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ORIGINAL PAPER

Dietary intake of minerals (Ca, P, Na, K, Mg, Fe, Zn, Cu, Mn, I, Se, and Mo) in young Korean adults with a self-selected diet

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Abstract

This study assessed dietary 12 mineral intakes in young Korean adults with a self-selected diet. The study aimed to investigate the intake status of minerals in young adults for balanced nutritional management. As a cross-sectional study, anthropometric measurements and a dietary intake survey using a 24-hour recall method were conducted in 100 adults aged 19–31 years. Then, 12 mineral intakes of the subjects were analysed using mineral content databases. The daily mineral intakes of all subjects were 525.02 mg for Ca, 1041.89 mg for P, 3538.83 mg for Na, 2270.92 mg for K, 204.62 mg for Mg, 12.21 mg for Fe, 6.80 mg for Zn, 726.11 ug for Cu, 4.43 mg for Mn, 147.35 ug for I, 77.93 ug for Se, and 58.23 ug for Mo. Cereals (Fe, Mo), vegetables (K, Mg), meat (P, Zn, Se), and teas·beverages·alcohols (Cu, Mn) were the main food groups of various mineral intakes along with milks and dairy products (Ca) and seaweeds (I). Dietary intake of Ca, K, Mg, and Zn did not meet the recommended nutrient intake (RNI) or adequate intake (AI). In addition, the minerals in which the index of nutrient quality value was less than 1 were Ca at 0.82, K at 0.79, Mg at 0.77, and Zn at 0.88. However, the daily intake of P, Na, and Mo significantly exceeded the RNI or AI. In young Korean adults with a self-selected diet, dietary intakes of some minerals (Ca, K, Mg, and Zn) did not meet the dietary reference intakes, while some (P, Na, and Mo) were met. Therefore, we can suggest that balanced mineral intake is needed along with intake exceeding the mineral reference value.

Keywords: minerals, dietary intake, nutritional status, food and beverages, young adult

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INTRODUCTION

Essential minerals, which account for approximately 4%-5% of body weight, are crucial for controlling and maintaining various physiological functions in the body. Minerals are divided into macrominerals and microminerals depending on their body content and requirements. Macrominerals in the body are more than 0.05% of their body weight or require more than 100 mg per day, and calcium (Ca), phosphorus (P), sodium (Na), potassium (K), chloride (Cl), sulfur, and magnesium (Mg) are included (Lukaski 2004). Minerals differ in the degree to which they are absorbed and used in the body according to bioavailability as well as their food content. The bioavailability of minerals is greatly influenced by physiological needs, as well as interactions between minerals, between vitamins and minerals, and between dietary fibre and minerals (Fairweather-Tai 1996, Harvey 2001). For example, polyvalent ions, such as Mg, Ca, iron (Fe), and copper (Cu), are similar in size or amount of charge, so they compete with each other when absorbed and affect bioavailability and metabolism (Gharibzahedi, Jafari 2017).

Minerals also interact in body function; for example, Ca and P play an important role in the formation and growth development of the skeleton. Mg or manganese (Mn) is essential for enzymatic action, and Na, K, and Cl are involved in the electrolyte balance, transmission of nerve impulses, and muscle contraction (Gharibzahedi, Jafari 2017). Recently, due to excessive energy intake and the decrease in nutrient density, there has been a concern about the deficiency of micronutrients, especially essential minerals, related to chronic diseases, and the research need is high (Mozaffarian 2016, Castiglione et al. 2018, Cheng et al. 2019). Most studies on mineral nutrition have been conducted in addition to assessing the intake of energy or macronutrients. Furthermore, studies on specific minerals such as Ca, Na, and Fe, which provide much information on mineral content in food, were focused on in our investigations. However, to consider the interaction between minerals and to establish appropriate intake standards for minerals that can contribute to disease prevention and health promotion, studies should be conducted to simultaneously evaluate the intake status for various minerals.

In the United States Health and Nutrition Examination Survey (NHANES), mineral intakes have been assessed on nine elements: Ca, P, Mg, Fe, Zn, Cu, Se, K, and Na (National Health and Nutrition Examination Survey 2020). In Korea, seven minerals, Ca, P, Na, K, Mg, Fe, and Zn, have been evaluated for intake, mainly because there are not enough databases of mineral content in food and beverages (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). According to the recent NHANES, the mineral intake of Koreans was reported as 64.3% for Ca, 143.7% for P, 158.6% for Na, 75.0% for K, 99.4% for Mg, 92.7% for Fe, and 124.0% for Zn compared to the recommended nutrient intake

(RNI) or adequate intake (AI) (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). These results show that the interactive minerals of Ca and P, and Na and K are not balanced. The minerals required by the body are diverse and affect the absorption of other minerals through their interactions, and the mineral content or utilization rate of food greatly differs. Therefore, for the appropriate consumption of minerals, there is a way to consume enough of each mineral, but it is important to consume various foods.

