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Relationship between macro- and micronutrient intakes with undernutrition among toddlers aged 12-23 months in Aceh, Indonesia

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ABSTRACT

Introduction: Foods consumed contain macro- and micronutrients necessary for the growth and development of children. This study aimed to analyse the relationship between macronutrient and micronutrient intakes with undernutrition in toddlers aged 12-23 months. **Methods:** This cross-sectional study was conducted in 18 Integrated Healthcare Centres *(Posyandu)* in Simpang Tiga, Aceh Besar Regency. A total of 138 toddlers were selected using simple random sampling technique. Data collected included family demographics, characteristics, nutritional status of children, and food consumption for macro- and micronutrient intake analyses. **Results**: Prevalence of malnutrition in toddlers was relatively high – severe underweight and underweight totaled 23.2%, severe wasting and wasting 18.1%, and severe stunting and stunting 27.5%. Significant associations (p<0.05) were found between underweight and intakes of energy, protein, carbohydrates, fat, calcium, phosphorus, zinc, thiamin, and niacin. Wasting was significantly associated (p<0.05) with intakes of energy, protein, and vitamin A. Stunting was significantly associated (p<0.05) with intakes of energy, protein, carbohydrates, fat, calcium, phosphorus, iron, calcium, zinc, vitamin A, thiamine, riboflavin, niacin, and vitamin C. **Conclusion**: Certain macro- and micronutrient intakes were correlated with undernutrition in toddlers. The results of this study can be used as a reference for planning the development of supplementary feeding programmes for children aged 12-23 months, considering that the critical period of child growth and development is in the first 1000 days of life.

Keywords: macronutrient intake, micronutrients, toddlers, undernutrition

INTRODUCTION

The World Health Organisation (WHO) defines malnutrition as a condition of cellular imbalance between the supply of energy and nutrients that the body needs to ensure growth, nutrition, and certain functions (deOnis, 2015). Currently, nutritional problems in Indonesia is still one of the serious issues in the field of public health. In 2018, the prevalence of stunting in Indonesia was 30.8%, with underweight and wasting rates at 17.7% and 6.7%, respectively. Stunting is a serious public health problem, while underweight and wasting are considered moderate problems (Balitbangkes, 2018).

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Aceh is one of the provinces in Indonesia with a high undernutrition rate and has the tenth highest underweight rate at 23.5% (Balitbangkes, 2018). The results of the Indonesian Toddler Nutrition Status Survey in 2021 showed that the prevalence of undernutrition in Aceh Besar Regency was relatively high, reaching 29.0% (MOH RI, 2021). The WHO defines the prevalence of undernutrition (with a *z*-score below -2 SD) at 20-29% as a critical public health problem that must be addressed immediately (WHO, 1995). Indonesia has 8.05% of its total population of 276.4 million aged <5 years. This shows that this generation determines Indonesia's future development.

During the toddler years, brain growth accelerates dramatically, making it a critical phase. The reason is because neural cells in the brain are growing fast, with branching speeds of up to a thousand per second. As a result, children beyond the age of two who experience developmental delays are often challenging to treat or cure (Prado & Dewey, 2014). Undernutrition is a particular concern for toddlers since it can cause short-term physical health problems, affecting growth and nutritional status, as well as long-term psychological health problems, impacting cognitive, mental, and psychomotor developments (Kristjansson, 2016). According to Grantham-McGregor *et al.* (2007), undernourished toddlers are most likely associated with permanent physiological and metabolic changes that result in impairment of the child's physical and intellectual developments in the future.

Macro- and micronutrients required for children's growth and development are found in the foods they consume. Each age has its own nutritional needs (Savarino *et al.,* 2021). Macronutrients, including carbohydrates, proteins, and fats, are the main energy supply for humans. They can be considered as the main components of different tissues and represent the total amount of caloric intake (Carreiro *et al.,* 2016). In addition, micronutrients are components of intake that do not contribute significantly to caloric intake, but can still be considered essential for health and vital functions, even if only required in smaller amounts. Adequate nutrition ensures physiological growth and prevents disease. Both macronutrients and micronutrients are essential for proper and balanced child nutrition. In addition, micronutrients are also essential because the lack of one of these nutrients can have significant consequences, such as disrupting growth, delaying maturity, or causing deficiency diseases such as rickets, scorbutus, and cretinism (Savarino *et al.,* 2021).

Many studies have been conducted regarding malnutrition and nutritional intake in children aged 6-23 months (Lewa *et al.,* 2019; Limardi *et al.,* 2022; Sewenet *et al.,* 2022); however, there are still limited studies that focus specifically on children aged 12-23 months. When children reach the age of 12-23 months, there is a transition in providing complementary feeding (CF) from porridge to family food. As a result, feeding problems and malnutrition are common while children's nutritional needs are increasing (WHO, 2009). Providing optimal and age-appropriate complementary foods will affect children's nutritional intake and determine whether or not they accept healthy meals (WHO, 2009). Therefore, this study aimed to analyse the relationship between macronutrient and micronutrient intakes with undernutrition in children aged 12-23 months.

