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Analysis of Magnesium Contents in Commonly Consumed Foods and Evaluation of its Daily Intake in Korean Independent-Living Subjects

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Abstract Magnesium, an element involved in a variety of biochemical and physiological processes in the human body, is closely linked to maintaining health and preventing disease. Even so, studies on the status of magnesium intake have never been conducted sufficiently since only recently a dietary reference intake value was proposed, and data on magnesium contents in food items have always been insufficient. Therefore, in this study, we selected 366 food items commonly consumed by Korean people and then analyzed their magnesium content with inductively coupled plasma atomic emission spectroscopy. With these results, we evaluated daily magnesium intake in 239 healthy adult males and females. Using these 366 values based on magnesium content measurements, we evaluated the status of magnesium intake by our participants and found that the average daily magnesium intake was 279.2 mg, 90.4% of the recommended intake (RI). The results also showed that the magnesium intake by 54.8% of the subjects was lower than the estimated average requirement. In addition to this, the magnesium intake by 45.2% of the cohort was less than 75% of the RI. As such, a high percentage of the subjects showed inappropriate magnesium intake.

Keywords Magnesium · Commonly consumed food · Food analysis · Food composition · Daily intake

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Introduction

Magnesium is a major mineral that exists in the human body at a level of approximately 25 g. Of the 25 g, 50~60% of the magnesium exists in the skeletal structure, approximately 30% is contained in intracellular fluid, and approximately 1% exists in extracellular fluid [1]. In particular, magnesium that exists inside the human body takes part in the formation of the skeletal structure. Also, as a constituent of ATP, magnesium acts as a cofactor in over 300 enzyme systems, such as the synthesis of proteins and nucleic acids, as well as in lipid metabolism; therefore, it takes part in a variety of biochemical and physiological processes inside the human body [2, 3]. These facts clearly show that the magnesium is closely related to maintaining health and preventing disease.

On the other hand, the magnesium, as a constituent of chlorophyll, is contained in large quantities of green leafy vegetables. While the magnesium contents in nuts, legumes, and cereals are sufficiently high, the contents in meats, fish, milk, and fat are relatively lower [4, 5]. In general, magnesium intake through ordinary meal consumption is sufficient enough to prevent deficiency. However, 80~96% of the magnesium contained in food items is lost during the course of polishing [6]. So, the magnesium intake may become lower in diets that are highly dependent on refined or processed food items. Therefore, the present dietary life of Korea has become more convenient and gradually simplified due to the westernization of food choice, which may result in an increased incidence of magnesium deficiency.

In Korea, the estimated average requirement (EAR), recommended intake (RI), and tolerable upper intake level of magnesium were first established in 2005 after evaluating the dietary reference intakes (DRI) for Koreans [7]. With their diets centered around vegetables, magnesium intake would sufficiently meet the RI. However, since the DRI for magnesium was established only recently, in-depth studies conducted on the daily intake and nutritional statuses of magnesium in Korean people were seen as insufficient. One of the reasons for this lack of study is due to an insufficient database of the magnesium content in foods whose magnesium intake could be measured.

The Food Composition Table by the National Rural Resources Development Institute [8], whose database of magnesium content in food is used in Korea, provides magnesium contents in 918 varieties of food items. However, with the exception of 104 food items analyzed in Korea in a study by the Korea Health Industry Development Institute [9], the remainder of the data were taken from Japan [10] and the USA [11]. In order to obtain a more accurate evaluation of magnesium intake, the magnesium content of foods produced and ingested in the same region should be evaluated. As such, currently there are insufficient data in Korea to carefully evaluate magnesium intake. This problem is primarily due to the fact that there are not enough data on the magnesium composition of newly developed functional or processed food items. Therefore, it is necessary to conduct studies to analyze magnesium contents in commonly ingested food items. A comprehensive nutrient database that accurately evaluates magnesium intake is important for studies on health-related functions of magnesium, and a study that accurately evaluates magnesium intake by healthy ordinary meal-taking adults is also necessary.

Therefore, in this study, we intended to analyze magnesium contents in the most commonly consumed food items within Korea and, use the data, to evaluate daily magnesium intake by adult males and females who take ordinary meals each day. This study will contribute to the food composition data with which magnesium intake can be estimated and will be continuously utilized in the studies on nutritional evaluation of magnesium.

Materials and Methods

Chemicals

Using the commonly consumed food items in the Korean National Health and Nutrition Examination Survey (KNHANES) of 2005 [12], we selected 366 varieties of food frequently favored by Korean people. We purchased the selected food items, with preference to domestically grown products, from two large discount malls located in Chungnam region, and for imported products, we noted the places of origin. We obtained magnesium ICP standard from AnApex (Dae Jeon, South Korea), and all other reagents used were of the highest purity available.