It is necessary to continuously assess the intake status of various minerals to establish appropriate standards of mineral intake and apply them to nutrition management. Therefore, the purpose of this study was to provide scientific evidence for proper nutrition management of various minerals by comprehensively assessing the intake status of 12 minerals in young Korean adults.

MATERIAL AND METHODS

Subjects

This study was conducted on 100 healthy young adults (50 men and 50 women) aged 19 to 31 years living in Chungcheongnam-do, Korea who understood the study purpose and contents, and agreed to participate. This study was approved by the Institutional Review Board of Kongju National University (KNU_IRB_2020_57), and written informed consent was obtained from all subjects.

Anthropometric measurements

The height and body weight of the subjects were measured using an automatic height measuring instrument (DS-102, Jenix, Seoul, Korea) and Inbody (DX-505, Biospace, Seoul, Korea), with all metal substances removed from their bodies, in light clothes, without shoes or socks, and while maintaining an upright posture. Body mass index (BMI) was calculated by dividing the measured body weight (kg) by the height squared (m^2).

Dietary intake survey and analysis

A dietary intake survey was conducted by a 24-hour recall method to investigate the name and quantity of the foods consumed the day before the survey. To help the study subjects remember their diets and to increase the intake accuracy, auxiliary tools such as actual photos of ingredients, food, and containers were utilized. Based on the survey data, daily food intake, energy, and nutrient intake were analysed using the nutrition analysis program Can-pro 5.0 (The Korean Nutrition Society, Seoul, Korea, 2016). This dietary intake analysis program does not have sufficient databases on the mineral content of food items. Therefore, the mineral intakes of the subjects were analysed using mineral content databases produced by the food composition table of the National Rural Living Science Institute, Korea (National Institute of Agricultural Sciences, Rural Development Administration 2021). Considering food items, the database of mineral content covered 99.6% for Ca, 99.9% for P, 99.1% for Na, 98.9% for K, 78.7% for Mg, 99.9% for Fe, 78.4% for Zn, 78.3% for Cu, 78.1% for Mn, 76.6% for iodine (I), 77.7% for Se, and 76.7% for molybdenum (Mo) in this study (Table 1). The mineral content of foods not included in the mineral content database was analysed by replacing it with a similar food from the database. The proportion of mineral intake to dietary reference intakes (DRIs) and index of nutrient quality (INQ) for minerals were also analysed. The INQ of minerals was calculated using the following formula: INQ = mineral intake per 1000 kcal/RNI (or AI) of minerals per 1000 kcal (Sorenson et al. 1976).

Statistical analysis

All results obtained in this study were calculated as the mean, standard deviation, frequency, and percentage using the SAS program (Version 9.4, SAS Institute Inc, Cary, NC, USA). The variable differences between male and female subjects were tested using Student's unpaired *t*-test for continuous variables and χ^2 test for discontinuous variables. The significance level of all tests was set at $p<0.05$.

RESULTS

General characteristics

As shown in Table 2, the age, height, and body weight of the male subjects were significantly higher than those of the female subjects, but there was no significant difference in the BMI. For energy and nutrient intake, the daily intake of men was also significantly higher than that of women, except for carbohydrates.

Daily mineral intake

Twelve mineral intakes of the subjects are shown in Table 3. The daily mineral intakes of all subjects were 525.02 mg for Ca, 1041.89 mg for P, 3538.83 mg for Na, 2270.92 mg for K, 204.62 mg for Mg, 12.21 mg for Fe, 6.80 mg for Zn, 726.11 ug for Cu, 4.43 mg for Mn, 147.35 ug for I, 77.93 ug for Se, and 58.23 μg for Mo. The P and Zn intake of men was significantly higher than that of women.

Table 1

Database on food content of 12 minerals in Korean food composition table[1)]

