IODINE FORTIFICATION OF DESSERT IN IODINE DEFICIENCY PREVENTION PROGRAM FOR PRIMARY SCHOOL CHILDREN, MAHA SARAKHAM PROVINCE, THAILAND

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Abstract. Iodine deficiency (ID) has adverse effects on the health of people. This study monitored in Maha Sarakham Province, northeastern Thailand iodine status of 114 primary school children, 7-12 years of age, who were at risk of ID. Urinary iodine concentration (UIC) was used for determining iodine status according to the WHO guidelines. Median UIC (employing an ammonium persulfate colorimetric method) and iodine intake were measured to assess iodine status. More than half (69.3%) of the children had urine iodine (UI) level lower than 100 mg/l, indicative of an inadequate iodine intake. Boys and girls 7-9 years of age had 40.7% and 70.0%, respectively of normal iodine status for their age. Iodine intake, calculated for each participant using the formula of the US Institute of Medicine, had a median value of ~61 μg/day, half of the Thai daily recommended intake of 120 μg/day. Although the Thai Ministry of Public Health supports an iodized-salt intake campaign but it would appear that there was still a too low consumption by the children in the target population, suggesting their respective family food was also deficient in providing RDI of iodine. Egg jelly iodine fortification improved the UIC level from severe (UIC ≤20 μg/l) to adequate IU level.

Keywords: iodine deficiency, iodine fortification, urinary iodine, school children

INTRODUCTION

Iodine deficiency (ID) is a major public health problem throughout the world, particularly in pregnant women and young children. This poses a threat to the social and economic development of affected countries (De Benoist *et al*, 2004). Thailand has a long history of iodine deficiency, especially the northeast region, which is the main area where the population is at risk of ID (Rajatanavin, 2007).

Iodine is an essential micronutrient that is a component of hormones produced by the thyroid gland. Thyroid hormone plays a crucial role in ensuring normal development of most organs, especially the brain (Vermiglio *et al*, 2004). Mild iodine deficiency affects cognitive function in school-aged children resulting in poor school performance, reduced intellectual ability and impaired work capacity (Santiago-Fernandes, 2004). Urinary iodine concentration (UIC) is accepted as being the most practical biochemical marker for monitoring iodine nutritional

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status (Dunn *et al*, 1993). The World Health Organization (WHO) assessment of iodine nutritional status in school-age children and adults is: ID status when UIC <100 μg/l, adequate iodine nutritional status when UIC = 100-199 μg/l, above normal iodine nutritional status when UIC = 200-299 μg/l, and excess iodine nutritional status when UIC ≥300 μg/l (WHO, 2007).

During the past century many kinds of food have been fortified with iodine, such as bread, milk, salt and water, with salt being the most common item (Boonstra and Jaiswal, 2010). In Thailand, ~66% of households use iodized salt (Winichagoon *et al*, 2006). The average intelligence quotient (IQ) among Thai children has dropped to just 91 points compared to the international average score of 90-110 (Ten Health Issues, 2011). Thus, iodine fortification of food, such as dessert and fish sauce in addition to salt, in lunch programs in day-care centers and schools has the potential of combating possible existing iodine (Pongpaew *et al*, 2002).

This study assessed in Maha Sarakham Province, northeastern Thailand, a designated region with iodine deficiency (Maha Sarakham Provincial Health Office, 2013), UICs in primary school children was used applied to evaluate food iodine consumption and to determine their iodine status implemented in relation to their taking iodine fortified egg jelly.

MATERIALS AND METHODS

Subjects

Participants consisted of children, 7-12 years of age, chosen using a multistage random sampling of schools identified in the Maha Sarakham Provincial Health Office annual report as having a prevalence of a mild ID level (Maha Sarakham Provincial Health Office, 2013). Sample size was calculated using the formula (Krejcie and Morgan, 1970):

$$n = \frac{NZ^2_{\alpha/2}\, P(1\text{-}P)}{e^2\,(N\text{-}1)+Z^2_{\alpha/2}\, P(1\text{-}P)}$$

where N = population size (196)

n = sample size (114)

$Z_{\alpha/2}$ = standard normal curve value under 95% confidence interval level (1.96)

e = degree of accuracy expressed as a proportion (0.02)

P = population proportion (0.0287) (Maha Sarakham Provincial Public Health Report, 2011).

All selected subjects were healthy primary school children, both boys and girls, 6-12 years of age with no previous history or clinical signs or symptoms suggestive of renal failure. The study was conducted in August 2015. The research protocol was approved by the ethics committee of Mahasarakham University (ID code: 0033/2558).and prior signed consent forms were obtained from parents or legal guardians.

