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Research Article

Egg supplementation to improve cognitive ability in elementary school children with iodine deficiency

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ABSTRACT

Background: Elementary school children who live in iodine deficient areas have lower cognitive abilities than children from iodine sufficient area. This study aimed to investigate the effect of supplementation of egg with iodine and iron on cognitive ability (IQ score) in elementary school children with iodine deficiency.
Methods: This was a randomized double-blind controlled trial involving 109 elementary school children aged 8-13 years in endemic iodine deficient District, Kismantoro, Wonogiri. Subjects were divided into 4 groups which are group A (iodine + iron + eggs); B (iron + eggs); C (iodine + eggs); and D (eggs) and supplementation were given for 16 weeks. Cognitive abilities (IQ score) was measured by CFIT (culture fair intelligence test) measured pre and post intervention.
Results: There was a significant difference on cognitive abilities (IQ) within group of intervention after 16 weeks of intervention ($p<0.05$). In cognitive abilities the difference not found among the group of intervention ($p>0.05$).
Conclusions: There was found that children who received egg alone or in combination with iodine and iron have the highest cognitive abilities compared with supplementation of egg with iron. In addition, children who received egg alone or combination with iron and iodine can increase the IQ score by 4 point. Supplementation with egg alone or in combination with iodine and iron improve the cognitive abilities (IQ score) of primary school children who suffer from iodine deficiency disorders.

Keywords: Egg, Iodine, Iron, Cognitive ability, Children, Iodine deficiency disorders

INTRODUCTION

The program to overcome iodine dificiency disorder has been started since 1970, however the prevalence of people suffering iodine deficiency is still relatively high, especially in Central Java, in example the Wonosobo district (42.3%) and Wonogiri district (24.1%), while the total goitre rate (TGR) in Indonesia is 11.1%.[1] According to WHO report approximately 2.2 billion citizens of the world are at risk to suffer the disorders from iodine deficiency because they are living in the area that lacks of iodine.[2-4] An individual who suffers the disorders from the iodine deficiency generally has low average mental capacity, cognitive abilities, and academic performance.[5,6] One of the nutrition insecure groups in Indonesia is elementary school students. Those who are nutrition deficit have low cognitive abilities.[1,2] A study in Thailand stated that the cognitive abilities of elementary school students who were micro-nutrient deficit could be enhanced.[7] Cognitive abilities are an identifying and organizing process, and to process information into an accurate, valid and beneficial knowledge to solve a problem or make a decision.

Based on advanced testing study on three elementary school (ES) in Kismantoro, Wonogiri District on early September i.e ES Miri, Pucung I, and Pucung II, here were 71 students (9-12 years old), there found 22 students (30.99%) suffered enlargement thyroid gland, 24 students (16.90%) stunted based on height per age parameter.[6] Results of cognitive abilities assessment using wechsler Intelligence Scale for Children-Revised (WISC-R) test, there found 29 (40.84%) mentally defective, 18 (25.35%) borderline, 12 (16.90%) quite low, 12 (16.90%) average, and clever student was not found. Results of food consumption recall showed that the energy intake is 52.60%, protein intake is 58.75% and iron intake is 22.20%.[6]

It is explained theoretically that inadequate intake of iodine is one of the factors that cause iodine deficiency disorder. Besides iodine, iron and protein are needed in thyroid hormones synthesis. During the thyroid hormone synthesis process, thyroperoxide enzyme is needed as a biocatalisator where about is depending on the availability of iron. Thyroid hormones affect many enzyme mechanisms on the development of brain function such as controlling ribonucleic acid (RNA) transcription. Iodine deficiency would decrease the RNA transcription, then influence inter neuron transmission and affect the development of brain function.8 Development process is a result of an interaction of many factors which initiated from inside the womb and then continued until the child is able to interact with its environment. This process would determine the child's brain growth to the next development period.[9]

Food ingredient which contains high protein and is common in the community is egg. Besides obtainable, egg is also more affordable than the other animal sources of protein. Egg is one of the animal-sourced proteins which has a good taste, easy to digest, and has a high nutritional value. Nutrition composition in egg contains 13% protein, 12% fat, vitamin and mineral. The highest value of nutrient is contained in the yolk. Amino acid essential in yolk is needed in human body.[10]

This study aimed to investigate the effect of supplementation of egg with iodine and iron on cognitive ability (IQ score) of elementary school children with iodine deficiency.

