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NUTRIENT INTAKE AND PHYTATE-TO-ZINC MOLAR RATIO AMONG STUNTED AND NON-STUNTED CHILDREN IN MALANG CITY

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ABSTRACT

Stunted is a condition of malnutrition caused by inadequate nutrient intake, especially in protein and zinc. Zinc deficiency can lead to impaired growth and increased risk of infectious disease due to inadequate zinc intake and low bioavailability of zinc in food. The purpose of this research was to analyze the nutrient intake and phytate-to-zinc molar ratio in children. This research was an analytical observational study with cross-sectional design. Children aged 6-59 months with stunted (n=61) and non-stunted (n=65) nutritional status were chosen by stratified random sampling in Ciptomulyo Health Center, Malang city. Nutrient and phytate intake were taken using 2x24 hour food recall method, while zinc bioavailability was calculated using phytate-to-zinc molar ratio. The difference of independent variables were analyzed using Independent t-test and Mann Whitney test. The result of this study showed that there were significantly different energy and protein adequacy levels (p=0.018; p=0.001) and phytate intake (p=0.016) among stunted and non-stunted children. On the other hand, fat, carbohydrate, and zinc adequacy level did not show any significant differences. Furthermore, there were no significant difference in phytate-to-zinc molar ratio in the two group (p=0.158) with more than half children had high phytate-to-zinc molar ratio category. In conclusion, the stunted and non-stunted children showed significant differences in energy, protein, and phytate intake, while their zinc intake was not significantly different resulting in similar phytate-to-zinc molar ratio between both groups. This study show that sufficient intake of zinc can help to lower phytate-to-zinc molar ratio regardless of nutritional status of children.

Keywords*: Nutrient intake, phytate intake, stunted children, zinc bioavailability*

INTRODUCTION

Stunted is a condition when children have Height for Age (HAZ) on < -2 SD (Minister of Health Republic of Indonesia No.2 of 2020 about Children Anthropometric Standard). The Indonesian Nutritional Status Survey (*Survey Status Gizi Indonesia/SSGI*) results in 2022 showed that 21.6% of children aged 0-59 months in Indonesia are experiencing stunted. Meanwhile, Malang city has stunted children's prevalence of 18%, close to average prevalence in East Java region as stated in percentage of 19.2%. This nutritional problem is currently becoming the focus of government program since stunted has negative impacts to children, in particular to their growth and development, including interference in children's cognitive development (Yadika et al., 2019). Children who are experiencing stunted, especially during their first 2 years of age, can experience brain and neurological development disorders resulted in decreases of IQ and learning achievement (Daracantika, 2021).

One of many causes of stunted is an inadequate food intake, especially in energy and protein. There are 46% of stunted children have insufficient protein intake (Ariati, 2019). (Damayanti et al., 2017) reported that children who have inadequate energy and protein intake are at risk from stunted exposure in 9.5 times and 10.6 times higher than children with adequate energy and protein intake. Protein is important macronutrient in the children's growth and development processes. Deficiency in protein will be resulted in decreasing the protein synthesis and degradation as well as linear growth failure (Tessema et al., 2018).

Protein insufficiency is often accompanied by zinc deficiency since zinc mostly found in animal protein foods such as red meat, seafood, poultry and dairy products. These nutrient has important role in the processes of cell and tissue growth,

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cell replication, bone formation, and regulation of protein synthesis (Gropper et al., 2009). Zinc deficiency in children is often associated with poor health, impaired growth, impaired intellectual development, and an increased risk of infectious diseases. These conditions can be caused by several reasons including low intake, low bioavailability, and zinc loss due to diseases such as diarrhea (Young et al., 2014). Research conducted by Losong & Adriani (2017) showed 85.71 % of stunted children have inadequacy zinc intake. Other research also showed that zinc intake < 77 % of the RDA is associated with the stunted incidence in children (Fatimah & Wirjatmadi, 2018).

Aside from the reason of low intake, zinc deficiency also can be caused by low zinc absorption. One of substances that able to inhibit zinc absorption is phytic acid. Phytic acid is a molecular form of phosphate storage mostly found in many types of cereal and plant protein foods where these substances unable to be absorbed inside small intestine. As a result, phytic acid will bind zinc and causing a zinc deficiency (Gropper et al., 2009).

