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The influence of adequate levels of zinc-iron and hemoglobin levels on linear growth and cognitive development in Toddlers: A Cross-sectional Study in Aceh, Indonesia

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Abstract

Toddlers are a period prone to nutritional problems which can impact growth and development, especially cognitive development. This study aimed to analyze the effect of adequate zinc-iron levels and hemoglobin levels on linear growth and cognitive development in toddlers. The research was conducted in Aceh Besar Regency, Indonesia from July to August 2023. The target subjects were 138 toddlers aged 12-23 months. Stratified random sample with proportional allocation. Nutritional problems among children under five are quite high in Aceh. These nutritional problems include toddlers with severe stunting and stunting nutritional status, low Hb levels (<11 g/dL) or anemia status, deficit of iron and zinc intake and cognitive development problems. Toddlers in this study had *severe stunting and stunting* nutritional status reached 28.3%, deficiency of iron (79.7%), deficit of zinc (13.0%), anemia (37%) and suspected cognitive development (48.5%). There is a significant influence between adequate levels of zinc and iron as well as hemoglobin levels on linear growth status (WAZ) and cognitive growth of toddler children. It is important to follow up with the local health department regarding the intake and nutritional status of toddlers as well as providing early development stimulation, to prevent short-term and long-term negative impacts on the quality of human resources in the future.

Keywords: Intake-iron, intake, zinc, stunting, cognitive development

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1. Introduction

Toddlers are the most fundamental period for further development. This period is also seen as a golden age, a sensitive period, a period of initiative and initiative, and self-development. [1]. Every child has the right to optimal cognitive, social and emotional behavioral development. Toddlers who have not fulfilled their developmental and growth potential are likely to struggle in school and have low lifetime earnings, resulting in greater socioeconomic inequality and leading to greater generational poverty [2]. Disordered linear growth or lack of height is one of the nutritional problems that occurs due to nutrient intake deficiencies and diseases and is commonly found in developing countries. [3]. One of the factors that influence child development is the environment. The environment is all the other people/humans who influence us. The influence of the social environment is something we receive directly, such as in daily interactions with other people, with our family, our friends, and so on. And there are indirect ones such as through radio, television, by reading books, magazines, newspapers, and so on [1].

In addition to the environment, factors that can affect growth and development in children are nutritional deficiencies that affect brain growth and cognitive function have been shown to reduce global IQ at least 10 points. Nutrients that are important for growth are zinc (Zinc) and iron (Fe) [4,5]. Zinc is an essential mineral that plays a role in the activation and synthesis of growth hormone (GH), maintaining immunity, as an antioxidant, taste function, and cell membrane stabilization. *The International Zinc Nutrition Consultative Group* (IZincG) states that the global prevalence of zinc deficiency is estimated at 31%. Zinc deficiency occurs mainly in the

infant and pediatric population which can be caused by several factors such as; inadequate intake and hindered absorption, loss of zinc concentration and excessive plasma albumin [5].

The body needs zinc in sufficient amounts. Daily zinc requirements based on the 2019 RDA of children aged 0-5 months, 6-11 months, 1-3 years, and 4-5 years are 1.1 mg, 3 mg, 3 mg, and 5 mg, respectively [6]. Children with zinc deficiency can have a growth disorder caused by the inhibition of the effects of Growth Hormone (GH) metabolites so that the synthesis and secretion of Insulin Like Growth Factor 1 (IGF-1) decreases [5]. In addition, there is impaired immune function so that children are susceptible to infection. Infectious diseases are related to child growth. The infectious diseases suffered by children cause decreased absorption and appetite so that food intake is reduced and the child's ability to accept food while the body's needs are increasing. This result in growth disorders characterized by stunted or stopped linear growth [7]. The lack of iron (Fe) affects more than 2 billion people globally. In preschool-aged children, the highest prevalence rate is at 4 to 23 months of age (47.4%). Iron is essential for the growth and differentiation of different tissues. Neurons and brain tissue in developing fetuses and newborns are more sensitive to nutrient deficiencies than those in childhood and into adult life [4]. Iron is needed by the toddler's body in sufficient quantities. Daily iron requirements based on the Recommended Dietary Allowances (RDA) in 2019 for children aged 0-5 months, 6-11 months, 1-3 years, and 4-5 years respectively are 0.3 mg, 11 mg, 7 mg, and 10 mg [6]. The observational study found an association in children with low cognitive growth, school achievement, and behavioral problems. Several possible pathways may connect iron deficiency anemia with cognition. Children with iron deficiency disorder tend to be inactive, which leads to developmental delays. In children with iron deficiency, auditory nerve transmission and optic nerve impulses occur at a slower rate. A study showed an association between changes in nerve myelination and iron deficiency status [8].

