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Correlation of Serum Antioxidant Minerals with Blood Lipid Parameters in Obese Middle School Students

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Abstract

The purpose of this study was to investigate the relationships of obesity, serum antioxidant mineral concentrations and blood lipid parameters in middle school students. Subjects were assigned to two groups, obese (BMI≥25, 32 boys, 24 girls) and normal group (18.5<BMI<23, 27 boys, 30 girls). Subjects were evaluated based on anthropometic measurements, 24-hr dietary recalls and blood analysis. The mean age of all subjects was 13.8 years. The mean weight (p<0.001), BMI (p<0.001) and body fat (p<0.05) of obese were higher than those of normal group. There were significant differences in serum HDL-cholesterol, LDL-cholestrol, Mn and Zn concentrations between the obese and normal groups. Anthropometric measurements of the subjects were significantly inversely correlated with serum Mn and Zn, and positively correlated with blood lipids. Serum total and LDL-cholesterol were negatively correlated with serum Mn and Zn, and positively correlated with serum Cu and Cu/Zn ratio.

Key words: serum antioxidant minerals, blood lipid parameters, obese, middle school students

INTRODUCTION

During middle school years, physical growth occurs rapidly and hormone action leads to changes in body-shape and increased body fat (1). The increased rate of adolescent obesity is associated with chronic diseases such as high blood pressure, hypertension, hyperlipidemia and coronary heart disease, which are generally considered to be adulthood illnesses (2,3).

Free radicals cause various chronic diseases and exacerbate the aging processes by weakening the function of the cell membrane, thus resulting in an imbalance in body metabolism. Recently, studies on oxidative stress have also focused on the pre-invasion period of obesity and chronic degenerative diseases. The antioxidant system, which inhibits these processes, is achieved by both enzymatic and the non-enzymatic systems. The known enzymatic systems are superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPX), D-T diaphorase, and enzymatic generation of glutathione (4,5).

As antioxidants, copper, zinc, and manganese play an important role in SOD (6-8), and selenium is known as the metal element of intracellular GPX (9). The lack of antioxidative nutrients decreases enzyme activities and damage cell stability. The blood concentration of copper, zinc and selenium in the obese differs from normal weight people (10-13). Laitinen et al. stated that serum copper concentrations are positively related to weight and body mass index (BMI) in 13～18 year olds (14). Chen et al. (15) and Di Martino et al. (16) stated that serum zinc of the obese was lower than normal. Although copper and selenium status may have an important impact on cardiovascular disease, less is known about the effects of many other trace elements (17,18).

This study focuses on examining differences in concentrations of the various antioxidant minerals and their relationship to blood lipid levels. Firstly, the study investigates the content of the antioxidant minerals such as copper, zinc, manganese and selenium in serum. Secondly the study examines the relationship between the content of these minerals and blood lipid parameters in middle school students.

MATERIALS AND METHODS

Subjects

A total of 113 male and female students attending the 2nd year of middle schools in I city area of Jun-buk at of December, 2000 participated.

Anthropometric measurements

Participant's heights were recorded using an automatic

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height measurement instrument and weights were measured while wearing light clothes. After calculating the BMI (body mass index=kg/m^2), subjects were classified as normal ($18.5 \leq BMI < 22.9$) or obese until $25 \leq BMI$. This classification was conducted in accordance with the standards for body mass index of Asians. Body fat masses were measured with regard to the age and height by using a bio-electrical impedance analyzer (TBF-105, TANITA, Japan). Circumference of the waist and hip were measured with a tape measure and used to calculate the waist hip ratio (WHR). Blood pressure was also measured on an empty stomach using a fully automatic blood pressure monitor (BP-750A, ITO Co., Japan).

Nutrient intakes

Dietary intakes were recorded by a trained interviewer who helped subjects to recall intakes by using food models and bowls that were used on a daily basis. The results were analyzed for overall nutrient intake using Can-Pro (Computer Aided Nutritional Analysis Program for Professionals, The Korean Nutrition Society, 1998). Copper and zinc intakes were calculated from the food composition tables of the Republic of Korea (19), United States of America (20), and Japan (21).

