Nutritional Sciences 2(2), November, 1999, pp. 88-92


# The Relationship of Dietary Heavy Metal Intake with Serum Trace Elements in College Women Living in Choong-Nam Area*

Ae-Jung Kim§

*Department of Food & Nutrition, Hyejeon College, Namjang-ri, Hongsung-eup, Hongsung-gun, Choongnam 350-800, Korea*

## ABSTRACT

The purpose of this study was to study the intake of heavy metals such as arsenic, lead and cobalt and the relationship of dietary heavy metals with serum iron, copper, and zinc, which play important roles in hematopoiesis, in healthy college women living in Choongnam Korea, where we have detected heavy metals (As, Pb, Co) in some marine products in previous studies. The nutritional status of the subjects (35 women) was evaluated by anthropometric measurements, 24-hr dietary recall for 3 days. And 3-day diets (by weighing method) and blood were collected to analyze As, Pb, Co, Fe, Cu, Zn, Hb, Hct, and MCHC. The mean age, height, weight, and BMI were 20 years, 158 cm, 55 kg and 22.42 $kg/m^2$, respectively. The mean daily energy intake was 85.85% of RDA for Koreans. The ratio of energy from carbohydrate, protein, and fat was 60 : 24 : 16. The mean daily intake of heavy metals (As, Pb, Co) was 1.77 mg/day, 75.21 μg/day and 21.12 μg/day. And the mean daily intake of iron, copper, and zinc concentrations were 97, 68, and 92% of normal values. The mean serum heavy metals (As, Pb, Co) were 16.14 μg/dl, 4.32 μg/dl and 0.02 μg/dl, respectively. Mean blood levels of Fe, Cu, Zn, Hb, Hct, and MCHC were at normal levels. Dietary heavy metals except Co were not significantly different from serum Fe, Cu, Zn and Hb, Hct, and MCHC. However, there was a tendency toward lower serum concentration of Fe, Hb, Hct, and MCHC in the subjects with higher heavy metals (As) intake. Among heavy metals, only dietary Co showed a significant negative correlation with Hb ($p < 0.001$) and Hct ($p < 0.001$).

KEY WORDS: dietary heavy metals, serum microminerals.

## INTRODUCTION

Although we have a very small quantity of microminerals, they have significant effects on the human body.[1-3] They are divided into 3 groups: those which are essential for the body (Fe, Cu, and Zn), those which are harmful even in very small quantities, and those which have unknown biological effects. Heavy metals such as As, Cd, and Pb, which have toxic effects on the body, are not the original components of living materials, but due to environmental pollution can enter during the growing process of animals or plants, or processing and manufacturing of foods.[4-11]

Heavy metals have been recognized as harmful agents since human beings started to use metals. Therefore, rapid industrial development and increased human activities caused environmental pollution and food pollution, threatening national health.[12]

With the rapid industrial development in Korea in recent years, there has been a rapid increase in pollution-caused diseases owing to factory waste and air pollution. Our previous studies[13-17] indicate that As, Pb and Co were present in marine products.

Excessive amounts of As, Pb, Mn, and Co compete with iron, resulting in a reduction of Fe absorption.[18] It is reported that the administration of 2 μg/day of As in rats hinders growth, Hb contents and the number of red blood cells. In addition, when 4.5 ppm of As (sodium arsenic 4ppm and sodium arsenic 0.5 ppm) was administered to female rats, more than 50% of iron in the spleen was destroyed.[19] Lead exists mainly in plants and the soil and it is mostly ingested through foods and air. Lead is known to inhibit the synthesis of porphyrin as well as the activity of ATPase lipoamide and dehydrogenase. The absorption of iron decreased with acute lead toxicity, resulting in Hb deficiency and causing anemia.[19] Excessive intake of cobalt inhibits iron absorption while excessive intake of Fe inhibits cobalt absorption.[20] Diarrhea, declines in blood pressure and body temperature can be seen due to acute cobalt toxicity in animals.[21]

There has been a continuous increase in heavy metal contamination from environmental pollution in Korea. However, there has not been much research examining the

*This study was supported by grants from Hyejeon College.
Accepted : November 25, 1999
§To whom correspondence should be addressed.

intake level of these heavy metals, levels of these elements in the blood or the relationship between these heavy metals and essential trace elements in humans.