Analysis on Magnesium Contents

We weighed the above-mentioned food items, removed the parts to be disposed of, and calculated the percentage of disposal and the percentage of edible parts. For two samples of each food item, we mixed them evenly by taking all edible parts from a food item such as an apple and by taking 100 g or more of food items eaten in consistent amounts, such as rice or meat. Then, by taking a prescribed amount of the evenly mixed sample, we created test solutions by breaking them down through a microwave digestion system (Ethos touch control, Milestone Inc., Italy). On the test solutions, we conducted quantitative analyses of magnesium content by using inductively coupled plasma atomic emission spectroscopy (ICP-AES; Thermoelemental Ltd., UK). The ICP-AES system was operated at 1,150 W forward power with a coolant flow of 12 $L min^{-1}$, sample uptake rate of 49 rpm, auxiliary gas flow rate of 0.5 $L min^{-1}$, and nebulizer gas flow rate of 0.6 $L min^{-1}$ with PFA nebulizer. The relative standard deviation obtained from four repetitive analyses on the same sample was less than 3%. Therefore, reproducibility was outstanding. Analytical recovery of the method has been checked by a parallel analysis of rice flour CRM 108-04-001 and oyster tissue powder 108-01-001 (Standard Reference Material, KRISS, South Korea), the certified reference materials. The detection limit and recovery of this method were 0.0003 mg Mg/kg and 102.01%, respectively. All instruments used in the experiment were washed thoroughly to prevent cross-contamination of minerals. Plastic products and glass products were, respectively, submerged in 0.4% EDTA solution and undiluted nitric acid solution for 24 h or longer. They were washed three times or more in secondary distilled water and desiccated in a dryer.

Drawing Up Database of Magnesium Contents

We categorized the results of our analysis on magnesium content per food group and created a database using the categorized results. A total of 366 food items consisted of 51 varieties of grains, seven varieties of potatoes and starches, seven varieties of sugar, 12 varieties of legumes, 11 varieties of nuts and seeds, 68 varieties of vegetables, seven varieties of mushrooms, 33 varieties of fruits, 13 varieties of meat, four varieties of eggs, 48 varieties of fishes and shellfishes, seven varieties of seaweed, 16 varieties of milk, eight varieties of fat, 27 varieties of beverages and liquors, 34 varieties of seasonings, and 13 varieties of other items. We gave five-digit food codes to each food item to be analyzed, and the codes were partially based on their groupings. The first two digits represent 17 food groups, and the remaining three digits represent the serial numbers in alphabetical order of the English names of food items for analysis. The analysis data were expressed as

mg magnesium per 100 g fresh-edible weight. Also, of the food items in the Food Composition Table from the Korea National Rural Resources Development Institute (2006), we presented the data of magnesium content together with the values of contents analyzed in this study.

Survey Subjects

We conducted a survey of 239 subjects, of which 100 were adult males and 139 were adult females, who were healthy, without any diseases, and did not take any medications or health supplements from Chungnam region. All participants gave their consent to participate in the survey. The age distribution of study targets ranged from 30 to 94 years, with no significant difference between men and women. The average age, height, weight, and body mass index were, respectively, 60.1 years of age, 166.7 cm, 66.4 kg, and 23.5 kg/m^2 for males and 59.5 years of age, 152.1 cm, 55.4 kg, and 23.9 kg/m^2 for the females. The survey study was approved by the Medical Research Ethnics Committee of the College of Medicine, Chung-Ang University in Seoul, Korea.

Dietary Intake Survey

The pre-trained research staff conducted dietary intake surveys through one-on-one interviews using the 24-h recall method. Surveys were conducted on types and quantities of food items consumed for breakfast, lunch, dinner, and snacks during the course of 1 day from the time of waking up in the morning to bedtime at night on the day before the survey. In order to standardize the surveys on meal intake, the research staff assisted survey targets in accurately remembering quantities of food items taken by presenting them with pictures and models of the food items prepared in advance. Then, using CAN-Pro 3.0 (The Korean Nutrition Society, South Korea), intakes of energy and major nutrients with magnesium exception were analyzed. Also, using magnesium contents in the food items analyzed in this study, we calculated magnesium intake.

Statistical Analysis

In relation to all results obtained in this study, we calculated the mean values and standard deviations by using an SAS program (version 9.1, SAS Inc., Cary, NC, USA). Differences in results of analysis between male and female subjects were analyzed through an unpaired *t* test. All results were verified as significant at a level of $p<0.05$.

Results

Magnesium Contents in the Commonly Consumed Foods

Magnesium content in commonly ingested food items are as shown in Table 1. Of the 51 varieties of grains, magnesium contents were in the range of 1.15~138.55 mg/100 g. The food item that showed the highest magnesium content per 100 g was Job's tears. The magnesium content of milled rice was 10.70 mg/100 g. In potatoes and starches, the magnesium content of potatoes and sweet potatoes were 17.98 mg/100 g and 13.70 mg/100 g, respectively. Korean vermicelli and devil's tongue jelly showed magnesium contents of 10 mg/100 g or less. For sugar items, the magnesium content of candy, honey, and sugar were, respectively,

