NUTRITIONAL STATUS OF SCHOOL CHILDREN IN AN ENDEMIC AREA OF IODINE DEFICIENCY DISORDERS (IDD) AFTER ONE YEAR OF IODINE SUPPLEMENTATION

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Abstract. To improve the health and nutritional status of school children in an area of iodine deficiency disorders (IDD) by means of different iodine fortifications in salt, fish sauce and drinking water, anthropometric assessment for nutritional measurement, including hematological status, were performed. There was a significant difference in the weight and height of the children from the four schools investigated, before and after supplementation in each school. The prevalence of anemia (as indicated by hematological measurement) and iodine deficiency (as indicated by urinary iodine concentration in the children from the four schools) were assessed and compared before and after iodine supplementation; a decrease in prevalence was found in all school children, however, serum ferritin did not change before and after supplementation.

INTRODUCTION

Endemic iodine deficiency goiter is a major public health problem in many areas of the world including Thailand (Pleehachinda *et al*, 1991). Knowing this Her Royal Highness Princess Sirindhorn kindly sought to improve iodine deficiency disorders by motivating iodinated salt distribution, especially in the endemic area of the Northern and Northeastern parts of Thailand. That project gave rise to exciting possibilities for controlling iodine deficiency disorders (IDD). It is known that goiter still persists in some areas (although it was previously well controlled) perhaps due to insufficient monitoring and maldistribution of the iodinated salt.

In the past, the prevalence of IDD in a village of Phrae Province could be as high as 84.4% (Nondasuta *et al*, 1960; Suwanik *et al*, 1961). A baseline survey conducted by a Thai-German cooperation project entitled "Promotion of health and nutritional status of rural women in Northeast Thailand" (undertaken in connection with this project in 12 villages of 3 districts of Khon Kaen Province) estimated 35.1, 58.4 and 71.6% prevalence in women of child bearing age (Supawan *et al*, 1993). In the Country Master Development Plan No. 7 (1992-1996) it was planned to reduce iodine deficiency disorders (IDD) to less than 10% in elementary school children (Wanarat, 1992).

A research study for improving iodine deficiency disorders (IDD) has found that the prevalence of goiter in children from 3 schools in Khon Kaen Province was 47, 44.9 and 93% before treatment (Pongpaew *et al*, 1994). It was the aim of this study to test the best method of iodine fortification among salt, fish sauce and drinking water for improving the health and nutritional status of school children. Anthropometric assessment for nutritional measurement, including hematological status, might be of interest in resolving improvements in IDD.

MATERIALS AND METHODS

School children from four primary schools, namely Ban Khao Wong, Na Fai Witaya, Ban Pa Num Tieng, and Ban Non Khom from 2 districts of Khon Kaen Province were randomly selected for

this study (Kahn and Sempos, 1989). General observations *ie*, age, sex, prevalence of goiter, as well as urinary iodine concentration and serum thyroid hormone were determined, before iodine supplementation was provided. After the results had been reviewed, implementation was planned as follows:

1. In Ban Khao Wong School, iodinated salt was used in a concentration of 50 g KIO_3 in 1,000 kg sodium chloride (NaCl) resettling in a concentration of 50 ppm KIO_3 in NaCl. This iodinated salt was given regularly to all school children throughout the study period of one year. The normal intake of salt was 5-10 g/day, meaning that the children should receive approximately 100-150 μg of iodine per day.

2. In Na Fai Witaya School, drinking water was iodinated by installing a concentrated iodine solution dispenser to the existing drinking water container in the school. The final iodine concentration was 200μg/1,000 ml of drinking water. It was estimated that the school children should receive at least 200 μg of iodine per day.

3. In Ban Pa Num Tieng School, fish sauce fortified with iodine was used. The final concentration of iodine in fish sauce was 80 μg/10 ml. The fish sauce was given to all school children as well as their families for cooking in the household. The estimated amount of fish sauce intake per day was 15-20 ml, which means that iodine intake should be about 120 to 160 μg/day. However, it was estimated that the children would receive iodine from other sources as well.