MATERIALS AND METHODS

This cross-sectional study was conducted in Aceh Besar Regency, Indonesia, from

June to July 2023. Using simple random sampling, a total of 138 mothers and toddlers from 18 *Posyandu* in the working area of Public Health Centre *Simpang Tiga,* Aceh Besar Regency, Indonesia, were chosen to participate in this study. The number of samples was calculated with a 95% confidence interval and 10% absolute precision, with the proportion of malnourished children under five in Aceh at 29% (MOH RI, 2019). Public Health Centres *(Puskesmas)* with high frequency of underweight toddlers were purposively selected. Furthermore, all *Posyandu* that were available in the working area of *Puskesmas Simpang Tiga* were chosen. Toddlers between the ages of 12 and 23 months were the target subjects for this study. To be eligible to participate, they had to be willing to participate and not be ill at the time of the study.

Data were collected through interviews using a structured questionnaire for family characteristics (parents' age, occupation, education, income, and total number of children in the family) and child characteristics (gender, weight, birth weight, immunisation status). Food consumption data were collected using a 2x24-hour food recall questionnaire to find out data on macro- and micronutrient intakes. In order to assess the nutritional status of toddlers, anthropometric measurements were conducted to measure their body weight and body length. Body weight measurements were carried out using digital scales that have been calibrated first. Mother's weight was subtracted from the combined weight of the child and mother to determine the child's weight. Meanwhile, body length measurements were carried out using a multifunctional measuring instrument, with an accuracy of 0.1 cm. The final body weight and body length measurements were identified from the average value of the child's measurements done twice.

The obtained data were initially verified by a number of processes including entry, coding, cleaning, and analysis. The assignment of numbers or codes made data entry into computers quicker. This process is known as coding. Data entry involved inputting survey answers, as well as additional information that have been identified as primary data for each variable. To ensure that the information gathered were accurate, cleaning was done. Each variable was analysed once the data were processed and examined. Data processing and analysis were done using Microsoft Office Excel 2010 software (Microsoft Corporation, Redmond, Washington, USA) and IBM SPSS Statistics for Windows version 21.0 (IBM Corporation, Armonk, New York, USA). The relationship between toddlers' nutritional status with their macro- and micronutrient intakes was examined using the Spearman's Rank Correlation Test at a 95% confidence level.

Before the collection of data, respondents were given information about the study and a consent form indicating their willingness to participate. An informed consent form was given to respondents to complete and sign. This research was approved by the Ethics Commission of the Research and Community Service Institute at Health Polytechnic of Aceh, Ministry of Health, Aceh (No reference: Dp.04.03/12.7/078/2023).

RESULTS

Data from a total of 138 respondents were successfully collected. Data on family characteristics were obtained from mothers or respondents who had toddlers aged 12-23 months. Socioeconomic characteristics data collected included father's and mother's age, education, job, income, family size, and number of children under five.

Table 1 showed that the average age of fathers was 35 years old and mothers was 30 years old. More than half of the fathers and mothers had a high school education. Most of the mothers did not work or were only a housewife (81.9%), while the fathers worked as construction workers, tailors, drivers, and other

Table 1. Sociodemographic and socioeconomic characteristics of families

Family demographic characteristics	*n*	%
Father's age (years)		
≤24	3	2.2
25-28	27	19.7
29-32	28	20.4
≥33	80	57.9
Mother's age (years)		
≤24	19	13.8
25-28	39	28.3
29-32	18	13.0
≥33	61	44.2
Number of children under five (person)		
≤1	122	88.4
>1	16	11.6
Mother's education		
≤Elementary School	10	7.2
Junior High School	15	10.9
Senior High School	78	56.5
University	35	25.4
Father's education		
≤Elementary School	10	7.2
Junior High School	15	10.0
Senior High School	78	56.5
University	35	25.4
Father's occupation		
Entrepreneur	25	19.5
Civil servant	9	6.5
Farmer/Fisherman	27	19.6
Construction labourer	15	10.9
Service/Driver	60	43.5
Mother's occupation		
Not working/Housewife	113	81.9
Working	25	18.1
Family size (person)		
Small (≤4 people)	91	65.9
Medium (5-6 people)	43	31.2
Large (≥7 people)	4	2.9
Family income (IDR/month)†		
≤Regional minimum wage 3,413,000	112	81.1
>Regional minimum wage 3,413,000	26	35.4

†1 US dollar =16,095 IDR (as of May 14, 2023)