	Food groups	The number of foods	Ca	Fe	Mg	P	K	Na	Zn	Cu	Mn	Se	Mo	I
1	Cereals	317	315(99.4)[#]	314(99.1)	201(63.4)	317(100.0)	315(99.4)	310(97.8)	201(63.4)	201(63.4)	198(62.5)	178(56.2)	166(52.4)	164(51.7)
2	Potatoes and starches	67	67(100.0)	67(100.0)	52(77.6)	67(100.0)	67(100.0)	66(98.5)	50(74.6)	52(77.6)	50(74.6)	48(71.6)	44(65.7)	44(65.7)
3	Sugars and sweeteners	51	44(86.3)	48(94.1)	36(70.6)	45(88.2)	44(86.3)	47(92.2)	39(76.5)	35(68.6)	32(62.7)	32(62.7)	23(45.1)	23(45.1)
4	Pulses	71	71(100.0)	71(100.0)	56(78.9)	71(100.0)	70(98.6)	70(98.6)	56(78.9)	56(78.9)	55(77.5)	54(76.1)	52(73.2)	51(71.8)
5	Nuts and seeds	84	84(100.0)	84(100.0)	51(60.7)	84(100.0)	79(94.0)	78(92.9)	51(60.7)	51(60.7)	48(57.1)	46(54.8)	38(45.2)	36(42.9)
6	Vegetables	620	618(99.7)	614(99.0)	392(63.2)	619(99.8)	582(93.9)	581(93.7)	391(63.1)	392(63.2)	392(63.2)	367(59.2)	357(57.6)	355(57.3)
7	Mushrooms	95	95(100.0)	95(100.0)	61(64.2)	95(100.0)	89(93.7)	89(93.7)	61(64.2)	61(64.2)	61(64.2)	61(64.2)	61(64.2)	61(64.2)
8	Fruits	260	260(100.0)	259(99.6)	199(76.5)	260(100.0)	254(97.7)	252(96.9)	191(73.5)	199(76.5)	192(73.8)	170(65.4)	152(58.5)	153(58.8)
9	Meats	329	31(96.7)8	309(93.9)	244(74.2)	329(100.0)	323(98.2)	323(98.2)	243(73.9)	244(74.2)	240(72.9)	232(70.5)	158(48.0)	157(47.7)
10	Eggs	28	28(100.0)	28(100.0)	23(82.1)	28(100.0)	27(96.4)	27(96.4)	23(82.1)	23(82.1)	23(82.1)	22(78.6)	20(71.4)	20(71.4)
11	Fishes	681	676(99.3)	664(97.5)	141(20.7)	664(97.5)	322(47.3)	323(47.4)	141(20.7)	141(20.7)	116(17.0)	89(13.1)	65(9.5)	67(9.8)
12	Seaweeds	57	53(93.0)	53(93.0)	8(14.0)	53(93.0)	26(45.6)	27(47.4)	8(14.0)	8(14.0)	5(8.8)	7(12.3)	7(12.3)	7(12.3)
13	Milks and milk products	52	52(100.0)	52(100.0)	52(100.0)	52(100.0)	52(100.0)	52(100.0)	52(100.0)	51(98.1)	48(92.3)	45(86.5)	36(69.2)	35(67.3)
14	Oils and fats	33	31(93.9)	33(100.0)	32(97.0)	31(93.9)	32(97.0)	33(100.0)	30(90.9)	31(93.9)	26(78.8)	29(87.9)	20(60.6)	20(60.6)
15	Teas, beverages, alcohols	110	109(99.1)	107(97.3)	78(70.9)	107(97.3)	103(93.6)	106(96.4)	72(65.5)	74(67.3)	78(70.9)	74(67.3)	59(53.6)	60(54.5)
16	Seasonings	97	97(100.0)	96(99.0)	74(76.3)	92(94.8)	96(99.0)	95(97.9)	73(75.3)	73(75.3)	71(73.2)	61(62.9)	54(55.7)	52(53.6)
17	Prepared foods	128	127(99.2)	127(99.2)	27(21.1)	127(99.2)	127(99.2)	127(99.2)	27(21.1)	27(21.1)	27(21.1)	27(21.1)	18(14.1)	18(14.1)
18	Others	33	33(100.0)	33(100.0)	20(60.6)	33(100.0)	29(87.9)	29(87.9)	20(60.6)	20(60.6)	17(51.5)	19(57.6)	15(45.5)	15(45.5)
Total number		3113	3078(98.9)	3054(98.1)	1747(56.1)	3074(98.7)	2637(84.7)	2635(84.6)	1729(55.5)	1739(55.9)	1679(53.9)	1561(50.1)	1345(43.2)	1338(43.0)
Coverage in this study, %			99.6	99.9	78.7	99.9	98.9	99.1	78.4	78.3	78.1	77.7	76.7	76.6

[1)] National Institute of Agricultural Sciences, Rural Development Administration. 2021. *Korean Food Composition Table (version 9.3)*. National Institute of Agricultural Sciences, Rural Development Administration. Wanju, Korea

[#] n (%)