Table 1 Magnesium Contents in Commonly Consumed Foods by Koreans

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
Grains	01001	Acorns starch jelly	1.15	NA
	01002	Barley biscuits for military	34.82	NA
	01003	Biscuits	26.00	22
	01004	Brown rice, germinated	88.86	110
	01005	Buckwheat flour	126.69	190
	01006	Buckwheat noodle	29.34	100
	01007	Cake	6.50	7
	01008	Cereals, whole grain	112.79	14
	01009	Choco pie	26.22	NA
	01010	Cooked rice, instant	2.47	NA
	01011	Corn	50.15	75
	01012	Corn, canned	16.93	NA
	01013	Cracker	23.71	18
	01014	Cream puff bread	8.54	9
	01015	Croissant	18.08	17
	01016	Custard	9.25	18
	01017	Doughnuts	26.61	14
	01018	Glutinous rice cakes, Gyeong Dan	23.17	NA
	01019	Glutinous rice cakes, In Jeol Mi	32.40	NA
	01020	Hamburger, Bulgogi	19.49	18
	01021	Job's tears	138.53	12
	01022	Loaf bread	20.89	18
	01023	Monaka	15.42	15
	01024	Naked barley	57.69	42
	01025	Pizza, combination	20.75	23
	01026	Prosomillet	121.30	84
	01027	Ra Myeon, noodle	21.47	22
	01028	Ra Myeon, cup ramyeon, large, noodle	22.35	NA
	01029	Ra Myeon, cup ramyeon, large, Yukgaejang, noodle	19.54	NA
	01030	Ra Myeon, cup ramyeon, small, noodle	25.73	NA
	01031	Ra Myeon, Jajang, noodle	20.94	NA
	01032	Rice, black	110.30	NA
	01033	Rice, glutinous	23.94	23
	01034	Rice, milled	10.70	18
	01035	Rice cake, Baek Seol Gi	13.86	NA
	01036	Rice cake, Ga Rae Tteok	13.01	12
	01037	Rice cake, honey cake	12.70	NA
	01038	Rice cake, Song Pyeon	11.68	NA
	01039	Rice cracker	17.13	34
	01040	Roll cake	8.19	NA

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	01041	Rye bread	43.36	NA
	01042	Small red bean paste bread	28.66	22
	01043	Snack	19.88	14
	01044	So Myeon	21.23	25
	01045	Sorghum	128.28	110
	01046	Spaghetti	50.85	55
	01047	Sponge cake	11.57	8
	01048	Udong, boiled	4.05	13
	01049	Wheat flour, frying powder	15.60	11
	01050	Wheat, medium flour	22.90	18
	01051	Wheat products, bread crumbs	38.73	NA
Potatoes and starches	02001	Devil's tongue	5.10	5
	02002	French fried potato	32.10	35
	02003	Potato	17.98	30
	02004	Potato chips	40.23	70
	02005	Starch vermicelli	3.97	3
	02006	Sweet potato	13.70	19
	02007	Yam	13.22	17
Sugars and sweeteners	03001	Candy	0.52	NA
	03002	Caramel, milk	10.31	13
	03003	Chocolate	59.75	67
	03004	Gum, chewing gum	45.07	NA
	03005	Honey	0.81	1
	03006	Jelly	0.45	NA
	03007	Sugar	0.98	0
Legumes	04001	Chung Tae, green bean	167.56	NA
	04002	Fried soybean curd	40.03	130
	04003	Kidney beans	86.64	150
	04004	Mungbeans	121.34	150
	04005	Peas	34.67	120
	04006	Red bean	101.84	NA
	04007	Seo Ri Tae, black bean	143.68	NA
	04008	Soybean curd	110.07	55
	04009	Soybean curd, soft	41.54	NA
	04010	Soybean milk	1.29	25
	04011	Soybean milk, black bean calcium soy milk	0.44	NA
	04012	Yak Kong, small black bean	189.01	NA
Nuts and seeds	05001	Chestnuts	42.01	26
	05002	Gingko nuts	46.41	53
	05003	Peanuts	178.53	200

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	05004	Perilla seeds powder	217.12	230
	05005	Pine nuts	181.87	290
	05006	Pistachio nuts, USA	108.61	120
	05007	Pumpkin seeds	379.71	530
	05008	Sesame seed, black, roasted, China	228.84	NA
	05009	Sesame seed, roasted, China	245.36	360
	05010	Sunflower seeds, China	253.55	NA
	05011	Walnuts, Vietnam	152.21	158
Vegetables	06001	Amaranth	265.67	55
	06002	Angelica keishei	24.98	NA
	06003	Beet	16.11	NA
	06004	Bracken, China	25.69	22
	06005	Broccoli, China	34.71	18
	06006	Bud, Aralia elats	27.51	9
	06007	Burdock	38.86	54
	06008	Butterbur	26.81	6
	06009	Cabbage	15.69	13
	06010	Carrot	12.20	12
	06011	Cauliflower	12.80	18
	06012	Chard	76.20	NA
	06013	Chicory	16.10	9
	06014	Chinese chive, *Allium senescens*	28.39	18
	06015	Cheong Gyeong Chae, Pak choi	24.72	NA
	06016	Crown daisy	26.25	26
	06017	Cucumber	10.54	10
	06018	Deo Deok, *Codonopsis lanceolata*	33.77	NA
	06019	Do Ra Ji, Balloonflower root, China	18.55	NA
	06020	Eggplant	16.05	17
	06021	Garlic, bulb	22.00	23
	06022	Garlic, young stem, China	10.47	NA
	06023	Ginger, tuber	29.57	27
	06024	Head lettuce	6.85	8
	06025	Kale	47.26	44
	06026	Kimchi, cucumber	24.29	NA
	06027	Kimchi, Korean cabbage	31.39	30
	06028	Kimchi, radish	20.62	13
	06029	Kimchi, small radish	37.06	26
	06030	Kimchi, watery plain	12.99	6
	06031	Kimchi, welsh onion	35.81	NA
	06032	Kkae Na Mul	122.69	NA
	06033	Korean Chinese cabbage, young	57.95	11

