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# Iron Nutritional Status of Infants and Young Children in the Seoul Area

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## ABSTRACT

The purpose of this study is to evaluate the iron nutritional status by investigating dietary intake and analyzing the hematological iron status indices including serum transferrin receptor (sTfR) in 8 to 28 month old infants and young children taking supplementary foods. The nutrient intake of 60 healthy infants and young children from 8 to 24 months of age was investigated by means of a 24-hour recall method, and the subjects were divided into 2 groups (8 − 12 months and 13 − 28 months) according to age. Venous blood samples from these groups were collected and measured for the following : hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration (MCHC), serum ferritin, serum iron, total iron binding capacity (TIBC), and sTfR. Anemia is defined as hemoglobin < 11g/dl ; serum ferritin level < 10ng/ml for iron deficiency ; serum transferring receptor (sTfR) > 4.5mg/l for iron deficient erythropoiesis. Total daily calorie intake was 934.6 ± 284.5kcal (98.32% of RDA) on average. Average daily iron intake in infants aged 8 to 12 months was 8.92 ± 3.32mg. The mean daily iron intake in infants aged 13 to 28 months was 7.15 ± 3.35mg (90% of Recommended Dietary Allowance, RDA). Mean values for Hb, Hct, serum ferritin and sTfR were 12.10 ± 0.77g/dl, 36.02 ± 2.31%, 20.91 ± 11.58ng/ml and 3.78 ± 1.47mg/l, respectively. In the young children from 13 to 28 months of age, the prevalence of anemia was 5.6%. The prevalence of iron deficiency was 9.5% in those from 8 to 12 months of age, and 27.8% in those from 13 to 28 months of age. The prevalence of iron deficient erythropoiesis was 16.7% in infants aged 8 to 12 months and 44.4% in those aged 13 to 28 months. The prevalence of both serum ferritin level < 10ng/ml and sTfR > 4.5mg/l was 22% in the young children aged 13 to 28 months. The measurement of sTfR may be a promising new tool in diagnosis of iron deficiency in early childhood when the iron deficiency is prevalent. It seems appropriate to emphasize nutritional education and evaluation to promote the iron nutritional status of infants and young children. (*J Community Nutrition* 4(1) : 3~11, 2002)

**KEY WORDS** : infants · iron status · serum transferrin receptor · iron deficiency.

## Introduction

Iron requirement during the first year of infancy is met through intrinsic (stored) iron and iron intake. To compensate unavoidable iron loss and promote rapid development, iron intake level should be gradually increased. It is estimated that the total amount of absorbed iron required for the first year during the infancy is 200mg, and the daily requirement is 0.55mg (Fomon 1993). When babies are born, iron is present in hemoglobin as well as in the liver ; however, during the first week of life, degradation rate of RBC (Red Blood Cell) exceeds its formation, which makes heme iron as a major form of stored iron. Ever since then, stored iron becomes almost exhausted with rapid growth and formation of blood and myoglobin (Fomon 1993). Therefore, to prevent iron deficiency, iron should be supplemented before stored iron is completely depleted. Dietary iron is required for formation of heme, a protoporphyrin, and heme, as a component of hemoglobin, carries oxygen and a component of myoglobin and helps to store oxygen in the muscle tissue. It is also present in some oxidative enzymes and works as cofactors to enzymes involved in the synthesis of DNA and

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neurotransmitters (Dallman 1988 ; Lozoff 1988).

It has been recognized that prolonged iron deficient anemia or iron deficiency during the rapidly growing infants' and young children's period can affect behavior, cognitive skills, development of intelligence, and brain function (Aukett et al. 1986 ; Lozoff et al. 1996 ; Walter et al. 1989). It has been known that there is a strong correlation between iron deficient anemia and underdevelopment of cognitive skill. Infants and young children with iron deficient anemia display abnormal underdevelopment of intelligence and muscular activity, which no treatment can reverse the consequence (Lozoff et al. 1987 ; Walter et al. 1989). However, some researchers found that deficiency in an early stage can be treated with iron supplement, improving cognitive skill and mental development score (Oski et al. 1983 ; Walter et al. 1983). Therefore, it is critical to start the treatment before profound deficiency occurs.

