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□ **Original Article** □

Nutritional Status of Iron, Zinc and Copper of Preschool Children Residing in Low-Income Area of Seoul

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ABSTRACT

This study was performed to investigate the biochemical status of iron, zinc and copper for 125 preschool children(Males : 69, Females : 56) residing in a low-income area of Seoul. The number of subjects aged 3, 4, 5 and 6 were 19, 41, 41 and 24, respectively. The hemoglobin level of the children aged 3 was 11.8g/dl and was lower than that of the other groups($p < 0.05$). Similar results were found for hematocrit and serum zinc. The percentage of children with an iron deficiency assessed by Hb(3 – 5 years : <11.0g/dl, 6 years : <11.5g/dl), Hct(3 – 5 years : 33%, 6 years : <35%), serum transferrin(<16%) and serum ferritin(<10ng/ml) were 4.3%, 9.5%, 18.2% and 17.7%, respectively. The mean serum zinc was 67.0μg/dl and urinary zinc was 0.1300mg/day. Low serum zinc (<61.0μg/dl) occurred in 28.0% of the children. The mean serum copper was 110.5μg/dl and urinary copper was 0.0126mg/day. The prevalence of children with elevated serum copper(≥130μg/dl) was 54.8%, which was higher than 7.4%, the prevalence of low serum copper(<70μg/dl). Children with higher status, more weight, larger girth of chest, or larger midarm circumferece showed higher values of Hb. The height and weight of children also showed a positive correlation with serum zinc($p < 0.001$ – $p < 0.05$). (*J Community Nutrition* 1(1) : 3~9, 1999)

KEY WORDS : preschool children · Hb · Hct · serum ferritin · serum transferrin · serum zinc · serum copper · urinary zinc · urinary copper.

Introduction

During the preschool-age period when physical growth is most rapid, nutritional requirements are high. The nutrient intake in this period is influenced by food habits, likes and dislikes and environmental factors like parental behavior and poverty(Pipes & Trahms 1993). Although evidence of malnutrition has reduced in the past 10 years, populations of children residing in a low-income area exhibited inadequate nutrient intake and biochemical parameters(Woo 1984 ; Ko 1994). If concerns over the nutritional problems of preschool children can be generalized, iron deficiency anemia appears to be the main problem.

Iron deficiency anemia of preschool children was frequently reported in the 1970's(Ju & Oh 1976 ; Tchai & Chu 1971). Iron intake of the children residing in farm areas was lower than 60% of the Korean Recommended Dietary Allowances(Park et al. 1980) and a similar result was observed for children from a low-income area of Seoul(Lee 1993 ; Ko 1994). The proportion of iron deficiency assessed with hemoglobin and hematocrit was 12.9 – 18.6% for children living in an orphanage. Twenty seven percent of the children had biochemical indexes signifying poor nutritonal status of iron (Ko 1994). It seems all preschool children are at risk of iron deficiency anemia, which appears to be a greater problem especially in children from low-income families.

It is well known that zinc is essential for the growth and development of children(Hambidge 1972). Children with a severe zinc deficiency are rarely found, but growing children of countries where cereal proteins are primary in the local diet are at risk of zinc deficiency(Prasad 1988). Phytic acid in the grains and fiber in vegetables are inhibiting zinc absorption(Solomon & Cousins 1984).

Copper is also essential for animal nutrition. Even though copper deficiency is not frequently found in humans, infants with low birth weight(Ashkenazi et al. 1973), and generally malnourished children were reported as having copper deficiency. Han & Lee(1994) reported forty-three percent of elementary school children showed lower serum

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copper levels. Few surveys assessing zinc and copper nutrition for preschool children status have been done in Korea.

This study was performed to investigate the biochemical status of iron, zinc and copper for preschool children residing in a low-income area of Seoul.

Subjects and Methods

1. Subjects

Total subjects were 125 children(Males : 69, Females : 56) aged 3 – 6. The number of children for each age group 3, 4, 5 and 6 years were 19, 41, 41 and 24, respectively. They included 68 preschool children(Males : 35, Females : 33) residing in a rental apartment complex in the Suseo area and 57 preschool children(Male : 34, Female : 23) residing in Bongchun-dong for reconstruction. Monthly income of the family was 921,000 won which is much lower than the average income of city family reported by the Bureau of Statistics in 1995.

