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Dietary Molar Ratios of Phytate : Zn and Phytate × Ca : Zn for Zn Nutrition Assessment in Koreans*

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ABSTRACT

Zinc nutriture in South Koreans was evaluated by estimating Zn, Ca, and phytate intake, and the molar ratios of phytate : Zn and the millimolar ratios of phytate × Ca : Zn. Food consumption data from the '95 National Nutrition Survey was used. For the present study, data from the nationwide, large city and urban area level were used. No standard deviation measures were provided in the '95 National Nutrition Survey: only mean values were reported. Nationwide daily intake of Zn and Ca were 10.1 mg/day and 426.5 mg/day, respectively. The estimated daily phytate intake was 1676.6 mg/day nationwide. The molar ratio of phytate : Zn, the millimolar ratio of phytate × Ca : Zn and the phytate × Ca : Zn mmol per 4.2 MJ (1000 kcal) were 15.9, 168.9 and 91.8 in nationwide, respectively. The major food groups for zinc intake were meat, poultry products (43%), and cereals and grain products (18%). Sixty two percent of zinc was from animal food sources. Cereal and grain products supplied most of the phytate intake (46%), followed by seasonings, fruits, and legume products. The major food source of phytate was rice (39%). The results of the present study suggest that Zn status of Koreans maybe influenced by high dietary intake of phytate and high molar ratios of phytate : Zn and phytate × Ca : Zn. These results raise concerns about Zn status of Koreans, who consume a diet higher in phytate than Western diets. Further research is necessary to confirm whether such poorly available dietary Zn has any impact on the health of Koreans.

KEY WORDS: Zn, Ca, phytate, molar ratio, Koreans.

INTRODUCTION

The nutritional adequacy of zinc depends on both dietary intkae and bioavailability. Phytate (myoinositol hexaphosphate), a compound found primarily in plant seeds, is widely reported as a major factor inhibiting the bioavailability of zinc.[1-4] Growth retardation, the major zinc-deficiency syndrome, has been observed in otherwise healthy children living in the United States and Canada.[5][6] In these two countries, meats and fish foods are the major food sources of readily available zinc, whereas grain products are a major food source of phytate, a component known to inhibit zinc absorption in their diet.

Use of the phytate : Zn molar ratio to predict the bioavailability of zinc from high phytate foods was suggested by Oberleas and Prasad.[7] The ratio has since been used for assessment of the inhibitory effect of phytate on Zn absorption in the diet.[2][3][8][9] Ca has also been reported to accentuate the effect of phytate. Thus, the inhibitory effect of phytate on Zn absorption is exacerbated by high levels of dietary Ca.[2][10] Because of the potentiation effect of Ca on phytate, it has been proposed that the dietary phytate × Ca : Zn molar ratio provides a more useful assessment of Zn bioavailability than the phytate : Zn molar ratio alone.[11-13] Thus, Zn nutrition can be influenced by three dietary variables : Zn, Ca and phytate. Suggested critical values for phytate : Zn molar and phytate × Ca : Zn millimolar ratios were reported as > 10 and > 200, respectively.[2][14][15]

The main dietary staples in South Korea have traditionally been rice and plant-based foods that are higher in dietary phytate and fiber, than Western foods. Hence, in the present study, we estimated the Zn, Ca, and phytate intake of Koreans and calculated the molar ratios of phytate : Zn and phytate × Ca : Zn using Korean food consumption data from the '95 National Nutrition Survey Report.[16]

METHODS

1. Daily Food Intake Data in '95 National Nutrition Survey Report ('95NNSR)

The food consumption data used for this study was taken from the '95 National Nutrition Survey, conducted in November 1 – 20, 1995 in South Korea.[16] The results of

