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Differences in the Nutritional and Micronutrient Malnutrition Status Among Primary School Children Aged 8–13 Years in Bogor, Indonesia

Perbedaan Status Gizi dan Malnutrisi Mikronutrien pada Anak Sekolah Dasar Usia 8–13 Tahun di Bogor, Indonesia

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ABSTRACT

Background: Indonesia is experiencing a triple burden of malnutrition, defined as the coexistence of undernutrition, overnutrition, and micronutrient deficiencies. The majority of previous research has focused on the first 1000 days of life, while studies on school-age children remain limited, despite this developmental period being crucial for determining future health and well-being.
Objectives: The objective of this study is to analyze the prevalence of undernutrition, overnutrition, and micronutrient deficiencies among primary school children in Bogor, Indonesia.
Methods: This cross-sectional study included 915 fourth- and fifth-grade students who were selected for inclusion. The collected data encompassed individual characteristics, family socioeconomic status, anthropometric measurements (actual body weight, height, and skinfold thickness), and blood biomarkers. Nutritional status was assessed using BMI-for-age (BMI/A), body fat percentage (Slaughter equation), hemoglobin levels (non-cyanide method), and serum concentrations of vitamin A and B12 (Liquid Chromatography and Mass Spectrometry, LCMS).
Results: The prevalence of chronic energy deficiency was 2.4%, overnutrition (overweight and obesity) was 12.4%, and high body fat was 12.8%. Micronutrient deficiencies were prevalent, with 40.1% of subjects experiencing anemia, 18.6% exhibiting vitamin A deficiency, and 52.2% demonstrating vitamin B12 deficiency. No statistically significant differences were found in nutritional status between boys and girls, as measured by BMI/A and blood biomarkers. However, girls had significantly higher body fat percentages (p-value<0.001).
Conclusions: The prevalence of micronutrient deficiencies was found to exceed that of both undernutrition and overnutrition. Further research is needed to explore the underlying factors contributing to these nutritional issues, considering various covariates. Targeted and specific interventions are critical in order to prevent and address the triple burden of malnutrition among primary school children in Bogor, Indonesia.

INTRODUCTION

Rapid economic growth has been experienced by various countries in Southeast Asia, including Indonesia. This growth has engendered numerous positive impacts, including increased access to healthcare services, which has resulted in a reduction in child mortality rates[1]. While the survival rates of children have increased, millions continue to experience growth failure due to a combination of malnutrition (e.g, stunting, wasting, and thinness), micronutrient deficiencies, and a rising prevalence of overweight and obesity[2,3].

Globally, a decrease in the prevalence of stunting among children has been, although the issue remains unresolved. Conversely, cases of overweight and obesity surged from 2000 to 2019, with Southeast Asia registering the most substantial increase[4,5]. This region is also confronted with challenges related to micronutrient deficiencies[6,7].

Micronutrients include vitamins and minerals that, although needed in small amounts, are indispensable for optimal physical and mental growth and development, especially in the production of enzymes, hormones, and other biomarkers[8,9]. Micronutrient deficiency, often referred to as "hidden hunger," is a global health concern that affects an

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estimated two billion individuals worldwide, particularly in low- to middle-income countries. These countries often rely on staple foods, resulting in a monotonous diet and limited food variety due to poverty[10].

Anemia is a nutritional problem that persists on a global scale. Anemia is generally caused by a deficiency in micronutrients, particularly iron (Fe), and is most prevalent among children and pregnant women[11]. In addition to iron deficiency, anemia can also result from deficiencies in other micronutrients, including vitamin A, vitamin B12, and folate[12]. Deficiencies in micronutrients such as vitamin A and vitamin B12 are are recognized as global health burdens, including in Southeast Asia[13–15]. Deficiencies in vitamin A can disrupt normal hematopoiesis, interfere with metabolism and immune function, hinder growth and development, impair vision, and increase the risk of infection[16,17]. Concurrently, vitamin B12 is essential for neural tube development, growth, immunity, and cognitive function. Prolonged deficiency in vitamin B12 can lead to neurological complications[13].