4. Ban Non Khom School served as the control. It was under the regular service of a national program initiated by the Ministry of Public Health. The school was occasionally provided with information, iodized salt or other forms of iodine supplement.

With the exception of the control school, the three implementation schools received different kinds of iodine-fortified items throughout the study period of one year. Monitoring and evaluation were carried out every third month by research teams with the co-operation of the teachers in the schools.

A carefully calibrated beam balance (Detecto) was used to measure the body weight of the children who were dressed in light clothing. The height of the children was also measured. The nutritional indicators weight-for-age, height-for-age, weight-for-height, were assessed in all school children before and after implementation.

From the subjects under study, about 10 ml of venous blood was taken in the morning after fasting overnight. Heparinized blood was used to determine hematological status. The blood samples were stored at 2-5°C for not more than 24 hours prior to laboratory investigation. Hemoglobin concentration and hematocrit values were determined. A serum aliquot was separated and stored frozen at -20°C for ferritin determination. Spot urine was collected from every school children before blood collection for the measurement of urinary iodine concentration.

Laboratory analysis

Hemoglobin concentrations in whole blood were determined by using the modified cyanmethemoglobin method (ICSH, 1978). The hematocrit values were measured by a micro-method using calibrated heparinized capillary tubes. After filling blood in the capillaries, they were centrifuged for five minutes at 14,000g in a IEC MB microhematocrit centrifuge. Hematocrit values were measured by using a micro-hematocrit reader (Hawksley, England). Serum ferritin was determined by using the enzyme-linked immunosorbent assay (ELISA) (Anaokar *et al*, 1979).

Casual urine samples were collected in the morning from all subjects. Twenty milliliter aliquots of urine samples were chilled upon collection and frozen within 18 hours and subsequently stored at -20°C. Urinary iodine concentrations were measured using acid digestion, a method recommended by WHO/ICCIDD/UNICEF (Anonymous, 1993). Thyroid palpation was carried out by the same physician throughout the study period (Dunn and van de Haar, 1990).

Data analysis

Data analysis was conducted with the standard statistical methods of the Minitab computer program (Ryan *et al*, 1985). Medians and 95% confidence intervals (CI) were calculated. The Mann-Whitney U-Wilcoxon Rank Sum W test was used to compare the differences between implementation and control groups.

Table 1

Medians and range of age, weight, height as well as hematological measurements of four school children before and after iodine supplementation.