From a study conducted in adults showed zinc absorption has negative correlation to phytate-to-zinc molar ratio (PA:Zn molar ratio) where zinc absorption would decrease by around 50% lower at an intake with an PA:Zn molar ratio value of 12-15 when compared to a diet with an PA:Zn molar ratio value of <5 (Gibson et al., 2018). Whereas other research by (Galetti et al., 2016) also showed the stunted children in Benin, West Africa had a low PA:Zn molar ratio value of 22.2. Unfortunately, there has not sufficient researches regarding the PA:Zn molar ratio in Indonesia as an indicator for determining zinc absorption due to limited sources of phytate data. Therefore, this research aimed to analyze nutrients intake and the PA:Zn molar ratio values in stunted and non-stunted children in Malang city.

METHODS

This research is an analytical observational study with a cross sectional design. The research was conducted from August to October 2023 in two sub-districts working area of Ciptomulyo Community Health Center, namely Ciptomulyo and Gadang Sub-districts of Malang City, East Java Province. These sub-districts had highest number of stunted children in Ciptomulyo Community Health Center.

The sample of this research was 126 children based on Lameshow et al. (1997) formula with the proportion between stunted and non-stunted children was 1:1. The selection of respondents was carried out by a stratified random sampling technique with strata division based on the children nutritional status which consist of stunted and non-stunted children (World Health Organization, 2006). As inclusion criteria for this study were: children with age of 6-59 months, not in a sick condition that involving regular medication like tuberculosis disease, cancer, HIV/AID, and autoimmune disease, and was willing to be a respondent during research process by signing the informed consent form by the children's parents.

The variables of this study were children' characteristics (age, gender, birth weight, history of exclusive breastfeeding, and caregiver), children's nutritional status (Height-for-Age Z-Score/HAZ), nutritional intake (energy, protein, fat, carbohydrate, zinc), phytate intake and phytate-to-zinc molar ratio (PA:Zn molar ratio).

Data of children ages were classified into three categories: (a) 6-11 months, (b) 12-36 months, and (c) 37-59 months based on 2018 Indonesian Nutritional Adequacy Rate (*Angka Kecukupan Gizi/AKG)*, and the data of birth weight history divided into two categories: (a) Low Birth Weight/LBW (<2500 g) and normal birth weight (>2500 g). Whereas for caregiver data about who is taking care for the children daily was included mother, grandmother, baby sitter, and other family members.

The measurement of nutritional status (HAZ) was carried out by direct anthropometric measurement through lengthboard and microtoise. Children with Z-score value < -2 SD were categorized as stunted and children with Z-score value ≥ -2 SD were categorized as non-stunted. Nutrient and phytate intake were measured by 2 x 24 hours food recall method on weekdays and weekends. Then, the intake data was processed by Indonesian Food Table Composition 2017 database and Nutrisurvey 2007 application. The result of intake data then compared with the 2018 Indonesian Nutritional Adequacy Rate (*Angka Kecukupan Gizi/AKG)*. Then, level of macronutrients adequacy (energy, protein, fat and carbohydrates) divided into five categories: (a) severe deficit (<70% RDA), (b) moderate deficit (70-79 % RDA), mild deficit (80-89% RDA), (d) normal (90-119% RDA) and (e) excessive (>120 % RDA) (WNPG, 2004). Whereas for data of zinc adequacy was divided into two categories based on Gibson (2005): (a) insufficient (<77 % RDA) and (b) sufficient (≥ 77 % RDA).

Phytate intake then analyzed through phytate database taken from FAO/IZiNCG (2018) whereas the Phytate to Zinc Molar Ratio (PA:Zn Molar Ratio) is calculated by following formula from FAO/IZiNCG (2018) as follow:

$$PA{:}Zn\ molar\ ratio = \frac{\frac{Phytate\ (mg)}{660\ (MW)}}{\frac{Zn\ (mg)}{65.38\ (AtW)}}$$

AtW: Atomic Weight
MW: Molar Weight

Next, the PA:Zn molar ratio value was then classified based on WHO/FAO (2004) into low (>15), medium (5-15) and high (<5) category.