Indonesia is the fourth most populous country globally in terms of children, with an estimated 80 million children[1]. Over half of these children reside in five provinces, with West Java having the highest percentage (18.6%) of children[1]. Optimizing children's nutritional status in Indonesia can be regarded as a long-term investment, with the potential to yield benefits for the country. An example of the benefits is the potential for a demographic dividend in the future, which could contribute to economic growth, enhanced competitiveness, and an overall enhancement in national welfare.

Despite a decline in malnutrition cases in Indonesia over the past decade, the nation continues to be among those with the highest rates of maternal and child nutrition issues worldwide. Furthermore, Indonesia is confronted with a triple burden of malnutrition[18], a condition where concurrent issues of undernutrition, overweight, and obesity often coexist and interrelate[4,19]. The 2022 Indonesian Nutrition Status Survey (SSGI) data indicate that 10.8% of children aged 5–12 years were classified as overweight, while 9.2% were obese. Among children aged 13–15 years, the rate reached 16%, and among those aged 16–18 years, it was 13.5%[20]. Additionally, the 2018 Indonesian Basic Health Survey data indicates that anemia in school-age children persists as a national health concern, with a prevalence exceeding 20%[21].

In recent decades, extensive research has been conducted on the first 1,000 days of life (the first two years) regarding the critical role of nutrition in early life. However, the majority of studies on nutrition have focused on children aged 2–5 years, while studies on the nutrition of school-age children (5–15 years) remain limited[22]. The school-age period is an important phase of life, characterized by various growth and developmental processes. These include transformational changes in the brain and cognitive processing, linear bone growth and bone mineralization, body composition, and the maturation of other organ systems. This period is also characterized by major sex-driven divergences, which are associated with growth and development.

Nutrition plays an essential and crucial role in this period, as it supports the many changes occurring in the body. Moreover, nutritional issues that are identified during early childhood can often be addressed during that same period. Consequently, the school-age period is significant as it signifies the final major window of opportunity to intervene in growth, development, and health status that will persist to adulthood[22]. The present study was conducted to analyze the prevalence of undernutrition, overnutrition, and micronutrient deficiencies (hemoglobin levels related to iron deficiency anemia, vitamin A, and vitamin B12) among primary school children in Bogor, West Java Province, Indonesia. This study is essential for health policy and nutrition initiatives, as it offers important insights into the nutritional issues encountered by children in Bogor. The proposed evidence-based interventions of the study are expected to enhance child health outcomes, foster economic growth in the long run, and promote the overall well-being of future generations.

METHODS

The present study was observational in nature, employing a cross-sectional design. The study was conducted in Cijeruk District, Bogor Regency, West Java Province, Indonesia. The selection of this location was purposive, as no similar studies had been conducted in this area prior to this one. Additionally, Cijeruk District is a semi-urban area, a transitional zone between urban and rural life. Previous studies were conducted in either urban or rural regions, but no studies have yet been conducted in this semi-urban area. Furthermore, the local Health Office has identified Cijeruk District as an area in need of special attention with regard to improving the nutritional status of its population. The data collection period spanned from October to December of 2019.

According to data from Statistics Indonesian (BPS) in 2019, the total population of public elementary school students in Cijeruk Subdistrict was 9,241 students. The Slovin formula was employed to calculate the minimum required sample size for this study, which was determined to be 384 students. Following the screening process, 1,017 students met the established inclusion criteria. These criteria included students in fourth and fifth grade, aged between 8 and 13 years old, in good health, without chronic illness or disability, exhibiting mental well-being, adept at communicating and cooperating, willing to provide informed assent, and willing to provide the requisite minimum blood sample for nutritional status examination, with signed informed consent from parents or guardians. During the data collection process, some students were absent, resulting in incomplete data. The final number of subjects with complete data in this study was 915 students (446 boys and 469 girls).

The study population consisted of fourth and fifth grade students, a group considered to have more developed cognitive and social abilities compared to their younger counterparts. These abilities enabled them to comprehend and follow simple instructions, such as interviews and anthropometric measurements. Moreover, children in this group tend to exhibit greater

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courage in undergoing blood draws for sampling. Sixth-grade students were excluded from the study due to their engagement in intensive preparation for their final school examinations. Sixteen public elementary schools (SDN) in Cijeruk District were selected for this study based on several criteria, which were as follows: the schools had to have fourth and fifth grade students attending morning sessions, not afternoon ones; they had to have adequate facilities to support data collection; and they had to be easily accessible by car for the safe transportation of blood samples to the laboratory.