These results are in line with research conducted by Medise (2021) that children who do not receive enough iron often experience permanent cognitive and motor deficiencies. Iron supplements are only effective when prescribed early after the patient is diagnosed with iron deficiency. In conclusion, it is better to fulfill iron needs according to the age of the child to avoid irreversible effects so more research needs to be carried out for iron supplementation to correct these negative effects [2].

2. Materials and Methods

This cross-sectional study was conducted in Aceh Besar District, Indonesia from July to August 2023. The intended population was toddlers aged 12-23 months in Simpang Tiga Subdistrict, Aceh Besar District. Subject recruitment was conducted in several stages. The first stage involved purposive selection of health centers based on the high prevalence of undernourished children. Next, the posyandu was selected based on the proportion of toddlers with malnutrition status, using data from the e-PPGBM of the Aceh Besar District Health Office. After that, the research location was determined based on the selected puskesmas and posyandu. The inclusion criteria for the target subjects were toddlers aged 12-23 months who were not sick and willing to participate in the study. To randomize the selection of subjects, multi-stage random sampling was conducted with proportional allocation. The allocation of subjects was conducted based on the proportion of toddlers in each selected health center and posyandu, in order to obtain a sample that could represent the population of toddlers aged 12-23 months in Simpang Tiga Subdistrict, Aceh Besar District.

Before starting data collection, the researcher will distribute informed consent forms to the families of the selected toddlers. This form must be completed and signed by the families as their consent to participate in the study. Furthermore, parents of subjects who agree to participate in data collection will receive a visit from trained professionals, known as enumerators. This study has been approved by the Ethics Committee for Research and Community Service at the Aceh Health Polytechnic, Ministry of Health (Reference Number: Dp.04.03/12.7/078/2023). The characteristics data of respondents or mothers include; age, occupation, education, household income, total number of family, total number of toddlers in the family. Characteristics of toddlers (gender, birth order, and weight at birth, linear growth, cognitive development, intake of zinc, fe and hemoglobin (Hb) levels, incidence of illness/infection. The child's health status will be evaluated based on the history of upper respiratory tract infection (URTI) and diarrhea that occurred in the last two weeks. Zinc and fe intakes were collected using the 2x24 hour food recall method. Measurement of hemoglobin levels was conducted using an easy touch device with health workers at the respective Posyandu.

Assessment of linear growth or nutritional status of toddlers, anthropometric measurements are used which include body length. Body length measurements were collected with a length board. Each measurement was taken twice, and the final result was based on the average of the measurements. All equipment used in data collection was routinely checked daily, including calibration and availability of backup equipment. The data regarding the motor development of the subject will be measured using the BKB (Bina Keluarga Balita) instrument which is appropriate for the age of the child. The process of recording cognitive development was carried out by observing the assessment aspects for 5-10 minutes. The intelligence/cognitive development of children aged 12-24 months was measured based on the BKB (Bina Keluarga Balita) indicators, adopted from the BKKBN module [9] which consists of 7 intelligence items including imitating people's words and actions, reacting to words and commands, being able to name and attach similar objects, having the ability to look at drawing books with help, differentiate between you and me, being able to concentrate even though limited and learning to find out and recognize things. The assessment uses 2 scales: can (1) and cannot (0). If the answer can is less than 5, a problem is suspected (suspec), if the answer can >5 is considered no problem (normal). During the testing session, each child will be given stimulation to reach the

highest developmental milestone. The child and/or caregiver will be instructed to provide encouragement for the child to accomplish the developmental function within their ability as much as possible [10].

The collected data were processed and analyzed descriptively and inferentially using the Microsoft Excel 2007 computer program and the SPSS 16.0 for Windows program. Before testing the data in SPSS, a normality test was first conducted to evaluate the distribution of the data. Univariate data analysis aimed to determine the frequency distribution of each variable, then presented descriptively. Bivariate analysis aimed to determine the relationship of the dependent variables, which are zinc status, Fe status and anemia status with the growth status of toddlers.

3. Results and Discussion

Mothers are parents who play a greater role in childcare. The characteristics of mothers in this study include age, education, occupation, total number of family, total number of toddlers and household income per capita. Table 1 shows that the average age of mothers of toddlers was 31 years old, more than half of the mothers had a high school education (56.5%) and most of them did not work or were housewives (81.9%). The type of occupation of parents represents the amount of income received each month, while education is the basic capital in getting a better job [11,12]. The average household income in this study was IDR 2,595,564, which is below the minimum wage of Aceh Province. The education of parents is usually related to knowledge, which will affect the selection of food ingredients and the fulfillment of the nutritional needs of family members. The total family in this research consists of parents, children, and relatives who live in the same house from the same source of food acquisition. Family size can be used to illustrate the amount of food received by family members. The subjects of this study were toddlers aged 12-23 months. Most of the subjects in this study were male (60.1%), with the average second child order and had a history of non-low birth weight (Table 2). The largest proportion of toddlers had no history of ARI (67.4%) and diarrhea (91.3%) in the last two weeks. The largest proportion of toddlers had an insufficient level of Fe (79.7%), while the zinc sufficiency rate was sufficient at 87%.