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	06034	Lettuce, green	62.48	19
	06035	Lettuce, red	41.55	NA
	06036	Lotus root, salted, China	4.72	16
	06037	Mallow	44.38	NA
	06038	Mugwort	17.52	29
	06039	Mungbean sprout, China	7.20	8
	06040	Onion	7.78	10
	06041	Parsley	36.96	42
	06042	Pepper, green	18.77	18
	06043	Pepper, green young	18.76	NA
	06044	Pepper, red	12.67	42
	06045	Perilla, leaves	94.52	63
	06046	Pumpkin, sweet	13.22	1
	06047	Pumpkin, immature	21.00	15
	06048	Pumpkin, Zucchini	12.90	9
	06049	Radish	5.58	7
	06050	Radish sprouts, USA	50.97	NA
	06051	Red cabbage	17.65	NA
	06052	Sedum	44.57	NA
	06053	Shepherd's purse	26.78	34
	06054	Soybean sprout	44.11	28
	06055	Spinach	102.20	87
	06056	Sprout vegetables	31.77	NA
	06057	Stem of taro, China	13.31	6
	06058	Sweet pepper, green	18.19	11
	06059	Sweet pepper, red	14.27	11
	06060	Sweet pepper, yellow	19.05	NA
	06061	Sweet potato, stalks	9.82	61
	06062	Tomato	11.26	9
	06063	Tomato, cherry tomato	9.26	13
	06064	Water dropwort	6.60	24
	06065	Welsh onion, large	14.47	1
	06066	Wild garlic	20.42	21
	06067	Wild plant, Cham Na Mul	47.18	NA
	06068	Wild plant, Chwi Na Mul	38.48	NA
Mushrooms	07001	*Agaricus bisporus*	13.95	NA
	07002	*Flamm velutipes*	10.03	NA
	07003	Juda's ear	187.73	210
	07004	*Lentinus edodes*	15.03	14
	07005	Manna lichen, North Korea	45.21	NA
	07006	Oyster mushroom	12.63	15

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	07007	Sae Song I mushroom	13.89	NA
Fruits	08001	Apple	4.92	5
	08002	Apple jam	0.13	2
	08003	Avocado, USA	32.93	33
	08004	Banana, USA	26.92	24
	08005	Citrus fruit, satsuma mandarin	10.65	11
	08006	Fruit cocktail	6.35	NA
	08007	Grape, Delaware	8.72	NA
	08008	Grape, green variety	9.54	NA
	08009	Grape, Kuho	7.61	7
	08010	Grape jam	0.27	10
	08011	Han Ra Bong	7.30	NA
	08012	Jujube, dried	61.52	39
	08013	Kiwi, New Zealand	15.78	13
	08014	Kumquat	22.30	19
	08015	Lemon, juice, USA	5.83	8
	08016	Lemon, raw, USA	7.42	11
	08017	Mango, Philippines	12.87	12
	08018	Melon, Musk	12.33	13
	08019	Melon, Yanggu	10.64	NA
	08020	Muskmelon	16.28	13
	08021	Olive, Spain	19.19	11
	08022	Orange, Australia	10.97	11
	08023	Peach	7.11	7
	08024	Peach, Chun Do	9.82	NA
	08025	Pear	7.19	5
	08026	Persimmon, hard	4.16	7
	08027	Persimmon, dried	15.86	NA
	08028	Pineapple, Philippines	15.77	14
	08029	Plum	6.88	5
	08030	Raisin, USA	43.62	31
	08031	Strawberry	12.87	12
	08032	Strawberry jam	0.66	7
	08033	Water melon	13.71	14
Meats	09001	Bacon	16.92	19
	09002	Beef jerky	38.09	NA
	09003	Beef, Korean cattle, brisket	19.67	21
	09004	Beef, Korean cattle, loin	19.25	19
	09005	Chicken	22.35	22
	09006	Ham, Bulgogi ham	12.25	NA
	09007	Ham, sliced	20.14	19