Parameters	Ban Khao Wong		Ban Na Fai		Ban Pa Num Tieng		Ban Non Khom		Total	
	Before	After	Before	After	Before	After	Before	After	Before	After
Age	8.9		9.6		9.4		9.4		9.4	
(years)	(6.0-12.0)		(8.0-12.0)		(7.0-11.0)		(8.0-11.0)		(6.0-12.0)	
Weight	24.7[a]	27.3[b]	25.5[a]	27.0[b]	25.5[a]	28.5[b]	24.9[a]	27.5[b]	25.1[a]	27.3[b]
(kg)	(15.3-41.0)	(17.5-43.1)	(20.0-45.1)	(21.1-56.1)	(18.4-45.5)	(19.9-48.4)	(17.2-71.9)	(18.6-84.2)	(15.3-71.9)	(17.5-84.2)
Height	129.8[a]	131.1[b]	127.7[a]	132.0[b]	129.2[a]	132.1[b]	129.0[a]	132.7[b]	129.0[a]	132.0[b]
(cm)	(111.6-147.0)	(120.0-149.5)	(115.0-147.6)	(121.5-151.0)	(113.0-156.2)	(121.5-158.0)	(112.0-150.6)	(118.5-155.0)	(111.6-156.2)	(120.0-158.0)
Weight for Age	-0.840	-0.725	-0.780	-0.840	-0.770	-0.715	-0.850	-0.830	-0.820	-0.800
	(-1.670-0.900)	(-1.420-1.960)	(-1.490-0.840)	(-1.490-3.470)	(-1.810-0.880)	(-1.800-0.920)	(-1.820-4.090)	(-1.800-4.560)	(-1.820-4.090)	(-1.800-4.560)
Height for Age	-0.920	-1.070	-1.485	-1.350	-1.180	-1.045	-1.210	-0.930	-1.180	-1.120
	(-2.140-0.500)	(-2.530-0.400)	(-3.570-0.300)	(-3.250-0.310)	(-4.300-1.650)	(-3.510-1.190)	(-3.250-1.170)	(-2.710-1.230)	(-4.300-1.650)	(-3.510-1.230)
Weight for	0.000	0.000	0.000[a]	-0.240[b]	-0.120	-0.165	0.000	0.000	0.000[a]	-0.750[b]
Height	(-1.700-0.410)	(-1.640-2.140)	(-0.970-1.300)	(-1.330-0.810)	(-1.210-1.250)	(-1.250-1.080)	(-1.520-2.030)	(-1.410-1.500)	(-1.700-2.030)	(-1.640-2.140)
Hemoglobin	12.6[a]	12.9[b]	12.5[a]	13.5[b]	12.9[a]	13.5[b]	12.6[a]	13.5[b]	12.6[a]	13.4[b]
(g/dl)	(8.1-15.0)	(7.4-15.8)	(9.3-14.8)	(9.9-15.7)	(10.3-15.1)	(9.8-15.2)	(9.3-14.9)	(9.6-15.5)	(8.1-15.1)	(7.4-15.8)
Hematocrit	37.7	38.1	37.3[a]	39.3[b]	38.2	38.5	38.3[a]	39.5[b]	38.0[a]	39.0[b]
(%)	(27.0-44.0)	(27.0-45.0)	(30.0-43.0)	(32.0-45.0)	(31.0-42.0)	(30.0-43.0)	(32.0-43.0)	(34.0-45.0)	(27.0-44.0)	(27.0-45.0)
MCHC	33.3[a]	33.9[b]	33.8[a]	34.1[b]	33.8[a]	35.2[b]	33.2[a]	34.1[b]	33.5[a]	34.2[b]
(g/dl)	(27.5-35.9)	(27.5-36.0)	(30.0-38.5)	(30.8-36.9)	(27.8-37.8)	(30.2-38.7)	(27.3-35.6)	(28.2-41.4)	(27.3-38.5)	(27.5-41.4)
Ferritin	52.7	49.5	48.8[a]	86.0[b]	76.0[a]	47.3[b]	60.5[a]	85.7[b]	57.0	67.0
(µg/l)	(10.0-431.0)	(12.0-268.0)	(16.0-312.0)	(14.0-172.0)	(18.0-476.0)	(16.0-196.0)	(12.0-272.0)	(20.0-484.0)	(10.0-476.0)	(12.0-484.0)
Urinary I	9.6[a]	19.5[b]	12.3[a]	29.3[b]	10.8[a]	18.8[b]	12.9[a]	30.2[b]	12.0[a]	22.0[b]
(µg/dl)	(2.1-400.0)	(5.5-112.0)	(1.2-84.0)	(4.0-150.0)	(3.2-71.0)	(5.8-85.0)	(3.2-77.0)	(4.2-150.0)	(1.2-400.0)	(4.0-150.0)

[ab] Different letter in the parenthesis indicated statistically significant different p-value < 0.05 with Wilcoxon Matched-Pairs Signed-Ranks test between before, and after, iodine supplementation in each school.

Table 2

Prevalence of anemia indicated by hematological measurement including iodine deficiency indicated by urinary iodine concentration in school children before and after iodine supplementation.