Variable data then analyzed by SPSS 25 followed by Univariate analysis that carry out afterwards to observe the frequency distribution of each research variable, while data normality test will be done by Kolmogorov-Smirnov. For observing differences in nutrient intake, phytate and PA:Zn molar ratio in stunted and non-stunted children groups, a differential test analyzed by Independent T-Test if data research was normally distributed or by Mann Whitney Test if the data research was not normally distributed. Additionally, this research has received an approval from Health Research Ethic Committee, Faculty of Nursing, Airlangga University under approval number No:2952/KEPK.

RESULTS AND DISCUSSIONS

The Characteristic of Children

Total respondents of this research were 126 children, categorized into two groups: 61 stunted children and 65 non-stunted children. The characteristic of children is displayed in Table 1.

Table 1. Children characteristics in Malang City

Variable	Nutritional Status	
	Stunted n (%)	Non- Stunted n (%)
Age		
6-11 month	3 (4.92)	5 (7.69)
12-36 month	34 (55.74)	27 (41.54)
37-59 month	24 (39.34)	33 (50.77)
Gender		
Male	29 (47.54)	36 (55.38)
Female	32 (52.46)	29 (44.62)
Birth Weight		
Low Birth Weight	9 (14.75)	9 (13.85)
Normal	52 (85.25)	56 (86.15)
Exclusive Breastfeeding		
Yes	52 (85.25)	44 (67.69)
No	9 (14.75)	21 (32.31)
Caregiver		
Mother	55 (90.16)	51 (78.46)
Grandmother	4 (6.56)	10 (15.38)
Baby Sitter	1 (1.64)	1 (1.54)
Other Family Member	1 (1.64)	3 (4.62)

According to distribution of the respondents' characteristics, more than a half of stunted children (55.74 %) at aged 12-36 months, while most of non-stunted children (50.70%) at aged 37-59 months. Mostly of stunted children were female (52.46%) while non-stunted children were dominated by male children (55.38%). In this study, both stunted and non-stunted children were had normal birth weight by percentages of 85.25 % and 86.5 %.

For exclusive breastfeeding variable, 14.75 % of stunted children did not receive exclusive breastfeeding. On the contrary, non-stunted children who did not receive exclusive breastfeeding were twice as high as stunted children (32.31 %). Most children in both children groups are raised directly by their mothers.

Nutrients Intake

Food is one of many primary factors that able to determine children nutritional status. Children who tend to consume food that does not comply with food recommendations have possibility to increase the risk of malnutrition. In this study, the type of nutrients being analyzed were energy, protein, fat, carbohydrates and zinc.

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The distribution of nutritional adequacy from stunted and non-stunted children is presented in Table 2. Almost half of stunted children had severely deficit energy adequacy (44.26%). On the other hand, more than 40% of non-stunted children had sufficient energy intake. For protein adequacy, more than half of stunted children (62.3%) and more than three quarters of non-stunted children (86.15 %) had excessive protein intake because majority of children respondents consumed formula milk as their daily source of protein. However, there are 18.03 % of stunted children experiencing a protein deficit.

The fat adequacy in stunted children fell into poor category because more than half of children have deficit intake (<90 % RDA). On the other hand, 36.92 % of non-stunted children consume sufficient fat and 16.92% have excessive fat intake. Meanwhile, in carbohydrate adequacy for both stunted and non-stunted children, most children experienced a severely deficit intake (62.29 % and 40 %).

In addition, this research also analyzed the micronutrient adequacy of zinc. In this study, more than half of stunted children (63.93%) and non-stunted children (64.62 %) had adequate zinc intake. Sufficient amount of zinc consumption able to promote children's growth since its role in cell and tissue growth, cell replication, bone formation, and regulation of protein synthesis (Gropper et al., 2009).