Linear growth status measured by anthropometric index WAZ with the largest proportion in the normal category (71.7%), but severe stunting and stunting nutritional status reached 28.3%. According to [13], the percentage of toddlers with severe stunting and stunting nutritional status in this study is a public health problem in the moderate level category because it is in the range of 20-29%. Severe stunting and stunting caused by a long-term undernutrition or frequent illnesses. [14]. The research results [15] mentioned that boy experience more stunting than girls, this is because gender determines the size of an individual's protein energy needs and the need is greater in boy than girl. Physically, boys are more active, so they spend more energy on activities and not on their growth [16]. Anemia status was measured by hemoglobin (Hb) levels showed the largest proportion of non-anemia (63%), while 37% of toddlers with anemia status had an average Hb level of 11.57 g/dL. The prevalence of anemia in these toddler is far below the rate of the results of a previous study conducted on toddlers in Aceh which was very high reaching 68.6% with an average Hb level of 10.1 g / dL [17]. Iron intake is one of the strong factors that influence anemia status in toddlers [17]. The lack of iron intake from complementary foods is a major factor in anemia in toddlers aged 12-23 months [18].

Tabel 1: Respondent variables (mother)

Mother's Characteristics	n (30)	%
Mother's age (years)		
(Mean±sd)	31±5.63	
Mother's Education		
Low (Elementary-Middle School)	25	18.1
Medium (Senior High School)	78	56.5
Higher (Diploma/graduate)	35	25.4
Mother's Occupation		
Not working / housewife	113	81.9
Work	25	18.1
Household income		
(Mean±sd) Rupiahs	2,595,564±1,448,029	
Large Household		
(Mean±sd)	4±1.08	

Table 2: Research subject variables

Subject Variables	n (130)	%
Gender		
Male	83	60.1
Female	55	39.9
Order of Children		
($\bar{x}$ ± sd)		2±1.07
Birth Weight		
($\bar{x}$ ± sd)		3127±4.32.44
Acute Respiratory Infections (ARI)		
Yes	45	32.6
No	93	67.4
Diarrhea Status		
Yes	12	8.7
No	126	91.3
Physical Growth (*Weight-for-age ,WAZ)*		
Severe stunting	11	8.0
Stunting	28	20.3
Normal	99	71.7
($\bar{x}$ ± sd) z-score		-,90 ± 1,87
Cognitive Development		
Suspect	67	48.5
Normal	71	51.4
Anemia (<11 mg/dL)		
Anemia (<11 mg/dL)	51	37.0
Normal (≥11 mg/dL)	87	63.0
($\bar{x}$ ± sd) z-score		11.57±2.58
Zinc Intake (RDA)		
≤ 77 % RDA	18	13.0
>77% RDA	120	87.0
($\bar{x}$ ± sd) mg		3.69 ± 1.36
Fe intake (RDA)		
≤ 77 % RDA	110	79.7
>77% RDA	28	20.3
($\bar{x}$ ± sd) mg		4.45 ± 1.48

Table 3: Effect of Hb and Zinc status on physical growth of toddlers

Variables Analysis	Linear growth (z-score PB/U) Severe stunting	stunting	Normal	p-(value)	Cognitive Development *Suspect*	Normal	p-(value)
	n(%)	n(%)	n(%)		n(%)	n(%)	
Hb levels							
Anemia (<11 mg/dL)	7(70.0)	14(50.0)	30(30.0)	0.012*	35(52.2)	16(22.5)	<0.001*
No Anemia (≥11 mg/dL)	3(30.0)	14(50.0)	70(70.0)		32(47.8)	55(77.5)	
Iron intake (Fe)							
Deficient (<77% RDA)	10(100)	24(85.7)	76(76.0)	0.047*	61(91.0)	49(69.0)	0.001*
Adequate (≥77% RDA)	0(0.0)	4(14.3)	24(24.0)		6(9.0)	22(31.0)	
Zinc intake (Zn)							
Deficient (<77% RDA)	4(40.0)	8(28.6)	6(6.0)	0.001*	13(19.4)	5(7.0)	0.042*
Adequate (≥77%RDA)	6(60.0)	20(71.4)	94(94.0)		54(80.6)	66(93.0)	