2. Anthropometric measurements

Anthropometric measurements were composed of height, weight, girth of chest, midarm circumference and triceps skinfold thickness. A narrow, flexible, nonstretch tape made of steel was used for measuring girth of chest. The measurement of the triceps skinfold was performed at the midpoint of the upper left arm, beween the acromion process and the tip of the olecranon, with the arm hanging relaxed.

3. Nutrient intake

Data of a twenty-four hour period recalled food eaten for breakfast, dinner and snack was collected from the mothers of the children by a trained dietition. The amount of foods consumed at lunch was weighed directly. This was done for 3 consecutive days in November, 1996. The average daily dietary intake of nutrients was calculated by using a computerized data base.

4. Analysis of hemoglobin(Hb), hematocrits(Hct), serum iron(SI), total iron binding capacity(TIBC) and serum ferritin

Blood samples were obtained from fasting subjects by venipuncture. Hb and Hct were measured with Coulter Counter(Coulter T 890, 1994).

SI was measured with a Clinical spectrophotometer(Shimadzu, CL-770) using an SI kit(Wako Co. 1995) and TIBC was analyzed by the Nitroso-PSA method(Tietz 1982). Serum ferritin was measured with the I^{125} IRMA kit using the two-side immunoradiometric assay(Addison et al. 1972).

5. Analysis of serum zinc(Zn), serum copper(Cu), urinary zinc(uZn), urinary copper(uCu), alkaline phosphatase(ALP)

For measurements of Zn and Cu, the serum sample was diluted with a glycerol solution(5% v/v) and analyzed in an AAS(Atomic Absorption Spectrophotometer, AA-680 Shimadzu Co.).

Twenty four hour urinary collection started at 9 o'clock when the children came to kindergarten. The kindergarten teacher collected urine during the time when the children were staying at school. Parents collected urine after school until 9 o'clock of the follwing day. Eight ml of urinary sample was centrifuged at the condition of 4000 rpm, 5℃. pH of the supernatant was adjusted to 3 – 4 with conc HCl and used for analysis of uZn and uCu.

The conditons used for analysis of zinc and copper are shown in Table 1.

ALP was analyzed by using a biochemical autoanalyzer (Hitachi 747, Japan Hitachi Co.) using the 3MP ALP kit.

6. Statistical analysis

Statistical analysis was done by using the Statistical Analysis System(SAS). Data were expressed as the mean±SD.

The differences among the means for each age group (3, 4, 5 and 6 years) were analyzed statistically by ANOVA and Tukey's test. The Pearson's correlation coefficients were used to assess the significance of correleation between blood parameters and nutrient intake and anthro-

Table 1. Measurement condition of AAS with the flame method analysis of zinc and copper

	Zinc	Copper
Analytical conditions		
HCL(MA)	4	3
SLIT(NM)	0.5	0.5
WL(NM)	213.9	324.8
MODE	B.G.C	B.G.C
Measurement conditons		
Signal-proc	INT-HOLD	INT-HOLD
Pre-Spray	3	3
TTG-Time	5	5
Repeat(N)	2	2
Max-N	2	2
CV(%)	99	99

pometric data.

Results and Discussion

1. Iron status

The mean Hb levels for the 3, 4, 5 and 6 age groups were 11.8g/dl, 12.2g/dl, 12.3g/dl, and 12.6g/dl, respectively showing trends of elevating as the age of children increases(Table 2). The hemoglobin level of the children aged 3 was significantly lower than that of other age groups($p<0.05$).

Regarding the Hb values of the upper limit of moderate iron deficiency are 11.0g/dl for children aged 3−5 and 11.5g/dl for children aged 6(Gibson 1990), 4.3% of the children showed moderate iron deficiency(Table 3).

The children aged 3 or 4 showed significantly lower values of Hct than the children aged 6.