Table 2

General characteristics of the subjects

Specification	Total subjects *n*=100	Men *n*=50	Women *n*=50	*p*-value
Age (years)	21.9±1.7[!]	22.5±1.4	21.3±1.8	<0.001[!!]
Height (cm)	167.3±8.9	174.7±5.5	160.0±4.5	<0.001
Body weight (kg)	66.5±14.0	74.0±10.3	59.0±13.3	<0.001
Body mass index (kg m^{-2})	23.6±3.9	24.2±2.8	23.0±4.7	0.119
Daily intake				
Food (g)	1200.8±525.9	1311.4±631.4	1090.1±368.0	0.035
Energy (kcal)	1929.6±701.7	2085.5±764.5	1773.8±600.7	0.026
Carbohydrates (g)	245.1±92.3	255.7±93.6	234.5±90.6	0.252
Fat (g)	59.5±34.3	67.8±39.2	51.1±26.8	0.014
Protein (g)	73.5±34.5	83.7±39.2	63.4±25.8	0.003

[!] Mean ±SD, [!!] *p*-value by Student's unpaired *t*-test

Table 3

Daily intake of 12 minerals of the subjects

Specification	Total subjects *n*=100	Men *n*=50	Women *n*=50	*p*-value
Ca (mg)	525.0±426.6[!]	511.8±355.1	538.3±491.1	0.758[!!]
P (mg)	1041.9±487.4	1146.5±545.0	937.3±400.7	0.031
Na (mg)	3238.8±1441.4	3511.8±1525.8	2965.9±1310.6	0.058
K (mg)	2270.9±1334.2	2388.8±1387.7	2153.0±1281.6	0.380
Mg (mg)	204.6±161.2	210.3±159.6	198.9±164.2	0.724
Fe (mg)	12.2±11.1	12.2±10.7	12.2±11.5	0.990
Zn (mg)	6.8±4.6	7.9±5.2	5.7±3.5	0.018
Cu (ug)	726.1±983.5	719.9±1053.5	732.4±918.8	0.950
Mn (mg)	4.4±10.3	4.2±10.2	4.6±10.5	0.854
I (ug)	147.4±500.2	84.2±206.9	210.5±674.2	0.211
Se (ug)	77.9±46.9	84.8±53.5	71.1±38.6	0.145
Mo (ug)	58.2±52.1	61.3±59.0	55.1±44.5	0.555

[!] Mean ±SD, [!!] *p*-value by Student's unpaired *t*-test

Daily mineral intake from food groups

Daily mineral intake from food groups of total subjects is shown in Table 4. The food groups that contributed to food intake were teas·beverages·alcohols (223.24 g, 18.6% of total intake) and cereals (209.96 g, 17.5%). In addition, the food groups that contributed to calcium intake were milks and milk products (93.87 mg, 17.9%), meats (257.64 mg, 24.8%) for P, seasonings