Therefore, we investigated the amount of dietary heavy metal intake (As, Pb, and Co) and the relationship of these heavy metals with essential hematogenic microminerals (Fe, Cu, and Zn) in female college students living around the west coast, where we have detected heavy metals in some marine products in our previous studies.[13-17]

## MATERIALS AND METHODS

### 1. Subjects and data collection

Thirty-five healthy college women living in the Choongnam area where we have detected heavy metals in some marine products in previous studies were selected and were fully informed of the purpose, significance, and protocol of the study. Dietary surveys for three days were carried out to determine the intake of energy and each nutrient by 24-hr recall method.

The collection of data for three days was conducted to determine the intake of heavy metals. The anthropometric measurements and blood pressure were measured, blood samples were collected to determine the levels of blood micromineral concentrations, and the correlation of dietary heavy metals (arsenic, lead, cobalt) with blood iron, copper, zinc, Hb, Hct, and MCHC was examined.

### 2. Anthropometric characteristics

Height and body weight were measured with Martin's instruments and mean balance scale (Continental scale corp., Chicago, USA). Blood pressure was measured with standard mercury manometer.

### 3. Energy and nutrient analysis

The amount of nutrient intake determined by 24-hr recall method was calculated by CAN program. Dietary samples collected for three days were homogenized and heavy metal contents were measured by wet method of Lim[22] using ICP (Inductively Coupled Plasma: Lactam 8440 Plasmalac).[23]

### 4. Blood analysis

Blood hemoglobin, hematocrit, MCHC were determined by coulter counter (model STKS, USA). Blood heavy metal concentration was measured by quintuple dilution of blood with secondary distilled waste followed by centrifugation for 10 minutes at 3000 rpm. Supernatants were then collected and used for measurement of heavy metal concentration (Inductively Coupled Plasma: Lactam 8440 Plasmalac).[23]

### 5. Statistical analysis

The statistical analysis was carried out with the Statistical Analysis System (SAS).[24] Mean and standard errors for all data were determined, and analysis of coefficient correlations was used to determine possible differences in heavy metals intake and serum blood levels, which play important roles in hematopoiesis.

## RESULTS AND DISCUSSION

### 1. Anthrophometric characteristics

Physical characteristics of the subjects are presented in Table 1. The mean age of the subjects was 20 years old, mean height was 158 cm, and mean body weight was 55 kg. The height and body weight of the subjects were similar to Koreans reference data.[25] Mean body mass index (BMI) of the subjects and PIBW were 22 kg/m$^2$ and 103 %, respectively, and were considered normal. Mean blood pressure was 107/72 mmHg, which is also in normal range. Therefore, subjects for this study were considered normal.

### 2. Energy and nutrient intakes

Daily nutrient intake and a comparison with the Korean RDA are shown in Table 2. Mean daily energy intake of the subjects was 1717 kcal. Mean daily total protein intake was 68 g. Animal protein intake was 54%, and vegetable protein was 46%. The ratio of energy from carbohydrate : protein : fat was 60 : 24 : 16, Therefore, carbohydrate intake was lower and protein intake was higher compared to Korean-recommended nutrient ratio (65 : 15 : 20). Mean daily Vitamin A intake was 654RE, 93% of Korean RDA and Vitamin $B_2$ intake was 0.98 mg, 82% of Korean RDA. Mean daily Vitamin B1, niacin and Vitamin C intakes were 1.72 mg, 24.48 mg and 103.14 mg, respectively. These were 172%, 188%, and 187% of Korean RDA.