METHODS

Subject

This study was implemented in endemic iodine deficiency sub district Kismantoro, Wonogiri district, Central Java. This was an experimental study with randomized double blind controlled trial design. Subject included in this study have to fullfil the inclusion criteria such as age 8-13 years old, not suffering chronic disease, suffering iodine deficiency with enlargement of thyroid gland grade 1, having mark from culture fair intelligence test (CFIT) used borderline mark with 70-109 IQ point. Subject excluded if suffering goitre.

Subject fullfilled the inclusion and exclusion criteria were given inform consent. Enumerator gave the inform consent obtained from the subject's parent/guardian before the randomization. Random allocation was done by using block random method.[11] This study protocol was agreed by Medical and Health Research Ethics Committee Faculty of Medicine Gadjah Mada University, Yogyakarta.

Intervention

Subject fullfiled inclusion and exclusion criteria were randomized into 4 group's treatment: group which received iodine, iron and egg (group A), group which received iron and egg (group B), group which received iodine and egg (group C), group which received egg only (group D). Iron supplementation was given using ferro sulfate tablet with the same form, size and package as placebo. Subtitute tablet in placebo contains amylum, talk, saccarum lactic and dye. Iodine was given in yodiol form (Kimia Farma, Watukadon, Indonesia) which is an iodine supplement in the form of vegetable oil.

Iodine capsule were given only once within research period and Iron tablet were given 1 times a week matched with the treatment group. Egg was given 3 times a week matched with the treatment group. Subject received treatment during 16 weeks. Subject's cognitive ability was measured before and after treatment used Cattellculture Fair Intelligence Test (CFIT) method according to Gregory's submitted method.[12] Culture fair intelligence test method contains 4 sub-components : a) series, b) classification, c) matrix, d) typology, where in each sub-component is consisted of multiple choices questions to observe visuospatial reason aspect. Total value from fourth component were calculated and converted into IQ value.[12,13] IQ value was measured 2 times before and after treatment used CFIT and was done by psychologist.

Household and family information

Demography characteristics of the household and family condition of subject are education level of father, education level of mother and total family load were obtained by questionnaires. Social-economy conditions such as level of family income were also obtained by questionnaires. Household and family condition data were taken by enumerator.

Nutritional assessment in children

Nutritional assessment was done by weight and height measurement of children according to WHO chart 2005. Weight and height measurement based on WHO/CDC method, which then plotted into WHO growth chart 2005.[14]

Measurement of haemoglobin level in children

Blood haemoglobin level was analyzed used beckman counter tools with cyanmethaemoglobin method. Generally, 0.02 mL blood mixed with drabkins reagent and incubated for 5 minutes. After incubated, the colour would change which later will be read on the 540 nm of wavelength.

Dietary intake measurement of subject

Dietary intake of subject such as energy, protein, iron, iodine, zinc and vitamin C intake were measured using multiple recall. Recall was done 6 times consecutively in different days according to Willet's calculation.[15]

Sample

To fullfill the aim of this study, sample was calculated using 95% confidence inteval, 90% power, 2.2 deviation standard and mean difference abilities after and before the treatment was assigned 2.16 Based on this assumption, then the result of calculation obtained 26 children of each group with asssumption 10% probability of subject's loss in observation, then 28 children were needed for each group or about 112 children over all.[17]

Statistical Analysis

All data was analyzed using SPSS program. Continuous variable data was presented in mean ± deviation standard while chategorical data was presented in total and percent. Chategorical data was analyzed with chi square. While, continous variable data inter group treatment was analyzed with one way ANOVA.

