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Association between hair mineral and age, BMI and nutrient intakes among Korean female adults*

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Abstract

This study was performed to investigate the association between hair mineral levels and nutrient intakes, age, and BMI in female adults who visited a woman's clinic located in Seoul. Dietary intakes were assessed by food frequency questionnaire and mineral levels were measured in collected hairs, and the relationship between these was examined. The average daily nutrient intakes of subjects were compared to those of the KDRIs, and the energy intake status was fair. The average intake of calcium in women of 50 years and over was 91.35% of KDRIs and the potassium intake was greatly below the recommended levels in all age groups. In the average hair mineral contents in subjects, calcium and copper exceeded far more than the reference range while selenium was very low with 85.19% of subjects being lower than the reference value. In addition, the concentrations of sodium, potassium, iron, and manganese in the hair were below the reference ranges in over 15% of subjects. The concentrations of sodium, chromium, sulfur, and cadmium in the hair showed positive correlations ($P < 0.05$) with age, but the hair zinc level showed a negative correlation ($P < 0.05$) with age. The concentrations of sodium, potassium, chromium, and cadmium in the hair showed positive correlations ($P < 0.05$) with BMI. Some mineral levels in subjects of this study showed significant correlations with nutrient intakes, but it seems that the hair mineral content is not directly influenced by each mineral intake. As described above, some hair mineral levels in female adults deviated from the normal range, and it is considered that nutritional intervention to control the imbalance of mineral nutrition is required. Also, as some correlations were shown between hair mineral levels and age, BMI, and nutrient intakes, the possibility of utilizing hair mineral analysis for specific purposes in the future is suggested.

Key Words: Hair minerals, nutrient intakes, age, body mass index, Korean female adults

Introduction

Since the establishment of the Recommended Dietary Allowances for Koreans, the recommended intakes for minerals have been continuously revised as basic researches on important physiological functions and requirements of each mineral are developed. Recently in 2005, with the concept of Dietary Reference Intakes for Koreans, the estimated average requirements (EAR), recommended intake (RI), and tolerable upper intake level (UL) were established for some micro-minerals such as iron, zinc, copper, iodine, and selenium, and the adequate intake (AI) and UL for manganese and fluoride, and the UL for molybdenum (The Korean Nutrition Society, 2005).

Minerals are very important in enzyme action, electrolyte balance, nerve impulse transmission, muscle contraction, bone formation, and growth and development in the body. Also, the absorption and utilization of minerals are varied by bioavailability as well as the content in foods. The bioavailability is influenced by physiological needs due to individual health status or age, competition between minerals, interrelationship between vitamins and minerals, and relationship to other dietary factors (Choi *et al.*, 2006).

As mineral imbalance such as excess or deficiency of essential minerals or excess of toxic minerals can cause metabolic disorders and diseases (Cambell, 2001), the degree of mineral accumulation in the body is a useful index as a diagnostic tool for clinical nutrition and disease state (Marshall, 2008).

Measurements for accurate diagnosis of mineral status are widely performed in many samples including body tissues such as liver or hair, and body fluids such as urine or spinal fluid, cell or non-cell fractions, and plasma proteins for several purposes including specific minerals or diseases (Kim *et al.*, 2007). Hair Tissue Mineral Analysis is relatively accurate in the evaluation of diseases, metabolic disorders, environmental exposure, and nutritional status. Also, it is convenient in sample collection, transport and storage and can assess various kinds of minerals at one time and reflects the long-term status of a mineral in the body (Dean *et al.*, 2001). Thus, it has been utilized

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in several countries around the world, and its use has been increased in domestic medical institutions; therefore, it is recently used as a tool for the measurement of minerals in various scientific studies (Cho, 2003).

Recently, as sufficient intakes of vitamins and minerals have been emphasized in the obesity management, the clinical value of hair mineral analysis has been increasingly interested in which mineral balance and mineral excess/lack are checked and the supplement can be prescribed accordingly (Shin *et al.*, 2004). Also, as studies have shown that securing essential nutrients in the body to prevent or delay aging is important above all things in the aging society (Bartali *et al.*, 2006a), various mineral assessments are being utilized. Clinical signs and symptoms to which hair mineral analysis is applied are premenstrual syndrome (Cho *et al.*, 2007a), obesity (Seo, 2005), diabetes Skalnaya & Demidov (2007). Endocrinological problems (Miekeley *et al.*, 2001), metabolic syndrome (Corica *et al.*, 2006), menopausal women (Cho *et al.*, 2007b), growth delay including height and weight (Park & Shin, 2004), and biological aging and degeneration (Batzevich, 1995; Gentile *et al.*, 1981).