**Table 1.** Anthropometric measurement of subjects

| Variables | Mean ± S.E. |
|---|---|
| Age (years) | 20 ± 1 |
| Height (cm) | 158.41 ± 0.69 |
| Weight (kg) | 55.12 ± 1.38 |
| BMI[1)] (kg/m$^2$) | 22.42 ± 0.44 |
| SBP[2)] (mmHg) | 106.57 ± 1.58 |
| DBP[3)] (mmHg) | 71.51 ± 1.03 |
| PIBW[4)] (%) | 103.30 ± 2.46 |

1) Body mass index
2) Systolic blood pressule
3) Diastolicn blood pressure
4) Percent ideal body weight = Body weight/ideal body weight × 100

**Table 2.** The mean daily energy and nutrients intakes of the subjects

| Variables | Mean ± S.E. | % of RDA |
|---|---|---|
| Energy (kcal) | 1717.03 ± 55.99 | 85.85 |
| Carbohydrate (g) | 257.63 ± 10.08 | |
| Protein (g) | 68.14 ± 2.60 | 113.57 |
| Animel protein | 37.08 ± 2.66 | |
| Plant protein | 31.06 ± 2.14 | |
| Fat (g) | 46.21 ± 2.68 | |
| Animel fat | 21.76 ± 1.91 | |
| Plant fat | 24.45 ± 1.88 | |
| Vitamin A (R.E.) | 653.41 ± 52.33 | 93.34 |
| Vitamin $B_1$ (mg) | 1.72 ± 0.72 | 172.00 |
| Vitamin $B_2$ (mg) | 0.98 ± 0.05 | 81.67 |
| Niacin (mg) | 24.48 ± 11.25 | 188.31 |
| Vitamin C (mg) | 103.14 ± 86.12 | 187.53 |

**Table 3.** The mean values of dietary heavy metals and trace elements

| Dietay levels | Mean ± S.E. |
|---|---|
| As (mg/day) | 1.77 ± 0.27 |
| Pb (μg/day) | 75.21 ± 4.12 |
| Co (μg/day) | 21.12 ± 12.34 |
| Fe (mg/day) | 15.20 ± 0.79 |
| Cu (mg/day) | 2.64 ± 0.06 |
| Zn (mg/day) | 11.35 ± 0.23 |

Therefore, Vitamin A and Vitamin $B_2$ intake were lower than Korean RDA and Vitamin $B_1$, niacin and Vitamin C intake were higher than Koran RDA.

### 3. Dietary intake levels of Fe, Cu, Zn, As, Pb, and Co

Dietary intake levels of subjects for microminerals including heavy metals are presented in Table 3. Mean daily intake of iron, copper and zinc, which have been known to play an essential role in hematopoiesis, were 15.20 mg, 2.64 mg and 11.35 mg, respectively. These were 84 – 88% of Korean RDA, and were the marginal amount for normal hematopoiesis.

There have been no reports of arsenic causing health problems in human beings or ecological destruction in normal environments. However, biological impediments in general environments are reported to be the result of environmental pollution from mines or factories.[26] Lately, intake of heavy metals such as As, Pb, and Co in affected food is increasing as a result of environmental pollution. In this study, mean daily intake of arsenic, lead and cobalt were 1.77 mg, 75.21 mg and 21.1 mg, respectively.