Low serum Hct(3−5 years : <33%, 6 years : <35%) occurred in 9.8% of the children(Table 3). The proportion of children indicating iron deficiency assessed by Hb or Hct was lower than 25%, previously reported by Ko (1994) who surveyed the same area in 1993. Hemoglobin and hematocrit are insensitive, concentrations falling only during the third stage of iron deficiency(Garby et al. 1969).

Transferrin saturation measures the iron supply to the erythroid bone marrow and it is more rapidly responds to iron deficiency. The mean transferrin saturation of the group aged 5 was 17.6%, which is significantly lower than 21.2%, of the children aged 6. Concentrations below 16% (Neumann et al. 1982) were noted in 16.7%, 20.5%, 25.0% and 4.2%, respectively for each age group. The proportion of the children indicating iron deficiency assessed with transferrin saturation was 18.2%, which was higher than the proportion assessed with Hb or Hct(Table 3).

Serum ferritin is most sensitive to iron status and an accurate parameter for diagnosing iron deficiency anemia. It can be used as an early diagnosis of iron deficiency anemia or iron overload. The mean serum ferritin levels were 16.6ng/ml, 16.6ng/ml, 16.8ng/ml, 18.2ng/ml, respectively for each age group. There were no significant differences between groups. Serum ferritin lower than 10ng/ml is generally regarded as depletion of iron storage and iron deficiency(Gibson 1990). 17.7% of the children had serum ferritin levels less than 10ng/ml(Table 3).

Assessing by all the biochemical indexes related to iron status, 4.1−18.2% of the preschool children showed biochemical findings indicative of iron deficiency anemia. The children aged 3 showed the highest prevalence(11−26.3%) and the children aged 6 showed the lowest prevalence(0.0−8.3%).

Dallman et al.(1984) reported the highest prevalence of anemia occurred from 4 months to 3 years of age. Because most infants are in a transient period from breast or bottle feeding to the regular meal and their iron intake does not meet the requirement which is almost

Table 2. Hematological observation of subjects by age 1

Parameters \ Age	3 (n=19)	4 (n=41)	5 (n=41)	6 (n=24)	Total (n=125)
Hemoglobin(g/dl)	11.8± 0.8^{b}	12.2± 0.8^{a}	12.3± 0.6^{a}	12.6± 0.7^{a}	12.3± 0.8
Hematocrit(%)	34.2± 2.5^{b}	32.1± 2.3^{b}	35.3± 2.0^{ab}	36.4± 2.0^{a}	35.3± 2.3
Ferritin(ng/ml)	16.6± 13.5	16.6± 9.9	16.8± 7.5	18.2± 7.3	17.0± 9.3
Serum Iron(μg/dl)	85.7± 28.8^{b}	81.0± 34.0^{b}	86.4± 30.7^{b}	116.0± 49.0^{a}	92.9± 37.1
TIBC(μg/dl)	462.8±127.2	514.8±179.9	492.2±149.3	513.6±128.4	499.4±152.6
Transferrin saturaton(%)	20.0± 7.2^{ab}	18.4± 5.5^{ab}	17.6± 4.4^{b}	21.2± 4.2^{a}	18.9± 5.4

Values are mean±SD
In each row, values not sharing the same superscript are significantly different($\alpha=0.05$)

Table 3. Distribution of subjects below the reference value in each hematological parameters N(%)

Parameter	Cutoff point	Age 3	4	5	6	Total
Hemoglobin(g/dl)	<11.0	2(11.1)	2(5.0)	1(2.4)	0(0.0)	5(4.0)
Hematocrit(%)	<33	2(11.1)	3(7.5)	5(12.2)	1(2.4)	11(8.8)
Serum ferritin(ng/ml)	<10	5(26.3)	11(27.5)	4(9.8)	2(8.3)	22(17.6)
Transferrin saturation(%)	<16	3(16.7)	8(20.5)	10(25.0)	1(4.2)	22(17.6)

doubled due to the growth spurt and rapid increase of red blood Cell.

Ko(1994) reported meal balance and food diversity of the children aged 3 are lower than those of the children aged 4, 5 or 6 and the nutrient intake was positively correlated with meal balance and food diversity.

Compared to the proportion of anemia, 25.0 – 26.7% shown at the previous survey done in a similar area in 1993, the prevalence of anemia decreased substantially, but iron deficiency anemia for preschool children was still present.