RESULTS

A number of 675 children in ES were examined on thyroid gland with palpation method, there found 175 (25.92%) were eligible and a number of 109 children fullfilled inclusion and exclusion criteria in this study. Two children were suffering from chronic disease, CFIT value on 12 children more than 109 IQ point and CFIT value on 52 children less than 70 IQ point. After randomization, 3 children in the group B were dropped out from the study because of sickness, 1 child from the group C transferred to other school, and 1 child from group D was dropped out because of circumcision (Figure 1).

Based on demography characteristics, most of the father and mother's education background were low, a number of 90 people (86.5%) and 91 people (87.5%) are low educated (only went through from elementary school to junior high). Analysis result shows there were not any significant difference of father and mother's education between the study groups ($p>0.05$). The family income between the study groups were almost the same, 57% families' income was ≤ Rp 400.000/month, and the result of statistic analysis showed there was not any significant differences between the study groups (Table 1).

As much as 67 (58.6%) male subjects and 37 (35.6%) female subjects were 125 months old of age in average. Based on the initial anthropometry measurement on the subject, as much as 49 (47.1%) subjects were underweight, 34 (32.7%) subjects were stunted and 19 (18.3%) subjects were wasting. Besides that, motivation for achievement and cognitive stimulation of the subjects had the average value of 18.6 dan 74.6. Statistic results showed that age, gender, nutritional status and cognitive stimulation not showed a significant difference ($p>0.05$) but showed a significant difference on motivation for achievement ($p<0.05$) between treatment groups. Besides that, the subjects hemoglobin level was 13.1 g/dL in average but not different in each of the treatment groups (Table 1).

Table 1: Subject characteristic in sub-district kismantoro elementary school.

Variable	Total		Groups								Sig.(p)
			A.Iodine+iron+ egg (n=28)		B. iron+egg (n= 25)		C. iodine+egg (n=26)		D. egg (n=25)		
	N	%	n	%	N	%	N	%	N	%	
Sex											
Female	37	35.6%	8	28.6	6	24.0	13	50.0	10	40.0	0.20 *
Male	67	64.4%	20	71.4	19	76.0	13	50.0	15	60.0	
Father's education											
High	14	13.5%	5	17.9%	2	8.0%	5	19.2%	2	8.0%	0.46 *
Low	90	86.5%	23	82.1%	23	92.0%	21	80.8%	23	92.0%	
Mother's education											
High	13	12.5%	7	25.0%	0	0%	4	15.4%	2	8.0%	0.04 *
Low	91	87.5%	21	75.0%	25	100%	22	84.6%	23	92.0%	
Family Income											

>Rp 400.000.-	57	54.8%	17	60.7%	15	60.0%	14	53.9%	11	44.0%	0.60 *
≤Rp 400.000.-	47	45.2%	11	39.3%	10	40.0%	12	46.1%	14	56.0%	
Family Load											
>4	43	41.4%	9	32.1%	10	40.00%	15	57.7%	9	36.0%	0.25 *
≤4	61	58.6%	19	67.9%	15	60.0%	11	42.3%	16	64.0%	
Weight /Age (z-score)											
≤-2 (underweight)	49	47.1	11	39.3	12	48.0	13	50.0	13	52.0	0.80 *
>-2 (normal)	55	52.9	17	60.7	13	52.0	13	50.0	12	48.0	
Height/Age (z-score)											
≤-2 (stunted)	34	32.7	11	39.3	8	32.0	7	26.9	8	32.0	0.81 *
>-2 (normal)	70	67.3	17	60.7	17	68.0	19	73.1	13	68.0	
Weight/Height(z-score)											
≤-2 (wasted)	19	18.3	4	14.3	2	8.0	9	34.6	4	16.0	0.45 *
>-2 (normal)	85	81.7	24	85.7	23	92.0	17	65.4	21	84.0	
Age (month)	124.8±10.7		125.9±12.4		125.6±9.2		123.1±10.9		124.4±9.9		0.77 **
Motivation	18.6±17.6		18.53±2.6		19.20±1.64		19.19±1.69		17.28±3.2		0.01 **
Cognitive stimulation	74.6±17.6		71.4±16.2		75.2±16.7		79.9±19.6		72.3±17.3		0.26 **
Haemoglobin level - pretest	13.10±0.79		13.01±0.78		13.14±0.71		13.00±0.72		13.24±0.9		0.69 **
Haemoglobin level - posttest	13.47±0.97		13.45±0.91		13.64±0.94		13.21±0.96		13.59±1.06		0.38 **