Mineral imbalance can be caused by many factors including dietary factors, genetic disposition, beverages, stress, aluminum cans, cooking utensils, contact with chemicals, shampoo, or residential or working environment (Kim, 1996). In particular, the interrelationship between the accumulation of toxic minerals and environment, gender, and age (Kim *et al.*, 2002; Lee, 2002) has been reported. Clinical utilization of hair mineral analysis is relatively well established for symptoms and diseases related to the accumulation of toxic minerals, but more fundamental studies are required in the areas of age, specific symptoms and diseases, hair nutrient minerals, micro-mineral contents, and balance among minerals.

In this study, hair mineral analysis and food frequency questionnaire were assessed in female adults who visited a woman's clinic located in Seoul, and the relationship among hair mineral levels and body mass index (BMI), age, and dietary intake was investigated to present the basic data for clinical utilization of hair mineral analysis.

Subjects and Methods

Subjects

This study was performed between January and August 2008 in female adults who visited a woman's clinic located in Seoul. Hair mineral analysis and food frequency questionnaire were performed, and the age, weight and height of study subjects were collected from the survey questionnaire and physical examination sheet.

Study contents & Methods

Dietary intake survey

Data on dietary intakes of the study subjects were collected using the food frequency questionnaire of the Korea Centers for Disease Control and Prevention. Some food items were modified and added (Martin-Moreno *et al.*, 1993; Pellegrini *et al.*, 2007). Subjects received a preliminary education about the food frequency questionnaire and were instructed to record the frequency for intake depending on foods or dishes by 9 scales of monthly (1 time, 2~3 times), weekly (1~2 times, 3~4 tomes, 5~6 times), daily (1 time, 2 times, 3 times), and seldom eaten, and to record the amount of 1 intake by choosing one among 3 different photos of amounts. The nutrient intakes were analyzed on the basis of investigated data by using a professional nutrition evaluation program (CAN-Pro 3.0, The Korean Nutrition Society).

Hair mineral analysis

Among 103 subjects who answered the questionnaire, 60 subjects were selected for hair mineral analysis and more than 80 mg of hair was sufficiently collected by cutting about 4~5 cm length from the back of the head with a sterilized, stainless scissor. The hair mineral analysis was requested to the Korean branch office of TEI (2001), a professional institution for hair mineral analysis, where hair samples were washed in the order of nonionic surfactants, deionized water, and acetone to eliminate not only micro elements settled inside the hair tissue but also pollutants such as dust, sweat, and debris from the atmosphere and outer environment. Samples were washed for 30 minutes while maintaining the washing condition as constant as possible by using an automatic shaking Plateform Shaker (Jeio Tech) which maintained constant time and speed to obtain accurate analytical results for sodium and potassium which were constantly flowed out during washing process, and then naturally dried in room temperature. Then about 70 mg of hair sample was taken and weighed to 0.1 mg, and placed in a clean container and mixed with nitric acid (Dongwoo Pure Chemicals Co., Ltd, electronic- grade, 70%) and the internal standard of KRISS (Korea Research Institute of Standards and Science) and then decomposed in an microwave oven (Milestone MLS-1, Bergamo, Italy). Decomposed sample was transferred into a clean washed polyethylene bottle and diluted to the analyzable concentration, and by using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (VG PZExCell, Thermo Lemental, UK), 14 mineral nutrients including calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), copper (Cu), zinc (Zn), phosphorus (P), iron (Fe), manganese (Mn), chromium (Cr), selenium (Se), cobalt (Co), molybdenum (Mo), and sulfur (S), and 4 toxic minerals such as mercury (Hg), cadmium (Cd), lead (Pb), and aluminum (Al) were quantitatively analyzed.

Statistical analysis

Among 60 survey questionnaires, data from a total of 54 subjects was included in this study after excluding incomplete data, and analyzed by using SAS version 9.1 (SAS INc., Cary, NC, USA). General characteristics were expressed as mean and standard deviation or frequency and ratio, and the interrelationship among BMI, age, each mineral content in hair, mineral content ratio and nutrient intake were examined using Spearman correlation analysis. Statistical significance was verified at $P < 0.05$ level.