3.1 *Effect of Iron, Zinc and Hb Adequacy Levels on Linear Growth and Cognitive Development of Toddlers*

Table 3 shows that there is a significant effect of Fe and Zn intake levels and hemoglobin levels on the linear growth (WAZ) and cognitive development of toddlers. The largest proportion of *severely stunted* and *stunted* toddlers had low Hb levels (<11 g/dL) or anemia status, and inadequate Fe intake. Zinc intake was inadequate in the largest proportion of *severely stunted* and *stunted infants*, but almost all (96.0%) toddlers with normal linear growth had adequate levels of zinc. This result is in line with studies conducted [15,19] Hemoglobin levels and macro mineral intake (iron and zinc) in stunted toddlers are lower than non-stunted toddlers. Previous studies have shown that there is a strong relationship between anemia and stunting in children [20] Zinc deficiency can inhibit children's linear growth (Retty, Anisa *et al.* 2016). Toddlers with inadequate zinc levels have a 7.8 times greater risk of stunting compared to toddlers with adequate zinc levels. [15]. Toddlers who receive zinc supplementation have better growth because zinc consumption can stimulate appetite, increase energy intake and increase fat-free mass in the body [21]. Another study conducted in Kenya on anemic children given iron supplementation resulted in increased appetite and growth [22]. Providing iron and zinc intake at the same time with the right dose to make it easily absorbed by the body (preferably not exceeding 2:1), this is because zinc uses transferrin as a transport tool which is also an iron transport [22].

The effect of Hb levels on child development was also shown in a study conducted on toddlers in Aceh, the development of fine motor skills, but not of gross motor skills. [23]. Iron is an important structural component of the hemoglobin molecule, which transports oxygen to all organs of the body, including the brain. Cognitive impairment in the short and long term is the result of low hemoglobin production due to iron deficiency. [24]. The results of research conducted in Bogor on pre-school children, cognitive development is also associated with nutritional status according to the PB/U index [25]. The study conducted on toddlers in Aceh also found that anemia not only affects cognitive development, but also fine motor development, but not gross motor development. [23]. The development of a child's brain that is sensitive to nutrient intake mostly occurs at the age of two years and if at the age of two years there is a lack of nutrient intake, the development will be inhibited

[26] Iron deficiency anemia in infancy is associated with poor mental and motor development, while Iron Deficiency Anemia in the later childhood is related to lower cognitive ability and school achievement [24] . Longitudinal studies have also consistently shown that children who have persistent anemia before the age of two years show deficits in cognition and school achievement from 4 to 19 years of age [24]. The nutrient zinc (Zn) also contributed to cognitive development in this study. Zinc is the fourth most abundant ion in the brain, contributing to brain structure and function through its role in DNA and RNA synthesis and protein, carbohydrate and fat metabolism [24]. The nutritional problems are not only caused by inadequate nutritional intake, but also by infectious diseases [27][27]. Children who get enough food but often experience diarrhea or ARI and fever, can eventually experience undernutrition. In children with insufficient consumption, it causes their immune system to be weakened, so in this situation the child is susceptible to diseases that can reduce their appetite and eventually the child suffers from undernutrition. Low immunity can also contribute to anemia [28,29].

Determinants of stunting in toddlers in Indonesia include non-exclusive breastfeeding, low household socio-economic status, preterm birth, short birth length, and low maternal height and education. [30]. In line with this, from an economic point of view, the subjects in this study came from households with a lower middle economy as evidenced by the average household income below the minimum wage of Aceh province (Table 1). The location of residence is also associated with children's nutritional status and risk of stunting [31,32] The location of the subjects of this study was in a rural area so that the risk of stunting in toddlers increased, supported by the results of this study which showed micronutrient deficiencies (Zn, Fe) experienced by toddlers.

4. Conclusions

Nutritional problems among children under five are quite high in Aceh. These nutritional problems include toddlers with severe stunting and stunting nutritional status, low Hb levels (<11 g/dL) or anemia status, deficit of iron and zinc intake and cognitive development problems. Toddlers in this study had *severe stunting and stunting* nutritional status reached 28.3%, defici of iron (79.7%), deficit of zinc (13.0%), anemia (37%) and suspected cognitive development (48.5%). There is a significant influence between adequate levels of zinc and iron as well as hemoglobin levels on linear growth status (WAZ) and cognitive growth of toddler children. It is important to follow up with the local health department regarding the intake and nutritional status of toddlers as well as providing early development stimulation, to prevent short-term and long-term negative impacts on the quality of human resources in the future.

Conflict of Interest

The authors state that there are no potential conflicts of interest associated with the research, authorship, or publication of this article.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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