To diagnose iron deficiency without anemic symptoms, serum iron and Total Iron Binding Capacity (TIBC), ferritin, iron saturation in transferrin (TS) can be measured. Serum iron and TIBC have wide ranges for the norm and fluctuate daily ; therefore, they are not very useful for diagnosis. Since TS, better than serum iron and TIBC, relies on iron concentration in serum, other tests are required (Kim et al. 1998). Although serum ferritin is used as a sensitive index for stored iron in the body, its disadvantage is that it is influenced by infection. It is diagnosed as iron deficiency when ferritin level is < 10ng / ml in infants and young children (Gibson 1990).

Recently, serum transferrin receptor (TfR) test has been introduced as a new sensitive and easy-to-run method for diagnosis of iron deficiency (Choi et al. 1999 ; Mast et al. 1998 ; Punnonen et al. 1997). K.Punnonen et al. (1997) reported that the number of TfR on the cell surface reflected the degree of iron requirement, and therefore, this increase in serum TfR concentration meant deficiency in the stored iron. Serum TfR has been known to be an excellent indicator for early iron deficiency, since serum TfR is related to the level of iron, which can be used for erythropoiesis, its concentration would increase with the increase in RBC formation due to reduction in the iron supply (Mast et al. 1998 ; Punnonen et al. 1997). It has been recognized that serum TfR level can complement the weakness of ferritin measurement in determining iron deficiency, since it is not influenced by inflammation or infection (Ferguson et al. 1992 ; Mast et al. 1998).

Due to economic improvement, recommendation on nursing with the mother's milk, introduction of iron fortification in milk and supplementary baby foods in Korea, the prevalence of iron deficiency in infants and young children has gradually fallen (50% in the 1960's [Kim 1966], 13% in the 1980's [Park et al. 1980], 7% in the 1990's [Min et al. 1993]). However, it is still considered to be crucial to maintain good nutritional status with iron in infants and young children since iron deficiency can affect future growth and brain development.

This study surveyed status of calorie and iron intake and determined levels of transferrin receptor, a recently introduced method, as well as serum iron nutritional indices in infants and children older than 8 months who take baby foods and dietary supplements.

## Survey Subjects and Methods

### 1. Selection of survey subjects

Total of sixty from families with a medium level of income (31 male, 29 female) were chosen with parent consent on the purpose of this study. Subjects were infants and young children older than 8 months of age. These children visited the H pediatric hospital (Dongjak Gu, Seoul) during the period from January to September, 1998 for vaccination or recovered illness associated with digestion or upper respiratory infection.

### 2. General information and physical measurement

Information on birth weight, nursing method, timing on weaning, and age of mother was collected. Body weights and heights were measured by scales and skin thickness of was determined by Lange caliper (Cambridge Scientific Industries) while maintaining 10g / mm pressure. All the measurements were made in duplicates, and averages were taken for calculation of Kauf index.

### 3. Evaluation of nutrient intake

Nutrient intake was obtained by having mothers use a 24 hour recall method to record total food ingestion. They were trained to use measuring devices and tables for estimating the amounts of foods and recording name of foods, ingredients, and amounts as accurate as possible. These estimates were converted to the weights according to the book by Korea Advanced Food Research Institute (1988) and analyzed using Can-pro for professionals, which was developed by the

Korean Nutrition Society. Intake of calorie and iron (both heme iron and nonheme iron) and their percentages were calculated and compared against recommended intake. These values were then compared to recommended dietary allowances for Koreans, 7th revision (The Korean Nutrition Society 2000).

### 4. Analysis of iron nutritional indices in blood

As soon as blood was collected by clinical doctors in pediatrics, platelet, RBC volume and the average level of hemoglobin were measured by using Coulter T50 (coulter Corp., FL. USA). The rest of blood was centrifuged to obtain serum for determination of serum iron and TIBC by spectrophotometer (Latron, Japan), and the degree of transferrin saturation by dividing serum iron by TIBC (%). Concentrations of serum transferrin and transferrin receptor (TfR) were determined by immunioenzymetry (Abbott Laboratories, USA), and IdeA sTfR kits (Orion Diagnostics), respectively (Choi et al. 1999). Based on prior studies, it was classified as anemic when hemoglobin level was < 11g / dl, iron deficiency when serum transferrin level was < 10ng / ml, erythropoietic iron deficiency when serum TfR level was > 4.5mg / l (Choi et al. 1999 ; Dallman & Siimes 1979 ; Mast et al. 1998 ; Gibson 1990).

