670.4	2797.7±1607.0
K (mg)	1848.6±1029.7	1889.6±1212.9	1879.0±1167.5
Vitamin A (RE)[2)]	573.1±690.3	62.6±827.7	609.8±794.1
Retinol (mg)	54.5±45.0	51.0±42.3	51.9±43.0
Carotene (mg)	2930.0±1843.1	3212.4±2598.6	3139.2±2413.9
Vitamin B_1 (mg)	0.85±0.36	0.88±0.51	0.87±0.47
Vitamin B_2 (mg)	0.75±0.56	0.76±0.67	0.75±0.64
Niacin	11.9±7.9	12.5±8.8	12.3±8.3

[1)]Each value represents mean±SD.
[2)]RE (retinol equivalent, unit).
*Values with asterisk in each row are significantly different between men and women at $p<0.05$ by *t*-test.

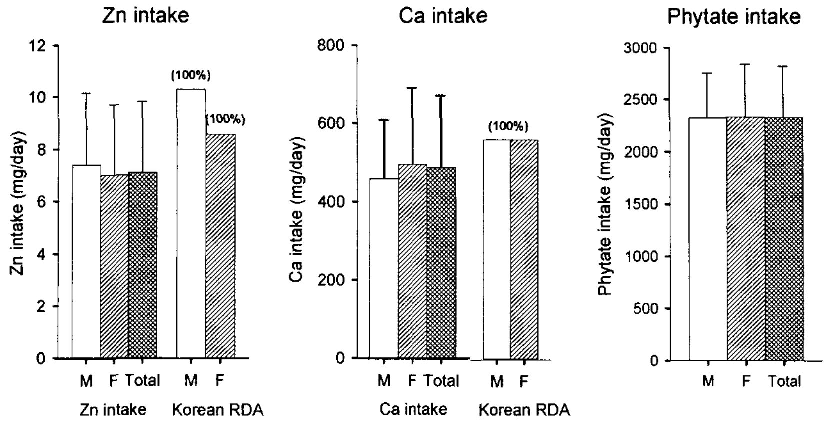

Fig. 1. Zn, Ca and phytate intake in South Koreans (mean±SD).

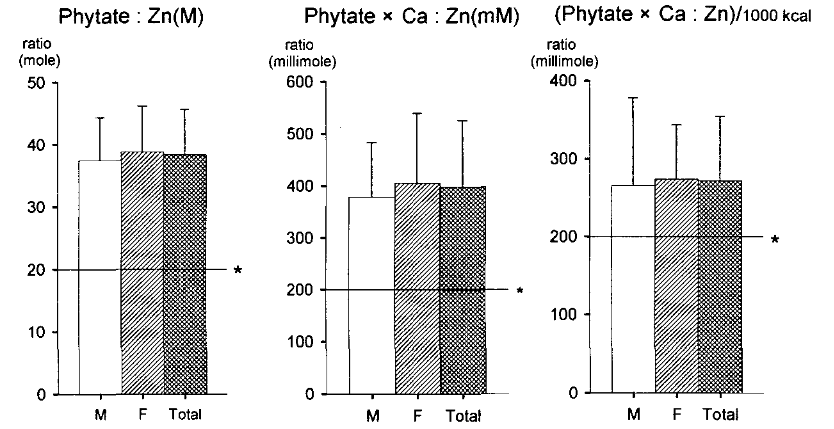

Fig. 2. Molar ratio of Zn, Ca and phytate in South Koreans (mean±SD). *Cutoff point for causing poor Zn nutriture above this ratio.

mg, which gives a phytate : zinc molar ratio of 38. The phytate×Ca : Zn millimolar ratio was 398 and the phytate×Ca : Zn millimolar ratio per 4.2 MJ (1000 kcal) was 272. The phytate×Ca : Zn millimolar ratio per 4.2 MJ was calculated taking into account differences in the amount of food consumed in order to compare it with the data from the different survey units.