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	09008	Lucheon meat	13.91	13
	09009	Pork, belly	16.83	16
	09010	Pork, loin	26.28	22
	09011	Sausage, Dongrang Ddaeng	15.31	NA
	09012	Sausage, Frankfurt sausage	17.58	13
	09013	Sausage, Vienna sausage	15.60	13
Eggs	10001	Chicken's egg, egg yolk	9.85	12
	10002	Chicken's egg, egg white	14.42	11
	10003	Chicken's egg, whole egg	7.18	10
	10004	Quail's egg	9.94	11
Fishes and shellfishes	11001	Abalone	76.46	54
	11002	Alaska pollack	25.73	26
	11003	Alaska pollack, dried strip	122.16	NA
	11004	Anchovy, larvae	295.18	NA
	11005	Anchovy, boiled and dried	201.44	483
	11006	Anchovy, medium anchovy	249.19	514
	11007	Anchovy, salt-fermented, liquid type	117.86	NA
	11008	Angler, China	37.65	19
	11009	Butter clam, North Korea	28.71	NA
	11010	Canned tuna	27.23	27
	11011	Chum salmon, smoked, USA	23.29	28
	11012	Clam, meat	71.10	NA
	11013	Common octopus, North Korea	41.32	55
	11014	Common squid	16.61	33
	11015	Common squid, dried	209.98	170
	11016	Common squid, fillet	54.17	NA
	11017	Common squid, salt-fermented	37.88	NA
	11018	Corb shell	21.33	NA
	11019	Crab, blue crab, Bahrain	89.84	60
	11020	Croaker	19.34	28
	11021	File fish, fillet	46.55	NA
	11022	Fish paste	16.17	19
	11023	Flat fish	25.18	26
	11024	Granulated ark shell	63.38	10
	11025	Hair tail	26.65	36
	11026	Hard-shelled mussel	60.06	NA
	11027	Harvest fish	27.00	25
	11028	Icefish, dried strip	221.25	NA
	11029	Imitation crab meat	11.39	NA
	11030	Jacopever	29.43	NA
	11031	Jelly-fish	86.55	4

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	11032	Krami	21.78	NA
	11033	Little neck clam	63.47	100
	11034	Mackerel	14.12	30
	11035	Oyster	42.42	74
	11036	Pacific cod	21.83	24
	11037	Pacific saury	0.16	28
	11038	River snail	71.04	NA
	11039	Sea bream	33.09	NA
	11040	Sea cucumber	92.02	160
	11041	Shrimp	34.86	45
	11042	Shrimp, dried	210.31	21
	11043	Shrimp, salt-fermented	183.50	110
	11044	Spanish mackerel	34.60	32
	11045	Turban shell	101.25	54
	11046	Warty sea squirt	76.03	NA
	11047	Webfoot octopus	43.31	NA
	11048	Yellow croaker	28.82	26
Seaweeds	12001	Laver, for rice roll	328.79	298
	12002	Laver, seasoned	217.92	NA
	12003	Sea lettuce	113.66	NA
	12004	Sea mustard, dried	741.22	781
	12005	Sea mustard, stem, salted	70.41	70
	12006	Sea tangle, dried	461.46	NA
	12007	Sea tangle, raw	61.56	50
Milks	13001	Butter	1.78	2
	13002	Cheese, cheddar slice	23.28	19
	13003	Cheese, mozzarella	21.55	19
	13004	Cow's milk	11.67	7
	13005	Cow's milk, banana flavored milk	10.55	NA
	13006	Cow's milk, low fat, chocolate milk	14.60	NA
	13007	Cow's milk, low fat, coffee milk	10.36	10
	13008	Cow's milk, low fat, strawberry flavored milk	5.41	NA
	13009	Ice cream, bar	2.84	NA
	13010	Ice cream, cone	38.14	11
	13011	Mother's milk, 2 month	4.75	3
	13012	Yogurt, curd type, peach	22.62	NA
	13013	Yogurt, curd type, plain	16.30	12
	13014	Yogurt, curd type, strawberry	13.69	12
	13015	Yogurt, liquid type	4.70	5
	13016	Yogurt, liquid type, peach	9.05	NA

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
Oils and fats	14001	Coffee whitener	0.27	9
	14002	Corn oil	0.19	0
	14003	Grape seed oil	0.15	NA
	14004	Margarine	1.48	2
	14005	Olive oil	0.19	0
	14006	Peanut butter	153.18	180
	14007	Sesame oil	0.30	3
	14008	Soybean oil	0.52	0
Beverages and liquors	15001	Aloe taste drink	1.19	NA
	15002	Beer	5.96	6
	15003	Black tea, canned	0.29	NA
	15004	Black tea, infusion	0.94	1
	15005	Brown rice and green tea	1.69	1
	15006	Carbonated beverages	0.40	0
	15007	Cider	0.18	NA
	15008	Citron tea, honey citron tea	5.86	NA
	15009	Cocoa	89.56	130
	15010	Coffee, canned	5.95	5
	15011	Coffee, powder, instant	346.04	410
	15012	Coffee, roasted beans, infusion	4.24	6
	15013	Coffee mix	47.23	50
	15014	Coke	0.35	NA
	15015	Fanta	0.42	0
	15016	Ginseng tea	6.22	NA
	15017	Green tea, canned	0.31	NA
	15018	Honey ginger tea	12.48	NA
	15019	Isotonic drink	0.81	NA
	15020	Job's tears tea	6.48	NA
	15021	Mae Sil Ju	11.95	2
	15022	Red ginseng tea, canned	1.15	NA
	15023	Red wine	22.12	9
	15024	Sik Hye, canned	4.11	1
	15025	Soju	0.05	NA
	15026	Ssang Haw tea	14.41	NA
	15027	Tak ju, Korean turbid rice liquor	3.79	4
Seasonings	16001	Cheong Guk Jang	112.59	NA
	16002	Chun Jang	54.20	NA
	16003	Cinnamon powder	50.77	87
	16004	Coleslaw dressing	2.24	NA
	16005	Curry, powder	44.59	220
	16006	Go Chu Jang	45.24	32