Arsenic levels of marine products are quite high. The intake of arsenic in a normal person is mostly from marine products,[27] and the amount of daily intake mostly depends on the kinds of foods eaten. Daily intake of arsenic is 0.07 – 0.17 mg in Japanese living in a normal environment. The level of arsenic intake which can cause death

**Table 4.** The mean blood levels of As, Pb, Co, Fe, Cu, Zn, Hb, Hct and MCHC

| Variables | Mean ± S.E. |
|---|---|
| As (μg/dl) | 16.14 ± 2.10 |
| Pb (μg/dl) | 4.32 ± 0.58 |
| Co (μg/dl | 0.02 ± 0.01 |
| Fe (mg/dl) | 116.24 ± 20.39 |
| Cu (mg/dl) | 81.34 ± 3.39 |
| Zn (mg/dl | 101.54 ± 4.01 |
| Hb (g/dl) | 13.24 ± 0.21 |
| Hct (%) | 39.80 ± 0.50 |
| MCHC (%) | 34.65 ± 1.43 |

is 60 – 120 mg and daily allowance level recommended by WHO is 3.5 mg. However, there was a report that showed no toxic effect in farm workers with a daily intake of 6.8 mg.[19] Mean daily arsenic intake of the present study was 1.77 mg and this is higher than that of Americans or Japanese but lower than the daily allowance recommended by WHO. The general public's lead intake is mostly from food and it is absorbed in the intestines. The absorption rate is 5 – 10%.[28]

Lead intake of a normal person who has not been exposed to lead is calculated as about 300 μg orally, and 30 μg by air. In America, it is estimated at 200 – 300 μg/day.[29] It is reported by FAO/WHO that maximum recommended lead intake level is 3 mg/week or 0.05 mg/kg body weight.[30] In Japan, the daily intake of lead from foods is reported as 70 – 170 μg, and the daily intake of lead for our study is 75.21 μg which is included in the range of the daily intake of Japanese.[28]

The cobalt levels reported for human foods and diets are extremely variable (5 – 600 μg/day), which is partly a reflection of soil and climatic effects and probably also partly a consequence of analytical errors.[19] Rossi *et al.*[31] reported that the mean dietary cobalt intake of small groups of adults in five Italian towns were 15, 10, 8.3, 13.5 μg/day. And Harp *et al.*[32] reported that young college women in the United States consuming high quality, self-selected diets were 5 to 8 μg/day. Mean daily cobalt intake of this study was 21.12 μg/day, lower than the safe intake level (2 – 7 mg/kg)[33] and higher than those of the Italians and the Americans.

#### 1) Blood levels of As, Pb, Co, Fem Cu, Zn, Hb., Hct., MCHC

Blood iron status and heavy metal concentrations are presented in Table 4. Mean serum iron, copper and zinc concentrations are 116.24, 81.34 and 101.54 μg/dl, respectively. These values were 97, 68 and 92% of normal value (Fe: 120 μg/dl, Cu: 120 μg/dl, Zn: 110 μg/dl).[19]

**Table 5.** The correlation between dietary intakes of heavy metals and serum Fe, Cu, Zn, Hb, Hct, and MCHC

| Diet \ Serum | As | Pb | Co | Cu | Zn | Fe | Hb | Hct | MCHC |
|---|---|---|---|---|---|---|---|---|---|
| As | – | 0.17518 | 0.22867 | 0.12731 | −0.11350 | −0.29983 | −0.20024 | −0.12068 | 0.00783 |
| Pb | | – | 0.04766 | −0.17099 | −0.09699 | −0.19742 | −0.15247 | −0.05276 | −0.05276 |
| Co | | | – | −0.05144 | 0.02277 | −0.20361 | −0.65421*** | −0.57597*** | −0.14590 |
| Cu | | | | – | 0.12526 | 0.35242 | 0.21280 | 0.22181 | 0.05754 |
| Zn | | | | | – | −0.09455 | 0.06847 | 0.15329 | −0.00001 |
| Fe | | | | | | – | 0.23573 | 0.13065 | 0.06690 |

***$p < 0.001$

Therefore, serum copper concentration was lower compared to Fe or Zn, Hemoglobin (Hb), Hematocrit (Hct), and MCHC values were 13.24 g/dl, 39.80% and 34.65%, respectively. The fact they were within normal range indicates that the subjects for this study had normal iron status. Blood arsenic levels increase during menstruation and early pregnancy and it is reported that 80% blood arsenic levels have been found in red blood cells in rats. Arsenic contents in normal blood are reported as 10−20 μg/dl,[19)26)] and the serum arsenic level in this study was 16.14 μg/dl, which is within normal range. NAS reported that mean blood arsenic level of 801 samples from 14 countries was 17 μg/dl (7−38 μg/dl).[34)]