Parametcrs	Ban Khao Wong		Ban Na Fai		Ban Pa Num Tieng		Ban Non Khom		Total	
	Before	After	Before	After	Before	After	Before	After	Before	After
Hemoglobin (g/dl)	18/68 (26.5%)	12/68 (17.6%)	18/75 (24.0%)	4/75 (5.3%)	7/57 (12.3%)	3/57 (5.3%)	14/63 (22.2%)	6/63 (9.5%)	57/263 (21.7%)	25/263 (9.5%)
Hematocrit (%)	12/68 (17.6%)	11/68 (16.2%)	14/75 (18.7%)	3/75 (4.0%)	7/57 (12.3%)	5/57 (8.8%)	11/63 (17.5%)	6/63 (9.5%)	44/263 (16.7%)	25/263 (9.5%)
Ferritin (µg/l)	3/68 (4.4%)	3/68 (4.4%)	2/75 (2.7%)	2/75 (2.7%)	2/57 (3.5%)	1/57 (1.8%)	1/63 (1.6%)	0/63 (0.0%)	8/263 (3.0%)	6/263 (2.3%)
Urinary 1 (µg/dl)	32/68 (47.1%)	8/68 (11.8%)	29/75 (38.7%)	10/75 (13.3%)	24/57 (42.1%)	7/57 (12.3%)	22/63 (34.9%)	10/63 (15.9%)	107 /263 (40.7%)	35/263 (13.3%)

* Cut-off points: Hemoglobin < 12 g/dl; hematocrit < 36%; serum ferritin < 20µg/l; urinary iodine < 10 µg/dl

Table 3

Relative risk of decreasing of hematological measurement including iodine deficiency indicated by urinary iodine concentration in school children before and after iodine supplementation.

Parameters	Ban Khao Wong			Ban Na Fai			Ban Pa Num Tieng			Ban Non Khom			Total		
	RR	OR	p-value	RR	OR	p-value	RR	OR	p-value	RR	OR	p-value	RR	OR	p-value
Hemoglobin	1.50	1.68	0.2163	4.50	5.61	0.0012	2.33	2.52	0.1873	2.33	2.71	0.0520	2.28	2.63	0.0001
Hematocrit	1.09	1.11	0.8197	4.67	5.51	0.0047	1.40	1.46	0.5433	1.83	2.01	0.1940	1.76	1.91	0.142
Ferritin	1.00	1.03	1.0000	1.00	1.00	1.0000	2.00	2.00	0.5602	-	-	-	1.33	1.34	0.5883
Urinary I	4.00	6.68	0.0000	2.90	4.10	0.0004	3.43	5.19	0.0003	2.20	2.84	0.0144	3.06	4.47	0.0000

$$RR = \text{relative risk} = \frac{\text{p before supplementation}}{\text{p after supplementation}}$$

OR = Odd's ratios

RESULTS

Median and ranges of age, anthropometric measurements as well as hematological measurements of children from four schools in three districts of Khon Kaen Province, before and after iodine supplementation are shown in Table 1. There were no significant differences in the ages of children among the four schools. The average age shown as median was 9.4 years. There was a significant difference in the weight and height of the children from the four schools investigated before and after supplementation within each school.

Except for weight-for-height of the children from Ban Na Fai School, no significant difference in weight-for-age, height-for-age and weight-for-height before and after supplementation, was found. Besides the ferritin value in the children from the Ban Khao Wong school, significant differences in hemoglobin, hematocrit, MCHC, ferritin and urinary iodine, before and after supplementation, were found in all school children.

Prevalence of anemia, as indicated by hematological measurement, and iodine deficiency, as indicated by urinary iodine concentration in the children from the four schools, before and after iodine supplementation, are shown in Table 2. When anemia and iodine deficiency before and after supplementation were assessed a decrease in prevalence was found in all the school children. However, the prevalence of ferritin deficiency, using the cut-off point < 20 μg/l, decreased only in the Ban Pa Num Tieng School. These results can be interpreted using Odds' ratio derived from relative risk, and calculated for p-value as shown in Table 3. Statistically significant differences in total risk can be shown in hemoglobin and urinary iodine measurements. In Ban Na Fai School there was a greater decrease in anemia prevalence than there was in the other three schools.