Biochemical indexes

The concentrations of zinc in plasma, RBCs, urine, hair and nail, and also plasma alkaline phosphatase activity, are shown in Table 4. No significant difference between men and women was found for any of the zinc status indices. Hair and nail zinc concentration was not measured separately for men and women. The mean (±

Table 4. Zn concentration in blood, urine, nail, and hair and plasma alkaline phosphatase activity

Zn concentration	Subjects			
	Men (n=280)	Women (n=377)	Total (n=657)	Reference Value
Plasma Zn (μg/dL)	83.6±48.4[1]	87.8±69.3	86.0±61.3	52.3~130.8[5]
RBC[2] Zn (μg/g protein)	8.2±1.5	7.9±1.4	8.0±1.4	-
Urinary Zn (μg/dL)	35.7±25.1	32.6±27.7	33.3±27.1	15.8~94.8[5]
Hair Zn (μmol/g)	-	-	1.7±0.8	1.8±0.7[6]
Nail Zn (μmol/g)	-	-	1.0±0.1	-
Plasma ALP[3] activity (mU[4]/mL)	99.2±45.3	102.7±55.3	101.6±52.3	97.3~102.3[7]

[1]Each value represents mean±SD.
[2]RBC (Red blood cell).
[3]ALP (Alkaline phosphatase).
[4]mU (Milliunit).
[5]Burgess et al., 1999. Proceeding of 10th Trace Element in Man and Animal.
[6]Gibson and Huddle, 1998, *Am J Clin Nutr* 67: 702-709.
[7]Cavan et al., 1993, *Am J Clin Nutr* 57: 334-343.

SD) plasma zinc concentration of the subjects was 86.4 ±61.3 μg/dL, which was within the reference range of 52.3±130.8 μg/dL (8). RBC zinc concentration was 8.0 ±1.4 μg/g protein which was much lower than plasma zinc level. Urinary zinc concentration was 33.3±27.1 μg/dL, which was within the reference range of 15.8~94.8 μg/dL (8). Hair zinc concentration was 1.7±0.8 μmol/g which is about the same level of normal adults, 1.8±0.8 μmol/g (9) and Nail zinc concentration was 1.0 ±0.1 μmol/g.

The activity of the zinc-containing enzyme alkaline phosphatase was 101.6±52.3 mU/mL which is within the normal range for human subjects (10).

DISCUSSION

In this study, zinc intake of the subjects was low compared to Korean RDA or previous reported data. There may be two possible explanations for a low zinc intake in Korean subjects in this study. Firstly, the study focused on aging subjects (mean age 54 yrs), and older people generally eat less food. The mean energy intake of the subjects in this study was 1478.4 kcal (75% of the Korean RDA), indicating a lower food intake and therefore a low intake of all nutrients including zinc. South Koreans in this study consumed zinc (7.2 mg/d) and calcium (485 mg/d) approximately at one third of the Korean RDA level for both men and women. Daily Zn intakes for men and women were 7.4 mg (62% of RDA) and 7.0 mg (70% of RDA), respeclively. When considering the subjects in this study consumed only 70% of the daily energy RDA, zinc intake can be improved if the subjects could consume a more appropriate energy intake. The second possible reason is that subjects in this study consumed plant food-dominated diets, which is predominant in rural and small city areas. Also this plant food-dominated diet is likely to be a much more in general pattern during late fall through to early spring in rural and small city areas, because people consume stored vegetables during this period. The low zinc intake of South Koreans in this study may reflect the timing of the dietary survey; during September to May, which coincides with the period of low animal food intake. The zinc intake of Koreans (7.2 mg/d) in this study is two thirds of the levels of normal healthy Americans (11.9~12.3 mg/d) (11).

The estimated daily phytate intake in the present study was 2332 mg/d which is 3~5 times higher than in Canadian children (422 mg/d) (12,13), or Americans (395~781 mg/d) (11,14,15). The molar ratio of phytate : Zn above which zinc status may be compromised, is above 20, and this is considered as a factor for zinc deficiency (12,16). In this study, the phytate : Zn ratio was 38, which may cause poor zinc nutriture in Koreans. The phytate : Zn molar ratios are reported with levels ranging from 5 in normal Western people (17) to 67 for vegetarian Trappist monks in the states (18). Millimolar ratios of phytate×Ca : Zn≥200 are considered as indicators of marginal zinc deficiency in men (17). The phytate×Ca : Zn millimolar ratio in the present study was 398 which was twice the level thought to present a risk for zinc deficiency. The ratio (271) was even >200 when corrected for energy intake, (Phytate×Ca : Zn) / 4.2 MJ, which is likely to cause poor zinc nutriture.