*p-value ($p<0.05$) according to X statistic from χ^2-*test*.**p-value ($p<0.05$) according to F from ANOVA.Value in table presented in n form and % or mean±Deviation standart.

According to result of 24 hours recall, the average consumption of energy on subject was 1634.9 Kcal/day, average intake of protein was 44.5 gram/day. Iodine consumption was 110.9 mcg/day with average consumpton of iron, zic and vitamin C were 5 mg, 4.5 mg dan 73.9 mg/day respectively. Statistical analysis result did not show any significant differences between treatment groups for energy, protein, iodine, iron and vitamin C consumption. However the difference showed in zinc consumption between treatment groups. There was a difference in zinc consumption in groups with egg+iron supplementation and group with iodine and egg supplementation (Table 2).

Table 2: Means of nutritional intake on subject in sub-district kismantoro elementary school.

Variable	Total	Groups				p
		A. Iodine+iron+egg (n=28)	B. iron+egg (n= 25)	C. iodine+egg (n=26)	D. egg (n=25)	
Energy	1634.9±415.0	1544.7±433.8	1528.4±381.8	1756.8±406.2	1715.9±407.2	0.06
Protein	44.5±11.8	42.2± 11.8	41.9± 11.8	48.4± 11.7	45.4± 11.5	0.11
Iodine	110.9±21.1	111.9±22.6	104.9±17.1	114.9±24.3	111.9±19.5	0.38
Iron	5.0±2.0	4.7±1.6	4.9±2.5	5.8±2.4	4.7±1.6	0.19
Zinc	73.9±55.5	4.3±1.2$^{a.c)}$	4.1±1.1$^{a.b)}$	4.8±1.1$^{c)}$	4.6±1.1$^{a.c)}$	0.02$^{**)}$
Vitamin C	4.5±1.1	72.6±44.6	79.6±52.8	79.1±70.2	64.5±53.6	0.75

* Data presented in means ± deviation standart. **Significance ($p<0.05$). (a.b.c) Different notation showed differences ($p<0.05$).

Before treatment, a number of 65 subject (62.5%) had low cognitive abilities, however there were no significant difference between treatment groups ($p>0.05$). In early treatment, subject's cognitive ability was 86.19±11.30 (Table 3). Statistical analysis result did not show any significant differences between treatment groups before implementation of treatment on subject ($p>0.05$) which showed cognitive ability's homogenity on each treatment group.

After 4 months of intervention, cognitive ability was increased on each group treatment. Cognitive ability (IQ) increased 4.17 point into 90.37±13.40 significantly. Cognitive abilitity value (IQ) significantly increased in group with iodine+iron+egg supplementation, which

increased 7 point and followed by egg treatment group with 6.88 point. Although the increasing point in group with iodine+iron+egg is higher than other groups, however ANOVA analysis result for delta value showed that there was no significant difference between treatment groups (Tabel 3). This result showed that all treatment groups could increase cognitive ability (IQ) in elementary school children with iodine deficiency.

Table 3: Cognitive abilities subject before and after treatment of egg with and without iodine and iron supplementation during 4*.