Table 2. Characteristics of toddlers

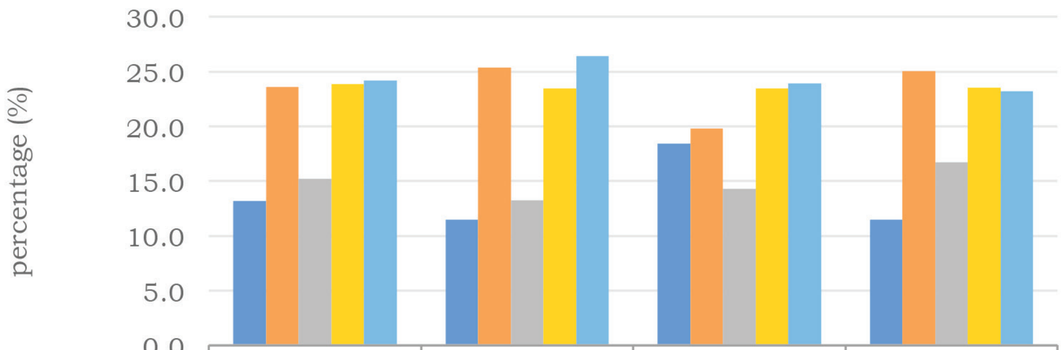
Variables	*n*	%
Age (months)		
12-18	76	55.0
19-23	62	44.9
Gender		
Boy	83	60.1
Girl	55	39.9
Birth weight (g)		
Low birth weight (≤2500)	1	0.7
Normal (>2500)	137	99.3
Immunisation status		
Complete	101	73.2
Not complete	37	26.8
WAZ status		
Severe underweight	2	1.5
Underweight	30	21.7
Normal	106	76.8
HAZ status		
Severe stunting	10	7.2
Stunting	28	20.3
Normal	100	72.5
WHZ status		
Severe wasting	5	3.6
Wasting	20	14.5
Normal	105	76.1
Overweight /obesity	8	5.8

WAZ: Weight-for-age; HAZ: Height-for-age; WHZ: Weight-for-height

related jobs. The average family income was Rp. 2,595,564 or below the standard Regional Minimum Wage. The average total number of family members was four, with an average of one toddler.

The characteristics of toddlers that were collected included age, gender, birth weight, immunisation status, and nutrition status. The subjects in this study were 12-23 months old and more than half of them were 12-18 months old (55.0%). Table 2 showed that a significant proportion of toddlers in the study areas were males (60.1%), had no history of low birth weight (99.3%), and were fully immunised (73.2%). Data on malnutrition in toddlers were measured using the indices of weight-for-age (WAZ), weight-for-height (WHZ), and height-for-age (HAZ). The average values for WAZ, WHZ, and HAZ indicators obtained from the analysis of z-scores were -1.15±1.20, -0.90±1.87, -0.95±1.18. Table 2 showed that the prevalence of malnourished children was relatively high, with severe underweight and underweight amounting to 23.2%, severe wasting and wasting 18.1%, and severe stunting and stunting 27.5%. Overweight or obesity, also a form of malnutrition based on weight-for-length indicator, was 5.8%.

Table 2 showed that children aged 12-23 months had energy intakes below the nutritional adequacy level, with an average energy intake of 836 kcal/day, while the recommended nutritional adequacy level was 1350 kcal/day. The average macronutrients intake, which included protein, reached the recommended level (25 g/day), while fat



	Energy	Proteins	Fat	Carbohydrate
breast milk	13.2	11.5	18.4	11.5
breakfast	23.6	25.4	19.8	25.1
snack	15.2	13.2	14.3	16.7
lunch	23.8	23.5	23.5	23.5
dinner	24.2	26.4	23.9	23.2

Figure 1. Contribution of mealtime to total energy and macronutrient intakes (%)

and carbohydrates (CH) were below the recommended levels (31.7 g/day and 106.4 g/day, respectively). The average micronutrients intake of toddlers did not meet the adequate daily intakes of zinc (1.6 g/day), calcium (387 mg), sodium (298 mg), potassium (733.9 mg), iron (1.6 g), thiamin (0.4 mg), vitamin A (205 RE), and vitamin C (16.1 g).

The nutritional intake of toddlers in this study was determined from the contributions of breast milk and complementary feeding intake, as shown in Figure 1. The intake of complementary feeding was calculated from the contribution of mealtime to energy and nutrients. This study only presented the contribution of mealtime to total energy and macronutrients. The contributions of macronutrient adequacy level from breast milk were 13.2% energy, 11.5% protein, 18.4% fat, and 11.5% carbohydrates, while the contributions of complementary feeding were 86.8% energy, 88.5% protein, 81.6% fat, and 88.5% CH. It can be seen from Figure 1 that the contribution of mealtime to total energy was mostly at dinner time (24.2%), followed by lunch (23.8%), breakfast 23.6%, and snack 15.2%. Meanwhile, the contribution of mealtime to total protein was mainly at dinner time (26.4%), followed by breakfast (25.4%) and lunch (23.5%), and finally, snack (13.2%). The contribution of mealtime to total fat was mainly at dinner (23.9%), followed by lunch (23.5%), breakfast (19.8%) and snack (14.3%). The contribution of mealtime to total carbohydrates was mainly at breakfast (25.1%), followed by lunch 23.5%, dinner 23.2%, and snack 16.7%.

