Zinc Intake, Zinc Serum Levels, and Intelligence in School Children in Rural Areas

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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 economy, 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

| Intelligence level (IQ) | n  | %   |
|-------------------------|----|-----|
| 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  | 95% CI   |
|-----------|----------------|-------|----|-----|----------|
| Low       | n  | %   | n  | %   | n  | %   | n  | %   | n  | %   |
| Deficient | 16 | 84.2| 3  | 15.8| 19 | 100 | 0.026| 4.923|
| Sufficient| 13 | 62.0| 12 | 38.0| 25 | 100 | (1.142–21.232)|
| Total     | 29 | 65.9| 15 | 34.1| 44 | 100 |        |      |

Table 4 shows that children with low zinc intake were 4923 times more likely to have low serum zinc levels. There was a significant relationship (p = 0.026; PR = 4.923) between zinc intake and serum zinc levels in children.
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 |
|---------------|--------------------|-------|---|----|-------|
| Low           | Below average | 29 | 100 | 0.001 | 24.500 |
|               | Average above     | 8  | 15 |     | (2.614–229.624) |
| Normal        | Below average | 36 | 81.8 |     |       |
|               | Average above     | 8  | 18.2 |     |       |

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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References

1. Dijkhuizen MA, Wieringa FT, West CE, Muherdiyantiningih, Muhilal. Concurrent micronutrient deficiencies in lactating mothers and their infants in Indonesia. Am J Clin Nutr. 2001;73(4):786-91. PMid:11273854
2. Herman S. Research Report on Micronutrient Problems in Indonesia, Exceptional Attention to Vitamin A Deficiency (VAD), Anemia, and Zinc. Jakarta: Ministry of the Republic of Indonesia; 2007.
3. World Health Organization. Malnutrition: The Global Picture. Geneva: World Health Organization; 2004.
4. International Zinc Nutrition Consultative Group. International Zinc Nutrition Consultative Group (IZiNCG) technical document #1. Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr Bull. 2004;25(1 Suppl 2):S99-203. https://doi.org/10.1177/156482650402500220 PMid:16046856
5. Khan AA, Bano N, Salam A. Child malnutrition in South Asia: A comparative Perspective. South Asian Surv. 2007;14(1):129-45. https://doi.org/10.17777/097162310701400110
6. Almatrsier S. Prinsip Dasar Ilmu Gizi. Jakarta: PT, Gramedia Pustaka Utama; 2010.
7. Jagveer C, Rakesh J, Pramod S, Ravinder G, Sushil. A study of iron and zinc deficiency on short term memory in children & effect of their supplementation. Asian J Biomed Pharm Sci. 2015;5:12-5. https://doi.org/10.15272/ajbps.v5i42.664
8. Setyaningrum R, Triyanti, Indrawani Y. Learning in early childhood education with cognitive development in children. Natl Public Health J. 2014;8(6):243-24.
9. Wessells KR, Brown KH. Estimating the global prevalence of zinc deficiency: Results based on zinc availability in national food supplies and the prevalence of stunting. PLoS One. 2012;7(11):e50568. https://doi.org/10.1371/journal.pone.0050568 PMid:23209782
10. Fesharakinia A, Zarban A, Gholam RS. Prevalence of zinc deficiency in elementary school children of South Khorasan Province (East Iran). Iran J Pediatr. 2009;19(3):249-54.
11. Gropper SS, Smith JL, Groff JL. Advanced Nutrition and Human Metabolism. 5th ed. Belmont, CA: Wadsworth Cengage Learning; 2009. p. 488-97.
12. Freake HC, Sankavaram K. Zinc: Physiology, dietary sources, and requirements. In: Encyclopedia of Human Nutrition. Vol. 4. UK: Elsevier; 2013. p. 437-43. https://doi.org/10.1016/b978-0-12-375083-9.00286-5
13. Ma G, Li Y, Jin Y, Zhai F, Kok FJ, Yang X. Phytate intake and molar ratios of phytate to zinc, iron and calcium in the diets of people in China. Eur J Clin Nutr. 2007;61(3):368-74. https://doi.org/10.1038/ajecn.1602513 PMid:16929240
14. Stipanuk MH, Caudill MA. Biochemical, Physiological, and Molecular Aspects of Human Nutrition. 3rd ed. USA: Elsevier; 2013. p. 841-2.
15. Frederickson CJ, Koh JY, Bush AL. The neurobiology of zinc in health and disease. Nat Rev Neurosci. 2005;6(6):449-62. PMid:15891778
16. Martini FH, Nath JL, Bartholomew EF. Fundamentals of Anatomy and Physiology. 9th ed. Canada: Pearson; 2012. p. 449-50.
17. Nissensohn M, Sánchez-Villegas A, Fuentes Lugo D, Henríquez Sánchez P, Doreste Alonso J, Skinner AL, et al. Effect of zinc intake on mental and motor development in infants: A meta-analysis. Int J Vitam Nutr Res. 2014;84(3):203-15. https://doi.org/10.1111/mcn.12045 PMid:25008010
18. Levenson CW. Regulation of the NMDA receptor: Implications for neuropsychological development. Nutr Rev. 2006;64(9):428-32. PMid:17002239
19. Packer L, Sies H, Eggersdorfer M, Cadenas E. Micronutrients and Brain Health. USA: Taylor and Francis; 2010. p. 99. https://doi.org/10.1201/9781420073522
20. Xuedong Y, Xiuzhen B. Relationship between contents of microelement zinc, cuprum, and lead in hair with children's intelligence quotient. J Math Med. 2006;4:430-2.
21. Chaudhary J, Jora R, Sharma P, Gehlot R, Sushil. A study of iron and zinc deficiency on short term memory in children & effect of their supplementation. Asian J Biomed Pharm Sci. 2015;5:12-5. https://doi.org/10.15272/ajbps.v5i42.664
22. Victoria P, Eugenia T, Iliana P. Zinc levels, cognitive and personality features in children with different socioeconomic backgrounds. Eur J Psychol. 2010;6(1):82-101.
23. Umamaheswari K, Bhaskaran M, Krishnamurthy G, Vasudevan H, Vasudevan K. Effect of Iron and Zinc Deficiency on Short Term Memory in Children. Indian Pediatr. 2011;48(4):289-93. https://doi.org/10.1007/s13312-011-0060-7 PMid:20972302
24. Gogia S, Sachdev HS. Zinc supplementation for mental and motor development in children. Cochrane Database Syst Rev. 2012;12:CD007991. https://doi.org/10.1002/14651858.cd007991 PMid:23235652