Control of body zinc homeostasis is maintained over quite a wide range of zinc intakes through regulation of intestinal zinc absorption and pancreatic secretion (19). However, it is well recognized that intakes below 1 mg Zn/d in adult humans cause severe deficiency and that marginal deficiency effects may be found between 1 and 10 mg/d (20). Unfortunately, there is no single reliable indicator of zinc status (21). Plasma zinc levels generally reflect zinc status but are influenced by other variables such as stress and infection. This indicator is also less useful for assessment of marginal status because plasma zinc levels may not be greatly reduced, if they are reduced at all. The situation with urinary zinc is much the same as for plasma zinc and efforts have been made to find other biomarkers. Alkaline phosphatase, a zinc-dependent enzyme, is readily measured and its activity is reduced in severe zinc deficiency. However, the sensitivity of this assay to detect marginal zinc deficiency is questionable (20). In the present study, a number of bioindices of zinc status were measured in order to try and obtain some consensus on the status of the subjects. The mean results for plasma zinc, urinary zinc and plasma alkaline phosphatase were all within the normal range, suggesting that the level of zinc deficiency was not sufficiently severe to affect these biomarkers. Plasma zinc concentration (86 μg/dL) in Korean adults was similar level of most of Western peoples (22-24), even with a low intake of zinc and high intake of phytate. However, it was higher than found in African adults who showed severe zinc deficiency (9). The RBC zinc concentration in Koreans (8 μg/g protein) was one quarter of the level reported in subjects from the USA (31 μg/g protein) (22). Bearing in mind the low dietary zinc and high phytate intakes, it is highly likely that a significant proportion of the subjects were marginally zinc deficient.

CONCLUSION

Zinc intake and status of 760 healthy male and female adult South Koreans with a mean age of 54 were assessed using a food frequency questionnaire and zinc biochemical markers. Daily Zn intakes for men (7.4 mg/d) and women (7.0 mg/d) were low (62% and 70% of the Korean RDA, respectively). The phytate : zinc and phytate × calcium : zinc molar ratios were high at 38 and 398, respectively. Both the low intake of zinc and the high phytate and phytate × calcium ratios with zinc suggest that South Koreans may be at risk of zinc deficiency. However, plasma zinc (86 ± 61 μg/dL), urinary zinc (33 ± 27 μg/dL) and plasma alkaline phosphatase (102 ± 52 mU/mL) levels were within the normal range, which indicates that these zinc status markers were not sufficiently sensitive to detect marginal zinc deficiency in these subjects. It is likely that at least a proportion of the subjects were marginally zinc deficient and the wider consumption of zinc rich, phytate deficient foods would be beneficial.

ACKNOWLEDGEMENTS

This research was supported by a grant of the Korea Health 21 R&D project, Ministry of Health & Welfare, Republic of Korea (HMP-00-B-22000-00153). Authors also gratefully thank to MD Hyun-Soo Shin, Mr. Baek-il Kim in Andong Medical Center, and Ms. Mal-Soon Ha, Mr. Sang-Yong Cho, and the group of Health Promotion in Andong Public Medical Center, and the group of Health Promotion in Taegu Public Medical Center.