The results of the association analysis (Table 4) showed that macronutrient intakes, such as energy, protein, fat, and carbohydrates, were significantly related to underweight, stunting, and wasting; only fat intake was not significantly related to wasting (p=0.113). Macronutrient intakes

Table 3. Proportion of macro- and micronutrient intakes according to type of undernutrition

Nutrition adequacy level (%RDA)	*Underweight*		*Wasting*		*Stunting*	
	Yes (n=32) n (%)	*No (n=106) n (%)*	*Yes (n=25) n (%)*	*No (n=113) n (%)*	*Yes (n=38) n (%)*	*No (n=100) n (%)*
Energy						
Severe deficit (<80)	32 (100)	93 (87.7)	24 (18.7)	101 (89.4)	37 (97.4)	88 (88.0)
Mild deficit (80-89)	0 (0.0)	8 (7.5)	1 (14.3)	7 (6.2)	1 (2.6)	7 (7.0)
Normal (>89)	0 (0.0)	5 (4.8)	0 (0.0)	5 (4.4)	0 (0.0)	5 (5.0)
Protein						
Severe deficit (<80)	25 (78.1)	22 (20.8)	13 (52.0)	34 (30.1)	20 (52.6)	27 (27.0)
Mild deficit (80-89)	3 (9.4))	17 (16.0)	1 (4.0)	19 (16.8)	5 (13.2)	15 (15.0)
Normal (>89)	4 (12.5)	67 (63.2)	11 (44.0)	60 (53.1)	13 (34.2)	58 (58.0)
Fat						
Severe deficit (<80)	30 (93.8)	63 (59.4)	18 (72.0)	75 (66.4)	32 (84.2)	61 (61.0)
Mild deficit (80-89)	1 (3.1)	8 (7.5)	1 (4.0)	8 (9.0)	1 (2.6)	8 (8.0)
Normal (>89)	1(3.1)	35 (33.0)	6 (24.0)	30 (26.5)	5 (13.2)	31 (31.0)
Carbohydrate						
Severe deficit (<80)	32 (100)	103 (97.2)	25 (100)	110 (97.3)	38 (100)	97 (97.0)
Mild deficit (80-89)	0 (0.0)	1 (0.9)	0 (0.0)	1 (0.9)	0 (0.0)	1 (1.0)
Normal (>89)	0 (0.0)	2 (1.9)	0 (0.0)	2 (1.80	0 (0.0)	2 (2.0)
Calcium						
Deficit (≤77)	30 (93.8)	79 (74.5)	19 (76.0)	90 (79.6)	34 (89.5)	75 (75.0)
Normal (>77)	2 (6.3)	27 (25.5)	6 (24.0)	23 (20.4)	4 (10.5))	25 (25.0)
Sodium						
Deficit (≤77)	32 (100)	100 (94.3)	23 (92.0)	109 (96.5)	37 (97.4)	95 (95.0)
Normal (>77)	0 (0.0)	6 (5.7)	2 (8.0)	4 (3.5)	1 (2.6)	5 (5.0)
Phosphorus						
Deficit (≤77)	16 (50.0)	29 (27.4)	8 (32.0)	37 (32.7)	15 (39.5)	30 (30.0)
Normal (>77)	16 (50.0)	77 (72.6)	17 (68.0)	76 (67.3)	23 (60.5)	70 (70.0)
Zinc						
Deficit (≤77)	11 (34.4)	6 (5.7)	2 (8.0)	15 (13.3)	12 (31.6)	5 (5.0)
Normal (>77)	21 (65.6)	100 (94.3)	23 (92.0)	98 (86.7)	26 (68.4)	95 (95.0)
Iron						
Deficit (≤77)	29 (90.6)	79 (74.5)	20 (80.0)	88 (77.9)	34 (89.5)	74 (74.0)
Normal (>77)	3 (9.4)	27 (25.5)	5 (20.0)	25 (22.1)	4 (10.5)	26 (26.0)
Vitamin A						
Deficit (≤77)	30 (93.8)	88 (83.0)	21 (84.0)	97 (85.8)	34 (89.5)	84 (84.0)
Normal (>77)	2 (6.3)	18 (17.0)	4 (16.0)	16 (14.2)	4 (10.5)	16 (16.0)
Thiamin						
Deficit (≤77)	31 (96.9)	50 (47.2)	17 (68.0)	64 (56.6)	32 (84.2)	49 (49.0)
Normal (>77)	1 (3.1)	56 (52.8)	8 (32.0)	49 (43.4)	6 (15.8)	51 (51.0)
Riboflavin						
Deficit (≤77)	12 (37.5)	19 (17.9)	6 (24.0)	25 (22.1)	13 (34.2)	18 (18.0)
Normal (>77)	20 (62.5)	87 (82.1)	19 (76.0)	80 (77.9)	25 (65.8)	82 (82.0)
Niacin						
Deficit (≤77)	8 (25.0)	8 (7.5)	4 (16.0)	12 (10.6)	7 (18.4)	9 (9.0)
Normal (>77)	24 (84.0)	98 (92.5)	21 (84.0)	101 (89.4)	31 (81.6))	91 (91.0)
Vitamin C						
Deficit (≤77)	27 (84.4)	89 (84.0)	21 (84.0)	95 (84.1)	36 (94.7)	80 (80.0)
Normal (>77)	5 (15.6)	17 (16.0)	4 (16.0)	18 (15.9)	2 (5.3)	20 (20.0)