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the survey were reported in the '95 national Nutrition Survey Report in March 1997. Food intake of each member in the 2,000 households which were surveyed in large cities, small cities, and rural areas, was measured for two consecutive weekdays by food record method. There were a Total 1,453 food items were included in the '95 National Nutrition Survey. Among them, the major food items in each food group were chosen, and the consumption of each food item was calculated on a daily per capita basis. The most-consumed 214 foods, -the intake of which was reported in the '95NNSR, were used for analysis of the minerals and phytate intake for the present study, and for establishment of the relative importance of each food group and its items with respect to mineral and phytate intake. The food consumption data in the '95 NNSR was shown at the nationwide, urban area (large city and small city), and rural area level. For the present study, the national, large city, and rural data was analyzed. Standard deviation values were not provided.

2. Assessment of minerals (Zn, Ca) and phytate intakes

Daily Zn, Ca, and phytate intake was calculated from food composition tables and the database,[27-32] a cross-referenced index and various values from the literatures.[3)10)18-26)33)] The daily molar ratio of phytate : Zn and millimolar ratio of phytate × Ca : Zn were calculated. The percentage contributions of each food group and food item to total daily mineral and phytate intake were calculated.

Phytate intake was calculated using a phytate food-composition obtained from the various literature values.[3)10)18-24)] Adjustments were made, when necessary, to take into account any known changes in phytate content arising from food processing and preparation methods.[23)25)26)] Values for Ca in consumed food items were obtained from literature values for Korean food components in the Korean Food Composition Tables,[27)28)] Korean food database,[29)] and other literature sources.[30-32)] Values for Zn which is not established in the Korean Food Composition Table were taken from USA food composition tables[30)] and other selected papers for Korean food analysis.[33)] Any changes in Ca and Zn content due to food processing and preparation methods were not regarded in the present study. For some foods for which the element values could not be found in the literature, the element values for a related food, grouped in the same food group and having similar element contents, were substituted. Ca and Zn intake valves compared with recommended dietary allowances for Koreans.[17)]

RESULTS

1. Daily mineral (Zn, Ca) and phytate intake

The calculated daily Zn, Ca, and phytate intake of South Koreans in rural areas, large cities and nationwide per capita are shown in Table 1. Estimated daily intake level of Zn and phytate were not included in the '95 NNSR data. The intake values as a percentage of Korean RDA for male and female adults are shown below the nutrients and phytate intakes.

Daily per capita intakes of Zn and Ca were 10.1 mg/day and 426.5 mg/day nationwide, respectively. Both daily Zn and Ca intake in the large city group was higher than in the rural areas (Table 1). Daily phytate intake was estimated to be 1676.6 mg/day nationwide. Unexpectedly, the phytate intake in the large city group was greater than in the rural residents (Table 1). This result might imply that people in the large city might have higher nutrition awareness than those in the rural areas. The people in the large city ate more high phytate-containing foods that are also high fiber foods, such as whole brown rice, potatoes, tofu, soybean milk drink, nuts, and tangerines, than the people in rural areas (3.9, 13.9, 27.4, 0.5, 1.3, and 33.5 g/day/capita vs 0.1, 8.7, 19.8, 0.1, 0.8, and 9.7 g/day/capita, respectively).

Table 2 shows Korean food sources that contain high levels of Zn, Ca and phytate. Oyster is the highest Zn-containing food source, and milk and milk products are the highest Ca-containing ones. Legumes and their products are the highest phytate-containing food sources.

2. Molar ratios of phytate : Zn and millimolar ratios of phytate × Ca : Zn

Table 3 shows the daily molar ratios of phytate : Zn,

Table 1. Daily intake of selected minerals and phytate in Korean diet (mg/day/capita)

Nutrient	Nationwide[a]	Large city	Rural area
	10.1	11.0	7.7
Zn[b]	M 67%	M 73%	M 51%
	F 84%	F 91%	F 64%
	426.5	455.2	348.9
Ca[b]	M 61%	M 65%	M 50%
	F 61%	F 65%	F 50%
Phytate	1676.6	1674.1	1610.5

a: Values were calculated from the food intake (per capita per day) in nationwide, large cities, small cities, and rural areas.
b: Percentage of male (M) and female adults (F) RDA for Koreans (6[th] revision, 1995) was shown below the daily intake. RDAs of each mineral for Korean adults are as followed: Zn, 15 mg for male and 12 mg for female: Ca, 700 mg for male and female: Fe, 12 mg for male and 18 mg for female.