### 5. Statistical analysis

All the data were analyzed using a SAS package program (SAS Institute Inc. 1995). Measurements were expressed as averages, standard deviations, and percentages. Significant differences in nutrient intake and iron nutritional indices between iron deficient group and normal group were determined by Students' t-test. Correlation amongst iron nutritional indices was analyzed by Pearson coefficient of correlation.

## Results and Discussions

### 1. General information and physical measurement

Data on general information on 60 infants and young children and their physical measurement are presented in Table 1.

Average ages of mothers were 29.48. Seventy percent of the children who participated in the study was 8 − 12 months of age, and 30% was 13 − 28 months of age. Average age of children was 11.85 months, and their birth weight was 3.29kg. Average age at the beginning of weaning was 4.12 months old. Fruit Juice was most frequently used as a food for weaning. Nursing method during the first 6 months from the birth was found to be mother's milk (16.7%), formula (55.0%), and the combination of the two (28.3%). Average body weight and height at the time of study were 9.95kg and 76.01 cm, respectively, which fell within normal ranges for weight and height (The Korean Pediatric Society 1998). Skin thickness of and Kauf index were 8.66 mm and 17.13, respectively.

### 2. Nutrient intake

The percentages of calorie and iron intake compared to RDA on are shown in Table 2.

For infants from 8 to 12 months of age, average daily calorie intake was 844.53kcal, 112.60% of the RDA, or 89.84kcal per body weight. Iron intake was 8.92mg per day, 111.25% of the RDA, or 0.94mg per weight. Heme iron and nonheme iron were 5.94mg and 2.98mg, respectively, and the intake ratio of heme iron : nonheme iron was 66.59 :

**Table 1.** General characteristics and anthropometric indices of the subjects

| | N(%) | Mean ± S.D. |
|---|---|---|
| Maternal age (yrs) | | 29.48 ± 3.57 |
| Age (months) | | 11.85 ± 3.81 |
| 8 − 12 | 42 (70.0) | |
| 13 − 28 | 18 (30.0) | |
| Birth weight (kg) | | 3.29 ± 0.39 |
| First weaning time (months) | | 4.12 ± 1.27 |
| Feeding pattern | | |
| Breast feeding | 10 (16.7) | |
| Formula feeding | 33 (55.0) | |
| Mixed feeding | 17 (28.3) | |
| Weight (kg) | | 9.95 ± 1.12 |
| Height (cm) | | 76.01 ± 3.12 |
| Triceps skinfold thickness (mm) | | 8.66 ± 1.24 |
| Kauf's index | | 17.13 ± 1.45 |

**Table 2.** Dietary iron intake of the subjects

| Nutrients | | 8 − 12 Months (n = 42) | 13 − 28 Months (n = 18) |
|---|---|---|---|
| Energy | kcal | 844.53 ± 274.49[1] (112.60)[2] | 1024.72 ± 294.44 (85.39) |
| | kcal / kg | 89.84 ± 28.43 | 93.98 ± 26.96 |
| Iron | mg | 8.92 ± 3.32 (111.25) | 7.15 ± 3.35 (90.00) |
| | mg / kg | 0.94 ± 0.39 | 0.65 ± 0.25 |
| Heme | mg | 5.94 ± 2.43 | 3.58 ± 1.82 |
| Nonheme | mg | 2.98 ± 1.50 | 3.57 ± 1.71 |
| Iron density | mg / 1000kcal | 10.65 ± 2.61 | 7.08 ± 3.00 |

1) Mean ± S.D. 2) % RDA

33.41. Average iron intake per 1000kcal was 10.65mg.

For young children aged from 13 to 28 months, daily calorie intake was 1024.72kcal, lower than RDA of 1200kcal, and 93.98kcal per body weight. Daily iron intake was in average 7.15mg, 90% of the RDA and 0.65mg per body weight. Intake of heme iron and nonheme iron was 3.78mg and 3.57mg, respectively, and the intake ratio of heme iron : nonheme iron was 50.07 : 49.93. Iron intake per calorie was 7.08, which was higher than recommended level of 6.67.