Goiter palpation was applied in the selection of those school children considered normal and those having IDD (iodine deficiency disorders). The medians and ranges of anthropometric measurements, and hematological assessments before and after iodine supplementation are shown in Table 4. In comparing the results before and after supplementation, statistically significant differences between weight, height, hemoglobin, hematocrit, MCHC, ferritin and urinary iodine concentrations were observed in both normal and IDD groups. However, except for weight-for-height in the normal group, no significant differences of weight-for-age, height-for-age and weight-for-height both in normal and IDD groups, before and after supplementation, was observed.

Prevalence of anemia and iodine deficiency, as indicated by urinary iodine levels among the normal and IDD group, before and after supplementation, is shown in Table 5. Anemic parameters and iodine deficiency indicators (using urinary iodine concentration) were compared between supplemented and controlled groups. Except for ferritin, a decrease in both normal and IDD groups was found, before and after supplementation. These results can be confirmed using relative risk and Odds' ratio calculation as shown in Table 6.

DISCUSSION

This study found a significant increase in the weight and height of the children from the four schools investigated before and after iodine supplementation. However, in comparing the nutritional parameters, weight-for-age, height-for-age and weight-for-height, no significant differences were found. Improvement of nutritional status might require much more time than was available in the 1-year period of this study. Weight-for-age, height-for-age and weight-for-height are the appropriate indicators being used as a simple community screening method for nutritional assessment of children (Schelp *et al*, 1986). They are better means to evaluate nutritional status than measurement of mid upper arm circumference (MUAC) (Akanji *et al*, 1996).

Hemoglobin, hematocrit and MCHC were increased in children from the four schools investigated, after iodine supplementation in each school. The results also showed a decrease in the prevalence of anemia and iodine deficiency in all schools. Using Odds' ratio which is derived from relative risk and calculated for p-value, as shown in Table 3 there is an indication of a highly significant difference between the prevalence of anemia before and after iodine supplementation. When the iodine deficiency disorder occurred, other micronutrients in the target population had been affected (Chaturvedi *et al*, 1994). It has been reported that vitamin B_{12} intake is extremely low, and at least

Table 4

Medians and range of age, anthropometric measurements and hematological measurements of school children among the normal and IDD before and after supplementation.

Parameters	Total (N = 263)			
	Normal (Goiter grade 0) (N = 122)		IDD (Goiter grade 1, 2, 3) (N = 141)	
	Before	After	Before	After
Weight (kg)	24.8[a] (16.2-59.3)	26.7[b] (18.0-69.2)	25.3[a] (15.3-71.9)	27.8[b] (17.5-84.2)
Height (cm)	127.9[a] (112.0-150.6)	131.7[b] (117.7-153.2)	129.3[a] (111.6-156.2)	132.4[b] (116.0-158.0)
Weight for Age	-0.827 (-1.820-1.990)	-0.807 (-1.800-2.420)	-0.780 (-1.810-4.090)	-0.797 (-1.800-4.560)
Height for Age	-1.180 (-3.250-0.800)	-1.155 (-2.670-0.830)	-1.180 (-4.300-1.650)	-1.095 (-3.510-1.230)
Weight for Height	-0.011[a] (-1.700-0.770)	-0.110[b] (-1.640-2.140)	-0.021 (-1.650-2.030)	-0.059 (-1.440-1.500)
Hemoglobin (g/dl)	12.5[a] (8.1-14.9)	13.2[b] (7.4-15.5)	12.8[a] (9.7-15.1)	13.5[b] (9.7-15.8)
Hematocrit (%)	37.5[a] (27.0-43.0)	38.3[b] (27.0-45.0)	38.1[a] (31.0-44.0)	38.9[b] (30.0-45.0)
MCHC (g/dl)	33.4[a] (27.5-38.5)	34.0[b] (27.5-41.4)	33.6[a] (27.3-37.8)	34.5[b] (30.2-38.7)
Ferritin (µg/l)	52.2[a] (12.0-272.0)	70.7[b] (12.0-294.0)	61.8 (10.0-476.0)	58.0 (14.0-484.0)
Urinary I (µg/dl)	12.0[a] (1.2-400.0)	24.5[b] (4.0-150.0)	11.9[a] (2.6-122.0)	19.7[b] (4.2-150.0)

[a,b] Different letter in the parenthesis indicated statistically significant different p value < 0.05 with Wilcoxon Matched-Pairs Signed-Ranks test between before, and after iodine supplemention in each school.