Table 2. Food items for high levels of Zn, Ca, and phytate in Korean diet (mg/g)[a]

Rank	Zn[b]	(mg/g)	Ca[c]	(mg/g)	Phytate[d]	(mg/g)
1	Oyster	(0.9095)	Powered milk	(11.8417)	Legume	(23.22)
2	Sesame and its products	(0.1029)	Cheese	(7.2857)	Walnut	(19.77)
3	Beef	(0.1027)	Sardine	(3.8319)	Sesame	(16.16)
4	Chicken	(0.0474)	Anchovy	(2.3149)	Garlic	(11.80)
5	Pinenuts	(0.0429)	Tofu	(1.0563)	Pinenuts	(9.33)
6	Crab	(0.0424)	Legume	(1.0233)	Peanuts	(9.33)
7	Milk and its products	(0.0402)	Crude molasses brown	(1.6500)	Buckwheat	(9.19)
8	Walnuts	(0.0343)	Figs	(1.4385)	Peas	(8.51)
9	Rice cake	(0.0333)	Sesame	(1.3158)	Brown rice	(5.18)
10	Peanuts	(0.0331)	Cowpeas	(1.2805)	Millet	(4.94)

a: Values were from the food composition tables and the database, a cross-referenced index and various values from the literatures.
b: Values for Zn were taken from the USA food composition tables (30) and other selected paper for Korean food analysis (33)
c: Values for Ca were obtained from the literature values for Korean food components in the Korean Food Composition Tables (27-28), Korean food database (29) and other literature values (30-32)
d: Phytate contents were from the phytate food-compositions in the various literature values (3, 10, 18-24)

Table 3. Molar and millimolar ratios of phytate, Zn, and Ca in Korean diets (per capita per day)

	Nationwide	Large city	Rural Area
Phytate : Zn (mol)	15.9	14.9	20.3
Phytate × Ca : Zn (mmol)	168.9	169.6	176.9
Phytate × Ca : Zn (mmol per 4.2 MJ)	91.8	90.0	103.4

a: The ratios were expressed as molar basis.
b: The ratios were expressed as millimolar basis.
c: The ratios were expressed in mmol per 4.2 MJ (1000 kcal) to account for differences in the amount of food consumed. The data of energy intake for calculation of the mmol was obtained from '95 NNSR.

millimolar ratios of phytate × Ca : Zn, and phytate × Ca : Zn mmol per 4.2 MJ (1000 kcal) in nationwide, large cities, and rural areas. The molar ratio of phytate : Zn and millimolar ratio of phytate × Ca : Zn were 15.9 and 168.9, respectively, nationwide. As expected, both the molar ratio of phytate : Zn and the millimolar ratio of phytate × Ca : Zn were higher in rural areas than in large cities. The phytate × Ca : Zn mmol per 4.2 MJ, which was calculated to account for differences in the amount of food consumed to compare with the data from the different survey units, was also highest in rural areas (Table 3).