Results

General characteristics

The general characteristics of study subjects are shown in Table 1. The average age was 41.26 ± 11.42 years and the average height and weight was 163.05 ± 6.81 cm and 55.81 ± 7.4 3kg, respectively, and the average BMI was 20.95 ± 2.02 kg/m^2, which was in the normal range. According to the standard of the Korean Society for the Study of Obesity, the study included 6 (11.11%) underweight subjects with BMI<18.5, 42 (77.8%) normal subjects with 18.5≤BMI<23, and 6 (11.11%) overweight subjects with BMI≥23.

Nutrient intakes

Daily energy and nutrient intakes of study subjects are summarized in Table 2. The average energy intake of all subjects was 1881.85 ± 634.01 kcal, and that of 20-49 years was 1852.65 ± 589.39 kcal, which was 92.63% of the estimated average requirement of KDRIs. The average energy intake of subjects over 50 years was 1984.06 ± 792.02 kcal, which was 116.89% of the estimated average requirement of KDRIs and thus the energy intake was fair. The percentage of energy from carbohydrate, protein, and fat of all subjects was 61.3 : 16.1 : 22.6, which was similar to the recommended ratio. The intakes of saturated fat, monounsaturated fat, and polyunsaturated fat was 8.63 ± 5.04 g, 7.39 ± 3.73 g, and 5.03 ± 2.88 g, respectively, and the intake ratio was 1: 0.86 : 0.58, showing that saturated fat intake was high and the polyunsaturated fat intake was very low. Although its intake is not suggested in the KDRIs, less than 300 mg of cholesterol intake is recommended by FAO/WHO (1994) and the average cholesterol intake of two age groups in this study was 310.58 ± 181.59 mg and 328.22 ± 224.773 mg respectively, which is slightly higher than the FAO/WHO recommendation. Dietary fiber was 98.13% of RI by KDRIs at 20-49 years, and 135.59% at 50 years and over, showing lower intake in the 20-49 years group. In case of minerals, calcium was 102.76% of RI by KDRIs at 20-49 years, and 91.35% at 50 years and over, showing lower intake in the 50 and over group, and potassium showed lower intakes in both age groups as 72.96% and 86.60%, respectively. For vitamin intakes, folic acid was low as 80.73% at 20-49 years group but other than that, the overall vitamin intake was high.

Table 1. General characteristics of subjects (n=54)

	Mean ± SD	Range
Age (year)	41.26 ± 11.42	19.0-66.0
Height (cm)	163.05 ± 6.81	150.0-180.0
Weight (kg)	55.81 ± 7.43	45.0-77.0
BMI (kg/m^2)	20.95 ± 2.02	16.6-27.9

Table 2. Nutrient intakes of subjects (n=54)

	20-49 ages (n=42)	%DRI	≥50 ages (n=12)	%DRI
Energy (kcal)	1852.65 ± 589.39[1)]	92.63	1984.06 ± 792.02[1)]	116.89
Carbohydrate (g)	285.65 ± 88.79		304.10 ± 123.45	
Protein (g)	74.11 ± 28.23	164.69	81.94 ± 36.59	182.09
Fat (g)	46.92 ± 20.10		50.69 ± 31.98	
Fiber (g)	23.55 ± 11.58	98.13	29.83 ± 13.02	135.59
Calcium (mg)	719.34 ± 322.84	102.76	730.83 ± 521.04	91.35
Phosphorus (mg)	1147.45 ± 438.69	163.92	1314.64 ± 566.89	187.81
Iron (mg)	14.96 ± 5.64	106.86	18.09 ± 6.73	201.00
Sodium (mg)	4471.22 ± 2281.54	298.08	5073.83 ± 2535.07	390.29
Potassium (mg)	3429.01 ± 1461.39	72.96	4070.11 ± 1731.35	86.60
Zinc (mg)	11.27 ± 4.74	140.88	12.54 ± 4.93	167.20
Vitamin A (μgRE)	932.20 ± 537.31	143.42	1442.83 ± 1148.10	240.47
Vitamin B_1 (mg)	1.29 ± 0.49	117.27	1.35 ± 0.63	122.73
Vitamin B_2 (mg)	1.38 ± 0.57	115.00	1.49 ± 0.85	124.17
Vitamin B_6 (mg)	2.24 ± 0.95	160.00	2.67 ± 1.11	190.71
Niacin (mg)	16.56 ± 6.54	118.29	19.34 ± 7.56	138.14
Vitamin C (mg)	151.40 ± 94.23	151.40	192.70 ± 117.65	192.70
Folate (μg)	322.92 ± 158.62	80.73	415.57 ± 192.05	103.89
Vitamin E (mg)	12.06 ± 5.71	120.60	15.67 ± 8.06	156.70
Cholesterol (mg)	310.58 ± 181.59		328.22 ± 224.77	
Carbohydrate (%)	62.32 ± 6.81		61.27 ± 11.57	
Protein (%)	15.81 ± 2.71		16.77 ± 3.63	
Fat (%)	22.24 ± 5.22		22.69 ± 8.44	
SFA (g)	8.65 ± 4.76		8.54 ± 6.16	
MUFA (g)	7.36 ± 3.42		7.46 ± 4.94	
PUFA (g)	4.63 ± 2.32		6.43 ± 4.14	