2. Zinc and copper status

The mean serum zinc of the children was 67.0μg/dl, which was lower than 75.3 – 83.0μg/dl Kye & Park (1993) reported for children from an orphanage. The mean serum zinc of the group aged 3 was 57.6μg/dl and was significantly lower than those of the other age groups($p < 0.05$)(Table 4).

A previous study(Kye & Park 1993) reported similar lower serum zinc for children aged 3. Serum zinc tends to respond to low zinc intake, but sustained 10 – 23 μmol/L within the wide range of zinc intake(Hambidge et al. 1986). Pilch & Senti(1984) suggested the cutoff point of assessing zinc deficiency as 61.0μg/dl. The proportion of subjects whose serum zinc was less than 61.0 μg/dl was 56.3%, 37.1%, 25.6% and 13.0% for each age group, respectively(Table 5). Low serum zinc occurred in 28.0% of all subjects, which shows substantial numbers of children, especially children aged 3 are at risk of zinc deficiency(Table 5).

The mean zinc excretion of the children was 0.013mg/day and there were no significant differences between groups (Table 4). It was reported urinary zinc excretion responds more rapidly to dietary intake than serum zinc and a valuable indicator for assessing zinc status in apparently healthy individuals(Bear & King 1984). Levels of zinc excretion in the urine usually range from 0.3~0.6mg per day(Gibson 1990).

ALP is a metalloenzyme containing zinc and this enzyme activity declines rapidly due to an inadequate zinc intake in experimental animals(Adeniyi & Heaton 1980), but the response is not consistent for humans(Nanji & Anderson 1983). Mean serum ALP of the children was 213.6 unit/L and was above the normal range of adults (20 – 100 unit/L).

The occurrence of severe zinc deficiency is rare and primarily associated with abnormal dietary practices or a diseased state, particularly hepatic and GI disorders associated with zinc malabsorption(Cousins & Hempe 1990). Nevertheless mild chronic zinc deficiency with evidence of low serum or urinary zinc excretion occurred more frequently than expected in pregnant women, children and the elderly(Cousins & Hampe 1990). Clinical signs of a marginal zinc deficiency in childhood include impaired growth and poor appetite(Smith-Vander Kooy & Gibson 1987).

The mean serum copper was 110.5μg/dl, which was higher than the serum copper 54.13μg/dl found in elementary school students reported by Han & Lee(1994), but was similar to the value 131.2μg/dl Jeong & Na (1993) reported for 11 year old children. Children showed higher values of serum copper compared to serum zinc. The range of serum zinc(5 – 95th) was 43.8 – 90.7μg/dl, whereas serum copper showed the range of 63.8 – 162.0μg/dl (Table 6). There were no significant differences in serum copper between groups(Table 4).

Serum copper concentration is at present routinely measured for the clinical assessment of severe copper deficiency, but are not sensitive and specific enough to be used as an index of copper status in apparently healthy individuals(Gibson 1990). Interpretive guidelines often used

Table 4. Parameters of subjects related to zinc and copper

Parameters \ Age	3 (N=16)	4 (N=35)	5 (N=39)	6 (N=23)	Total (N=113)
Serum zinc(μg/dl)	57.6±17.5[b]	67.9±14.4[a]	66.4±11.9[a]	73.5±12.5[a]	67.0±14.3
Serum copper(μg/dl)	142.5±33.7	110.6±29.2	99.4±26.4	106.2±33.3	110.5±32.6
Serum alkaline phosphatase(Unit/L)	194.5±39.5	209.2±44.6	221.3±32.5	223.2±37.5	213.6±39.6
Urinary zinc(mg/day)	0.1188±0.0600	0.1286±0.0759	0.1310±0.0988	0.1411±0.0821	0.1300±0.0830
Urinary copper(mg/day)	0.0191±0.0094[ab]	0.0188±0.0091[b]	0.0251±0.0121[a]	0.0221±0.0107[ab]	0.0216±0.0110

Values are mean±SD
In each row, values not sharing the same superscript are significantly different(α=0.05)