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	16007	Horseradish	56.27	39
	16008	Hot sauce	36.02	13
	16009	Mat Sogum	12.72	NA
	16010	Mirim	0.58	2
	16011	Miwon	0.80	NA
	16012	Mixed soybean paste	58.70	NA
	16013	Mustard	71.41	83
	16014	Pepper	179.44	150
	16015	Pepper paste with vinegar	31.39	NA
	16016	Pork cutlet sauce	35.97	NA
	16017	Ra Myeon, flake	98.91	NA
	16018	Ra Myeon, seasoning	57.98	NA
	16019	Ra Myeon, cup ramyeon, large, block	33.28	NA
	16020	Ra Myeon, cup ramyeon, large, seasoning	41.55	NA
	16021	Ra Myeon, cup ramyeon, large, Yukgaejang, seasoning	30.43	NA
	16022	Ra Myeon, cup ramyeon, small, seasoning	33.96	NA
	16023	Ra Myeon, Jajang, flake	156.72	NA
	16024	Ra Myeon, Jajang, oil	0.32	NA
	16025	Ra Myeon, Jajang, seasoning	42.81	NA
	16026	Red pepper powder	167.91	15
	16027	Rice vinegar	1.28	6
	16028	Salt, table salt	25.51	23
	16029	Seasoning powder, beef	33.35	NA
	16030	Soybean paste	81.37	64
	16031	Soy sauce	53.28	36
	16032	Spaghetti sauce	23.13	NA
	16033	Tomato ketchup	21.98	20
	16034	Worcester sauces	7.79	NA
Prepared foods and others	17001	Curry, retort pouched	13.48	NA
	17002	Ginseng	53.85	NA
	17003	Ginseng, fresh	53.45	NA
	17004	Gom Kuk, thick beef soup	1.17	NA
	17005	Ja Jang, retort pouched	15.50	NA
	17006	Kimchi dumpling	36.46	NA
	17007	Miyok Kuk, sea mustard soup	2.39	NA
	17008	Pork rolls	24.89	NA
	17009	Rice gruels with pumpkin	8.37	NA
	17010	Sa Gol Gom Tang, beef bone broth	1.90	NA

Table 1 (continued)

Food group	Food code	Food description	Magnesium content (mg/100 g)	
			This study	Food composition table[a]
	17011	Silkworm pupa	48.92	NA
	17012	Soups, beef	32.04	NA
	17013	Spinach soybean Kuk	8.49	NA

NA not available

[a] National Rural Resources Development Institute, Rural Development Administration, South Korea (2006)

0.52 mg/100 g, 0.81 mg/100 g, and 0.98 mg/100 g. Among legume items, the magnesium content of soybean curd and black bean were, respectively, 110.07 mg/100 g and 143.68 mg/100 g. With magnesium contents of 100 mg/100 g or higher, green beans, red beans, and small black beans displayed higher levels of magnesium content compared to other food groups. As for nuts and seeds, magnesium contents were in the range of 42.01 mg/100 g for chestnuts to 379.71 mg/100 g for pumpkin seeds. Compared with legumes, nuts and seeds were found to have higher magnesium content. Among the 68 varieties of vegetables, magnesium content was lowest at 4.72 mg/100 g for lotus root and highest at 265.67 mg/100 g for amaranth. The magnesium content of cabbage kimchi was 31.39 mg/100 g, while for radish and onion, it was 5.58 mg/100 g and 7.78 mg/100 g, respectively. For fungi, the magnesium content of all mushrooms with the exception of Juda's ear mushroom (187.73 mg/100 g) were within the range of 10.03~45.21 mg/100 g. As for 33 varieties of fruits, the magnesium content of jujube and raisin were, respectively, 61.52 mg/100 g and 43.62 mg/100 g, which were higher than those of other fruits. In most varieties of fruits with the exception of jujube, raisin, avocado, banana, and kumquat, magnesium content was found to be 20 mg/100 g or less.