Blood lead concentrations increase as exposure to automobile exhaust increases. The normal range of blood lead concentration of the Japanese showed the biggest range (6−15 μg/dl) according to survey years, survey areas and analytical methods. Yatanabe *et al.* examined more than 2500 subjects and reported that mean blood lead levels of males living in rural areas was 4.9 μg/dl and that of females was 3.2 μg/dl.[19)28)] In this study, serum lead concentration was 4.32 μg/dl and showed levels similar to those of Japanese living in uncontaminated areas.

Blood cobalt concentrations in men are 0.02−1.5 μg/dl but vary widely from person to person.[19)35)] Blood cobalt levels of the present study showed 0.02 μg/dl, which was in normal range (0.018 μg/dl).[36)]

(1) Correlation coefficients between dietary intakes of heavy metals and blood levels of Fe, Cu, Zn, Hb, Hct and MCHC

Correlations of various blood iron indices, microminerals and dietary heavy metals are shown in Table 5. Dietary intake of arsenic and lead had no significant correlation with serum Fe, Cu, Zn, Hb, Hct, and MCHC levels, which suggests that intake levels of As and Pb by the subjects in this study did not affect hematogenesis. Co is one of the low toxic elements among heavy metals. Toxic symptoms in humans such as weight loss, polycythemia, myxedema and heart failure appear when daily intake exceeds 25−30 mg. In animals, intake of more than 4 mg/kg causes weight reduction and anemia leading to death. In this case, the cause of anemia is excessive intake of Co, which interferes with iron absorption.[19)] Co intake level of this study was in normal range, but the results indicate that subjects with higher dietary Co intake had lower Hb and Hct levels ($p < 0.001$). It is shown that the Fe intake level of this study (15 mg) was lower than recommended daily intake (18 mg/day), so Fe absorption interferes with Co in the body.[19)25)]

## CONCLUSION

Environmental pollution from heavy metals has recently become a serious problem in Korea. However, there is no well-established theory about heavy metal intake levels and the effects of heavy metals on the general public. Therefore, this study examined the mean daily intake level of heavy metals and correlation of intake level of heavy metals with the microminerals which play an essential role in hematopoiesis (production of blood) of subjects who live in an area where heavy metals were detected in marine products in our previous study. According to our previous study, the amount of heavy metals (As, Pb, and Co) in some marine products was 0.77−1.62 ppm, and 0.02−4.13 ppm, and 0.13−0.63 ppm, respectively.

Intakes of the heavy metals in our study were lower than or similar to levels seen in foreign studies, in which subjects were living in normal environmental areas. And blood levels of heavy metals in this study were in normal range.

The blood index, which indicates iron status (Hb and Hct) and dietary Co was significantly negatively correlated. It is considered that Fe intake level in this study (15 mg) was lower than the recommended daily allowance (18 mg/day), so Fe absorption was thus determined to interfere with Co in the body.

I expect that this data showing the effect of heavy metals on the diet and blood will be helpful to those conducting further studies in this field.

