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Abstract

BACKGROUND: Children in rural areas are susceptible to zinc deficiency. Zinc deficiency in children can affect cognitive function in children. Zinc plays a role in cellular function and critical brain growth processes, including cell replication, DNA and RNA synthesis, and the release of neurotransmitters.

AIM: This study aimed to analyze the condition of zinc deficiency and its relationship with the level of intelligence in children in rural areas.

METHODS: The study design was cross-sectional, with a sample of 44 elementary school children aged 9–12 years taken randomly. Blood was drawn to measure serum Zn-levels, and serum Zn-levels were measured using Colorimetric Assay Kit (E-BC-K137). Zinc intake data were obtained from the food recall form, which was carried out 3 × 24 h. The level of intelligence is measured by the Culture Fair Intelligence Test method. The sample characteristics data obtained through a questionnaire. Furthermore, the data were analyzed using the Chi-square test.

RESULTS: About 84.2% of children with insufficient zinc intake had low serum Zn-levels. There was a significant relationship between zinc intake and serum zinc levels ($p = 0.026$; PR = 4.293). Children with low serum zinc levels of 96.5% have intelligence levels below average. There was a significant relationship between serum zinc levels and intelligence level as well ($p = 0.001$; PR = 24,500).

CONCLUSION: Zinc deficiency in children is characterized by low serum Zn-levels. Low serum Zn-level is caused by low zinc intake, thus children with low serum Zn-levels are at risk of having intelligence level below average. Therefore, health education about the importance of zinc intake in children should be given to parents, so that the incidence of zinc deficiency in children can be reduced.

Introduction

In Indonesia, micronutrient deficiency in children is relatively high. The Zn deficiency rate reaches 17% [1]. In 2006, the prevalence of zinc-deficient children in Indonesia was 36.1% [2]. According to the WHO, zinc deficiency is one of the causes of death in children in moderate developing countries [3]. While according to the International Zinc Nutrition Consultative Group, zinc deficiency can cause 40% of children to become stunted [4]. Indonesia has a low rate of zinc intake >25% and a stunting rate >20%, so it can be concluded that Indonesia is still at risk of experiencing severe zinc deficiency [5].

Zinc (zinc) is a micronutrient with an essential function in brain development, especially in the nervous system's function (neurotransmitter). Zinc plays a role in increasing brain intelligence and learning ability in children [6]. Zinc is related to protein and functions as a brain cell structure and neurotransmitters involved in brain memory to affect cognitive development and learning achievement [7]. Zinc supplements can improve children's memory and concentration in learning and IQ [8].

Factors causing micronutrient deficiencies include poverty, low education levels, and low access to health-care centers [9]. Research in Iran states that zinc deficiency tends to be higher in rural areas than in urban areas. In children who have families with low-income levels, zinc deficiency often occurs because most of the intake comes from plant foods and eating little animal foods [10]. Vegetable foods contain a lot of phytate which inhibits zinc absorption, while animal foods do not contain phytate so that zinc can be absorbed optimally [11]. This study aimed to analyze the condition of zinc deficiency and its relationship with the level of intelligence in children in rural areas..

Method

This research was a cross-sectional study which was conducted in Lubuk Rumbai Village, Tuah Negeri District, with a total sample of 44 children. The sample was carried out randomly on elementary school children aged 9–12 years. Measurement of serum zinc levels was carried out by taking blood through cubital veins and measured using the Zinc (Zn) Colorimetric Assay Kit (E-BC-K137), while the zinc intake data were obtained from a food recall form that was carried out 3 × 24 h with non-consecutive days. The results of food intake recall were recorded, analyzed with Nutrisurvey software, averaged, and compared with the Nutritional Adequacy Rate (RDA). Zinc intake was included in the insufficient category if <77% of the value of the Adequacy Rate of Nutrition (RDA) and in the sufficient category if ≥77% of the value of the Adequacy Rate of Nutrition (RDA). Measurement of the level of intelligence was carried out using the Culture Fair Intelligence Test method. Data on the characteristics of children were obtained through a questionnaire. Further data were analyzed using the Chi-square test. This research had received ethical approval from the Ethics Commission of the Faculty of Public Health, Sriwijaya State University No. 161/UN9.1.10/KKE/2020.