Table 4

Daily intake of 12 minerals from food group of the subjects

	Food groups	Food (g)	Ca (mg)	P (mg)	Na (mg)	K (mg)	Mg (mg)	Fe (mg)	Zn (mg)	Cu (ug)	Mn (mg)	I (ug)	Se (ug)	Mo (ug)
1	Cereals	210.0± 123.9[1]	51.1±83.6	186.6± 111.3	310.4±386.5	264.4±156.4	20.8±22.0	2.9±2.7	0.9±1.4	99.9±122.6	0.4±0.4	3.5±9.0	16.9±24.6	14.2±20.6
2	Potatoes and starches	36.5±55.5	6.2±11.9	22.8±45.6	23.1±77.1	153.8±258.6	8.8±14.4	0.3±0.5	0.1±0.2	43.3±71.7	0.1±0.3	0.3±1.4	1.4±2.9	1.1±2.5
3	Sugars and sweeteners	14.0±30.6	6.4±23.9	10.0±35.7	4.7±22.0	18.9±65.6	3.5±16.5	0.1±0.6	0.1±0.3	18.0±87.0	0.0±0.1	0.8±4.7	0.5±1.7	0.5±1.6
4	Pulses	23.6±46.3	14.3±26.4	37.4±68.9	1.8±14.6	46.8±114.5	17.9±33.1	0.4±0.7	0.3±0.5	37.7±80.9	0.2±0.3	0.0±0.2	0.3±0.6	10.2±18.9
5	Nuts and seeds	33.6±75.3	17.4±35.6	27.2±63.8	22.3±50.9	60.0±196.1	10.9±28.1	0.3±0.6	0.2±0.4	47.0±137.3	0.4±1.8	0.0±0.2	0.6±1.5	2.3±12.8
6	Vegetables	184.5± 146.8	73.2±99.1	81.2±77.9	202.8±198.9	475.6±409.4	31.3±43.8	1.0±1.2	0.6±0.6	72.9±84.4	0.4±0.4	2.9±4.7	2.8±2.4	12.2±22.2
7	Mushrooms	4.0±19.0	0.1±0.7	3.8±18.1	0.2±0.7	16.9±76.5	0.4±2.2	0.0±0.2	0.0±0.1	2.8±14.0	0.0±0.0	0.0±0.1	0.3±2.5	0.0±0.2
8	Fruits	53.7±135.9	4.4±13.5	9.0±26.0	1.9±13.0	82.4±208.3	4.1±10.6	0.1±0.2	0.1±0.1	17.0±43.8	0.0±0.1	0.0±0.2	0.1±0.3	0.6±2.1
9	Meats	130.3± 105.1	11.6±10.9	257.6±213.2	324.9±491.3	325.5±286.9	22.7±33.9	2.0±3.9	2.6±2.9	48.5±56.7	0.2±1.5	0.3±0.8	21.9±23.3	0.9±1.2
10	Eggs	42.5±55.7	22.4±29.8	81.8±108.7	56.2±74.1	56.1±74.3	4.7±6.2	0.8±1.0	0.5±0.7	15.2±20.8	0.0±0.0	29.3±42.8	15.2±20.2	2.1±2.8
11	Fishes	31.5±46.6	91.0±256.2	96.8±120.1	217.5±337.7	79.7±104.3	16.2±27.6	0.7±1.4	0.3±0.5	37.6±111.3	0.0±0.1	4.6±13.3	7.4±13.4	0.4±0.8
12	Seaweeds	2.3±8.9	8.8±22.8	5.5±10.6	46.2±137.3	64.2±193.2	3.1±15.1	0.1±0.2	0.0±0.1	0.3±1.2	0.0±0.0	93.1±485.6	0.3±1.6	0.0±0.2
13	Milks and dairy products	76.9±134.4	93.9±163.3	73.4±126.4	42.6±76.9	105.7±195.5	8.4±15.0	0.1±0.3	0.3±0.6	5.1±25.6	0.0±0.0	6.2±11.6	3.2±5.8	2.1±3.5
14	Oils and fats	12.3±10.6	1.3±1.5	2.8±3.5	0.8±2.2	1.7±2.1	1.0±1.2	0.1±0.1	0.0±0.0	2.3±3.0	0.0±0.0	0.2±0.2	0.5±0.5	0.0±0.3
15	Teas, beverages, alcohols	223.2± 418.2	57.1±210.7	52.7±148.7	5.1±20.5	259.1±901.5	29.3±99.5	1.9±7.6	0.5±1.8	234.7±938.3	2.3±9.4	1.1±3.2	1.2±3.7	0.4±1.1
16	Seasonings	30.3±27.6	13.3±14.5	29.7±27.2	1590.4±1137.0	152.4±136.3	16.4±15.8	0.5±0.6	0.2±0.2	25.0±25.9	0.2±0.2	4.2±30.2	1.9±3.5	4.3±4.2
17	Prepared foods	91.6±135.7	52.6±112.7	63.7±144.6	387.9±621.8	107.6±208.9	5.2±14.5	1.0±2.3	0.2±0.6	18.9±57.1	0.1±0.2	0.7±4.0	3.5±10.4	6.9±35.6
Total		1200.8±526.8	525.0±426.5	1041.9± 486.9	3238.8±1441.4	2270.9± 323.0	204.6± 160.7	12.2±11.1	6.8±4.6	726.1± 982.3	4.4±10.3	147.4±500.2	77.9± 46.9	58.2±52.1

[1] Mean ±SD

(1590.38 mg, 49.1%) for Na, vegetables (475.64 mg, 20.9%) for K, vegetables (31.27 mg, 15.3%) for Mg, cereals (2.85 mg, 23.3%) for Fe, meats (2.61 mg, 38.4%) for Zn, teas beverages alcohols (234.7 ug, 32.3%) for Cu, teas beverages alcohols (2.32 mg, 52.4%) for Mn, seaweeds (93.12 ug, 63.2%) for I, meats (21.87 ug, 28.1%) for Se, and cereals (14.20 ug, 24.4%) for Mo.

Assessment of mineral intake compared to dietary reference intake (DRI)

When the mineral intake of the subjects was compared with the RNI or AI, Ca, K, Mg, and Zn did not meet the DRIs (Table 5). In addition, I (80%), Mn (79%), Mg (78%), Zn (69%), Ca (68%), and K (66%) were the minerals with the highest proportion of subjects consuming less than the estimated average requirement (EAR) or 75% of AI. The proportion of subjects with Fe intake above the EAR showed significant differences, with 58% for men and 36% for women ($p<0.05$).

Index of nutritional quality (INQ) of minerals

The INQ of 12 minerals of the subjects is shown in Table 6. In all subjects, the minerals in which the INQ value was less than 1 were Ca at 0.82, K at 0.79, Mg at 0.77, and Zn at 0.88. The INQ of iron was 1.44 for men but 0.98 for women, which did not reach 1 ($p<0.05$).