## Literature cited

1) Luckey TD, Venngopal. Physiological and chemical basis for metal toxicity. Plenum Press, New York and London, 1977
2) Patty FA. Industrial hygiene in toxicology, Intersience Publishers New York and London, 1962
3) Klein M, Naver R, Harpur E, Corbin R. Earthenware containers as a sources of fatal lead poisoning. *New Eng J Med* 283: 669, 1970
4) Guthrie FE, Perry JJ. Introductuion to environmental toxicology. Elsevier, New York, chapter, pp.3, 1980
5) Doll J, Klaassen CD, Amdur MO. Casarett & Doull's toxicology 2nd ed. Macmillan, New York, chapter, pp.17, 1980
6) Seiler HG, Sigel H, Sigel A (eds). Handbook on toxicology of inorganic compounds. Marcel Dekker, New York, 1988
7) Concon JM. Food toxicology. Marcel Dekker, New York, chapter, pp. 18, 1988
8) Oehme FW. Toxicology of heavy metals in the environment. 2 vols. Marcel Dekker, NewYork, 1978
9) Friberg L. Toxicology of metals. 3 vols, US EPA, 1976 – 1978
10) Friberg L. Nordberg GF, Vouk VB. Handbook on the toxicology of metals. Elsevier/North-Holland Biomedical Press, Amsterdam, 1979
11) Berman E. Toxic metals and their analysis. Heydon, London, 1980
12) Lee SR. Food safety and toxicology. Ewha Womans University Press, 1993
13) Kim SK, Lee JW, Kim AJ. The study on the sea food pollution according to environmental pollution of the western coast in Korea 26(5): 851-859, 1997
14) Kim AJ, Kim SY, Lee WC, Park MJ. Contents of Aresenic in some fisheries caught in western coast. *J of Food Hygiene and Safety* 13(3): 201-205, 1998
15) Kim AJ, Kim SK. A study on the Mg and Mn contents of seafoods in western coast of Korea 3(2): 677-681, 1997
16) Kim SK, Kim AJ. The study on the amount of trace elements in some fermented fish products from some ares of the west coast in Korea 26 (6): 1063-1067, 1997
17) Kim AJ, Kim SY, Lee WC. Contents of Cr and Co in some fisheries caught in the west coast. *Anatical Science & Technology* 10(5): 29-35, 1998
18) L Fowden, FRS, GA Garton FRS, Mills CF. Trace element deficiency: Metabolic and physiological consequences, London the Royal Society, pp.91-104, 1981
19) Sung CJ. Nutrition of trace elements, Minymsa, pp.40, 264, 307, 1997
20) Valberg LS in Skoryna SC, Waldron-Edward D. Trace elements and Radionuclides, 257, Pergamon Press Oxford, 1971
21) Underwood EJ. Trace elements in human and animal nutrition. Academic Press, New York, 1975
22) Lim JN. Analysis of food minerals. *Food & Nutriton* 7(1): 42-46, 1986
23) Joo HG. Food analysis: Wet digestion, Hak Mun Publishing Co., pp. 338, 1996
24) Steel RGD, Torrie JH. Principles procedures of stastistics. MaGrow-Hill Book Co., New York, pp.1, 1980
25) Ministriation of Health Walfare. Recommendard dietary allowances for Korea 6th Revision, 1995
26) Dickerson OB. Arenic. Metals in the environment. Academic Press, New York, 1980
27) Lee DHK. Metabolic contaminants and human health. Academic Press, New York, 1978
28) Dictionary of Food Safety. Committee of Junior College, 1997
29) National Academy of Sciences, National Research Council, Airborn lead in Perspective, Washington DC, 1971
30) World Health Organization. Technical Report Series Nr, pp.505, 1972
31) LC Rossi, GF Clemente, GP Santaroni. Studies on the trace element distribution in the diets and populations of Italy. *Rev Environ Health* 3: 19-41, 1978
32) MJ Harp, FI Scouler. Cobalt metabolism of young college women on self-selected diets. *J Nutr* 47: 67-72, 1952
33) Davies IJT. The clinical significance of the essential biological metals. William Heinmann Med Book London, pp.949, 1972
34) NAS. Lead. National Academy of Science, 1974
35) Kipling MP. Cobalt. Metals in the environment, Academic Press, pp. 133, 1980
36) Mary O, Amdur, John Doull, Curits D, Klassen. The basic science of poisons 4th edit, Pergamon Press, New York, Oxford, Beijing, Frankfurt, 1988