Table 4. Nutrient intake and its relationship with undernutrition of toddlers

Nutrient intake	*Mean*	*SD*	*%RDA*	*Underweight (p-value)*	*Stunting (p-value)*	*Wasting (p-value)*
Energy (kcal)	836	171	61.9	<0.001**	<0.001**	0.004**
Carbohydrate (g)	106.4	23.0	49.5	<0.001**	<0.001**	0.049*
Protein (g)	25.0	7.7	96.2	<0.001**	<0.001**	0.006**
Fat (g)	31.7	12.7	70.5	<0.001**	0.010**	0.113
Calcium (mg)	387.0	241.2	59.5	0.061	0.001*	0.826
Phosphorus (mg)	474.1	158.8	103.0	0.017*	0.035*	0.114
Iron (mg)	4.3	1.3	62.1	0.011*	0.040*	0.072
Sodium (mg)	298.4	158.8	37.3	0.042*	0.489	0.066
Potassium (mg)	733.9	232.5	28.2	0.002**	<0.001**	0.632
Zinc (mg)	1.6	1.2	54.9	<0.001**	<0.001**	0.158
Vitamin A (RE)	205.6	119.7	51.4	0.517	0.042*	0.047*
Vitamin B1 (mg)	0.4	0.1	74.3	0.006**	0.005**	0.066
Vitamin B2 (mg)	0.6	0.4	134.6	0.104	0.024*	0.847
Vitamin B3 (mg)	7.2	2.8	120.9	0.002**	0.031*	0.086
Vitamin C (mg)	16.6	16.1	40.4	0.109	0.006**	0.796

Spearman's Rank Correlation Test; $*p<0.05$&$**p<0.01$

associated with underweight included energy, carbohydrates, protein, and fat, while micronutrient intakes included phosphorus, sodium, calcium, zinc, vitamin B1 or thiamine, and B3 or niacin. In stunting, macronutrients that were significantly related were energy, carbohydrates, protein and fat, while micronutrients included calcium, phosphorus, iron calcium, zinc, vitamin A, vitamin B1 or thiamine, vitamin B2 or riboflavin, vitamin B3 or niacin, and vitamin C. For wasting, macronutrients that were significantly related were energy, carbohydrates, and protein, while fat was not significantly related. The only micronutrient that was significantly associated with wasting was vitamin A.

DISCUSSION

A child who has a body weight that is low for his/her age is called underweight, a height that is too short for age is called stunting, and a body weight that is low for height is called wasting (Sguassero *et al.,* 2012). Height and weight are the most commonly used indicators of nutritional status among toddlers. According to WHO, appropriate HAZ reflects a child's linear growth and can measure long-term growth faltering or stunting, while appropriate WHZ reflects proper body proportion or the harmony of growth. WHZ is particularly sensitive to acute growth disturbances and is useful to detect the presence of wasting. WAZ represents a convenient synthesis of both linear growth and body proportion, thus can be used for the diagnosis of underweight children. Undernutrition is a condition in which a child has a body weight below normal standards; based on WHO standards, a toddler is said to be undernourished if the z-score value of WAZ or WHZ is between -2SD to >-3SD. WHO classifies the problem of moderate malnutrition as underweight (WAZ, Z-3.0 SD to <-2.0 SD), wasting (WHZ, Z-3.0 SD to <-2.0 SD), less upper arm circumference or LUAC (<125 mm), and stunting (HAZ, Z-3.0 SD to <-2.0 SD) (WHO, 2012).

The growth rate in a child's first two years of life is lower than in the first year of life (WHO, 2009). In the first year, a child's weight increases threefold, reaching an average of 9.5 kg and length increases by 25%. By the second year, the child weighs about 12.0 kg in males and 11.5 kg in females, with an average increase of 25% in the second year. Length increases by an average of 15% in both boys and girls. From ages 12 to 24 months, children are called toddlers because there are changes in body composition, reduction of subcutaneous tissue, increases in weight and length, maturation of all organs, and development of new neurocognitive and motor functions.