Table 4. Contributions of the selected minerals and phytate from the food groups in Korean diet [mg/day/capita (% total intake)][a]

Food group	Zn	Ca	Phytate
Plant foods			
Cereals and grain products	1.85 (18.2)	37.7 (8.8)	768.7 (45.9)
Potatoes and starches	0.06 (0.6)	6.1 (1.4)	10.4 (0.6)
Sugars and sweets	0.01 (0.1)	1.4 (0.3)	0.3 (0.02)
Legumes and their products	0.27 (2.7)	31.7 (7.4)	191.1 (11.4)
Seeds and nuts	0.07 (0.7)	1.3 (0.3)	12.1 (0.7)
Vegetables	0.86 (8.5)	151.9 (35.6)	116.1 (6.9)
Fungi and mushrooms	0.02 (0.2)	0.1 (0.0)	–
Fruits	0.19 (1.9)	11.5 (2.7)	214.0 (12.8)
Seaweeds	0.09 (0.9)	24.8 (5.8)	–
Beverage	0.01 (0.1)	0.7 (0.2)	19.5 (1.2)
Seasonings	0.42 (4.1)	14.8 (3.5)	270.8 (16.1)
Oils and fats (vegetable)	–	–	60.6 (3.5)
Others	0.02 (0.2)	1.6 (0.4)	11.6 (0.6)
Animal foods			
Meat, poultry and their products	4.39 (43.3)	11.7 (2.7)	–
Eggs	0.24 (2.4)	10.9 (2.6)	–
Fish and shellfish	1.37 (13.5)	38.7 (9.1)	–
Milk and dairy products	0.27 (2.6)	81.6 (19.1)	1.41 (0.08)
Oils and fats (animal)	–	–	–
Subtotal plant foods	3.87 (38.2)	283.6 (66.5)	1675.2 (99.9)
Subtotal animal foods	6.27 (61.8)	142.9 (33.5)	1.4 (0.1)
Total	10.1 (100.0)	426.5 (100.0)	1676.6 (100.0)

a: Values were calculated from daily food intake in '95NNSR nationwide in South Korea.

3. Major food groups and food items for mineral and phytate intakes

The amounts and percentage contribution of each food group and the major food items to the daily intake of Zn, Ca, and phytate are shown in Tables 4 and 5, respectively. Cereals and grain products, vegetables, and legumes and their products were the major food groups for Zn, Ca, and phytate intake in plant food sources, contributing 29% for Zn, 52% for Ca, and 64% for phytate intake (Table 4). Rice, a major dietary item that provided one-third of the daily energy and protein intake in Korea,[19] was a major source of Zn (12%), and phytate (39%), except in Ca (6%) (Table 5). Vegetables provided one third of the daily Ca intake, mainly from radish leaves, chinese cabbage, spinach, garlic, and kimchi. Anchovy, known as the major source of Ca for Koreans, did not contribute much to Ca intake (3%). The best animal food source for Ca was milk (19%) (Table 5).

More than half (62%) of Zn was from animal food sources. This was unexpected, given the traditional Korean diet. As animal sources, meat, poultry and their pro-

Table 5. Contributions of the major food items to daily selected minerals and phytate intake in Koreans [mg/day/capita (% total intake)][a]

Rank	Zn		Ca		Phytate	
1	Beef	[3.23 (32)]	Milk	[66.8 (16)]	Rice	[653 (39)]
2	Rice	[1.25 (12)]	Kimchi	[58.4 (14)]	Soybean paste	[193 (11)]
3	Pork	[0.55 (5)]	Tofu	[26.9 (6)]	Tofu	[96 (6)]
4	Chicken	[0.39 (4)]	Rice	[25.0 (6)]	Soybean	[84 (5)]
5	Oyster	[0.36 (4)]	Radish leaves	[19.4 (5)]	Garlic	[70 (4)]
6	Kimchi	[0.29 (3)]	Chinese cabbage	[12.7 (3)]	Tangerine	[64 (4)]
7	Eggs	[0.24 (2)]	Spinach	[10.9 (3)]	Plant oil products	[61 (4)]
8	Soybean paste	[0.23 (2)]	Anchovy	[10.9 (3)]	Apple	[37 (2)]
9	Milk	[0.21 (2)]	Eggs	[10.8 (3)]	Instant noodle	[27 (2)]
10	Tofu	[0.20 (2)]	Garlic	[9.8 (2)]	Kimchi	[22 (1)]

a: Values were calculated from the daily food intake nationwide in '95NNSR in South Korea.

ducts were the most important source of dietary Zn, providing > 43% (Table 5). Among the foods consumed, the best sources of zinc were beef (31.8% of total daily Zn intake), rice, pork, chicken, oyster, kimchi, eggs, and soybean paste etc. (Table 5).