Table 5. Distribution of subjects below the cutoff value in each parameter N(%)

Parameters	Cutoff point	Age				Total
		3	4	5	6	
Serum zinc(μg/dl)	<61	9(56.3)	13(37.1)	10(25.6)	3(13.0)	35(31.0)
Serum copper(μg/dl)	<70	0(0.0)	1(2.9)	4(10.2)	3(13.6)	8(7.1)

Table 6. Values according to the percentiles of parameters

Parameters \ Percentile	5	10	25	50	75	90	95
Serum zinc(μg/dl)	43.8	51.5	58.7	66.9	75.3	85.0	90.7
Serum copper(μg/dl)	63.8	73.5	87.6	104.2	131.3	151.6	162.0
Urinary zinc(mg/day)	0.0316	0.0417	0.0665	0.1231	0.1604	0.2446	0.2726
Urinary copper(mg/day)	0.0075	0.0102	0.0148	0.0199	0.0279	0.0362	0.0402

Table 7. Correlation coefficient between blood parameters and nutrient intakes

Nurient intakes \ Parameters	Hemoglobin	Hematocrit	Ferritin	Iron	TIBC	TS	ALP	Zn	Cu
Vitamin A	-.0549	.0781	.0646	.0650	.1184	-.0256	.1312	-.1491	.1554
Vitamin B_1	.0308	.0905	.0436	-.0268	.0076	-.0422	-.0180	-.0651	.2962
Vitamin B_2	-.0351	.0499	.0034	.1098	.1430	.0534	-.1361	-.0314	.2960**
Niacin	.1076	.1480	.0425	.0212	.0298	.1109	-.0438	-.0467	.1881
Vitamin C	-.0896	.0006	.1413	.0293	.0531	-.0027	-.0952	.0032	.3166**
Ca	-.0485	-.0222	-.1447	.1836	.0806	.2120	-.0711	.0221	.0631
P	-.0469	.0444	-.0563	.0836	.1000	.0932	-.1671	-.0549	.2806**
Fe	-.0435	.0570	-.0322	.0555	.0892	.0416	.0002	-.1446	.1371

TIBC : total iron binding capacity, TS : transferrin saturation, ALP : alkaline phosphatase
*Significant at $p<0.05$, **Significant at $p<0.01$, ***Significant at $p<0.001$

for normal serum copper concentration is 70 – 130μg/dl (Tietz 1983). The low serum copper concentration(<70 μg/dl) occurred in 7.4% of the children and the higher serum copper concentration(≥130μg/dl) was found in 54.8% of children. Copper deficiency has not been reported in humans consuming a varied diet. However low serum coppers concentrations have been reported in patients receiving TPN solutions without copper supplementation(Krause & Mahan 1972). It is known that serum copper levels rise in inflammatory conditions, infectious diseases, diabetes and cardiovascular disease(Davis & Mertz 1987). Acceleration of serum copper concentration is also observed in infants when copper salts are applied to burned skin, drinking water from contaminated water supplies, or consumption of acidic food or beverages that had been stored in copper containers(Turnlund 1994). The proportion of concentration indicating copper overload was higher than the proportion of values signifying copper deficiency.

Copper is a component of cuproprotein and important in oxidation reduction procedure and iron metabolism. It is also important in the formation of collagen and elastin as well as in the synthesis of melanin(Hambidge 1997) and abundant in connective tissue(Hambidge 1977).

3. Correlation between nutrition intake and zinc and copper indexes

Hematological parameters related to iron or zinc status did not show any correlation with nutrient intake(Table 7). Serum copper showed a significant positive correlation with vitamin B_2, vitamin C and phosphorus($p<0.01$ – $p<0.001$).

4. Correlation between anthropometric data and parameters

Hemoglobin levels were positively correlated with height, weight, girth of chest and midarm circumference($p<0.05$ – $p<0.001$)(Table 8).

Children with higher status, more weight, larger girth of chest, or larger midarm circumference showed higher hemoglobin levels. Similar results were found for Hct. Serum ferritin was positively correlated with height and transferrin saturation was positively correlated with BMI (Table 7). Son & Yang(1998) reported iron status was positively correlated with anthropometric data for elementary school children and children with a suboptimal iron status were shorter and weighed less.