DISCUSSION

In this study, 12 mineral intake statuses were evaluated in young Korean adults with a self-selected diet. The main results showed insufficient dietary intake of Ca, K, Mg, and Zn. However, the intake of P, Na, and Mo significantly exceeded the DRI. Koreans have insufficient Ca intake, which is considered an important nutritional problem. According to the Korea NHANES, the daily calcium intake (% of RNI) of Koreans was reported to be 503.2 mg (70.3%) in 2012, 499.4 mg (69.8%) in 2015, 516.2 mg (68.4%) in 2018, and 484.1 mg (64.3%) in 2021 (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). The Ca intake of the subjects in this study was 525.02 mg/day, which was 70.43% of the RNI, which was a low intake level similar to the NHANES. In addition, the proportion of people who consumed less than the EAR was high at 68.0%, which was also similar to 71.7% of the NHANES (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022), and the INQ was 0.82, indicating that Ca intake was insufficient.

One of the main reasons why Koreans lack sufficient Ca intake is their low consumption of milk and dairy products with high Ca content. In addi-

Table 5

Comparative assessment of daily 12 mineral intakes to dietary reference intakes of the subjects

Specification	Total subjects n=100	Men n=50	Women n=50	p-value
Ca (% RNI)	70.4±58.8[!]	64.0±44.4	76.9±70.2	0.274[#]
≥ EAR	32(32.0)[!!]	15(30.0)	17(34.0)	0.668[^]
P (% RNI)	148.8±69.6	163.8±77.9	133.9±57.2	0.031
≥ EAR	85(85.0)	43(86.0)	42(84.0)	0.779
Na (% AI)	215.9±96.1	234.1±101.7	197.7±87.4	0.058
≥ 75% AI	96(96.0)	49(98.0)	47(94.0)	0.307
K (% AI)	64.9±38.1	68.3±39.7	61.5±36.6	0.380
≥ 75% AI	34(34.0)	21(42.0)	13(26.0)	0.091
Mg (% RNI)	64.7±52.1	58.4±44.3	71.0±58.6	0.228
≥ EAR	22(22.0)	10(20.0)	12(24.0)	0.629
Fe (% RNI)	104.6±96.8	122.0±107.4	87.3±82.3	0.073
≥ EAR	47(47.0)	29(58.0)	18(36.0)	0.028
Zn (% RNI)	75.2±48.1	78.8±51.9	71.6±44.2	0.461
≥ EAR	31(31.0)	18(36.0)	13(26.0)	0.280
Cu (% RNI)	98.7±133.0	84.7±124.0	112.7±141.4	0.295
≥ EAR	40(40.0)	18(36.0)	22(44.0)	0.414
Mn (% AI)	118.9±276.4	105.9±254.8	131.9±298.6	0.640
≥ 75% AI	21(21.0)	8(16.0)	13(26.0)	0.220
I (% RNI)	98.2±333.4	56.2±137.9	140.3±449.4	0.211
≥ EAR	20(20.0)	11(22.0)	9(18.0)	0.617
Se (% RNI)	129.9±78.2	141.3±89.1	118.5±64.3	0.145
≥ EAR	72(72.0)	37(74.0)	35(70.0)	0.656
Mo (% RNI)	212.5±186.8	204.4±196.6	220.5±178.1	0.669
≥ EAR	71(71.0)	34(68.0)	37(74.0)	0.509

[!] Mean ±SD, [!!] n (%), [#] p-value by Student's unpaired t-test, [^] p-value by χ^2 test.

tion to the Ca content in food, the absorption rate of Ca should be considered important. The absorption rate of Ca is approximately 25%-40% for milk and dairy products, but the absorption rate for vegetable foods is low, approximately 5% for spinach, and the absorption rate is as low as approximately 10%-30% for vegetarian meals. On this basis, milk and dairy products are evaluated as the best sources of Ca both in bioavailability and high content (Taylor, Curhan 2013). Although the food group that contributed the most to Ca intake in this study was milk and dairy products, the intake was only 76.91 g/d, which is less than half a glass of milk. On the other hand, due