[1)] Mean ± SD

Hair mineral levels

The hair mineral levels of subjects are shown in Table 3. The mineral levels except calcium, copper, and selenium were in the reference range. That is, calcium was 116.94 ± 67.42 mg% and copper was 5.62 ± 9.71 mg%, both were higher than the reference values, and selenium was 0.06 ± 0.02 mg%, which was lower than the reference value. For toxic mineral levels in Table 4, concentrations of mercury, cadmium, and aluminum were below the reference ranges but lead was 0.097 ± 0.025 mg%, which was higher then the reference value. The ratios of nutritional minerals are shown in Table 5 and calcium/phosphorus was 8.34 ± 5.20

Table 3. Hair nutritional mineral levels of subjects (n=54)

Nutritional minerals	Mean ± SD (mg%)	Reference Range[1)] (mg%)	<Reference Range n (%)
Ca	116.94 ± 67.42	22-97	0 (0.00)
Mg	7.76 ± 4.78	2-11	1 (1.85)
Na	8.56 ± 9.27	4-36	16 (29.63)
K	6.07 ± 8.04	2-24	12 (22.22)
Cu	5.62 ± 9.71	0.9-3.9	1 (1.85)
Zn	20.70 ± 21.73	10-21	0 (0.00)
P	14.35 ± 2.61	11-20	1 (1.85)
Fe	0.73 ± 0.29	0.5-1.6	8 (14.81)
Mn	0.02 ± 0.03	0.010-0.130	13 (24.07)
Cr	0.04 ± 0.018	0.02-0.08	1 (1.85)
Se	0.06 ± 0.02	0.08-0.18	46 (85.19)
Co	0.002 ± 0.003	0.001-0.003	0 (0.00)
Mo	0.003 ± 0.003	0.001-0.008	0 (0.00)
S	3901.37 ± 824.599	2651-5336	2 (3.70)

[1)] By TEI (Trace Elements, Inc, Dallas, TX, USA)

Table 4. Hair toxic mineral levels of subjects (n=54)

Toxic mineral	Mean ± SD	Reference Range[1)] (mg%)	>Reference Range n (%)
Hg	0.136 ± 0.103	< 0.360	1 (1.85)
Cd	0.002 ± 0.002	< 0.028	0 (0.00)
Pb	0.097 ± 0.025	< 0.060	51 (94.44)
Al	0.84 ± 0.535	< 3.600	0 (0.00)

[1)] By TEI (Trace Elements, Inc, Dallas, TX, USA)

Table 5. Hair mineral ratios of subjects (n=54)

Hair mineral ratios	Mean ± SD	Reference Range[1)]
Ca/P	8.34 ± 5.20	1.4-3.60/1
Ca/K	49.27 ± 52.20	2.20-6.20/1
Ca/Mg	16.05 ± 4.51	3.00-11.00/1
Na/K	2.01 ± 1.82	1.40-3.40/1
Na/Mg	1.91 ± 3.20	2.00-6.00/1
Zn/Cu	8.64 ± 7.46	4.00-12.00/1
Fe/Cu	0.32 ± 0.230	0.20-1.50/1

[1)] By TEI (Trace Elements, Inc, Dallas, TX, USA)

/1, calcium/potassium was 49.27 ± 52.20 /1, and calcium/magnesium was 16.05 ± 4.51 /1, which were all higher than the reference values, but sodium/magnesium was 1.91 ± 3.20 /1, which was lower then the reference value.