Calorie intake by infants and young children in this study was higher than 676kcal by weaning children in rural area (Kim & Paik 1978) and 771.9kcal by infants and young children in the Seoul area (Kim et al. 1998). Iron intake by infants and young children in this study was close to the RDA, and the range of intake was 0.95 − 18.99mg, reflecting a huge individual difference. Iron intake of 27 out of 60 children (45%) in the study was lower than the RDA of 8mg. Intake per body weight decreased, but percent heme iron intake increased with older children showing intake of better quality iron. Iron intake by infants and young children in this study was higher than 5.5mg in young children aged from 5 to 24 months in the Seoul (Kim et al. 1998) and higher than 7.4mg by elementary school children in the Puchun area (Son & Yang 1997). On the other hand, lower than 8.9 − 12mg by infants and young children aged from 6 months to two years in US (Pennington & Young 1991).

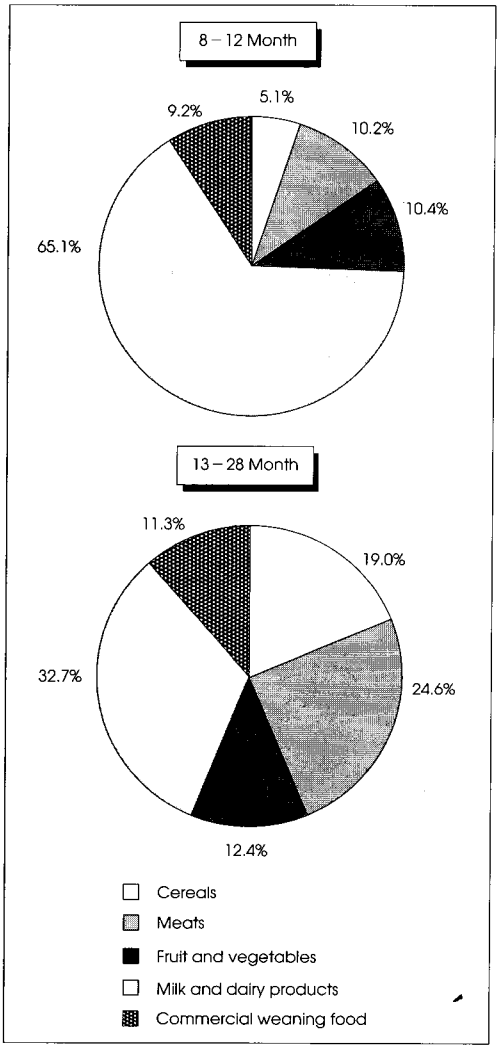


**Fig. 1.** Percentage iron intake of various food group in the subjects.

### 3. Dietary source of iron intake

Children's diet and percent iron intake were investigated according to five food groups ; cereals, meats (beef, pork, fish, eggs, beans), fruits and vegetables, milk and dairy foods (baby formula included), and commercially prepared baby foods (Fig. 1).

Iron intake by 8 to 12 month old infants from the five food groups was in the following order : milk and dairy foods (32.7%) > meats (24.6%) > cereals (19.0%) > fruits and vegetables (12.4%) > commercially prepared baby foods (11.3%). Infants and young children in this study obtained their iron from a variety of foods including baby formula but least from commercially prepared baby foods, thanks to their mother's efforts. Most of mothers were housewives and had great interest in nutrition, which led to low ingestion of commercially prepared baby foods. Homemade baby foods were preferred over commercially prepared baby foods.

### 4. Hematological iron indices and prevalence of iron deficiency

Hematological iron indices of children in this study is shown in Table 3. In infants from 8 to 12 months of age, hemoglobin level, corpuscular volume, ferritin level and TIBC were 12.13g/dl. 36.04%, 24.48ng/ml and 295.24 μg/dl, respectively. Serum TfR level was 3.46mg/l. In children from 13 to 28 months of age, average hemoglobin level was 12.07g/dl. Serum ferritin level, serum iron, iron, TfR level were 17.34ng/ml, 89.39 μg/dl, and 3.91mg/l, respectively. Average biochemical indices of infants and young children in this study were within normal range (Normal Value of Young Korean Children. 1992 ; Choi et al. 1999 ; Dallman & Siimes 1979 ; Gibson 1990).