Ethical approval was granted by the Ethics Committee of IPB University (reference number 242/IT3.KEPMSM-IPB/SK/2019, dated September 30, 2019). Blood samples were collected by a phlebotomist from the inner arm vein, and hemoglobin levels were analyzed using the non-cyanide hemoglobin method. Meanwhile, serum vitamin A and vitamin B12 levels were measured using liquid chromatography and mass spectrometry. Anthropometric data, including weight (kg), height (cm), and skinfold thickness (mm), were measured using a body weight scale (minimum reading scale of 0.1 kg), microtoise (minimum reading scale of 0.1 cm), and skinfold caliper at the triceps and subscapular sites (minimum reading scale of 1 mm), with two repetition for each measurement. A range of subject characteristics were collected through questionnaires and structured interviews with the subjects' parents. These characteristics included age, sex, daily allowance, parents' age and educational attainment, and monthly family income. The nutritional status of the subjects was determined based on anthropometric measurements to calculate body mass index (BMI) for age and body fat percentage.

The data were processed and analyzed using Microsoft Office Excel and SPSS version 16 for Windows. An analysis was conducted to calculate z-scores and determine body mass index for age (BMI-for-age) using data on weight and height. Based on BMI-for-age, subjects were grouped as follows: severely thin (<-3SD), thin (-3SD to <-2SD), normal (-2SD to +1SD), overweight (+1SD to +2SD), and obese (>+2SD)[23].

Skinfold thickness, as measured at the triceps and subscapular sites, was used to calculate body fat percentage. This calculation was performed using the Slaughter equation (1988). For girls, the equation was 1.33(triceps + subscapular) - 0.013(triceps + subscapular)^2 - 2.5. For prepubertal boys, the equation was 1.21(triceps + subscapular) - 0.008(triceps + subscapular)^2 - 1.7. For girls exhibiting triceps and subscapular thickness greater than 35mm, the following formula was employed: 0.546(triceps + subscapular) + 0.97. For boys with triceps and subscapular thickness greater than 35mm, the following formula was employed: 0.783(triceps + subscapular) + 1.724[24]. The subjects were categorized based on their body fat percentage, which was as follows: low (body fat percentage of less than 10%), normal (body fat percentage of 10–19.9% for boys and 20–29.9% for girls), slightly high (body fat percentage of 20–24.9% for boys and 30–39.9% for girls), and very high (body fat percentage greater than 25% for boys and greater than 40% for girls)[25].

Subjects between the ages of 5 and 11 were classified as non-anemic (normal) if their hemoglobin (Hb) level was greater than 11.4 g/dL. Hemoglobin levels ranging from 11 to 11.4 g/dL were classified as mild anemia, those ranging from 8 to 10.9 g/dL were classified as moderate anemia, and levels below 8.0 g/dL were classified as severe anemia. For subjects over the age of 11 years, hemoglobin (Hb) levels of 11.9 g/dL or higher were classified as normal, 11–11.9 g/dL were mild anemia, 8–10.9 were moderate, and levels below 8 g/dL were categorized as severe anemia[26]. The serum vitamin A levels of the subjects were categorized as follows: normal (serum vitamin A levels ≥300 ng/mL); marginal deficiency (200–300 ng/mL); and severe deficiency (<200 ng/mL)[27]. Serum vitamin B12 levels were considered to be within the normal range at 200 pg/mL or higher, and were classified as deficient if they were less than 200 pg/mL[28]. Univariate analysis included descriptive testing to determine the mean, standard deviation, and distribution. Bivariate analysis was conducted using Mann-Whitney and Chi-square tests to assess differences between boys and girls.