Cereals and grain products supplied most of the dietary phytate (46%), followed by legumes and their products, fruits, and seasonings. All of these accounted for 86% of daily total phytate intake (Table 4). These food groups supplied the majority of phytate intak : rice (39% of total daily phytate intake), soybean and its products (soybean paste, tofu, and Chong-guk-jang, a type of soybean paste), garlic, tangerines, plant oil products, and apples *etc.* (Table 5). The foods highest in phytate consumed in Korea were soybeans (23.2 mg/g) and sesame (16.2 mg/g).

DISCUSSION

Populations consuming a predominantly vegetarian diet may be limited in quantity or quality of dietary Zn. The Korean diet may be characterized as being plant food-based with high consumption of grain products, legumes, and vegetables, and low intake level of flesh food and milk products. The daily Zn intake of the Koreans in this study ranged from 7.7 – 11.0 mg/day. This was below the range of RDA for both males and females (51 – 91% of Korean RDA). Zinc consumption was considerably lower in rural area (51 – 64%). The average daily Zn intake of Koreans was similar with that of pregnant Guatemalan women (11.3 mg/day)[9] and that of East African women (9.0 mg/day).[34] Korean daily zinc intake was lower than that of low-income, Black pregnant (14.5 mg/day) and white pregnant women (12.2 mg/day) in the USA,[35] and normal healthy Americans (11.9 – 12.3 mg/day).[36,37] In the present study, interpretation of Zn adequacy in Koreans must be carried out with caution: comparison of the daily Zn intake in Koreans does not account for varition in intake among age groups or individuals because the data was estimated on per capita daily basis. Lower Zn intake in Koreans may be a risk factor for Zn deficiency.

The primary Zn source in the normal Korean diet, was animal products, a rich source of readily available Zn (Table 4, 5). Flesh and fish food groups provided 57% of dietary Zn in the Korean diet, compared with 19% in the diets of Guatemalan pregnant women. This is comparable to the major Zn sources in the North American omnivorous adult diet which showed higher Zn intake,[35-37] than in Koreans. This seems to imply changes in the Korean diet patterna shift from a plant-oriented to an animal-oriented diet. Actually, Koreans derived 61% of their food energy from plant sources, while animal protein intake accounted for half of their total protein intake.[16] The Zn content of rice, soybean, and tofu, the main food items in normal Korean diets were 4.9 mg/g, 11.5 mg/g, and 7.9 mg/g, respectively.[27,33]

Ca intake levels (349 – 455 mg/day) were considerably below (50 – 61%) recommended amounts, which was much lower than the Western omnivorous diet.[9,35,37,38] However, it was higher than in the African diet.[37] In the present study, only 19% of the calcium was from dairy products, which are known as the best Ca sources.

It is not surprising that the estimated phytate intake (1676.6 mg/day) of Koreans was higher than that of omnivorous Canadians (422 mg/day),[13] Americans (395 – 781 mg/day),[36,39,40] or English people (600 – 800 mg/day).[41] The phytate intake in Koreans was even higher than that of some lacto-ovo vegetarians in USA (568 – 972 mg/day).[9,11] This can be attributed to the high phytate content of grain products (1.6 – 2.6 mg/g), legumes (23.2 mg/g), and their products (Tofu and Korean soybean paste *etc.*). However, the phytate intake estimated in the present study is lower than that of the normal Guatemalan diet (2254 mg/day).[8] Daily phytate intake was similar to that of American lactoovovegetarians (1656 mg/day).[37] The dietary components that had the most effect on phytate values appeared to be the grain products and sesame in normal Korean diets.