Urine collection

Morning mid-stream urine 40 ml samples were collected in clean containers and one drop of 10% formalin solution was added to each sample, which were kept in ice boxes before being transferred to the laboratory for storage at -20°C until being assayed. The standard ammonium persulfate colorimetric method was used for determination of UIC urine (Dunn *et al*, 1943). In brief, ammonium persulfate reacts with iodine present in the urine to convert ceric ammonium sulfate (yellow) to cerous ammonium sulfate (colorless). The degree of reduction in the yellow color is a measure of the iodine content in the urine. A standard curve was constructed over a concentration range of

20-300 μg/l iodine from a stock solution of 0.168 mg of KIO_3 in 100 ml of deionized water (0.168 mg of KIO_3 is equivalent to 0.1 mg of iodine). The frequency, percent, mean, median and standard deviation (SD) were used in data analysis. Assessment of participants' iodine nutritional based on their UICs followed the criteria of WHO/UNICEF/ICCIDD (WHO, 2007).

Dietary iodine intake determination

Dietary recall was assessed through three non-consecutive 24-hour food recalls conducted over an average period of one week. The interview was carried employing a semi-quantitative food frequency questionnaire (FFQ) (Grootenhuis *et al*, 1995). Dietary consumption for 40 primary school children who had UIC <50 μg/l were obtained with the subjects completing 24-hour food recalls, followed by an FFQ interview to assess dietary source intake, iodine and goitrogen consumption, and source of dietary iodine. The 24-hour food intake recall calculations were performed using an INMUCAL-Nutrients version WD.4.4 (provided by the Institute of Nutrition, Mahidol University, Thailand), and the daily iodine intake was calculated using the formula of the US Institute of Medicine (2001):

Daily iodine intake (μg) = UIC (μg/l) x 0.0235 x body weight (kg)

Iodine-fortified egg jelly preparation and consumption

The Thai DRI for iodine is 120 μg/day for 7-12-year old children (Committee on Recommended Daily Intake for Thais, 2003). The aim was to increase the content of iodine in desserts (egg jelly). Participating selected crucial 42 school children with UIC<100 μg/l consumed egg jelly enriched by adding as potassium iodide to yield a final concentration of 150 μg/100 g. Iodine content of egg jelly was determined by the method of Moxon and Dixon (1980). UIC of each child (completed recall, $n = 42$) was measured before and after consumption of iodine-enriched egg jelly. Iodine-fortified egg jelly distribution commenced from June 1, 2015 to September 30, 2015 (a total of 65 days). The mean daily egg jelly consumption was 100 g.

RESULTS

Nutritional iodine status

A survey in August 2015 of 114 school children in Maha Sarakham Province showed 79 (69%) with ID (UIC <100 μg/l), 24 (21%) adequate nutritional iodine status (UIC 100-199 μg/l and 11 (10%) above normal nutritional iodine status (UIC >199 μg/l). The proportions of both boys and girls with adequate or above iodine intake and excess iodine increased with increasing age, while the converse was observed for those with ID as illustrated on Table 1.

Daily food and iodine consumption

From analysis of the school children 24-hour dietary recall of three days' daily consumption data, median [1^{st} (Q_1) and 3^{rd} quartile (Q_3)] energy intake was 1,295 (1,086, 1,627) kg-cal and that of protein, lipid and carbohydrate was 53 (39, 71), 32 (24, 42) and 205 (153, 248) g, respectively (Table 2). Daily median iodine intake of children 7-12 years of age based on median UIC (83 mg/l) and median body weight (29 kg) was estimated to be 61 μg/day. FFQ survey for iodine-containing and goitrogen food sources revealed 10% from iodinated eggs, 2.5% from milk and occasionally from goitrogenous food, such as bean (25%), cauliflower (5%) and garlic (5%) (Table 2).

Table 1
Number, age, gender and urinary iodine concentration (UIC) of primary school students, Maha Sarakham Province, August 2015.

UIC (μg/l)	7-9 years of age		10-12 years of age		Total
	Boy	Girl	Boy	Girl	
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
<20	1 (3)	2 (10)	1 (4)	6 (18)	10 (8.8)
20-49	11 (41)	3 (15)	4 (12)	8 (23)	26 (22.8)
50-99	11 (41)	14 (70)	12 (36)	6 (18)	43 (37.7)
100-199	4 (15)	1 (5)	10 (30)	9 (26)	24 (21.7)
200-299	0 (0)	0 (0)	6 (18)	5 (15)	11 (9.6)
≥300	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	27	20	33	34	114 (100)

Table 2
Consumption of sources of dietary iodine and goitrogen by primary school students, Maha Ssarakham Province, August 2015.