Results

Based on the characteristic data obtained from the questionnaire, it was found that 59% of the children were male, 22.7% of the children had a nutritional status of stunting. Data on child characteristics revealed that 63.6% of mothers and 65.9% of fathers have low education. Most of the mothers did not work (54.5%) and 45.5% of fathers worked as farmers. Most of the parents (77.3%) had a low economic status (Table 1). The results of measuring zinc in children proved that 43.2% of children had insufficient zinc intake and 65.9% of children had low serum zinc levels (Table 2). As for measuring the level of intelligence, it was found that 81.8% of children had a level of intelligence below average (Table 3). This finding may also be associated with low level of parental education, not only zinc deficiency

The results of the Chi-square test in Table 4 shows that children with a low zinc intake of 84.2% had low serum zinc levels as well. There was a significant relationship (p = 0.026; PR = 4.923) between zinc intake and serum zinc levels in children. Children with low zinc intake were 4923 times more likely to have low serum zinc levels. Table 5 shows that, for children who have low serum zinc levels, 96.5% have an intelligence level below the average. There was a significant relationship (p = 0.001; PR = 24.500) between serum zinc levels and intelligence levels in children. Children who have low serum zinc levels are at 24,500 greater risk of having intelligence levels below average.

Table 1: The frequency distribution of characteristics of elementary school children in Lubuk Rumbai Village

Frequency distribution	n	%
1. Gender		
a. Male	26	59.0
b. Female	18	41.0
2. Nutritional status		
a. Stunting	10	22.7
b. Normal	34	77.3
3. Mother's level of education		
a. Low	28	63.6
b. High	16	36.4
4. Mother's job		
a. Civil Servant	2	4.6
b. Farmer	12	27.3
c. Private-Employee	6	13.6
d. Unemployment	24	54.5
5. Father's level of education		
a. Low	29	65.9
b. High	15	34.1
6. Father's job		
a. Civil Servant	2	4.5
b. Farmer	20	45.5
c. Private-Employee	19	43.3
d. Unemployment	3	6.7
7. Economic status		
a. Low	34	77.3
b. High	10	22.7

Table 1 shows that 59.0% of children are male and 22.7% of children are stunted, and 77.3% of children come from families with low economic status. As many as, 63.0% of mothers have low education, and 54.5% of mothers are not working. About 65.9% of fathers have low education, and 45.5% of fathers work as farmers.

Table 2: The frequency distribution of zinc measurement results in children

Frequency distribution	n	%
1. Zinc intake		
a. Deficient	19	43.2
b. Sufficient	25	56.8
2. Zinc serum level		
a. Low	29	65.9
b. Normal	15	34.1

Table 2 shows that 43.2% of children had insufficient zinc intake, and 65.9% of children had low serum zinc levels.

Table 3: The frequency distribution of measurement results for intelligence level in children

Frequency distribution	n	%
Intelligence level (IQ)		
a. Below average	36	81.8
b. Average and above average	8	18.2
Total	44	100

Table 3 shows that 81.8% of children have a level of intelligence below average, and only 18.2% of children have an intermediate level of intelligence and above average.

Table 4: The relation between zinc intake and serum zinc levels in children

Zn Intake	Serum Zn-Level				Total		p	PR
	Low		Normal					95% CI
	n	%	n	%	n	%		
Deficient	16	84.2	3	15.8	19	100	0.026	4.923
Sufficient	13	52.0	12	48.0	25	100		(1.142–21.232)
Total	29	65.9	15	34.1	44	100		

Table 4 shows that children with less zinc intake of 84.2% had low serum zinc levels. There was a significant relationship between Zn intake and serum Zn-levels in children (p = 0.026; PR 4.923).