RESULTS AND DISCUSSIONS

Characteristics of the Subjects and Their Family Socioeconomic Status

Table 1 presents a comparison between male and female subjects' characteristics, encompassing age and daily allowance, along with their socioeconomic status, which included the age of both parents, the educational attainment of the parents, and the monthly household income. The subjects were fourth and fifth-grade students, with a total of 915 students, consisting of 446 male students and 469 female students. The mean age of the subjects in this study was 10.6 years, and the Mann-Whitney test showed a statistically significant difference between the ages of boys and girls (p-value<0.05). The mean daily allowance of the subjects was IDR 6,447.

The mean age of the mothers of the subjects was under 40 years, while that of the fathers was 42 years and 6 months. The majority of the subjects' parents had obtained a primary school diploma as their highest level of educational attainment, with 51.6% of the mothers and 47.0% of the fathers falling onto this category. In this study, a proportion of the parents had not received formal education, with 15.5% of the fathers and 18.1% of the mothers having never attended school. The majority of subjects hailed from households with a monthly income of less than IDR 1,500,000, with only a small percentage (approximately 6.9%) having an income above IDR 3,500,000.

Table 1. The subject's characteristics and the socioeconomic status of their family

Variable	Boys (n=446)		Girls (n=469)		All (n=915)		p-value[a]
	Mean ± SD	n (%)	Mean ± SD	n (%)	Mean ± SD	n (%)	
Age (years old)	10.7 ± 0.84		10.5 ± 0.77		10.6 ± 0.81		<0.001[b]*

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Variable	Boys (n=446)		Girls (n=469)		All (n=915)		p-value[a]
	Mean ± SD	n (%)	Mean ± SD	n (%)	Mean ± SD	n (%)	
Daily allowance (IDR)	6.130 ± 3.560		6.747 ± 3.534		6.447 ± 3.558		0.001[b]*
Mother's age (years old)	37.3 ± 6.82		36.3 ± 6.58		36.8 ± 6.71		0.019[b]*
Father's age (years old)	42.8 ± 7.80		42.2 ± 8.05		42.5 ± 7.93		0.151[b]
Mother's educational attainment							
No formal education		51 (11.4)		47 (10.0)		98 (10.7)	0.927[c]
Primary school diploma		89 (19.9)		90 (19.2)		179 (19.6)	
Secondary school diploma		229 (51.4)		243 (51.8)		472 (51.6)	
Higher education diploma		77 (17.3)		89 (19.0)		166 (18.1)	
Father's educational attainment							
No formal education		73 (16.4)		96 (20.5)		169 (18.5)	0.294[c]
Primary school diploma		89 (19.9)		85 (18.1)		174 (19.0)	
Secondary school diploma		221 (49.6)		209 (44.6)		430 (47.0)	
Higher school diploma		63 (14.1)		79 (16.8)		142 (15.5)	
Household income (IDR/ month)							
> IDR 3,500,000		23 (5.1)		40 (8.6)		63 (6.9)	0.066[c]
IDR 2,500,000–IDR 3,500,000		50 (11.2)		40 (8.5)		90 (9.8)	
IDR 1,500,000–IDR 2,500,000		101 (22.7)		128(27.2)		229 (25.0)	
< IDR 1,500,000		272 (61.0)		261 (55.7)		533 (58.3)	

SD= standard deviation, [a]Comparison test conducted between boys and girls, [b]Mann whitney test, [c]Chi-square test, significant at a p-value of <0.05.

Various studies have shown that a family's socioeconomic status is one of the significant predictors of a child's nutritional status. Food insecurity, which limits access to a diverse and nutrient-rich diet, is predominantly observed among households with lower economic status. Socioeconoic status is a contributing factor to both overnutrition and undernutrition, leading to a double or even triple burden of malnutrition. Children from food-insecure households were found to be more prone to wasting or underweight[29]. A study conducted in India revealed a correlation between socioeconomic factors and various nutritional deficiencies. Households with higher economic status tend to exhibit higher rates of overweight, while undernutrition and anemia are more prevalent in households with lower economic status. Low socioeconomic households often experience food insecurity, which results in their limited access to nutritionally adequate food and their subsequent reliance on food items with inadequate nutritional value. This predicament often leads to a deficiency in calories and nutrients. Children from these houseolds are not being well nourished, which is a key factor in the prevalence of malnutrition. On the other hand, households with higher socioeconomic status are more prone to overweight, attributable to their ample resources. These households often provide their children with processed or packaged foods that are unhealthy, high in sugar, fat, and salt[30].