It is advised that children consume a balanced diet that contains a variety of foods from each of the food groups, including flour and cereals, vegetables and fruits, dairy products, meat and alternative meats, as well as fats and sugars (Schönfeldt & Hall, 2012). The diet of toddlers is outlined in the guidelines for child feeding practices (WHO, 2009), with a recommended frequency of three main meals, 1-2 snacks, and breastfeeding as desired by the child. According to the Ministry of Health Republic of Indonesia (MOH RI, 2023), the percentage of toddlers' needs from breast milk is 30%, while from complementary feeding is above 70%. Therefore, providing a balanced intake of breast milk, meals (breakfast, lunch and dinner), and snacks will determine the adequacy of macro- and micronutrient intakes in toddlers.

The energy intake of toddlers in the study was close to the results of the South East Asian Nutrition Survey (SEANUTS) study in Indonesia, showing that more than half of the children had nutritional intake below the recommended dietary allowance (RDA), with an average energy intake of only 840 kcal/day in children aged 6-23 months (Sandjaja *et al.,* 2013). A study conducted in Aceh on toddlers aged 12-23 months had an average energy intake of 584 kcal per day (Suryana *et al.,* 2016). Toddlers need high energy and nutrient intakes because intakes of these nutrients from breast milk begins to decrease as they enter the age of 12-23 months; breast milk is only able to fulfil energy needs ≤50%, so more intake is needed from complementary feeding (WHO, 2009). Infants and toddlers need energy from food for activities, growth, and normal development (EFSA, 2017).

Inadequate energy intake leads to various physiological adaptations, including growth restriction, loss of fat, muscle, and visceral mass, decreased basal metabolic rate, and reduced total energy expenditure (Dipasquale *et al.,* 2020). Pathophysiological mechanisms in acute malnutrition involve metabolic, hormonal, and glucoregulatory mechanisms. In the initial phase, there is rapid gluconeogenesis, with consequent loss of skeletal muscle due to amino acid, pyruvate, and lactate utilisation. There is then a phase of protein conservation, with fat mobilisation causing lipolysis and ketogenesis, including major changes in electrolyte content, such as sodium retention and intracellular potassium depletion (Grover & Ee, 2009).

The results of this study implied that the intake of macronutrients and micronutrients is important to overcome the problem of undernutrition in children. A child with macronutrient deficiency is more likely to become stunted (Fikawati *et al.* 2021). Inadequate consumption of protein and energy can cause children to experience micronutrient deficiencies (Pem, 2015). Intakes of energy, protein, fat, carbohydrates, calcium, phosphorus, iron, potassium, zinc, vitamin A, thiamine, riboflavin, niacin, and vitamin C are factors associated with stunting. Low energy and protein intake is a risk factor for stunting in children, with a 4-6 times risk of being stunted compared to children with normal or adequate intake (Nguyen *et al.,* 2020).

The carbohydrate adequacy for children aged 1-3 years, as determined in the Indonesian RDA, is 215 g/day (MOH, 2019). Another recommendation for carbohydrate intake in children aged >1 year is suggested to be around 130 g/day, which is estimated to be sufficient to reach the glucose needs of a child's brain, according to the European Food Safety Authority (EFSA, 2017). An intake of 50 to 100 gram per day will prevent ketosis (EFSA, 2017). Study results from Nguyen *et al.* (2020) showed that carbohydrate intake or its subtypes in early childhood was not associated with body composition, but higher carbohydrate intake in infancy, especially monosaccharides and disaccharides, were associated with higher triglyceride levels and lower high-density lipoprotein (HDL). However, a previous study by Sawe & Keino (2022) found that underweight, wasted, and stuntied children had lower levels of carbohydrate consumption.

Protein-energy malnutrition can damage several human tissues, such as the brain, immune system, and intestinal mucosa (Grover & Ee, 2009). Protein deficiency in infants and toddlers not only causes growth impairment and increases the risk of infectious diseases, but also contributes to other nutrient deficiencies (including vitamin A and iron) and deteriorates their metabolic profiles (Wu, 2016). On the contrary, excessive protein intake (>15%E) appears to be associated with the risk of overweight or obesity in adulthood, which may also increase the risk of developing chronic diseases (Lagstro *et al.,* 2013). A protein intake of 15% is recommended as an upper limit in children aged 12 months, as there is no risk of protein intake being too low at this level, but there may be an increased risk of being overweight in the future with higher intakes.