Groups Treatment	Cognitive Abilities (IQ)			
	Before treatment	After treatment	Delta	p[1)]
Iodine+Iron+Egg	85.21±11.7	92.21±13.01	7.00± 12.07	0.05
Iron+Egg	84.96±11.74	84.76±13.59	-0.20±14.28	0.95
Iodine+Egg	87.96±10.56	90.88±14.09	2.92±13.42	0.28
Egg	86.68±11.49	93.36±11.89	6.68±13.00	0.02
Total	86.19±11.30	90.37±13.40	4.17±13.32	0.02
p[2)]	0.76	0.10	0.17	-

According to Table 3 and Figure 2, the analysis between treatment groups found that the group given egg, iron and iodine had IQ point 0.32 higher than the group that was given egg only, 4.08 higher than the group that was given egg and iodine, and 7.20 higher than the group that was given egg with iron.

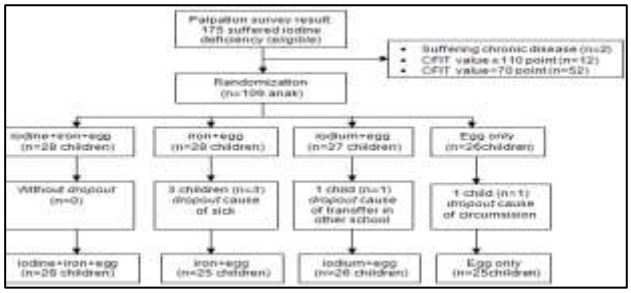

Figure 1: Subject determination scheme.

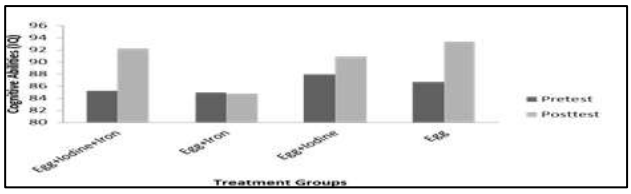

Figure 2: The change of marginal average of cognitive abilites (IQ) before and after the treatment. Black line shows the average score of pre-test and grey line shows the average score of post-test in each treatment group. Group A (egg+iodine+iron), group B (egg+iron), group C (egg+iodine), group D (egg).

DISCUSSION

Iodine deficiency disorder is a health problem in developed country such as Indonesia which could affect in decreasing of human cognitive ability. Study results found that proportion of subject who has cognitve ability <90 IQ (below average) is quite high as much as 62.55%. This fact shows that endemic iodine deficiency area has a significant cognitive problem. A study in endemic iodine deficiency area in Malang district found that elementary school children who have cognitive ability < 80 IQ point have troubles in speaking, writing and counting. Then, children who have one of the disorders could be identified as suffering with mild cretin.[18]

Supplementation and fortification of iodine have been used as methods to decrease iodine deficiency rate in Indonesia. Zimmermann, demonstrates that iodine supplementation in elementary school children with iodine deficiency could improve their cognitive abilities during receiving iodine capsul in 24 weeks. The other study conducted by Gordon, elementary school children with moderate level of blood iodine, receiving iodine supplementation significantly could improve cognitive abilities.[16,19] A study conducted by van den Briel in 10-12 years old elementary school children during 24 weeks in Benin, showed that iodine supplementation treatment on elementary school children could improve perceptual logical ability and intelligence compared with elementary school children without iodine supplementation.[20]

Based on the result of this study, it is known that the egg supplementation combined with iodine and iron has the same effect on increasing the cognitive abilities in the iodine deficit elementary students. However, even though it has the same effect in increasing the cognitive the administration of egg only supplement has a high impact on increasing the cognitive in the iodine deficit elementary school students. This showed that egg only administration could be another alternative program to enhance the cognitive abilities of iodine deficit elementary school students.