Analysis of blood

Venous blood samples were collected into vacuum tubes after an overnight fast and centrifuged at 3,000 rpm for 15 minutes. The serum obtained was separated and frozen at -80°C until the time of analysis. Serum aliquots of 2 mL each were mixed with 2 mL of the ternary solution composed of nitric acid, sulfuric acid, and perchloric acid in a 10:1:4 ratio. Next, using a sample diluted with an ion removal water as a standard, an analysis was conducted on fixed-volume content of copper, zinc, manganese and selenium using ICP (Inductively coupled plasma, Thermo Jarrel Ash, USA). Total cholesterol, HDL-cholesterol and triglyceride in serum were measured using a kit based on an enzymatic method (Boeringer Manheim, Germany). The serum concentration of LDL-cholesterol was calculated according to the formula of Friedenwald (22). In addition, TPH (total cholesterol / HDL-cholesterol), LPH (LDL-cholesterol / HDL-cholesterol), and atherogenic index {AI=(total cholesterol − HDL-cholesterol) / HDL-cholesterol} were also calculated.

Statistical analysis

The results are expressed as means and standard deviations. The significance of mean differences between groups was determined by Student's t-test. Chi-square tests were used to test significance of the distribution rate within the groups. Also, to study the relationship among all variables, correlation coefficients (r) were calculated. Data analysis were conducted using statistical software package for windows (SAS version 8.01, SAS institute, USA).

RESULTS AND DISCUSSION

Characteristics of participants

The age and anthropometric measurement of the subjects are shown in Table 1. The average age was 13.8 in both normal and obese groups. Average weights were 58.0 and 73.9 kg in normal and obese group, respectively. Mean BMIs of obese and normal subjects were 28.2 kg/m^2 and 21.8 kg/m^2, respectively. Both weight ($p<0.001$) and body mass index ($p<0.001$) of obese subjects were significantly higher than those of the normal group. The average systolic and diastolic blood pressures were not significantly different between the two groups.

Percent body fat was significantly higher in the obese (35.0%) than the normal (26.0%) subjects. Also, WHR of the obese group was significantly higher than that of the normal group ($p<0.05$).

Nutrient intakes

Nutrient intakes per day are shown in Table 2. The obese group consumed more of nearly all nutrients, including energy, than the normal group, but the differences were not statistically significant. The obese group had a lower daily protein intake (62.1 g) than the normal

Table 1. Anthropometric measurements of obese and normal middle school students

	Obese (n=56)	Normal (n=57)	Significance[6]
Age (years)	13.8±0.5[5]	13.8±0.5	NS[7]
Sex			
male	57.1%	47.4%	NS[8]
female	2.9%	52.6%	
Height (cm)	161.7±7.0	162.9±7.7	NS
Weight (kg)	73.9±9.7	58.0±6.1	p<0.001
BMI[1] (kg/m^2)	28.2±2.5	21.8±1.1	p<0.001
Röhrer	190.7±16.7	143.0±9.2	p<0.001
SBP[2] (mmHg)	126.3±13.8	122.2±15.4	NS
DBP[3] (mmHg)	76.7±15.7	73.6±11.6	NS
Body fat (%)	35.0±8.4	26.0±7.9	p<0.05
Waist (cm)	85.0±8.0	70.4±4.4	p<0.001
Hip (cm)	100.6±14.0	91.7±4.2	p<0.001
WHR[4]	1.0±1.1	0.8±0.0	p<0.05

[1]Body mass index.
[2]Systolic blood pressure.
[3]Diastolic blood pressure.
[4]Waist/hip ratio.
[5]Mean±SD.
[6]Significance determined by Student's *t*-test.
[7]Not significant.
[8]Significance determined by Chi-squire test.