Fats are an essential source of solid energy and facilitate the absorption of fat-soluble food components such as vitamins (EFSA, 2017). Fats and oils are also important sources of essential fatty acids. It is vital to consider the quality of fat rather than the amount of fat in the consumption of fat among toddlers. In early childhood, the quality of fat consumed is more important than the quantity (Savarino *et al.*, 2021). Fat intake is very important in the first two years of age to support brain growth and development (Savarino *et al.*, 2021). The high fat intake of infants during the breastfeeding period can be reduced progressively from the beginning of complementary feeding until the age of three years. Total fat intake for infants aged 6-12 months is 40%, while at 2-3 years of age is 35-40%. Fat intake below 25% is associated with low vitamin levels in some toddlers (EFSA, 2017). The consumption of relatively excessive fat in toddlers does not promote overweight and obesity, as measured by the adiposity index at a later age.

Micronutrients are an important part of the intake of infants and toddlers. The necessity of most micronutrients increases with increasing age of the child. A stable supply of vitamins and minerals from the diet is necessary for optimal growth and function. Micronutrients are dietary components that do not contribute significantly to caloric intake, but are essential for health and vital functions. Micronutrients are required in smaller amounts, but deficiencies can have serious consequences (Carreiro *et al.,* 2016).

Nutrition has a crucial impact on a child's growth, especially in infants and children. Optimal growth requires a proper diet so that macronutrient and micronutrient intakes are well fulfilled. Macronutrients are compounds that humans consume in large amounts, including carbohydrates, proteins and fats; while micronutrients are needed in small amounts and are essential for children's growth, especially zinc, iron, and vitamin B (Savarino *et al.,* 2021). The intake of microminerals, such as vitamins and minerals, in underweight, wasted, and stunted children generally comes from vegetables and fruits. However, a previous study has shown that underweight, wasted, and stunted children have lower intake of vegetables and fruits (Khan *et al.,* 2022). A study conducted in Zambia found that micronutrient deficiencies in undernourished children were associated with intake of B vitamins, which are biotin, vitamin B12, folate, niacin, pantothenic acid, vitamin B6, riboflavin, and thiamin (Titcomb *et al.,* 2018). In addition, low iron consumption was found in underweight children (Sawe & Keino, 2022). Adequate iron intake with zinc can affect nutritional status and significantly changes a child's height (Alfonso Mayén *et al.,* 2022). Zinc and vitamin A intakes are correlated with children's nutritional status, such as underweight and stunting.

This research has limitations in collecting data on nutritional intake of toddlers. The collection of food consumption data in this study relied on the food recall method. It is known that this method is limited by the mother's memory to provide information related to her toddler's food consumption. Thus, data collection for this research used tools from food photo books (Ministry of Health) and trained enumerators to minimise data bias.

CONCLUSION

This study showed the relationships between undernutrition among toddlers and intakes of energy, macronutrients, and micronutrients. The high prevalence of malnutrition and low intake of macronutrients (except protein) and micronutrients in children aged 12-23 months indicated that there is a need for attention from parents and the government to improve the food consumption of toddlers to increase balance and diversity in terms of both quality and quantity. The results of this study can be used as a reference for planning the development of supplementary food programmes for children aged 12-23 months as the critical period of child growth and development is in the first 1000 days of life.

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Authors' contributions

Marliyati SA, writing and original draft preparation, conceptualised and reviewed the manuscript; Suryana, writing and original draft preparation, data analysis and interpretation, reviewed the manuscript; Khomsan A, data analysis and interpretation, review and editing, supervision; Dwiriani CM, methodology, review and editing, supervision. All authors discussed the results and contributed to the final manuscript.

Conflict of interest

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

References

Alfonso MV, Ogunlusi A, Wright CM & Garcia AL (2022). Childhood stunting and micronutrient status unaffected by RCT of micronutrient fortified drink. *Matern Child Nutr* 18(1):1-10.

Balitbangkes (2018). *Basic Health Research, Aceh Province Report. Institute for Health Research and Development.* Ministry of Health Republic of Indonesia, Jakarta.

Carreiro AL, Dhillon J, Gordon S, Higgins KA, Jacobs AG, McArthur BM, Redan BW, Rivera RL, Schmidt LR & Mattes RD (2016). The macronutrients, appetite, and energy intake. *Annu Rev Nutr* 17 (36):73-103.

deOnis M (2015). The who child growth standards. *World Rev Nurt Diet* 113:278-294.

Dipasquale V, Cucinotta U & Romano C (2020). Acute malnutrition in children:Pathophysiology. *Nutrients* 12(8):2-9.

EFSA (2017). *Dietary Reference Values for Nutrients Summary Report.* From: https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/sp.efsa.2017.e1511 [Retrieved September 4 2019].

Lewa AF, Kusika SY, Muliani, Rahmawati & Jannah I (2019). Risk factors of stunting event in child 6-23 month old in Biromaru Public Health Center Sigi. *Enfermeria Clinica* 3(suplement 4):131-135.