In addition to poverty, maternal education is also found to be a major factor in determining the nutritional status of children. A study conducted by Gebregergis revealed that the socioeconomic status of the family, particularly the mother's educational attainment and household income or wealth, are critical factors in influencing malnutrition in children. Higher levels of maternal education engender a heightened awareness regarding the importance of utilizing healthcare services effectively during pregnancy and after childbirth. The optimal utilization of healthcare services by mothers can minimize malnutrition in children[31,32]. A study in Papua found that toddlers whose mothers have attained higher levels of education exhibited better nutritional status, indicating that mothers with advanced educational attainment have better nutritional literacy[33].

Addressing the nutritional challenges faced by children necessitates a multifaceted approach that encompasses not only socioeconomic status but also cultural practices, regional variations, and governmental policies. Empirical evidence suggests that socioeconomic determinants, including household income and maternal education, are significantly associated with nutritional outcomes in children[33]. However, additional factors, such as community characteristics and public policy frameworks, also exert a substantial influence on the nutritional status of children.

Nutritional Status of the Subjects Based on Anthropometric Measurements

As illustrated in Table 2, the nutritional status was calculated based on anthropometric measurements, including body weight, height, and skinfold thickness. A total of 2.4% of the subjects were identified as undernourished (thin and severely thin), with 1.64% of these subjects being boys and 0.76% being girls. Additionally, 12.4% of the subjects were classified as overweight or obese, with 5.46% of boys and 6.88% of girls falling within this category. These results suggest a higher prevalence of undernutrition in boys, while overweight and obesity are more commonly observed in girls. The observed differences between male and female subjects are thought to stem from their ages, which mark the onset of puberty. The pubertal period is accompanied by changes in body composition, including rapid increases in height. The onset of puberty in girls is typically earlier than in boys, with changes commencing in girls as early as age 8, whereas in boys, it generally starts around age 10. Consequently, girls experience increases in weight and height sooner than boys, with peak height velocity occurring at approximately age 12

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for girls and age 14 for boys[34]. However, the statistical test showed no significant difference in BMI-for-age status based on sex.

Low BMI-for-age, otherwise referred to as undernutrition, has serious consequences for a child's developmental, health, and overall well-being. Undernutrition can be caused by poor nutritional practices or medical disorders[35]. On the other hand, overnutrition, including both overweight and obesity, is as problematic as undernutrition, given its association with an increased risk of type 2 diabetes, hypertension, cardiovascular disease, and liver disease, which can persist into adulthood, resulting in long-term health problems and increased morbidity, and mortality[36]. Moreover, many studies have found that overweight or obesity is negatively correlated with academic performance in school.

Table 2. Nutritional status based on anthropometric measurements

Variable	Boys (n=446)			Girls (n=469)			All (n=915)			p-value[a]
	Mean ± SD	n	%	Mean ± SD	n	%	Mean ± SD	n	%	
Body mass index for age										
Severe thinness		1	0.2		0	0		1	0.1	0.111[b]
Underweight		14	3.1		7	1.5		21	2.3	
Overweight		22	4.9		30	6.4		52	5.7	
Obese		28	6.3		33	7		61	6.7	
Normal		381	85.4		399	85.1		780	85.2	
Body fat percentage (%)	16.9±6.90			19.5±4.94			18.3±6.11			
Low		35	7.8		240	51.2		275	30.1	<0.001[c*]
Slightly high		55	12.3		7	1.5		62	6.8	
Very high		55	12.3		0	0		55	6.0	
Normal		301	67.5		222	47.3		523	57.1	

SD= standard deviation, [a]Comparison test conducted between boys and girls, [b]Chi-square test, [c]Mann whitney test, significant at a p-value of <0.05.

A review by Taras and Potts-Datema showed that children who were overweight or obese exhibited substandard academic performance, as evidenced by lower scores in mathematics, reading ability, IQ, and report cards[37]. This review was subsequently expanded upon by Booth *et al.* in 2014, who also found that academic performance was worse in children with obesity[38]. The effects of industrialization and urbanization have precipitated alterations in dietary patterns, marked by an increased consumption of unhealthy processed foods and a decreased level of physical activity, thereby contributing to the escalating prevalence of overweight and obesity[5].