Average hemoglobin level and corpuscular volume of children in this study were 12.10g/dl and 36.02%, respectively, which are similar to 12.1g/dl and 36.1% in 7 − 24

**Table 3.** Level of biochemical indices and prevalence rate of iron deficiency in the blood of the subjects

| | | 8 – 12 mo. (n = 42) | 13 – 28 mo. (n = 18) | Total (n = 60) | Criteria for deficiency | No. of subjects below criteria |
|---|---|---|---|---|---|---|
| Hb | g / dl | 12.13 ± 0.74 | 12.07 ± 0.79 | 12.10 ± 0.77 | <11.0[1)] | 1( 1.67%) |
| Hct | % | 36.04 ± 2.27 | 35.99 ± 2.35 | 36.02 ± 2.31 | <33[2)] | 4( 6.67%) |
| MCV | FL | 79.83 ± 3.05 | 80.07 ± 3.88 | 79.95 ± 3.47 | <73[2)] | 3( 5.00%) |
| MCH | pg | 26.88 ± 1.31 | 26.85 ± 1.40 | 26.87 ± 1.36 | <23[3)] | 3( 5.00%) |
| MCHC | g / dl | 33.65 ± 0.99 | 33.56 ± 0.99 | 33.61 ± 0.99 | <33[3)] | 14(23.33%) |
| Ferritin | ng / ml | 24.48 ± 15.22 | 17.34 ± 7.93 | 20.91 ± 11.58 | <10[2)] | 9(15.00%) |
| Iron | μg / dl | 80.24 ± 23.61 | 89.39 ± 39.47 | 84.82 ± 31.54 | <60[2)] | 11(18.33%) |
| TIBC | μg / dl | 295.24 ± 93.95 | 298.28 ± 92.19 | 296.76 ± 93.07 | – | – |
| TS | % | 31.06 ± 15.26 | 34.10 ± 20.67 | 32.58 ± 17.97 | <12[2)] | 2( 3.33%) |
| sTfR | mg / l | 3.64 ± 1.64 | 3.91 ± 1.29 | 3.78 ± 1.47 | >4.5[4)] | 15(25.00%) |

Values are Mean ± S.D.
MCV : Mean corpuscular volume
MCHC : Mean corpuscular hemoglobin concentration
TS : Transferrin saturation
Hb : hemoglobin, Hct : hematocrit
MCH : Mean corpuscular hemoglobin
TIBC : Total iron binding capacity
sTfR : serum transferrin receptor
1) Dallman and Siimes (1979)
2) Gibson (1990)
3) Min et al. (1993)
4) Choi et al. (1999)

month old young children in the Seoul area invested by WJ. Jung et al. (1995), 12.3g / dl and 35.9% in 11 – 2 year old US children studied by Yip et al. (1984). In addition, these values were the same as 12.1g / dl and 36.0% in 6 – 24 month old children in the Gyunggi area, investigated by Kim et al. (1998) and similar to 12.07g / dl and 36.21% in 9 month old infants (Min et al. 1993).

The range of serum ferritin level, which reflects iron storage level in the body, was found to be wide (as low 3.0ng / ml and as high as 81.2ng / ml). Serum ferritin level of each age group was 24.48ng / ml and 17.34ng / ml, which were significantly lower than 56.6ng / ml and 98.4ng / ml in children 6 – 12 months and 1 – 2 years of age in the Chung Nam area, respectively (Kim et al. 1982). Average TIBC was 296.76g / dl, which was lower than 358g / dl in infants 12 months of age (Saarinen and Siimes 1997) and 371.5g / dl in children 18 – 36 months of age (Byun et al. 1993). Since serum iron level decreases and TIBC increase with iron deficiency, TS (%) which is a percent blood index, is calculated. In this study, average TS in children was 32.58%, which was higher than 21.2% in infants and young children in Inchun area (Yang et al. 1998).