Table 2. Daily nutrient intakes of obese and normal middle school students

	Obese (n=56)	Normal (n=57)	Significance[2)]
Energy (kcal)	2053.9±642.4[1)]	1937.3±491.2	NS[3)]
Protein (g)	62.1±23.1	71.0±28.3	NS
Animal protein (g)	25.5±16.2	30.9±17.2	NS
Plant protein (g)	36.6±12.8	40.1±14.8	NS
Fat (g)	58.5±31.8	50.2±20.0	NS
Animal fat (g)	21.0±15.5	20.7±12.2	NS
Plant fat (g)	37.5±27.0	29.5±18.1	NS
Cholesterol (mg)	243.1±174.2	252.0±193.3	NS
Carbohydrate (g)	319.8±108.0	300.4±90.3	NS
Crude fiber (g)	4.6±1.8	4.9±2.1	NS
Vitamin A (R.E.)	529.1±297.7	536.6±332.9	NS
Vitamin B_1 (mg)	1.2±0.5	1.4±0.6	NS
Vitamin B_2 (mg)	1.0±0.5	1.0±0.5	NS
Niacin (mg)	12.2±4.6	13.4±5.1	NS
Vitamin C (mg)	106.8±109.5	104.7±98.3	NS
Calcium (mg)	401.4±282.4	431.0±250.8	NS
Phosphorus (mg)	933.8±373.0	1037.1±379.5	NS
Iron (mg)	9.0±3.9	10.1±4.8	NS
Zinc (mg)	6.3±2.7	7.1±2.8	NS
Copper (g)	982.0±329.3	1048.9±343.1	NS

1)Mean±standard deviation.
2)Significance determined by Student's *t*-test.
3)Not significant.

group (71.0 g) but notable differences between the two groups did not exist. The daily carbohydrate intakes for the obese and normal groups were 319.8 g and 300.4 g, respectively; and for fat and cholesterol were 58.5 g and 243.1 mg, and 50.2 g and 252.0 mg, respectively.

When we estimated nutritional status using the Dietary reference intakes for Koreans (23), over 50% of the subjects from both groups consumed less that the estimated average recommended amounts (EAR) of vitamin B_2, vitamin C, calcium and iron (Table 3).

Blood lipid parameters

Serum lipid concentrations are shown in the Table 4. Serum LDL-cholesterol levels of the obese group were markedly and significantly higher than that of the normal group ($p<0.05$). Serum HDL-cholesterol concentrations were lower in the obese groups than in their counterparts ($p<0.001$). The obese also had significantly higher ratios of total cholesterol to HDL-cholesterol, LDL-cholesterol to HDL-cholesterol ($p<0.001$), and atherogenic index (each $p<0.001$). It is concluded that the increase in the adolescent obesity obviously leads to changes in blood lipid which indicates they also have an increased risk of cardiovascular diseases.

Table 3. Percent of subjects consuming less than estimated average requirements (EAR) of selected nutrients

	Obese (n=56)	Normal (n=57)	Significance[1)]
Protein	8.9%	14.0%	NS
Vitamin A	55.4%	49.1%	NS
Vitamin B_1	17.9%	31.6%	NS
Vitamin B_2	69.6%	66.7%	NS
Niacin	26.8%	40.4%	NS
Vitamin C	51.8%	61.4%	NS
Calcium	91.1%	89.5%	NS
Phosphorus	25.0%	36.8%	NS
Iron	51.8%	54.4%	NS
Zinc	21.4%	36.8%	NS

1)Significance determined by Chi-squire test.

Table 4. Blood lipid parameters of obese and normal middle school students

	Obese (n=56)	Normal (n=57)	Significance[9)]
TC (mg/dL)[1)]	248.6±217.3[8)]	304.0±262.6	NS
TG (mg/dL)[2)]	91.0±41.8	68.7±74.9	NS
HDL-C (mg/dL)[3)]	43.8±11.3	48.7±9.5	p<0.05
LDL-C (mg/dL)[4)]	110.5±32.7	85.6±30.1	p<0.001
TPH[5)]	4.2±1.5	3.1±0.7	p<0.001
LPH[6)]	2.7±1.3	1.8±0.7	p<0.001
AI[7)]	3.2±1.5	2.1±0.7	p<0.001

1)Total cholesterol. 2)Triglyceride.
3)HDL-cholesterol. 4)LDL-cholesterol.
5)Total cholesterol / HDL-cholesterol.
6)LDL-cholesterol / HDL-cholesterol.
7)Atherogenic index=(total cholesterol − HDL-cholesterol) / HDL-cholesterol.
8)Mean±SD.
9)Significance determined by Student's *t*-test.