The present study also measured skinfold thickness at the tricep and subscapular areas. This measurement is used to determine body composition, specifically body fat percentage. The tricep and subscapular areas are commonly assessed in various international settings to determine body fat percentage in school-age children[39,40]. The analysis in Table 2 indicates that 30.1% of subjects had low body fat percentage, 6.8% had slightly high body fat percentage, and 6.8% had very high body fat percentage. The Mann-Whitney test revealed a statistically significant difference in average body fat percentage based on sex, with girls having a higher average compared to boys (p-value<0.001). Many studies have consistently demonstrated that girls generally have higher levels of body fat percentage compared to boys[41–43].

Furthermore, a positive relationship was identified between BMI-for-age and body fat percentage (p-value<0.001), with higher BMI-for-age categories corresponding to higher body fat percentages (data not shown). As Grundy *et al.* have indicated, sex differences become more apparent during this age and puberty period. In subjects with the same BMI, girls exhibit approximately 10% more body fat than boys. In boys, weight gain during this period is largely due to an increase in lean body mass, whereas in girls, weight gain is attributable to an increase in fat mass, accompanied by the development of android and gynoid fat distribution[43].

Micronutrient Status Based on Biochemical Measurements

The trend in malnutrition has shifted from undernutrition to overnutrition in recent years, as supported by numerous studies. However, micronutrient status of the population remains suboptimal. One method for assessing the body's micronutrient status is through blood testing. The analysis of the blood biomarkers of the subjects, including hemoglobin levels, serum vitamin A, and serum vitamin B12, is presented in Table 3.

The prevalence of anemia and vitamin B12 deficiency was higher in boys compared to girls, while vitamin A deficiency was more prevalent in girls. However, no statistically significant differences were observed in the mean levels of hemoglobin, serum vitamin A, and vitamin B12 between sexes. As indicated in Table 3, 40.1% of the subjects had anemia, consisting of 28.4% with mild anemia, 20.4% with moderate anemia, and 0.2% with severe anemia.

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Table 3. Biochemical markers of the subjects by sex

Variables	Boys (n=446)			Girls (n=469)			All (n=915)			p-value[a]
	Mean ± SD	n	%	Mean ± SD	n	%	Mean ± SD	n	%	
Serum Hb (g/dl)	11.57 ± 0.99			11.65 ± 0.93			11.61 ± 0.96			0.595[b]
Severe anemia		2	0.4		0	0		2	0.2	
Moderate anemia		90	20.2		97	20.7		187	20.4	
Mild anemia		141	31.6		119	25.4		260	28.4	
Normal		213	47.8		253	53.9		466	50.9	
Vitamin A (ng/mL)	1081.41± 31.43			1019.47 ± 29.83			1049.66 ± 655.08			0.104[b]
Deficient		6	1.3		15	3.2		21	2.3	
Marginal deficient		63	14.1		86	18.3		149	16.3	
Normal		377	84.5		368	78.5		745	81.4	
Vitamin B12 (pg/mL)	236.18 ± 181.72			249.08 ± 220.11			242.79 ± 202.30			0.511[b]
Deficient		236	52.9		242	51.6		478	52.2	
Normal		210	47.1		227	48.4		437	47.8	

SD= standard deviation, [a]Comparison test conducted between boys and Girls, [b]Mann whitney test. Classification of Anemia: severe (<8.0 g/dL), moderate (8.0–10.9 g/dL), mild (11–11.4 g/dL), and normal (>11.4 g/dL). Vitamin A status: severe deficiency (<200 ng/mL), marginal deficiency (200–300 ng/mL), and normal (≥300 ng/mL). Vitamin B12 status: deficient (<200 pg/mL) and normal (≥200 pg/Ml)