Correlation of hair mineral levels with age and BMI

As shown in Table 6, the levels of sodium ($P < 0.01$), chromium, and sulfur were higher in older subjects ($P < 0.05$) with positive correlation coefficients, but zinc ($P < 0.05$) showed a negative correlation coefficient with age and its concentration was decreased as age increased. In the correlation between nutritional minerals and BMI, the concentrations of sodium, potassium, and chromium were increased as BMI increased, showing significant positive correlations ($P < 0.01$), but other nutritional minerals were not related with BMI. In case of toxic minerals, cadmium showed significant positive correlation coefficients with both age ($P < 0.01$) and BMI ($P < 0.05$), but other toxic minerals were not related with these.

Table 6. Correlation coefficient between hair minerals and age and BMI (n=54)

	Age (year)	BMI (kg/m^2)
Nutritional minerals		
Ca	0.0399	-0.0700
Mg	-0.0029	-0.1242
Na	0.3800**	0.3322*
K	0.2419	0.2921*
Cu	0.0037	-0.2158
Zn	-0.2783*	-0.2583
P	-0.0323	0.0822
Fe	0.0756	-0.1381
Mn	0.2430	-0.0871
Cr	0.2802*	0.3216*
Se	0.0528	0.0258
Co	0.2042	-0.0822
Mo	0.0853	0.1570
S	0.3345*	0.2088
Toxic minerals		
Hg	0.1408	-0.0195
Cd	0.3522**	0.3040*
Pb	-0.0641	-0.0118
Al	0.0712	-0.1200

*$P < 0.05$, **$P < 0.01$
Significant correlation by Spearman's correlation coefficient (r).

Table 7. Significant correlations ($P < 0.05$) between hair mineral levels and dietary intakes (n=54)

Hair minerals	Dietary Intakes	Correlation coefficient[1)]
Na	Potassium	0.2702
	Vitamin C	0.3533
Mn	Protein (%)	0.3140
Cr	Cholesterol	0.2759
	Protein (%)	0.2853
Mo	Energy	-0.3238
	Fat	-0.3105
	Vitamin A	-0.2922
	Vitamin B2	-0.3050
	Vitamin B6	-0.2728
S	PUFA	0.1855
Cd	Fiber	0.3377
	Sodium	0.3010
	Vitamin C	0.3291

[1)] By Spearman's correlation coefficient (r)

Correlation of hair mineral levels with dietary intakes

Significant correlations between the hair mineral levels of subjects and nutrient intakes are summarized in Table 7. Among nutritional minerals, sodium showed significant positive correlations with potassium ($P < 0.05$) and vitamin C ($P < 0.01$) intakes, and the chromium level showed positive correlations with cholesterol ($P < 0.05$) and protein energy intake ratio ($P < 0.05$). Manganese showed a positive correlation with protein energy intake ratio ($P < 0.05$), and molybdenum showed negative correlations with energy ($P < 0.05$), fat ($P < 0.05$), vitamin A ($P < 0.05$), vitamin B_2 ($P < 0.05$), vitamin B_6 ($P < 0.05$) intakes, and sulfur showed a positive correlation with polyunsaturated fatty acid intake ($P < 0.05$).

In the correlation between toxic minerals and dietary intakes, cadmium showed positive correlations with dietary fiber ($P < 0.05$), sodium ($P < 0.05$), and vitamin C ($P < 0.05$) intakes.

Discussion

Lack of minerals or excess minerals in the body can cause several health problems. For some micro-minerals, the normal range is very narrow and thus fine control of mineral concentrations is required. Also, the mineral imbalance due to deficiency or excess of several minerals can bring about the incapability of roles and functions of each mineral or cause abnormalities due to excess of one side. Therefore, several studies have been performed to seek the possibility of correction and disease treatment through nutrition therapy by confirming the lack or excess of nutrients due to mineral imbalance using tissue mineral analysis (Cambell, 2001; Dean *et al.*, 2001; Kim *et al.*, 2007; Klevay *et al.*, 1987). In this study, the relationship among hair mineral levels and age, body mass index (BMI), and nutrient intakes was investigated in female adults to present the basic data for clinical utilization of hair mineral analysis.