Although a normal range for serum TfR is debatable, iron nutritional status was evaluated based on 4.5mg / l reported by Choi et al. (1999), who studied children 4 – 24 months of age. Serum TFR level for children of 8 – 12 months and13 – 28 month of age were 3.64mg / l and 3.91mg / l, respectively, which were lower than 4.09mg / l and 4.76mg / l reported by Choi et al. (1999). In addition, average level of serum TfR of all children in the study was 3.78mg / l, which was lower than 4.4mg / l in children 9 – 15 months of age (Yeung & Zlotkin 1997). Ferguson et al. (1992) reported that average serum TfR level was 13.92mg / l for iron deficient anemia and 5.36mg / l for normal level.

Percent iron deficiency changes depending on the type of index and evaluation criteria of each index. Based on general criteria, iron deficiency of children in this study was evaluated (Table 3). A report suggested that hemoglobin, hematocrit, and MCHC had a wide range of errors in diagnosing anemia, and therefore, these are not sufficient to determine the cause of anemia although these are widely used due to relatively easy to run assays (Kye & Paik 1993).

In this study, only one child (1.67%) had anemia with < 11g / dl, which was less frequent than in other studies, and most of the children were better than normal range. In the 1980's, Park et al. (1980) reported 13% anemic children, Choi et al. (1995) reported 15.6% anemic young children in the Yong Nam area. In the Seoul area, 11.9% in children 9 months of age reported by Min et al. (1995), 12.0% of children 7 – 24 months of age (Jung 1995) and 7.3% of children 5 – 24 months of age were reported to be anemic.

6.67% of the children were below 33% of normal corpuscular volume, which was lower than 15.1% of infants 9 months of age in the Seoul area (Min 1993). Twenty three percent of the children had below 33g / dl of MCHC, which is more prevalent than the prevalence based on hemoglobin level and corpuscular volume. These results were similar to the results reported by Chae et al. (1981) and Choi et al.

(1995). Therefore, for sound evaluation of iron nutritional status, comprehensive evaluation should be conducted based on serum iron level, ferritin level, TIBC, TS and sTfR level.

Serum ferritin level below 10ng / ml, a criteria for iron deficiency, was 15.00% (9 children), which was slightly lower than 16.7% in 4 − 9 month old infants in the Yong Nam area (Choi et al.1995) and 32.3% in 5 − 24 month old children (Kim et al. 1998). Our results showed that percent iron deficiency increased based on serum ferritin rather than hemoglobin and corpuscular volume, which was also reported earlier by others (Kye & Paik 1993). 3.33% of children in the study had TS below 12% (normal level) and 25% of children had serum TfR level of higher than 44.5mg / l. Therefore, amongst many iron nutritional indices, TfR provided the highest prevalence of iron deficiency. The prevalence of anemia and iron deficiency based on age group is summarized in Table 4.

None of the children 8 − 12 months of age and one (5.6%) out of 18 children 13 − 26 months of age were anemic based on Hemoglobin level of 11g/dl. 27.8% (5 children) in 13 − 28 month old group had lower than 10ng / ml serum ferritin, which was higher than younger group. 16.7% (7 children) in 8 − 12 month old group and 44.4% (8 children) in 13 − 28 month old group had higher than 4.5mg / l of serum. Four children (22.2%) in 13 − 28 month old group had both serum ferritin level below 10ng / ml and serum TfR level above 4.5mg / l. These children are clearly considered to be iron deficient. For diagnosis of iron deficiency, serum TfR level in combination with various iron nutritional indices widely used can provide results with higher accuracy. However, standard level and a normal range for serum TfR have not been established yet ; therefore, our results are not conclusive. Extensive research for establishment of normal value and its application should be conducted.

### 5. Correlation amongst iron nutritional indices

Correlation amongst serum iron nutritional indices for the children in this study was summarized in Table 5. Hemoglobin level had a positive correlation with corpuscular volume, MCH and TS, and a negative correlation with TIBC. TS showed a significant positive correlation with hemoglobin level, corpuscular volume, and serum iron level. TS had a significant negative correlation with TIBC.