Among the 13 varieties of meat, the magnesium content of Bulgogi ham was the lowest at 12.25 mg/100 g, and it is highest in jerked beef with 38.09 mg/100 g. In most meats, the magnesium content was low at 40 mg/100 g or less. Of eggs, the magnesium content of chicken eggs and quail eggs were, respectively, 7.18 mg/100 g and 9.94 mg/100 g, and the magnesium content in egg yolks was 9.85 mg/100 g. In 48 varieties of fishes and shellfishes, the magnesium contents of dried seafood, such as dried anchovy, dried Alaska pollack, dried squid, dried icefish and dried shrimp, etc., were in the high level of 122.16~295.18 mg/100 g. However, in fish such as hair tail, mackerel, Spanish mackerel, yellow croaker and Pacific saury, etc., the magnesium content was low at 0.16~34.60 mg/100 g. In seaweed, the magnesium content was higher than in other food groups, with measurements of 328.79 mg/100 g in laver, 741.22 mg/100 g in sea mustard, and 461.46 mg/100 g in sea tangle. In dairy, magnesium content was 11.67 mg/100 g in milk and 4.70 mg/100 g in yogurt. Of the 16 varieties of dairy products, the lowest magnesium content of 1.78 mg/100 g was displayed in butter, while magnesium content in corn ice cream was the highest at 38.14 mg/100 g. Magnesium contents in fat, such as sesame oil, soybean oil, and corn oil, were at lower levels of 2 mg/100 g or less. However, the magnesium content of peanut butter was high at 153.18 mg/100 g.

Of the 27 varieties of beverages and liquors tested, black tea, carbonated drink, green tea, isotonic drinks, and Soju were displayed low at the magnesium contents of 1 mg/100 g or less.

On the other hand, the magnesium content of instant coffee powder was 346.04 mg/100 g, which was the highest found among all beverages and liquors. The second highest magnesium content was in cocoa (89.56 mg/100 g). Among the 34 varieties of seasonings, pepper, red pepper powder, and flakes in instant Chinese noodle and Cheonggukjang showed magnesium contents, respectively, at 179.44 mg/100 g, 167.91 mg/100 g, 156.72 mg/100 g, and 112.59 mg/100 g. On the other hand, the magnesium content in vinegar, Worcester sauce, Miwon, Mirim, and coleslaw dressing were low at 10 mg/100 g or less. As for other food items, the magnesium contents in ginseng and fresh ginseng were high at 53.85 mg/100 g and 53.45 mg/100 g, respectively. Precooked items of thick beef soup, sea mustard soup, and beef bone broth displayed low magnesium contents of 3 mg/100 g or less.

The magnesium contents analyzed in this study were compared with corresponding items from the Korean Food Composition Table [8] shown in Table 1. A highly significant and positive correlation was found between our values and their counterparts from the Korean Food Composition Table (data not shown).

Status of Magnesium Intake

Table 2 shows the results of evaluating the status of magnesium intake by 239 adult males and females using the data to analyze magnesium contents in 366 varieties of food items commonly taken by Korean people. The daily average calorie intake was 7,698.9 kJ for males, which was significantly higher than 6,301.6 kJ for females ($p<0.001$). As for daily average magnesium intake, 306.5 mg of male was significantly higher than 259.1 mg of female ($p<0.001$). However, magnesium intake per 1,000 kcal was found to be 172.9 mg/1,000 kcal and 171.2 mg/1,000 kcal for males and females, respectively. Therefore, there was no significant difference between the sexes. Also, on average, males and females consumed, respectively, 87.6% and 92.4% of RIs for magnesium. The percentage of magnesium intake less than 75% of the RI was 43.0% in males and 46.8% in females. As for the percentage of magnesium intake less than the EAR, more than half of males (54.0%) and females (55.4%) had magnesium intakes less than the EAR.

Table 2 Daily Intakes of Energy and Magnesium in the Subjects

Variables		Male (n=100)	Female (n=139)	Total (n=239)
Energy (kJ/day)**,a		7,698.9±2,784.5[b]	6,301.6±2,253.7	6,893.5±2,581.3
Mg intake (mg/day)*,c		306.5±137.7	259.1±202.1	279.2±178.9
Mg intake (mg/1,000 kcal/day)		172.9±66.9	171.2±92.1	171.9±82.2
% RI		87.6±39.3	92.4±72.2	90.4±60.4
Distribution of the subjects	<EAR	54 (54.0%)	77 (55.4%)	131 (54.8%)
	≥EAR	46 (46.0%)	62 (44.6%)	108 (45.2%)
	<75% RI	43 (43.0%)	65 (46.8%)	108 (45.2%)
	75~125% RI	37 (37.0%)	47 (33.8%)	84 (35.1%)
	≥125% RI	20 (20.0%)	27 (19.4%)	47 (19.7%)