REFERENCES

1. Hambidge M. 2000. Human zinc deficiency. *J Nutr* 130: 1344S-1349S.
2. Korean Nutrition Society. 2000. *Korean Recommended Dietary Allowance*. 7th ed. Seoul, South Korea.
3. Kwun IS, Kwon CS. 2000. Dietary molar ratios of phytate : zinc and millimoar ratios of phytate × calcium : zinc in South Koreans. *Biol Trace Ele Res* 75: 29-41.
4. Ministry of Health and Welfare of Republic of Korea. 1997. *1995 National Nutrition Survey Report*. Ministry of Health and welfare of Republic of Korea, Seoul.
5. Food and Drug Safety Section of Korean Ministry of Health and Welfare. 2002. *Korean Food Composition Table*. Seoul, South Korea.
6. Korean Food Drug Association. 1996. *Korean Food Composition Table*. Seoul, South Korea.
7. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. 1951. Protein measurement with the Folin phenol reagent. *J Biol Chem* 193: 265-275.
8. Burgess E, Audette R, Knudtson M, Wyse G. 1999. Trace elements as determined by ICP-MS analysis in patients with coronary artery disease. Proceeding of 10th International Symposium on Trace Elements in Man and Animal.
9. Gibson RS, Huddle JM. 1998. Suboptimal zinc status in pregnant Malawian women: its association with low intakes of poorly available zinc, frequent reproductive cycling, and malaria. *Am J Clin Nutr* 67: 702-709.
10. Cavan KR, Gibson RS, Grazioso CF, Isalgue AM, Ruz M, Solomons NM. 1993. Growth and body composition of periurban Guatemalan children in relation to zinc status : a cross-sectional study. *Am J Clin Nutr* 57: 334-343.
11. Moser-Veillon RT. 1990. Zinc: consumption patterns and dietary recommendations. *J Am Diet Assoc* 90: 1089-1093.
12. Gibson RS, Smit Vanderkooy PD, Thompson L. 1991. Dietary phytate × calcium/zinc millimolar ratios and zinc nutriture in some Ontario preschool children. *Biol Trace Ele Res* 30: 87-94.
13. Smit Vanderkooy PD, Gibson RS. 1991. Food consumption patterns of Canadian preschool children in relation to zinc growth status. *Am J Clin Nutr* 45: 609-616.
14. Ellis R, Kelsay RD, Reynolds RD, Morris ER, Moser PB, Frazier CW. 1987. Phytate : zinc and phytate × Ca : Zn millimolar ratios in self-selected diets of American, Asian Indians, and Nepalese. *J Am Diet Assoc* 87: 1043-1047.
15. Murphytate SP, Calloway DH. 1986. Nutrient intakes of women in NAHNES II, emphasizing trace minerals, fiber, and phytate. *J Am Diet Assoc* 86: 1366-1371.
16. Davies NT. 1982. Effects of phytatetic acid on mineral availability. In *Dietary Fiber in Health and Disease*. Vahouny G, Kritchevsky D, eds. Wilson and Wiley Publisher, New York. p 105-116.
17. Bindra GS, Gibson RS, Thompson L. 1986. (Phytate) (calcium)/(zinc) molar ratios in Asian immigrant lacto-ovo vegetarian diets and their relationship to zinc nutriture. *Nutr Res* 6: 475-483.
18. Harland BF, Smith SA, Howard MP, Ellis R, Smith JC. 1988. Nutritional status and phytate : zinc and phytate × calcium : zinc dietary molar ratios of lacto-ovo vegetarian trappist monks : 10 years later. *J Am Diet Assoc* 88: 1562-1566.
19. Hambidge M, Krebs NF. 2001. Interrelationships of key variables of human zinc homeostasis: Relevance to dietary zinc requirements. *Ann Rev Nutr* 21: 429-452.
20. Hambidge KM, Casey CE, Krebs NF. 1986. Zinc. In *Trace Elements in Human and Animal Nutrition Fifth Edition*. Mertz W, ed. Western Publisher, New York. Vol 2, p 1-137.
21. Hambidge M. 2003. Biomarkers of trace mineral intake and status. *J Nutr* 133: 948S-955S.
22. Wallock LM, King JC, Hambidge KM, English-Westcott JE, Pritts J. 1993. Meal-induced changes in plasma, erythrocyte, and urinary zinc concentrations in adult women. *Am J Clin Nutr* 58: 695-701.
23. Helgeland K, Haider T, Jonsen J. 1982. Copper and zinc in human serum in Norway. Relationship to geography, sex and age. *Scand J Clin Lab Invest* 42: 35-39.
24. Madaric A, Ginter E, Kadrablva J. 1994. Serum copper, zinc and copper/zinc ratio in males : influence of aging. *Physio Res* 43: 107-111.

(Received November 19, 2003; Accepted January 16, 2004)