Several other studies have likewise determined an absence of difference in hemoglobin levels between male and female toddlers, preschoolers, and school-age children[44]. Hollowell *et al.* conducted a comprehensive analysis of the NHANES III dataset, which revealed that the median hemoglobin levels were comparable between boys and girls aged 1–9 years across different ethnic groups[45]. Adeli *et al.* also examined the Canadian Health Measurement Survey and found no difference in hemoglobin levels between boys and girls aged 3–10 years[46]. Asberg *et al.* found no statistically significant difference in hemoglobin levels between boys and girls in the Norwegian population aged 0–14 years[47]. Despite the absence of statistically significant differences in mean Hb levels among the subjects, the higher prevalence of anemia in school-age boys relative to girls can be ascribed to an interplay of physiological, hormonal, and dietary variables. Some studies suggest that boys may face greater nutritional deficiencies due to increased iron demands during the pubertal transition, while other studies indicate that dietary patterns and socioeconomic factors play a significant role in this regard[48]. Further research is needed to address this issue.

Anemia has severe impacts on social and economic development. On a global scale, an estimated 68.36 million individuals were living with disabilities attributable to anemia in 2010. By 2019, this figure had decreased to 58.6 million[49]. Anemia can disrupt and compromise the physical and cognitive development of children. This condition can subsequently lead to diminished academic performance in school, which, in the long term, reduces their productivity in adulthood[50]. Anemia also affects immune system function, increasing the risk of infection by impacting both humoral and cellular immunity[51,52].

Anemia is a multifactoral condition, arising from a veriety of etiologies such as inadequate nutritional intake, infections, bleeding, and genetic mutations in hemoglobin genes[53]. Among school-age children, socioeconomic and demographic factors, including family income, parental education, and area of residence, are also associated with anemia[54–56]. A higher prevalence of anemia has been observed among children from low-income families compared to their counterparts from higher-income families. Financial constraints have a significant impact on the ability of children from low-income families to afford and access iron-rich foods, often leading to diets that are monotonous in both variety and quantity[57].

A meta-analysis study has shown that iron supplementation can improve hematologic outcomes in primary school children in low- and middle-income countries. Micronutrient fortification programs can also contribute to reducing anemia prevalence. Moreover, iron bioavailability, defined as the body's ability to absorb iron, influences an individual's iron status. The consumption of a diverse range of food groups, especially animal-based foods and fruits, supports iron absorption. Animal-based foods have higher bioavailability in comparison to plant-based sources, while fruits, despite being classified as plant-based, contain vitamin C that can enhance iron absorption within the body[58].

In the present study, an analysis was also conducted on serum vitamin A levels. As indicated by the results presented in Table 3, 18.6% of the subjects exhibited signs of vitamin A deficiency, a condition that, according to the criteria established by WHO, is classified as a moderate public health concern[15]. Deficiencies in vitamin A can have a number of adverse effects on children, including impaired growth and development, visual impairments, an increased risk of infection, and potential risks to cognitive and mental development[17,59–61]. The prevalence of vitamin A deficiency was found to be higher among girls than boys. However, no statistically significant difference in mean serum vitamin A levels between boys and girls was observed (p-value>0.05). The factors that contribute to vitamin A deficiency include inadequate nutrition, lipid absorption disorders, and chronic illnesses such as diarrhea and cirrhosis[62].

Moreover, the present study revealed that vitamin B12 deficiency was present in 52.2% of the subjects, with a slightly higher prevalence among boys than girls, although no significant difference was observed between sexes (p-value≥0.05). Vitamin B12 deficiency is a salient health concern in Indonesia, primarily attributable to a low intake of animal-based foods. Other factors such as low bioavailability, malabsorption, and impaired transport of vitamin B12 have also been identified as contributors to vitamin B12 deficiency[63].

The triple burden of malnutrition, defined as the coexistence of undernutrition, overnutrition, and

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micronutrient deficiencies, is rooted in various factors. This phenomenon predominantly manifests in low- and middle-income countries undergoing rapid economic and nutritional transitions. Urbanization and rapid economic changes have led to an increase in the availability of calorie-dense but nutrient-poor foods, resulting in poor diet quality and shifts in the food system that increase access to sugary drinks and unhealthy foods high in salt, sugar, and fat but low in essential nutrients[64,65] .This has further contributed to the emergence of obesity and micronutrient deficiencies[66,67]. Obesity itself has also been demonstrated to induce inflammation within the body by modifying metabolic processes and increasing the demand for nutrients, which can further exacerbate existing nutrient deficiencies[65]. The presence of underlying issues such as poor sanitation, substandard water quality, deficient hygiene practices, sociocultural factors, inequality, and poverty further complicates the situation[19].