Concentrations of the Cu, Zn, Mg and Se in serum

Serum concentrations of antioxidant minerals relating are in the Table 5. Serum Se and Cu concentrations were not significantly different between obese and normal groups. However Yakinici et al. (24) reported that serum copper concentrations of obese subjects were significantly higher than normal. Tungtrongchitr et al. (25) also reported that serum Cu was significantly higher in overweight subjects than in the controls. In a study of upper elementary students, Lee (26), pointed out that the obese tended to have higher Cu levels, even though the difference was not statistically significant.

Serum Zn concentrations in obese students were 95.5

Table 5. Serum antioxidant mineral concentrations of obese and normal middle school students

	Obese (n=56)	Normal (n=57)	Significance[2)]
Se (μg/dL)	24.8±3.0[1)]	25.9±2.9	NS
Mn (ng/mL)	0.15±0.3	0.29±0.3	p<0.01
Cu (μg/dL)	110.8±14.5	104.4±17.2	NS
Zn (μg/dL)	95.5±12.6	101.3±12.0	p<0.05
Cu/Zn	1.2±0.2	1.0±0.2	p<0.05

1)Mean±SD.
2)Significance determined by Student's *t*-test.

μg/dL and in obese students were 101.3 μg/dL, this shows that the obese group had notably lower serum Zn concentrations ($p<0.05$). According to Chen et al. (15), both genetically engineered mice and diet induced obese mice had lower serum Zn concentration than the normal mice. Furthermore, numerous human studies have demonstrated that obese people have lower blood Zn levels (16,25,27-29). A recent study of weight-loss programs for obese adults females found that plasma and erythrocyte Zn concentrations are lower in obese subjects, and interestingly, the plasma Zn concentrations were markedly higher at the end of the weight loss program (27). Those findings again support the result of this study that obesity and Zn appears to be negatively related. Zinc has important effects on metabolism, and on the thermo regulation of obese individuals. Di Martino et al. referred to a possible relationship of serum Zn levels with the anabolic and catabolic mechanisms of obesity, although the exact metabolic role of this bio-element remains unclear (16).

Serum Mn concentrations in the obese group (0.15 μg/dL) were also significantly lower than in the normal group (0.29 μg/dL) ($p<0.01$). There are few studies on serum Mn concentration of obese people. Mn is a component of manganese superoxide dismutase (MnSOD), and plays important roles in antioxidant process in the body (8). However, further study is needed to elucidate the metabolic mechanism of decreased serum Mn concentrations in obese.

Analysis of the correlation

The correlation analysis among the height, blood lipid, and content of the antioxidant minerals is shown in Table 6. Weight, BMI, waist circumference, hip circumference, and percent body fat were positively correlated with triglyceride, total cholesterol, LDL-cholesterol, atherogenic index, TPH, and LPH, while negatively correlated with HDL-cholesterol. However, waist/hip circumference ratio did not correlate with the blood lipids. This indicates that adolescent obesity significantly contributes to changes of blood lipid. It also points out that the waist/hip ratio did not coincide with the health index in middle school adolescents.

The serum concentrations of manganese and zinc negatively correlated with weight, body mass index, circumference of the waist and percent body fat. These findings indicate that the increase in obesity results in a reduction in antioxidant minerals, such as the manganese, and zinc.

The correlation analysis among blood lipids and contents of the antioxidant minerals is shown in Table 7. The serum concentration of Mn negatively correlated with the total cholesterol, LDL-cholesterol, atherogenic index, TPH and LPH; serum copper content was positively correlated with total and LDL-cholesterol. Serum zinc was negatively correlated with total cholesterol, only. The serum Cu/Zn ratio had a positive relationship with total and LDL-cholesterol. A recent study on cardiovascular disease reported that the higher the serum Cu/Zn ratio, the higher the lipids in blood, and the greater the risk of getting coronary arterial heart diseases (30). These findings have again confirmed that serum Cu/Zn ratios of cardiovascular patients are much higher than in normal people (31,32). An animal study on mice (33,34), reported that the ratio of copper and zinc in serum has dropped as total cholesterol increased. According a study by Kim et al., serum copper concentrations in normal females negatively correlated with total and LDL-cholesterol concentrations (35). All these findings