RI recommended intake, *EAR* estimated average requirement

*$p<0.05$; **$p<0.001$

[a] Significance between male and female determined by Student's t test

[b] Mean±standard deviation

[c] Mg intake was calculated using data from the current study

Discussion

Recently, there is a growing concern about mineral deficiency due to excessive energy intake. With studies conducted on the functionality of minerals in relation to chronic diseases [13, 14], the need for studies of minerals is further highlighted. Of the minerals, magnesium is known to be an essential nutrient in skeletal formation as well as for nucleic acid, protein, and lipid metabolism [2]. However, studies of magnesium intake by Korean people have been very limited and insufficient. One reason is the lack of a comprehensive database of the magnesium content of a wide variety of food items. As a constituent of chlorophyll, magnesium is contained in large quantities of green leafy vegetables as well as in seeds, legumes, and grains. On the other hand, the magnesium content of meat, fish, milk, and fat are relatively lower [4, 5]. Therefore, in the dietary life of Korean people, which mainly entered on the intake of vegetables, magnesium can be supplied through a variety of source food items such as green leafy vegetables, legumes, and grains, etc. Also, the magnesium intake can be easily estimated when data on the magnesium content in food items that mainly contribute to magnesium intake are available. In this study, we analyzed the magnesium content of 366 food items commonly ingested by Korean people that were selected according to their frequency as seen in the KNHANES of 2005 [12]. The Food Composition Table [8] lists the magnesium content of 918 varieties of food items, which is greater than the number of food items analyzed in this study. However, in many cases, a single food item was subdivided per species, part, and cooking method. So, of the 366 food items analyzed in this study, 104 were not found in the Food Composition Table (28.4%). Also, with the exception of 104 varieties of food items analyzed in Korea [9], most data in the Food Composition Table cited composition data from Japan [10] and the USA [11]. Therefore, it is a problem to utilize these data in estimating magnesium intake by Korean people. So, more accurate evaluation of magnesium intake will be achieved by jointly using the results of this study in which analysis was carried out on the frequently consumed food items together with the Food Composition Table [8]. Furthermore, in order to completely establish a comprehensive database on the food composition of magnesium, it is necessary to accumulate results through repetitive analyses. Also, by comparatively reviewing accumulated data, the reliability of the data must be assessed and studied, and the selection of representative values must be conducted in the future.

In Korea, the daily recommended magnesium intake for 30 years old and over in adult males and females was set as 350 and 280 mg, respectively, as of 2005 [7]. Of the studies evaluating the status of magnesium intake, a study by Yoon et al. [15] was conducted on male elementary students reporting that their magnesium intake was 178.8 mg/day. Also, a study targeted to women aged 20~24 [16], by Sung et al. [17] targeted for adult males and females aged 26~59, and postmenopausal women [18] reported the magnesium intakes to be 228.5, 240.4, and 345.9 mg/day, respectively. As such, since no DRI for magnesium was set prior to 2005 in Korea, only the absolute level of magnesium intake was analyzed and reported. Even the KNHANES did not analyze magnesium intake. Therefore, there is insufficiency of more comprehensive evaluations on the status of magnesium intake. The National Nutrition Survey of Japan [19] conducted a survey on 9,825 healthy adults aged 20 or higher and reported that daily magnesium intake per male was 287 mg and per female was 258 mg. Also, the study by Peacock et al. [20] on 7,731 Americans aged between 45 and 64 reported that the daily magnesium intake per males and females to be, respectively, 241~252 and 270~279 mg. In this study, the daily average magnesium intake by 239 adult males and females was found to be 279.2 mg, which was 90.4% of the RI and this can be evaluated to be appropriate. However, the percentage of target people with magnesium

intake lower than the EAR was 54.8%, and the percentage of target people with magnesium intake less than 75% of the RI was 45.2%. As such, the percentage of target people with inappropriate magnesium intake was found to be high. Therefore, in order to enhance the magnesium intake level, it will be necessary to administer appropriate nutritional education by identifying people with insufficient magnesium intake.

There was no significant difference between magnesium intake evaluated with the database of magnesium content in 366 varieties food items analyzed in this study and with 918 varieties of food items in the database of Food Composition Table [8]. On the other hand, the two results displayed significantly positive correlation (data not shown). The reason for this result despite the number of data for magnesium contents in food items analyzed in this study being smaller than that of the Korean Food Composition Table was because reliability was high for the values of magnesium contents analyzed in this study. In other words, many of the food items analyzed in this study were source items that contained large amounts of magnesium and were frequently used in the current dietary life. Therefore, it is believed that values of this study will be useful in the evaluation of magnesium intake.

Mineral contents in food items differ according to mineral contents in soil. A study by Marr et al. [21] reported that the mineral content in the same variety of brown rice varied according to mineral contents in the soil. Also, there is a difference in mineral content between the East and the West. This is believed to be because of the differences in the species of food items used in daily meal intake. Additionally, for analysis of magnesium content in actual food items, the methods of purchasing, pre-treating, and analyzing food items have differed per researcher. This also is believed to cause the difference in reported magnesium contents. Due to these reasons, in this study, there were also some foods showing a large difference with the database of Food Composition Table [8]. This study reports the analysis of magnesium contents in specific regions, of specific varieties, and by specific methods. Therefore, it has limitations in being utilized as generalized data to estimate intake levels globally. However, with the current insufficient data of magnesium content in Korean food, this research will contribute to promoting studies on magnesium and is significant in the sense that it estimated the true magnesium intake by healthy adult males and females according to their daily meal intake and the source of their food.

So, in conclusion, we analyzed the magnesium content in 366 food items commonly ingested by Korean people using ICP-AES. Using the analysis data of magnesium contents, we evaluated the status of magnesium intake by 239 adult males and females. We found that the daily magnesium intake was 279.2 mg, which was 90.4% of the RI. However, the intake level by 54.8% of the subjects was found to be below the EAR. Also, for 45.2% of the cohort, the magnesium intake was less than 75% of the RI. As such, the percentage of subjects with inappropriate magnesium intake was high.

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