Food item	Number of students (%) (n = 40)			Never
	Daily	Sometimes (4-6 times/week)	Rarely (1-3 times/week)	
Dietary iodine				
Eggs	4 (10.0)	21 (52.5)	15 (37.5)	0
Milk	1 (2.5)	13 (32.5)	26 (65)	0
Mackerel	1 (2.5)	21 (52.5)	18 (45)	0
Fresh octopus	0	2 (5)	15 (37.5)	23 (57.5)
Dried octopus	0	1 (2.5)	18 (45)	21 (52.5)
Shrimp	0	2 (5)	12 (30)	26 (65)
Iodized salt	1 (2.5)	8 (20)	21 (52.5)	10 (25)
Dietary goitrogen				
Cabbage	0	1 (2.5)	22 (55)	17 (42.5)
Cauliflower	0	2 (5)	12 (30)	26 (65)
Chinese kale	0	0	11 (27.5)	29 (72.5)
Soy bean	0	0	16 (40)	24 (60)
Peanut	0	10 (25)	11 (27.5)	19 (47.5)
Garlic	0	2 (5)	8 (20)	30 (75)

Effect of iodide-fortified egg jelly dietary supplementation

Implementation of iodized salt fortification with an egg jelly dessert supplementation (100 g/day) to the daily lunch meal for 65 days of 42 children with ID had a positive sustainable impact on their respective UIC, with 24 individual (57%) achieving normal nutritional iodine status and no one had UIC <20 μg/l (from 4 prior

Table 3
Urinary iodine concentration (UIC) before and after consumption of iodine-fortified egg jelly by primary school children (n = 42) with iodine deficiency, Maha Sarakham Province, August 2015.

Median UIC (μg/l)	Before consumption		After consumption[a]	
	No. (%)	UIC (mg/l)	No. (%)	UIC (μg/l)
≤20	4 (9)	18.22 ± 2.01	N/A	0
21-49	15 (36)	39.34 ± 6.72	3 (7)	43.44 ± 3.02
50-99	23 (55)	87.90 ± 15.10	15 (36)	90.75 ± 8.65
100-199	0	0	20 (48)	167.02 ± 21.81
200-299	0	0	4 (9)	210.34 ± 5.66

[a]138.1 ± 3.9 μg/day iodine for 65 days.

to supplementation) (Table 3). The regular egg jelly had a mean (SD) iodine content of 25.8 (0.6) μg/100 g and 138.1 (3.9) μg/100 g after fortification.

DISCUSSION

UIC is a convenient marker of dietary intake of iodine and a useful index for evaluating both the degree of iodine deficiency and toxicity (WHO, 2007). Among 114 randomly chosen primary school children (6-12 years of age) in Maha Sarakham Province 69% were considered ID based on their UICs, a slightly lower prevalence than that (83%) reported by Thurlow *et al* (2006) among 567 children of similar age range in northeastern Thailand nearly a decade earlier. The present study revealed 65% of the children attending an urban area school consumed salt with the stipulated level of iodine and had adequate iodine levels in their urine while 35% of the urban area children had a mild iodine deficiency (UIC 50-99 mg/l) (unpublished). Gowachirapant *et al* (2009) studied UI of school-aged children in Thailand reported optimal iodine status of median (range) UIC of 200 (25-835) μg/l in children. Our findings suggest that primary school children in Maha Sarakham Province probably have a history of insufficient iodine consumption reflecting a lack of awareness by their parents of the importance of iodine in their diets despite the promotion of consumption of iodized salt by the Thai Ministry of Public Health.

The 24-hour dietary recalls were used to assess the dietary intake and the frequency of food consumption that is appropriate for dietary iodine assessment in the form of a semi-quantitative FFQ (Zhang *et al*, 2015). Median daily dietary iodine intake of the participating children was only half of that of the Thai DRI for 7-12 years old children. FFQ shows sources of dietary iodine consumption to be egg, milk and mackerel, but these food items constituted only 2.5-10% of the Thai DRI for 7-12 years old children. Natural iodine content of such food as bread, milk, eggs, and meat, if taken frequently enough, may help prevent iodine deficiency (Boonstra and Jaiswal, 2010). FFQ was administered to all participants to assess whether the frequency of consumed peanut, garlic and cauliflower as a high intake of these goitrogens can counteract the effect of dietary iodine (Lakshmy *et al*, 1995).

Iodine-enriched dessert (egg jelly) (about 5 folds higher than regular egg jelly) had a significant impact in improving nutritional iodine status of primary school children with ID. It is important to measure iodine content of dessert after preparation as cooking may decrease iodine content (Venkatest Manner and Dunn, 1995). This indicates legislation should be modified to recommend use of iodized salt in food processing (Sinawat and Choticichian, 2015).

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