The average hair calcium concentration of the subjects in this study was 116.94 ± 67.42 mg%, which was similar to the average hair calcium level, 113.88 mg%, in male and female adults in Seoul from the study by Bae and Cho (2008), and much higher than the average hair calcium level, 80.79 ± 43.79 mg%, in male adults in Gyeonggi area from the study by Kong *et al.* (2007). In addition, for the ratio between hair nutritional minerals, calcium/phosphorus, calcium/potassium and calcium/magnesium were all beyond the reference range due to high calcium concentration. It has been reported that the calcium/magnesium ratio in the cell was increased because the calcium level was abnormally increased due to the disturbance of overall ion regulation in the metabolic syndrome including hypertension, insulin resistance, left ventricular hypertrophy, and arteriosclerosis (Resnick, 1992). Although the calcium intake of subjects in this study did not greatly exceed the KDRIs, the hair calcium level was abnormally increased and calcium/magnesium ratio was exceeding the standard content, suggesting possible disturbance of mineral regulation in the body as mentioned by Resnick (1992). The concentration of hair copper, for which the effectiveness of hair mineral analysis for mineral status in the body is thought to be relatively well established (Cambell, 2001), was 5.62 ± 9.71 mg% in subjects of this study, which was higher then the reference range. This tends to be higher than the hair copper concentrations in male and female adults from the study by Bae and Cho (2008) and women with premenstrual syndrome (Cho *et al.*, 2008) and menopausal women (Cho *et al.*, 2007b). It is not certain why Copper level is higher than other studies findings, so it needs further investigation. The hair selenium in subjects of this study was 0.06 ± 0.02 mg%, which was lower than the normal range and lower than 0.063 mg% from the study by Bae and Cho (2008). Bartali *et al.* (2006b) observed the fast progress of degeneration older women in Baltimore who had low levels of serum selenium. Selenium plays a significant role, along with vitamin E, in strengthening immune system and inhibiting oxidative reactions in the body. If it is lacking, it can be a risk factor for cancer development and aging, and thus it is thought that future studies on nutrition intervention and its methods is needed to maintain certain levels of concentration (Cambell, 2001).

The concentrations of hair toxic minerals such as mercury, cadmium, and aluminum of subjects in this study were in the reference ranges but lead was 0.097 ± 0.025 mg%, which was higher than the reference value and 94% of the subjects exceeded the reference value, suggesting the possibility of excessive lead accumulation. People absorbs the daily average of 0.3 mg lead from foods and beverages and 0.03 mg lead from the atmosphere, and urban residents absorb 15 mg lead from the atmosphere, 5 mg from beverages, and 100 mg from foods each year, and 8% of oral intake is absorbed and 30% of lead from the atmosphere is absorbed (Kim, 1996). Thus, it is considered that improvement of living environment, environment-friendly menu, less-processed foods, improved food packaging materials, and decreased contact to chemicals are necessary to reduce the ingestion and absorption of toxic minerals such as lead.

It was reported that some toxic mineral levels were significantly increased as growth developed in preliminary animal experiments (Lee, 2003), and the relationship between mineral concentrations in the body and aging has been continuously studied. In the correlation analysis between age and hair mineral levels in this study, sodium, chromium, sulfur and cadmium showed significant positive correlation coefficients with age and zinc showed a significant negative correlation coefficient. These results are consistent with the results from the study by Lee (2006) in which the older group showed higher sodium level and lower zinc level in the hair minerals analysis in outpatients of a university hospital in Daegu. Also in the correlation analysis between age and hair minerals in male and female adults in Daegu by Lee (2002), cadmium showed a positive correlation with age, which is also consistent with the result of this study. On the other hand, zinc did not show significant differences by age in the same study. However, it has been reported in many studies that the zinc concentration in the body was decreased as the age increased from adult to elderly (Bunker *et al.*, 1984; Smit Vanderkooy & Gibson, 1987; Swanson *et al.*, 1988), and therefore, the zinc level in the body is considered to be decreased as age increases. In a study on Americans with 50 years of age and over by Abernethy (1979), 40% of black and 20% of white subjects had higher sodium concentrations in the serum and also had hypertension. Such results suggest that the positive correlation between sodium and age in this study might be related to the increased blood pressure by age.