Although serum ferritin in our study did not show significant correlation with other indices, a study by Jung et al. (1991) showed a significant positive correlation among hemoglobin level, corpuscular volume, and ferritin level. In addition, Son and Yang (1997) and Cook et al. (1974) reported a significant negative correlation between serum ferritin level and TIBC.

**Table 4.** Age distribution of anemia and iron status in the subjects

| Age | Anemia (hemoglobin < 11g / dl) | Iron deficiency (ferritin < 10ng / ml) | Iron-deficient erythropoiesis (sTfR > 4.5mg / l) | Ferritin < 10ng / ml and STfR > 4.5mg / l |
|---|---|---|---|---|
| | N(%) | N(%) | N(%) | N(%) |
| 8 − 12 mo. (n = 42) | 0 | 4( 9.5) | 7(16.7) | 0 |
| 13 − 28 mo. (n = 18) | 1(5.6) | 5(27.8) | 8(44.4) | 4(22.2) |
| Total (n = 60) | 1(1.7) | 9(15.0) | 15(25.0) | 4( 6.7) |

sTfR : serum transferrin receptor

**Table 5.** Correlation coefficient between hematological values

| | Hb | Hct | MCV | MCH | MCHC | Ferritin | Iron | TIBC | TS |
|---|---|---|---|---|---|---|---|---|---|
| Hct | 0.888*** | | | | | | | | |
| MCV | 0.208 | 0.226 | | | | | | | |
| MCH | 0.282* | 0.010 | 0.789*** | | | | | | |
| MCHC | 0.195 | 0.271* | 0.044 | 0.574*** | | | | | |
| Ferritin | 0.037 | 0.063 | 0.146 | 0.160 | 0.059 | | | | |
| Iron | 0.171 | 0.133 | 0.159 | 0.068 | 0.109 | 0.053 | | | |
| TIBC | −0.308* | −0.372** | −0.124 | −0.190 | −0.180 | −0.054 | −0.048 | | |
| TS | 0.396** | 0.417*** | 0.211 | 0.201 | 0.064 | 0.029 | 0.563*** | −0.757*** | |
| TfR | −0.210 | −0.054 | −0.162 | −0.330* | −0.325* | −0.131 | −0.268* | 0.195 | −0.036 |

* : $p<0.05$, ** : $p<0.01$, *** : $p<0.001$

**Table 6.** Comparison of daily nutrients intakes and hematological values between the iron-deficient erythropoiesis and normal group

| | | Iron-deficient erythropoiesis (sTfR > 4.5mg/l) (n = 15) | Normal (sTfR ≤ 4.5mg/l) (n = 45) |
|---|---|---|---|
| Energy | kcal/d | 992.38 ± 357.54 | 867.31 ± 261.40 |
| Iron | mg/d | 8.01 ± 4.58 | 8.51 ± 2.89 |
| Heme | mg/d | 4.82 ± 3.97 | 5.70 ± 2.99 |
| Nonheme | mg/d | 3.20 ± 1.41 | 2.81 ± 1.89 |
| Hb | g/dl | 12.04 ± 0.88 | 12.14 ± 0.71 |
| Hct | % | 36.01 ± 2.55 | 36.04 ± 2.21 |
| MCV | fL | 79.21 ± 2.51 | 80.13 ± 3.51 |
| MCH | pg | 26.51 ± 1.34 | 26.99 ± 1.31 |
| MCHC | g/dl | 33.45 ± 1.20 | 33.68 ± 0.90 |
| Ferritin | ng/ml | 22.44 ± 17.47 | 23.57 ± 15.32 |
| Iron* | μg/dl | 70.73 ± 27.81[a] | 87.07 ± 28.83[b] |
| TIBC | μg/dl | 277.00 ± 98.11 | 302.53 ± 91.01 |
| TS | % | 30.86 ± 19.78 | 32.02 ± 16.16 |
| sTfR*** | mg/l | 5.46 ± 1.43[a] | 3.14 ± 1.07[b] |

Values are Mean ± S.D.
a, b : Values with the same letter are not significantly different from between groups(* : $p<0.05$, *** : $p<0.001$)

### 6. Comparison between iron intake and iron nutritional indices based on serum transferrin receptor level

Analysis of iron intake and iron nutritional indices between infants and young children with iron deficient erythropoiesis (sTfR > 4.5mg/l) and normal children (sTfR < 4.5mg/l) was summarized in Table 6.