Table 5

Prevalence of anemia indicated by hematological measurement including iodine deficiency indicated by urinary iodine concentration among the normal and IDD before and after supplementation in all school children.

Parameters	Total (N = 263)			
	Normal (N = 122)		IDD (N = 141)	
	Before	After	Before	After
Hemoglobin (g/dl)	29/122 (23.8%)	11/122 (9.0%)	28/141 (19.9%)	14/141 (9.9%)
Hematocrit (%)	22/122 (18.0%)	12/122 (9.8%)	22/141 (15.6%)	13/141 (9.2%)
Ferritin (µg/l)	3/122 (2.5%)	1/122 (0.8%)	5/141 (3.5%)	5/141 (3.5%)
Urinary I (µg/dl)	49/122 (40.2%)	15/122 (12.3%)	58/141 (41.1%)	20/141 (14.2%)

* Cut-off points: Hemoglobin < 12 g/dl; hematocrit < 36%; serum ferritin < 20 µg/l; urinary iodine < µg/dl

Table 6

Relative risk of decreasing of hematological measurement including iodine deficiency indicated by urinary iodine concentration among the normal and IDD before and after supplementation in all school children.

Parameters	Normal (N = 122)		IDD (N = 141)			
	Relative risk comparing between before and after	RR p-value	Relative risk comparing between before and after	RR p-value	Odds Ratio	OR p-value
Hemoglobin	2.87	0.001	2.00	0.020	2.77	0.000
Hematocrit	1.83	0.060	1.69	0.100	1.91	0.020
Ferritin	3.00	0.300	1.00	0.700	1.34	0.780
Urinary Iodine	3.27	0.000	2.90	0.000	4.47	0.000

$$\text{Relative Risks} = \frac{\text{p before supplementation}}{\text{p after supplementation}}$$

mild to moderate iodine deficiency (IDD), is present in Kenya (BÍuyÍukgebiz *et al*, 1996). Dietary analysis revealed a low energy intake as well as dietary deficiencies of folic acid, ascorbic acid, vitamin A, nicotinic acid, iron, riboflavin and calcium in the primary school children living in an endemic goiter area in eastern Caprivi, Namibia (Jooste *et al*, 1994). Therefore it is not surprising that school children in this study were anemic before iodine treatment. However, after iodine supplementation, the prevalence of anemia decreased. Therefore there is a possible relationship between iodine and iron improvement. Further study will be required.

The prevalence of ferritin using the cut-off point of < 20 µg/l, did not change much in all school children before and after iodine supplementation. However, ferritin might not be a sensitive enough indicator for assessing iron deficiency in cases of concurrence with iodine deficiency. The other reason might relate to the nature of ferritin itself, because even in malnutrition with infection or chronic diseases, serum ferritin might be increased at any given level of stored iron (Milman *et al*, 1995; Lee and Means, 1995; Ola *et al*, 1995; Ho *et al*, 1996). In order to accurately assess iron status, the serum ferritin value was used to estimate body iron, whereas the functional relative stored iron was estimated from the hemoglobin level. Therefore serum ferritin of those children might not change much when comparing the period before and after iodine supplement in contrast with the hemoglobin level.

In comparing anemic status between normal and IDD groups before and after supplementation, significant differences between all parameters (except weight-for-age, height-for-age and weight-for height), were observed. Therefore it seemed that IDD children showed similar growth development to the normal group either before or after iodine supplementation.

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