The result of this study support the result of Van Den Briel study, which found that iodine or iron supplementation could increase the cognitive abilities of treatment groups.[20] However in this study is also found that the group which was given egg supplementation with iron was not as effective as the group which was given the complete supplementation (egg+iodine+iron) even though the increasing cognitive abilitites of both groups were not different.

Even though there was no difference between the treatment groups, however there was an escalation in cognitive abilities in iron deficit children after the treatment. The highest uplift of cognitive abilities was in the group given egg supplementation with iron and iodine compared with the other treatment groups even though there was not any significant differences between the treatment groups. This result showed that egg is a right comestible to enhance the cognitive abilities of the iron deficit children.

Egg contains aromatic amino acids which are important in synthesizing DNA and RNA, producing neurotransmitter, synthesizing growth factor and neurit prolongation. The change of amino acid profile in plasma could alter the neurotransmitter synthesis pattern in the brain which could impact in the absence of neurotransmitter synthesis and manifests towards the digression of cognitive function.[21] Rosier proved that post-depression patient who received low aromatic amino acid diet would sustain a digression of cognitive abilities significantly which was measured with comprehensive battery of well-validated computerized cognitive test.[21]

Egg contains 21% of branched-chain amino acid that are leusin, isoleusin, and valin. Some studies showed that branch chain amino acid could repair cognitive disorders caused by trauma.[22,23] Branched-chain amino acids (BCAA) supplementation is proved to increase the cognitive abilities animal, which was shown by them doing less mistakes when given obstacles.[24] Egg is consisted of amino acids, one of them is triptofan. Triptofan is a precursor of serotonin. High carbohydrate food intake could increase the triptofan uptake of brain.[25] Serotonin is a monoamina neurotransmitter which located in the central nervous system and synthesized in serotonergic neuron in the central nervous system. Serotonin has several functions, including mood regulation, muscle contraction, and some cognitive functions such as memory and learning. This corresponds to the study conducted by Booji, which said that acute triptofan depletion could affect the mood through mood regulation, emotional information process, and normal information process.[26]

The combination supplementation of egg, iodine, and iron is the group that has the highest cognitive abilities compared to the other treatment groups. This shows that egg, iodine, and iron supplementation is one effective strategy in enhancing the cognitive abilities of those who suffer iron deficiency syndromes because of the mutual interactions between protein, iron, and iodine.

Protein also plays the role as “ligand” (binder) and “clathrin” which is used in the absorption of iron, transferin, feriitin, hemoglobin, and myoglobin.[27] Besides that iron also takes effect on the first two steps of thyroid hormon synthesis which is catalyzed by thyroperoxidasethat is contained in iron. Iron deficiency anemia lowers thyroxine (T4) andtriiodothyronine (T3) plasma and might also increase the tirotropin concentration (Hess et al., 2002). Iron deficiency also significantly lowers the activity of thyroid Peroxidase (TPO).[28]

Results of the study groups showed that egg supplementation with or without iodine and iron combination could give a higher effect in increasing the cognitive abilities. However, cognitive abilities in the iodine deficit elementary school students didn’t show any significant difference among the treatment groups.

The result of this study could be used as a basis of cognitive abilities enhancing program in elementary school students who are iodine deficit using egg supplementation or complete supplementation (iodine, iron, and egg combined) adjusted to the availability of founds in the area. The results of this study may be one of the basic education to parents in preparing family meals menu, because parents were still lack of learning on how to prepare a healthy menu, to give awards to maintain good eating behavior of children.[29] Erikson's stages of development according to school-age children need to develop a sense of the industry, so parents need to provide an appreciation of the ability of children who have healthy eating behaviors.[29,30]

CONCLUSION

The conclusion of the study groups showed that egg supplementation with or without iodine and iron combination could give a higher effect in increasing the cognitive abilities. However, cognitive abilities in the iodine deficit elementary school students didn’t show any significant difference among the treatment groups.

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