For the molar ratio of phytate : Zn above which Zn status may be compromised, some investigators suggest a critical value of 10 – 15[2,3,14] and ratio above 20 for clinical Zn deficiency.[2,41] The daily molar ratios of phytate : Zn (14.9 – 20.3) in the present study showed ratios high enough for Zn nutriture to be compromised in Koreans, specially in rural area where the ratio was shown to be nearly 20.0 (Table 1). The results of the present study indicate that most Koreans have dietary phytate : Zn molar ratios above 15.0, which suggests that they must be at risk for Zn deficiency. Even though rural people had lower daily phytate intake than the urban people, the people in rural areas had higher daily phytate : Zn molar ratio (20.3) than in the large cities (14.9) (Table 3). The reason for this is that Zn intake in the rural area was lower than in the large city (Table 1). The daily phytate : Zn molar ratios in Korean diets (14.9 – 20.3) were higher than those of most Western omnivorous diets (4.0 – 5.8)[2,37,40-42] and some American ovo-lacto vegetarian diets (5.0).[42] The molar ratios of phytate : Zn in urban Koreans were lower than those of the diets of pregnant Guatemalan women,[8] cereal-based Eastern African diets (21.0 – 27.0).[43] or Trappist monks in America (67.0).[9] The molar ratios of phytate : Zn in Koreans were similar with those in Western lactoovovegetarian.[9,11,37]

Millimolar ratios of phytate × Ca : Zn equal to or greater than 200 are considered to induce marginal Zn deficiency in men.[11] Most Koreans in rural and city areas showed phytate : Zn molar ratio above the critical levels for zinc absorption. Meanwhile, the millimolar ratios of phytate × Ca : Zn were shown to be below the critical levels. Phytate × Ca : Zn millimolar ratios below the critical levels would be positive for zinc absorption. However, this implied another negative aspect : low phytate × Ca : Zn millimolar ratios were due to the low intake of Ca. Ca intake in urban, rural, and national areas of South Korea were 455.2 mg, 348.9 mg, and 426.5 mg, respectively, which are 65%, 50%, and 61% of Korean RAD for normal adults. The large discrepancy between phytate : Zn and phytate × Ca : Zn millimolar ratios as indices of phytate effect on bioavailability of zinc in the Korean diet appears to be a result of the low dietary Ca content of the Korean diet.

The suggested critical millimolar ratio of phytate × Ca : Zn, which was expressed per 4.2MJ (1000 kcal) to account for differences in the amount of food consumed, was $>$ 22. This ratio induces marginal Zn deficiency.[11] The mean daily ratio of phytate × Ca : Zn in Korean diets (mmol/4.2MJ) (90.0 – 103.4) were nearly four times higher than the suggested critical ratio. The daily phytate × Ca : Zn mmol/4.2 MJ in Korean diets were higher than in Canadian adult omnivorous diets (73 mmol/4.2MJ)[44] and in periurban Guatemalan pregnant women (40 mmol/4.2MJ).[8] However, it was considerably lower than in eastern African children's preschool diets (172 – 225 mmol/4.2 MJ) or the diets of adult Asian immigrant to canada (251 mmol/4.2 MJ).[11]

CONCLUSION

The results of the present study indicate a relatively high suboptimal Zn nutriture in Koreans. These results may be attributed to their high intake of phytate relative to Zn, high molar ratios of phytate : Zn, and phytate × Ca : Zn mmol per MJ. In addition, lower-than-RDA intakes of Zn and Ca may attenuate Zn deficiency more severely.

The results of the present study show that the Zn status of Koreans was influenced by a high dietary intake of phytate and the molar ratios of phytate : Zn and phytate × Ca : Zn. These results raised concerns about the Zn status of South Korean people, who consume a diet higher in phytate than in Western diets. Further research is necessary to confirm whether such poorly available dietary Zn has any impact on the health of Koreans.

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