Table 2. Distribution of nutrition adequacy among stunted and non-stunted children

Nutrition Adequacy	Nutritional Status				p-value
	Stunted		Non-Stunted		
	n	(%)	n	(%)	
Energy Intake					
Severely Deficit	27	44.26	14	21.54	
Moderately Deficit	8	13.11	7	10.77	
Mildly Deficit	6	9.84	12	18.46	0.018[a]*
Normal	14	22.95	27	44.26	
Excessive	6	9.84	5	7.69	
Protein Intake					
Severely Deficit	3	4.92	0	0	
Moderately Deficit	6	9.83	1	1.54	
Mildly Deficit	2	3.28	1	1.54	0.001[a]*
Normal	12	19.67	7	10.77	
Excessive	38	62.3	56	86.15	
Fat Intake					
Severely Deficit	21	34.43	11	16.92	
Moderately Deficit	6	9.84	13	20	
Mildly Deficit	5	8.2	6	9.23	0.323[b]
Normal	16	26.23	24	36.92	
Excessive	13	21.31	11	16.92	
Carbohydrate Intake					
Severely Deficit	38	62.29	26	40	
Moderately Deficit	6	9.84	14	21.54	
Mildly Deficit	5	8.2	9	13.85	0.093[b]
Normal	10	16.39	13	20	
Excessive	2	3.28	3	4.61	
Zinc Intake					
Insufficient	22	36.07	23	35.38	0.937[b]
Sufficient	39	63.93	42	64.62	

[a]*Mann-Whitney Test, significant if p <0.05
[b] Independent T-Test, significant if p <0.05

The study showed there is a significant difference between energy and protein adequacy in stunted and non-stunted children ($p < 0.05$). This finding is similar to research by Damayanti, et al (2016) which showed there are significant differences in energy and protein adequacy in stunted and non-stunted children. In addition, other researches also reported there are statistically different between the energy and protein intake of stunted and non-stunted children. Children who consume low energy and protein will be at risk of being stunted 6 times and 4 times higher compared to children with adequate energy and protein intake (Fikawati et al., 2021).

In this research, stunted children had deficit of fat and carbohydrate intake that lead into energy deficiency. This condition caused by imbalance of feeding practice especially in energy intake. Based on recall data, stunted children in Malang City consume formula milk in high quantities and frequency. Therefore, their main food intake becomes inadequate. In addition, children also consume a lot of snacks with low nutritional content that make energy deficiency (unpublished data).

Protein is one of important macronutrients needed by children on their growth period. Protein functions as a builder for the body structures such as bones, muscles, and tissues. A deficiency in protein can decreasing protein synthesis and degradation of muscle protein resulted in linear growth failure of children. (Tessema et al., 2018) showed there was a positive relationship between protein intake and linear growth in children. Consumption high quality protein has a significant impact on gene expression, in particular to IGF-1 which has an important role in growth.

In this study, almost all children had adequate protein intake. However, more than half stunted children had deficit carbohydrate intake. As a result, insufficient of carbohydrate causing gluconeogenesis pathways, the process to form energy form non-carbohydrate sources. This resulted in protein cannot be used to growth process in children.

Whereas the adequacy of fat, carbohydrates and zinc showed no significant difference between stunted and non-stunted children. The present study also reported that there was no significant difference between zinc intake in stunted and non-stunted children (Van Stuijvenberg et al., 2015). Another study by Fikawati et al. (2021) also showed that there was no significant difference between zinc intake in stunted and non-stunted children. In that study, more than half of stunted and non-stunted children had adequate zinc intake (52.8% and 68.2%). This data is relevance with our research where more than half of stunted and non-stunted children had sufficient intake of zinc.

Based on the result of this research, the macronutrient intake, especially energy and protein can affect children nutritional status. However, as for zinc, it is not a risk factor for stunted in children because this study showed most of children's zinc intake was good. An inadequate energy and protein intake can increase global DNA methylation level significantly, where this condition occurs when children had stunted status. Meanwhile, lower intake of zinc had higher but no statistically significant in global DNA methylation level ($p = 0.043$) (Iqbal et al., 2019).

Phytate Intake

Phytate is a storage molecule form of phosphate found in many types of cereals and plant foods. Since phytic acid cannot be absorbed in small intestines due to inability to degrade in human body, as a result, it will bind several minerals such as zinc, iron, magnesium, calcium, potassium, manganese and copper. These resulted in deficiency of several micronutrients in human (Brouns, 2021).

The phytate intake from several developing countries in Asia tends to be higher than western countries. (Ma et al., 2007) reported the phytate intake in Chinese population was 1186 mg, higher than the average of American population (750 mg). However, in Indonesia, the average phytate intake for children in Pontianak city was 113.92 mg for stunted children and 100.88 mg for non-stunted children (Sari et al., 2016).