Table 6. Correlation coefficients among anthropometric measurements, blood lipid parameters and serum antioxidant minerals of middle school students

	Weight	BMI[1)]	Waist	Hip	WHR[2)]	Body fat	SBP[3)]	DBP[4)]
TG[5)]	0.2472***[12)]	0.2568***	0.2064**	0.2271**	-0.0334	0.3002***	0.0654	-0.0300
TC[6)]	0.2995***	0.4356***	0.4207***	0.1069*	0.0991	0.4294***	0.0929	0.1014
HDL-C[7)]	-0.2230**	-0.2634***	-0.2862***	-0.2124**	0.0340	-0.2592***	-0.0784	0.0369
LDL-C[8)]	0.2875***	0.4386***	0.4495***	0.0907	0.1058	0.4140***	0.0964	0.0149
AI[9)]	0.4241***	0.5452***	0.5099***	0.2533***	0.0249	0.4670***	0.1172	-0.0499
TPH[10)]	0.4241***	0.5452***	0.5099***	0.2533***	0.0249	0.4670***	0.1172	-0.0499
LPH[11)]	0.3829***	0.5246***	0.5014***	0.2075**	0.0415	0.4436***	0.1065	-0.0466
Se	-0.0806	-0.1285	-0.0542	-0.0057	0.0664	-0.1043	0.0213	0.0208
Mn	-0.2863***	-0.2970***	-0.1889*	-0.0788	0.0143	-0.1843*	-0.0677	-0.1590*
Cu	0.1342	0.1269	0.1664	-0.0391	-0.0933	0.0008	0.0119	0.0081
Zn	-0.2323**	-0.2671***	-0.1103	-0.2483***	0.1240	-0.3578***	0.1166	-0.0462

[1)]Body mass index. [2)]Waist/hip ratio. [3)]Systolic blood pressure. [4)]Diastolic blood pressure.
[5)]Total cholesterol. [6)]Triglyceride. [7)]HDL-cholesterol. [8)]LDL-cholesterol.
[9)]Atherogenic index={(Total cholesterol) − (HDL-cholesterol)} / HDL-cholesterol.
[10)]Total cholesterol / HDL-cholesterol. [11)]LDL-cholesterol / HDL-cholesterol.
[12)]Pearson's correlation coefficient. Significance *at $p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 7. Correlation coefficients between blood lipid parameters and serum antioxidant minerals of middle school students

	TG[1]	TC[2]	HDL[3]	LDL[4]	AI[5]	TPH[6]	LPH[7]
Se	0.0539	-0.0340	0.0406	-0.0685	-0.1147	-0.1147	-0.1344
Mn	-0.0185	-0.1525*[8]	0.0318	-0.1614*	-0.1714*	-0.1714*	-0.1794*
Cu	-0.0125	0.1576*	0.0320	0.1698*	0.0051	0.0051	0.0887
Zn	-0.0030	-0.1588*	-0.0977	-0.1343	-0.0833	-0.0833	-0.0975
Cu/Zn	0.0131	0.1579*	0.0751	0.1709*	-0.0787	-0.0787	0.1121

[1]Total cholesterol. [2]Triglyceride. [3]HDL-cholesterol. [4]LDL-cholesterol.
[5]Atherogenic index=(Total cholesterol − HDL-cholesterol) / HDL-cholesterol.
[6]Total cholesterol / HDL-cholesterol. [7]LDL-cholesterol / HDL-cholesterol.
[8]Pearson's correlation coefficient. *Significance at $p<0.05$.

suggest that blood zinc and copper concentrations are closely related to blood lipids and may be important risk factors for cardiovascular diseases.

CONCLUSION

In conclusion, the obese adolescents tend to have lower levels of manganese and zinc. The serum zinc and manganese were significantly inversely correlated with blood lipids and the numerical indices of cardiovascular disease risk. Copper and the ratio of Cu/Zn had significantly positive relationship with blood lipids. These results indicate that adolescent obesity leads to a decrease in the serum concentration of some antioxidant minerals. These changes may be related to risk factors for cardiovascular disease, but, further study is needed to clarify the metabolic mechanism of the relationship between serum concentrations of antioxidant minerals and blood lipid parameters in obese adolescents.

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