Table 6

Index of nutritional quality on 12 minerals of the subjects

Specification	Total subjects *n*=100	Men *n*=50	Women *n*=50	*p*-value
Ca	0.8±0.6[!]	0.8±0.4	0.9±0.7	0.421[!!]
P	1.8±0.5	2.0±0.5	1.5±0.5	<0.001
Na	2.6±1.1	3.0±1.1	2.3±0.9	<0.001
K	0.8±0.4	0.8±0.3	0.7±0.4	0.223
Mg	0.8±0.5	0.7±0.4	0.9±0.7	0.132
Fe	1.2±1.0	1.4±1.0	1.0±0.8	0.017
Zn	0.9±0.5	0.9±0.5	0.8±0.5	0.233
Cu	1.1±1.4	1.0±1.2	1.3±1.6	0.221
Mn	1.3±2.9	1.1±2.5	1.4±3.2	0.595
I	1.2±4.0	0.7±1.7	1.6±5.4	0.236
Se	1.5±0.8	1.8±0.9	1.3±0.6	0.004
Mo	2.6±3.2	2.7±4.0	2.6±2.1	0.889

[!] Mean ±SD, [!!] *p*-value by Student's unpaired *t*-test

to the high intake of cereals and vegetables, this vegetarian diet not only shows a quantitative lack of Ca intake, but also problems such as low-bio-availability Ca sources.

P is the second most abundant mineral in the body after Ca, and plays a role in bone formation, pH balance of body fluids, body composition, enzyme activation, and energy metabolism (Calvo, Lamberg-Allardt 2015). P is evenly contained in almost all foods and widely used in various processed foods in the form of phosphate, a food additive, so it is rare for people to have P deficiency from consuming ordinary meals (Takeda et al. 2014). Rather, because too much P intake inhibits Ca absorption and increases Ca loss, it is necessary to maintain the intake ratio of Ca:P at 1:1 (Calvo et al. 1996, Whybro et al. 1998). The RNIs of Ca and P in Korea are 800 mg and 700 mg for adult men in their 20 s, respectively, and 700 mg for women (Bu et al. 2022). The recommended intake of Ca:P is mostly close to 1:1, with 1,000 to 700 for the US (Calvo et al. 1990, Kemi et al. 2006), 800 to 1,000 for Japan (Ministry of Health, Labour and Welfare 2020), and 1,000 to 1000 for Australia and New Zealand (National Health and Medical Research Council 2006). However, the Ca intake of the subjects in this study was 70.43% of the RNI, but the intake of P was 148.84%, which has the possibility of reducing the absorption of Ca.

The Na intake of Koreans has been evaluated as consistently high for a long time, with 4549.4 mg (241.0% of the goal intake of 2000 mg) in 2012, 3874.2 mg (204.4%) in 2015, 3255.0 mg (171.5%) in 2018, and 3038.0 mg (158.6%) in 2021 (Ministry of Health and Welfare, Korea Centers for Disease

Control and Prevention 2022). The Na intake of the subjects in this study was 3238.83 mg/d, which was also high at 215.92% of the AI. Unlike Na, K intake has recently been decreasing due to a decrease in the intake of cereals, vegetables, and fruits, which are the main sources of K, and accordingly, the proportion of adults who do not meet AI is high (Lee et al. 2013, Bailey et al. 2016). According to the Korea NHANES, K intake compared to AI was reported to decrease to 85.3% in 2012, 86.8% in 2015, 76.2% in 2018, and 75% in 2021 (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). In this study, the K intake was 2270.92 mg/d, which was 64.88% of the AI, and the INQ was 0.79, which was less than 1. The food group that contributed the most to the K intake was vegetables. K, the most abundant monovalent cation in cells, is an essential mineral for normal cell function, such as maintaining the volume of intracellular fluid and the difference in electrochemical concentration inside and outside cells (Gumz et al. 2015). In a study by Kwon et al. (2022), when 143,050 Koreans were analysed for the association between Na and K intake and mortality and cardiovascular mortality, it was reported that Na intake was not associated, while high consumption of K was associated with a decrease in mortality and cardiovascular mortality, but the actual K intake was insufficient at 2225.7 mg/d. Considering these studies, it is necessary to lower Na intake and increase the intake of K-rich fruits, vegetables, and whole cereals for the balanced intake management of Na and K.

Mg is mostly contained in plants in nature, and approximately 50%-60% of the body's content is present in bones and an important mineral for bone formation along with Ca and P (Saris et al. 2000). According to the Korea NHANES, the Mg intake of Koreans was 308.4 mg (107.4% of RNI) in 2016, 295.0 mg (102.9%) in 2018, 276.8 mg (96.6%) in 2020, and 282.7 mg (99.4%) in 2021 (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). However, the Mg intake of the subjects in this study was 204.62 mg/d, which was 64.73% of the RNI, and the proportion of subjects who consumed EAR or higher was 22%, indicating a low Mg intake status and an INQ of 0.77, which was less than 1. In a study by Shim et al. (2023), which analysed data from the Korea NHANES, Mg intake in adults in their 20s was 276.6 mg/d, and the proportion of EAR or higher was 45%, which was slightly higher than that of the subjects in our study, and similar results were reported in other previous studies (Bae, Choi 2011, Choi, Weaver 2017). The low Mg intake of this study can be interpreted as follows: the average intake of vegetables, the main sources of Mg, was 280.6 g/d for Koreans aged 19 or older (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022), while the intake of our subjects was low at 184.45 g/d. Vegetables are decreasing in consumption despite various health benefits (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022), which may also affect the Mg intake. Therefore, we suggest that it is necessary to maintain a sufficient intake of vegetables for the nutritional management of Mg intake.