Table 3. Difference of phytate intake between stunted and non-stunted children

Phytate Intake (mg)	Nutritional Status		p-value
	Stunted	Non-Stunted	
Median (Q1, Q3)	114.46 (11.81; 1118.6)	168.17 (31.03; 1088.74)	0.016*

*Mann-Whitney Test, significant if $p < 0.05$

The median of phytate intake for stunted and non-stunted children in this study is presented in Table 3. Median phytate intake for stunted group is 114.46 mg, significantly lower than median phytate intake in non-stunted group (168.17 mg).

The previous study from Iqbal et al. (2019) in Bangladesh showed there is a significant difference in phytate intake between stunted and non-stunted children (p = 0.004). This study also has the result as same as our research. It suggests that condition may due to the absence of relationship between phytate intake and increase in global DNA methylation which occurs in stunted children.

In infants and children, the effect of phytate intake on zinc absorption was very low when zinc intake is controlled. An increase in phytate intake by 500 mg/day can reduce zinc absorption by 0.04 mg/day. This condition caused by gastric pH is higher in children than in adults (Miller et al., 2015).

Phytate-to-Zinc Molar Ratio

Zinc deficiency can be caused by inadequate intake and low of zinc absorption. The bioavailability of zinc is determined by three factors: (a) the individual's zinc status, (b) the amount of zinc intake, and (c) the availability of zinc that able to be absorbed from food (Gibson, 2020). Type of nutrient that role as enhancer for the zinc bioavailability is protein, because of amino acid from animal protein will retain zinc in body fluids (Roohani et al., 2013) Whereas, the substance that can inhibit the bioavailability are phytic acid, oxalate, and polyphenols (Gropper et al., 2009).

Animal protein like red meat, poultry, fish, egg, and seafood have a high content of zinc. Meanwhile, phytate is mostly found in plant foods such as cereals, legumes, roots, and nuts. The food sources of zinc and phytate that are consumed by children are explained in Table 4. Around 65.57% of stunted children had chicken as the primary animal protein source, with zinc content of 0.6 mg/100 g. Meanwhile, the most zinc source consumed by non-stunted children is egg (69.23%) which has 1 mg/100 g of zinc. Besides that, both groups of children had the same pattern of phytate intake, where all of the children consumed rice as their staple food. Cooked rice has phytate content of 39.38 mg/100 g. Moreover, tempeh is the second phytate source that is consumed by stunted and non-stunted children (32.79% and 46.15%).

Table 4. The top three food sources of zinc and phytate consumed by respondents

Food Source	Amount in Food (mg/100 g)	Respondents Who Consume the Food Source	
		Stunted n (%)	Non-Stunted n (%)
Zinc Source			
Egg	1[a]	37 (60.66)	45 (69.23)
Chicken	0.6 [a]	40 (65.57)	36 (55.38)
Meatball	3.8 [b]	33 (54.1)	26 (40)
Phytate Source			
Rice	39.38 [c]	61 (100)	65 (100)
Tempeh	62.09 [c]	20 (32.79)	30 (46.15)
Potato	40.48 [c]	18 (29.51)	24 (36.92)

References: a. Indonesia Food Table Composition (2017)
b. Nutrisurvey Application 2007
c. FAO/IZiNCG. (2018)

In this study, children in Malang City tend to have high protein but low phytate consumption. More than half children consumed animal protein like egg and chicken as their protein sources. On the contrary, only 46.15% children that consumed phytate like tempeh as their protein sources. This result had similarity with the literature study by Idawati et al. (2023), showed that dietary pattern on Indonesia children tend to consume animal sources like egg and chicken nugget more often than plant source like tempeh, tofu, and nuts.

Phytate-to-Zinc molar ratio (PA:Zn Molar Ratio) is the indicator to determine the bioavailability of zinc. Distribution of PA:Zn molar ratio values is illustrate in Figure 1. It showed that more than half of stunted (62 %) and non-stunted group (52%) had a high category of PA:Zn molar ratio values (<5). Our suggest because the food sources of phytate consumed by children were reduce through many production processes. Rice for instance, as the staple food has gone through a grinding and washing process. Moreover, tofu and tempeh as the main source of vegetable protein also through a fermentation process (Brouns, 2021; Gupta et al., 2015).