Table 5: The relation between levels of zinc serum and level of intelligence

Zn serum level	Intelligence level				Total		p	PR 95% CI
	Below average		Average above average					
	n	%	n	%	n	%		
Low	28	96.5	1	3.5	29	100	0.001	24.500
Normal	8	53.3	7	46.7	15	100		(2.614–229.624)
Total	36	81.8	8	18.2	44	100		

Table 5 shows that children who have low serum Zn-levels of 96.5% have intelligence levels below the average. There was a significant relationship between serum Zn-levels and children's intelligence (p = 0.001; 24.500).

Discussion

Based on the research results, it was found that 43.2% of children had insufficient zinc intake and 65.9% of children had low serum zinc levels (Table 2). Low zinc intake results in low serum zinc levels in children. Inadequate zinc intake is caused by a low intake of zinc-containing foods. The results of this study also indicated that there was a significant relationship between zinc intake and serum zinc levels (Table 4). Food intake is very dependent on the level of education and economic status of parents. In rural areas, low economic status or poverty occupies the first position in society which causes malnutrition. In this study, most of the parents had low education and had a low economic status (Table 1). Educational factors and low economic status will interact with each other in influencing nutritional intake in children [9].

Besides, limited employment opportunities in rural areas result in limited family ability to meet children's nutritional needs. This results in children consuming more plant-based foods and consuming less animal foods, while plant-based foods contain lots of phytates which inhibit the absorption of zinc [11]. Zinc is found in food, especially in animal protein sources [12]. Zn absorption is inhibited by interactions with iron, calcium, fiber, as well as phytates, which are found in grains, nuts, wheat, and whole grains [13]. Low concentrations of zinc in the body are an indicator of zinc deficiency.

Zinc deficiency in children can result in loss of appetite, taste disorders, growth disorders, alopecia, immune dysfunction, hypogonadism, difficult to heal wounds, and cognitive impairment [14]. Zinc concentrations are highest in the hippocampus (located in the temporal lobe) and cortex (outer layer) big brain [15] The cerebrum influences the level of intelligence and the ability to think [16]. Animal studies have shown that severe zinc deficiency is associated with damage to brain structures such as anencephaly, microcephaly, and hydrocephaly as well as impaired motor and behavioral responses [17].

Zinc can affect cellular function and critical processes of brain growth, including cell replication, synthesis of DNA and RNA, release of neurotransmitters, protein synthesis, and macronutrient metabolism [18], [19]. The results of this study indicated that there was a significant relationship between serum zinc levels and intelligence level (Table 5). About 96.5% of children who have low serum zinc level have intelligence level below average. The results of this study are in line with research conducted by Xuedong *et al*. on children aged 7–10 years, which stated that zinc levels in hair were positively related to IQ scores, namely, the higher zinc levels in hair, the higher the IQ score [20]. Jagveer *et al*. on children aged 6–11 years also stated that zinc deficiency is associated with memory and concentration deficits in children [21]. Research by Victoria *et al*. stated that high serum zinc levels have a beneficial impact on intellectual development [22]. Results of the Umamaheswari *et al*. study, stated that, giving zinc supplementation had an effect on short-term memory in children [23]. Likewise research conducted by Jagveer *et al*. showed that, there was a significant increase in children's memory and concentration in learning and children's brain intelligence or IQ after zinc supplementation was given [21].

According to Gogia and Sachdev, zinc is an essential nutrient that plays a role in the preparation, and migration of neurons (nerve cells) along with the formation of neuronal synapses. Zinc will release the neurotransmitter aminobutyric acid which will affect nerve stimulation. Aminobutyric acid neurotransmitters have a role in the growth and differentiation of nerve cells. Zinc deficiency can interfere with the formation of nerve pathways and neurotransmission, so that it indirectly affects development, including cognitive development [24].

Conclusion

Zinc deficiency in children is characterized by low serum Zn-levels. Low serum Zn-level is caused by low zinc intake, thus children with low serum Zn-levels are at risk of having intelligence level below average. Therefore, health education about the importance of zinc intake in children should be given to parents, so that the incidence of zinc deficiency in children can be reduced.

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