Fikawati S, Syafiq A, Ririyanti RK & Gemily SC (2021). Energy and protein intakes are associated with stunting among preschool children in Central Jakarta, Indonesia: a case-control study. *Mal J Nutr* 7(1):81-91.

Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L & Strupp B (2007). Child development in developing countries 1 developmental potential in the first five years for children in developing countries. *Lancet 369*: 60-70.

Grover Z & Ee LC (2009). Protein energy malnutrition. *Pediatr Clin North Am* 56(5):1055-1068.

MOH RI (2023). *Technical Guidelines for Supplementary Food Provision made from local food for toddlers and pregnant women.* Ministry of Health Republic of Indonesia, Jakarta.

MOH RI (2019). *Regulation of Minister of Health Republic Indonesia No.28 in 2019 on Recommended Nutritional Adequacy for Indonesian People.* Ministry of Health of the Republic of Indonesia, Jakarta.

MOH RI (2021). *Pocket Guide to the Results of the Study on the Status of Nutrition in Indonesia at the National, Provincial and District/City.* Ministry of Health of the Republic of Indonesia, Jakarta.

Khan DSA, Das JK, Zareen S, Lassi ZS, Salman A, Raashid M, Dero AA, Khanzada A & Bhutta ZA (2022). Nutritional status and dietary intake of school-age children and early adolescents: systematic review in a developing country and lessons for the global perspective. *Fronti Nurt* Front 8(39447):1-18.

Kristjansson E (2016). Supplementary feeding for improving the health of disadvantaged infants and children what works and why *? Systematic Review Summary 5* (pp. 1-53). International Initiative for Impact Evaluation (3ie), London.

Lagstro H, Lande B & Thorsdottir I (2013). Protein intake from 0 to 18 years of age and its relation to health: a systematic literature review for the 5th Nordic Nutrition Recommendations. *Food Nutr Res* 21803 (57):1-43.

Limardi S, Hasanah DM & Utami NMD (2022). Dietary intake and stunting in children aged 6-23 month in rural Sumba, Indonesia. *Paediatr Indones* 62:341-356.

Nguyen AN, Santos S, Braun KVE & Voortman T (2020). Carbohydrate intake in early childhood and body composition and metabolic health: Results from the generation R study. *Nutrients* 12(7):1-11.

Pem D (2015). Factors affecting early childhood growth and development : golden 1000 days advanced practices in nursing. *Adv Practice Nurs* 1(1):1-4.

Prado E L & Dewey KG (2014). Nutrition and brain development in early life. *Nutrition Reviews* 72(4):267-284.

Sandjaja S, Budiman B, Harahap H, Ernawati F, Soekatri M, Widodo Y, Sumedi E, Rustan E, Sofia G, Syarief SN & Khouw I (2013). Food consumption and nutritional and biochemical status of 0·5-12-year-old Indonesian children: The SEANUTS study. *Br J Nutr* 110(3):S11-20.

Savarino G, Corsell A & Corsello G (2021). Macronutrient balance and micronutrient amounts through growth and development. *Italian Journal of Pediatrics* 47(1):1-14.

Sawe C & Keino S (2022). Tripartite of malnutrition: co-existence of underweight, overweight and micronutrient deficiency among children in Kisumu County, Kenya. *Curr Dev Nutr* 6:71-75.

Sewenet T, Selassie MW, Zenebe Y, Yimam W, Woretaw L (2022). Undernutrition and associated factors among children aged 6-23 months in Dessie Town, Northeastern Ethiopia:, 2021: A community based cross-sectional study: *Front Pediatr* 10:916726.

Schönfeldt HC & Hall NG (2012). Dietary protein quality and malnutrition in Africa. *Br J Nutr* 108(2):S69-76.

Suryana, Madanijah S, Sukandar D (2016). Prevalence and factors associated with anaemia in children aged 12-24 months in Darul Imarah Sub-District Aceh Besar District. *Pakistan J Nutr* 15(8):708–714.

Titcomb TJ, Schmaelzle ST, Nuss ET, Gregory JF & Tanumihardjo SA (2018). Suboptimal vitamin B intakes of Zambian preschool children: Evaluation of 24-hour dietary recalls. *Food Nutr Bull* 39(2):281-289.

WHO (2009). *Infant and Young Child Feeding: Model Chapter for Text Books for Medical Students and Allied Health Professionals*. World Health Organization, Geneva.

WHO (1995). *Physical Status: The Use and Interpretation of Anthropometry*. WHO Technical Report Series, Geneva.

WHO (2012). *Technical note: Supplementary Foods For The Management Of Moderate Acute Malnutrition In Infants And Children 6–59 Months Of Age.* World Health Organization, Geneva.

Wu G (2016). Dietary protein intake and human health. *Food Funct* 37(3):1251-65.