The height and weight of children was significantly, po-

Table 8. Correlation coefficient between blood parameters and anthropometric measurements

Anthropometric data \ Parameters	Hemoglobin	Hematocrit	Ferritin	Iron	TIBC	TS	ALP	Zn	Cu
Height	.3056***	−.2400***	.1772*	.1557	−.0320	.0837	.2865	.2809***	−.2516**
Weght	.2453**	.2201*	.1482	.1356	−.0673	.1831	.2211	.0187*	−.1115
Girth of chest	.2138*	.2320**	.2094	.1274	−.0536	.0411	.2312	.0764	.0208
MAC	.2405**	.2409**	.1718	.1178	.0663	.2508	.0996	.1663	.0208
Skinfold thickness	.1658	.2300	.0748	.0634	−.0663	.1752	.0142	.0239	.1364
BMI	.0755	.0972	.0562	.0548	−.0670	.2126	.0558	.0040	.1255

TIBC : total iron binding capacity, BMI : body mass index, TS : transferrin saturation, MAC : mid-arm circumference
*Significant at $p<0.05$, **Significant at $p<0.01$, ***Significant at $p<0.001$

sitively correlated with serum zinc, respectively. There were many reports that zinc has a growth promoting effect through thymidine kinase(Dreosti & Hurley 1975), RNA polymerase(Wu & Wu 1987) and providing a structural role required for binding to DNA(Klug & Rhodes 1987). For apparently healthy children with low height for their age percentiles, growth was promoted with a small dose (5mg) of a zinc supplement(Walravens et al. 1989).

Taller students also showed higher serum copper levels ($p<0.01$).

Summary and Conclusion

This study was performed to investigate the biochemical status of iron, zinc and copper of preschool children. The subjects were 125 children(Males : 69, Females : 56) aged 3 – 6, residing in a rental apartment complex in the Suseo area and in Bongchun dong for reconstruction.

The results are as follows

1) The hemoglobin level of the children aged 3 was 11.8g/dl and was lower than that of other groups($p<0.05$). The mean hemoglobin levels showed trends of elevating as age increases. The low concentrations of hemoglobin(3 – 5 years : <11.0g/dl, 6 years : <11.5g/dl) occurred in 4.3% of the children. Children aged 3 or 4 showed significantly lower values of Hct than the group aged 6. Low serum Hct(3 – 5 Years : <33%, 6 Years : <35%) was found in 9.8% of the children.

2) The mean transferrin saturation of the group aged 5 was 17.6%, which was significantly lower than 21.2% of the children aged 6. The proportion of the children showing iron deficiency assessed with transferrin saturation (<16%) was 18.2%.

Serum ferritin was not significantly different among age groups. The children observed with low serum ferritin(<10ng/ml) was 17.7%.

3) The mean serum zinc of the group aged 3 was 56.7μg/dl and was significantly lower than that of other groups.

Lower serum zinc(<61.0μg/dl) was found in 56.3% of the children aged 3 and 28.0% of all subjects were at risk of zinc deficiency.

The mean zinc excretion of the children was 0.013mg/day and there were no significant differences among groups.

4) The mean serum copper was 110.5μg/dl and children showed higher values of serum copper compared to serum zinc. The low serum copper level(<70μg/dl) occurred in 7.4% of the children and the higher serum copper level(≥130μg/dl) was found in 54.8% of children.

5) Children with higher status, more weight, larger girth of chest, or larger midarm circumference showed higer hemoglobin levels. Serum ferritin was positively correlated with height and transferrin saturation was positively correlated with BMI.

The height and weight of children also showed a positive correlation with serum zinc($p<0.001$ – $p<0.05$).

The results showed 4.3 – 18.2% of preschoool children showed evidence of having iron deficiency anemia.

The proportion of children with a risk of zinc or copper deficiency was 28.0% or 7.4%, respectively. It was observed that more children had a risk of zinc deficiency than iron deficiency. The group aged 3 had the highest prevalence of undernourishment, 11.1 – 26.3% of them were observed with a risk of iron deficiency and 56.3% with a zinc deficiency.

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