In the past, obesity research has emphasized the intake levels of energy and three major nutrients but recently the results has been reported that the degree of mineral accumulation in the tissues or body may be related to metabolic disorders that induce overweight or obesity. That is, the energy intake was excessive but micro-minerals were not reached to the recommended intake in obese subjects, causing nutritional imbalance and possibly further secondary problems (Luque-Diaz *et al.*, 1982), and the mineral levels in the body of patients with obesity or diabetes were relatively higher or lower, suggesting the mineral imbalance (Lee & Kim, 2005; Skalnaya & Demidov, 2007; Teegarden, 2003). Accordingly, the hair mineral levels depending on body weight, height, and BMI were reported in the country (Park & Shin, 2004; Seo *et al.*, 2005). In the correlation analysis between BMI and hair mineral levels in subjects of this study, the concentrations of sodium, potassium, chromium, and cadmium were increased as BMI increased, showing significant positive correlations. In the study of Bae and Cho (2008), the levels of magnesium, sodium, potassium, iron, and zinc showed significant positive correlations with BMI, which is consistent with the result of this study showing significant positive correlation between sodium and potassium and BMI. In the hair minerals analysis of 46-60 years old women in Moscow, obese women showed increased concentrations of potassium, mercury, and lead and decreased concentrations of calcium, magnesium, zinc, and iodine (Skalnaya & Demidov, 2007). According to Cambell (2001), chromium has decreased when refined grain products such as white rice, white sugar, and white bread were eaten and then decreased chromium was related to obesity, but the result of this study showing positive correlation between chromium and BMI was not consistent with such result. In the study of Bae and Cho (2008), chromium in the hair showed lower levels in overweight group and obese group than in normal weight group and in the study of Shin *et al.* (2004), chromium was not related to the degree of obesity, suggesting that more in-depth studies are needed to reveal the relationship between chromium and obesity.

In the correlation between hair mineral levels and nutrient intakes in subjects of this study, the hair sodium level showed significant positive correlations with potassium and vitamin C, and the hair chromium level showed significant positive correlations with cholesterol and protein energy ratio and negative correlation with carbohydrate energy ratio. Although the direct correlations between hair chromium level and cholesterol, protein, and carbohydrate intakes are not clear, it is considered that some relationships may be existed because chromium is transported in the body by binding to proteins such as transferrin or albumin and helps insulin action as a component of glucose tolerance factor, and is involved in carbohydrate metabolism and cholesterol synthesis (Choi *et al.*, 2006). Hair molybdenum showed negative correlations with calorie, fat, vitamin A, vitamin B_2, and vitamin B_6 intakes and hair sulfur showed a significant positive correlation with polyunsaturated fatty acid. Although molybdenum showed closer relations to dietary intakes such as calorie, fat, and particularly vitamins, than other hair minerals, it has been pointed out that it is unreasonable to relate the causes for the lack or excess of molybdenum in the body to the general aspects of dietary intakes (Howerde, 1999), and it is thus considered that the study on the cause for the lack of or excess of molybdenum and the proper nutritional assessment for molybdenum is continuously needed.

In the correlation between hair toxic minerals and nutrient intakes, cadmium showed a significant positive correlation with dietary fiber, sodium, and vitamin C. In the study of Spanish college students by Gonzalez-Munoz *et al.* (2008), the correlation between dietary intakes and hair toxic mineral levels was examined on the basic assumption that the major course of exposure to toxic minerals is through foods, but there was no significant correlation between the hair toxic mineral levels and the exposure to toxic minerals through foods. It is also pointed out that the dietary intakes are not instantly reflected in the hair mineral levels, and even though foods are the major route of exposure to minerals, it is pointed out that hair is also contaminated by dust, sweat, age, gender, and residential environment.

In the interpretation of the results of this study, there are some limitations to be considered. Cho (2003) pointed out the problem of reliability for hair analysis results, which were handled by western-type medical information database due to the lack of medical information database for Koreans to interpret and handle the hair analysis results. Also, as pointed out by several preceding studies on hair and environmental factors (Combs *et al.*, 1982; Kim, 1996; Kim *et al.*, 2007; Pinheiro *et al.*, 2005), there are many factors that can affect hair mineral levels and thus more reliable hair mineral analysis protocol should be established.

As described above, some hair mineral levels in female adults were deviated from the normal range, and it is considered that nutritional intervention to control the imbalance of mineral nutrition is required. Also, as the results of this study showed some correlations between hair mineral levels and age, BMI, and nutrient intakes, the possibility of utilizing hair mineral analysis for specific purposes in the future is suggested.

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