It is common knowledge that nutritional management should be done so that mineral intake does meet the requirement or dietary reference value. However, it is easy to overlook the need for an intake balance between minerals. It is important to balance the intake of Fe, Zn and Cu along with Ca and P, Na and K, as mentioned above. Fe and Zn, as bivalent cations, are mutually competitively absorbed by divalent metal transporter 1 (Whittaker 1998), and both Zn and Cu are competitively absorbed by binding with metallothionein (Fischer et al. 1984). In addition, Fe and Cu interact similarly in body function or metabolism (Arredondo, Núñez 2005), so if one mineral's intake is too high, the bioavailability of the other mineral decreases. Since Zn and Cu are maintained in a 8:1 ratio in tissue, it has been reported that their preferable intake ratio is between 10:1 and 30:1 (Rosado 2003, Osredkar, Sustar et al. 2011). The Zn intake of the subjects in this study was 6.80 mg, the Cu intake was 726.11 ug, and the ratio was 9.36:1, which was relatively low. Zn intake was 75.18% of the RNI, the proportion of subjects who consumed EAR or higher was 31%, and the INQ was 0.88, indicating that the intake level was low. The main source of Zn was meat in this study, but it is necessary to maintain adequate Zn intake by increasing the intake of various food groups according to a study showing that Zn intake from brown rice or tofu is decreasing due to recent changes in eating habits.

In this study, the intake of Mn, I, Se, and Mo, including Cu, was evaluated in addition to the minerals currently evaluated in the Korea NHANES (Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention 2022). These minerals were close to the dietary reference values or significantly higher (double the reference value) for Mo, and all INQs were 1 or more, indicating that intake was sufficient. However, Mn and I showed that only 21% and 20% of subjects consumed more than 75% of AI and EAR, respectively, so the difference in intake between subjects was wide. In particular, although I intake was 56.16% of the RNI for men and 140.30% for women, the individual differences were large, but there was no significant difference between men and women. Since inter- and intraindividual variation in the meal has a significant effect on the intake of trace minerals, repeated surveys of multiple days of dietary intake are required to evaluate the exact intake of trace minerals.

It is not easy to evaluate the exact intake of trace minerals due to insufficient databases on their content in food. Even if it is the same food, the mineral content varies depending on the type of food, cultivation, or region produced, so analysis data should be prepared based on data about the foods produced in a given country (Marles 2017). In addition, data on mineral content for new foods such as processed foods, convenience foods, and home meal replacements, which are highly used by modern people, should be continuously prepared. Therefore, to continuously evaluate the intake status of trace minerals, including Mn, I, Se, and Mo, research should be conducted first to prepare a database on trace mineral content in food.

This study has limitations in generalizing the results. First, since mineral intake was assessed in a small number of subjects in a limited country of Korea, there will be limitations in applying it to countries with different dietary intake patterns. Second, the one-day dietary intake survey has limitations in adjusting for intraindividual variation in mineral intake. Therefore, in the future, research should be conducted to evaluate mineral intake through several days of dietary intake surveys in many subjects that can reduce dietary variations between and within subjects. Third, this study assessed the intake status of 12 different minerals, but some trace minerals may have measurement errors in the intake derived from the lack of a database on their food content. Despite these limitations, the strength of this study is that the intake status was evaluated in various aspects for 12 minerals, and the problem and importance of the intake balance between minerals were suggested.

CONCLUSIONS

In young Korean adults with a self-selected diet, dietary intakes of Ca, K, Mg, and Zn were found to be insufficient. However, the intake of P, Na, and Mo significantly exceeded the DRIs. Cereals (Fe, Mo), vegetables (K, Mg), meat (P, Zn, Se), and teas·beverages·alcohols (Cu, Mn) were the main food groups of various mineral intakes along with milks and dairy products (Ca) and seaweeds (I). These results suggest that balanced mineral intake is needed along with the intake exceeding mineral reference value.

Ethics declarations

This study was approved by the Institutional Review Board of Kongju National University (KNU_IRB_2020_57), and written informed consent was obtained from all subjects.

Conflict of interest

The authors of this study declare no conflict of interest.

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