The nutritional challenges in Indonesia require serious and focused attention. The present study indicates that, among school-age children, the prevalence of micronutrient deficiencies is higher compared to the prevalence of overweight or undernutrition in. This result may be because children over the age of seven begin to make independent food choices while at school or in other locations outside their home, potentially leading to inadequate dietary quality and quantity. Additionally, children of this age group often become cognizant of their body image, which may result in some of them restricting their food intake[68].

The study findings highlight that issues of undernutrition, overnutrition, and micronutrient deficiencies persist among the subjects, with micronutrient deficiencies being more prevalent. Given the prevalence of multiple micronutrient deficiencies, programs aimed at addressing these deficiencies should adopt a holistic approach, targeting overall micronutrient improvement rather than focusing on a single nutrient[69].

Endeavors aimed at improving the nutritional status of children through the implementation of integrated nutrition programs are crucial. These programs can be implemented through collaboration across various sectors, including health, agriculture, education, and social services, to create a comprehensive approach. A range of interventions exists that can be applied to address this issue. These include school meal programs, which provide nutritious breakfasts or lunches; micronutrient fortification and supplementation of food; optimization of local food resources; and provision of continuous nutrition education.

As reported by Plakida *et al.* (2023), the global reach of school meal initiatives has been documented as extending to 388 million children, with these initiatives playing an essential role in providing daily nutrition, particularly in low-income countries[70]. These school meal programs have the potential to collaborate with local farmers to supply fresh and nutritious food items, thereby contributing to local food security[71].Furthermore, the addition of essential vitamins and minerals to food, a process referred to as micronutrient fortification, has been demonstrated to significantly improve children's health and reduce the prevalence of malnutrition[72].

In addition to school meal programs and micronutrient fortification, continuous nutrition education, such as the promotion of healthy eating practices for children and families, is essential for enhancing nutritional knowledge and encouraging long-term dietary changes[73]. It is imperative to engage local communities in the planning and implementation of nutrition programs to ensure the cultural appropriateness and long-term sustainability of these initiatives[71]. Collectively, these interventions target the triple burden of malnutrition, defined as the concurrent presence of undernutrition, overnutrition, and micronutrient deficiencies, in school-age children.

One limitation of this study is the absence of dietary intake data, which hinders the ability to support the findings on nutritional status and to elucidate subjects' eating habits. Additionally, the anemia assessment relied solely on hemoglobin levels, with a paucity of data concerning iron status, ferritin, transferrin, or transferrin receptors. Strengths of the study include a large sample size, the utilization of body fat percentage as a nutritional status indicator through anthropometric measures, and the incorporation of blood biomarker data (hemoglobin, serum vitamin A, and vitamin B12 levels), a practice that is rarely employed in Indonesia.

CONCLUSIONS

An assessment of the nutritional status of school-age children was conducted to identify the prevalence of undernutrition, overnutrition, and micronutrient deficiencies. The findings revealed that 2.4% of the children exhibited chronic energy deficiency, 12.4% were classified as overweight and obese due to overnutrition, 12.8% had elevated body fat percentage, 40.1% experienced anemia, 18.6% were found to have vitamin A deficiency, and 52.2% had vitamin B12 deficiency. Micronutrient deficiencies are more prevalent than overnutrition and undernutrition. Further research is needed to analyze the underlying factors contributing to these three nutritional issues in school-age children, considering various covariates. Additionally, the implementation of sensitive and specific programs is imperative to prevent and address the triple burden of malnutrition among primary school children in Bogor, Indonesia.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

HAK was responsible for the conceptualization, data curation, formal analysis, investigation, methodology, project administration, resource acquisition, software operation, original draft writing, review, and editing. HH contributed to the conceptualization, funding acquisition, supervision, validation, methodology, and review. MD participated in the conceptualization, supervision, review and validation processes. AR contributed to the validation, visualization, and funding acquisition processes, as well as the writing, review, and editing. PRA participated in the funding acquisition, validation, visualization, and writing.

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