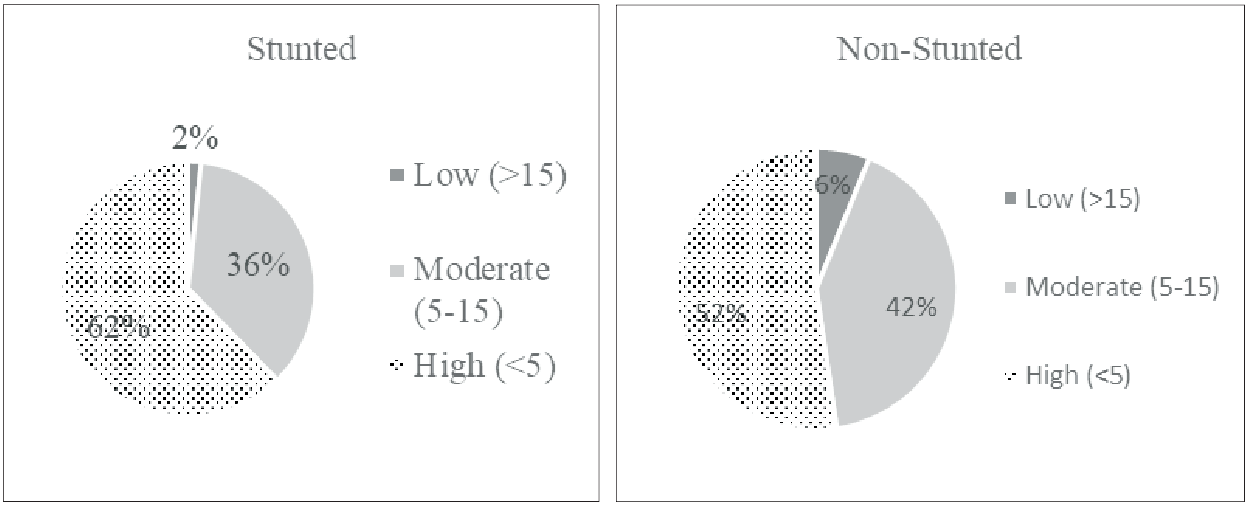

Figure 1. Distribution percentage of PA:Zn molar ratio category between stunted and non-stunted children

Table 5. Difference of PA:Zn molar ratio value

PA:Zn Molar Ratio	Nutritional Status		p-value
	Stunted	Non-Stunted	
Mean ± SD	5.32 ± 4.29	6.05 ± 4.67	0.158[a]

a Independent t-test, significant if $p < 0.05$

The average of PA:Zn molar ratio from the stunted children group was 5.32 ± 4.29 higher but no statistically different than non-stunted children group (6.05 ± 4.67) as explained in Table 5. At the contrast from research of Galetti et al. (2015) which showed the stunted children that caused by zinc deficiency had low PA:Zn Molar Ratio values (22.2 ± 4.8). In this study, in addition, the zinc intake from both groups had good category. However, it still unexplained whether stunted and non-stunted children have zinc deficiency because there is no biochemical markers data available.

The average of PA:Zn molar ratio value for both groups is considered into moderate category. According to the WHO & FAO (2004), if the PA:Zn molar ratio value is ranging from 5 – 15 % with diet type is a mixed diet, then percentage estimation for absorbed zinc will be 30 %. Thus, the zinc absorbed in the stunted group was 1.15 ± 0.56 mg and non-stunted group was 1.2 ± 0.62 mg.

CONCLUSION

In conclusion, energy, protein, and phytate intake are significantly different between stunted and non-stunted groups in Malang city, East Java. Most of stunted and non-stunted children have high PA:Zn molar ratio values (<5) because both groups consume sufficient amounts of zinc from chicken, egg, and meatballs. Further research can be performed to observe the influence of PA:Zn molar ratio on stunted children by analyzing biochemical markers to detect the presence of zinc deficiency. This study can be a consideration for policymakers regarding reducing stunting and infant and young child feeding, especially the adequacy nutritient intake in stunting risk population.

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