There was no difference between two groups in calorie and iron intake, but heme iron intake by iron deficient erythropoiesis group trended to be lower than the normal group. Average serum iron in the group with iron deficient erythropoiesis was 70.73 μg / dl, which was significantly lower ($p<0.05$) than 87.07 μg/dl in the normal group. Serum TfR level in the group with iron deficient erythropoiesis was 5.46mg/l, which was significantly higher than 3.14mg/l in the normal group ($p<0.001$).

Based on analysis of iron nutritional indices between normal group and iron deficient erythropoiesis, only serum iron and TfR levels showed a significant difference but not others. Based on their study with elementary school children in the Bucheon area, Son and Yang(1998) reported that hemoglobin level, corpuscular volume, and serum ferritin in iron deficient children was significantly lower than those in normal children. As presented in the results of a significant negative correlation between serum TfR level and iron level (Table 5), a significant correlation was shown for serum iron level between iron deficient erythropoiesis group with high TfR level and normal group Serum TfR level.

## Summary and Conclusion

The purpose of this study is to investigate intake of calorie and iron in infants and children 8 − 28 months of age receiving dietary supplements. It is also to evaluate hematological iron nutritional status and serum transferrin receptor level for various evaluations of food intake and iron nutritional status in these children. In addition, the study was intended to provide data helpful for managing nutrition and health by improving nutritional issues associated with iron deficiency. The summary of this study is as follows :

1) Total daily calorie intake was 934.6 ± 284.5kcal (98.32% of RDA) on average. Average daily iron intake in infants aged 8 to 12 months was 8.92 ± 3.32mg (111.25% of RDA). Heme iron and noneheme iron were 5.94 ± 2.34mg and 2.98 ± 1.50mg, respectively, which, of total iron intake, represent 66.59% and 33.41%, respectively. The mean daily iron intake in infants aged 13 to 28 months was 7.15 ± 3.35mg (90% of RDA), but percent heme iron was rather high in total iron intake (50.07%).

2) In all the children, amongst various sources of food intake (cereals, meats, vegetables and fruits, milk and dairy products, commercially prepared baby foods), iron intake from milk and dairy foods was highest (49.0%) making milk and diary products as major source of iron supply. Percent iron intake from cereals, fruits and vegetables, and commercially prepared baby foods was relatively low (12.1%, 11.45 and 10.3%, respectively).

3) Mean corpuscular hemoglobin, mean corpuscular volume and hemoglobin of the children in the study were 12.10 ± 0.77g/dl, 36.02 ± 2.31%, and 84.82 ± 31.54 μg/dl, respectively. TS, TIBC, and serum ferritin level were 32.58 ± 17.97%, 296.76 ± 93.07 μg / dl, and 20.91 ± 11.58ng / ml, respectively. Serum TfR level was 3.78 ± 1.47mg/l.

4) The measurement of sTfR may be a promising new tool in diagnosis of iron deficiency in early childhood when the iron deficiency is prevalent. It seems appropriate to emphasize nutritional education and evaluation to promote the iron nutritional status of infants and young children.

The results from this study showed that iron intake by

infants and children was good and high quality based on high heme iron intake. However, hematological iron nutritional status indicated presence of iron deficiency and anemia despite of upper and middle class status. A higher percentage of iron deficiency based on serum TfR test than serum ferritin. When diagnosed with both serum ferritin test and serum TfR test, more accurate results are to be obtained. Iron indices in infants and young children reflect other nutrient status, and therefore, testing and evaluation of these indices is considered to be important. Serum TfR is, especially, a sensitive index for iron requirement in the body, and to evaluate iron nutritional status, serum TfR test along with other test methods can be used as an informative index. However, for accurate diagnosis of iron deficiency, a normal range and the standard value for serum TfR should first be established. Therefore, more active research on iron nutrition using serum transferrin receptor should be encouraged, and various evaluation and education on nutrition to enhance iron nutritional status in infants and young children should be emphasized.

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