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RESEARCH ARTICLE
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Association between Working Memory Deficits and Iron Deficiency Anemia Status among Elementary School Children in Jakarta, Indonesia: A Cross-Sectional Study using the Working Memory Rating Scale

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Abstract:

Background/Objectives: Deficits in working memory and anemia in primary school children represent potential public health issues in terms of cognitive and educational development in Indonesia. This cross-sectional study investigates the relationship between working memory deficits and the presence of iron deficiency anemia in elementary school children in two schools in Jakarta, Indonesia, including the factors of nutritional intake and anthropometric status. The design of the study does not allow for causal inferences.

Methods: This cross-sectional study was conducted between May and August 2023 and included 335 elementary school students (grades 3-5) from two schools in Jakarta, Indonesia. A non-invasive hemoglobinometer was used to assess students' hemoglobin levels. The Working Memory Rating Scale (WMRS) was used to assess working memory. To evaluate nutritional status, anthropometric measurements (weight, height, age) and a 24-hour food recall exercise were performed.

Results: The study reports that 19.7% of the students were anemic, and 22.1% of the students had working memory deficits. Students with working memory deficits had significantly lower mean hemoglobin levels (12.1±1.1 g/dL) than those with normal working memory (12.4±0.9 g/dL, p=0.035). Children who were short for their age had working memory scores that were low three times more often (OR = 3.04, 95% CI: 1.15-8.01). All students were found to have an inadequate intake of fat and protein, while anemic children had significantly poorer protein intake.

Discussion: The findings show that even small changes in cognitive function can be linked to varying levels of hemoglobin and that iron plays an important role in the development of the neural system and the synthesis of crucial neurotransmitters. The relationship between chronic undernutrition (as evidenced by height deficit) and working memory limitations emphasizes the gradual, reciprocal relationship between cognitive development and nutritional status. The global deficiency in protein and fat intake is a serious nutritional problem that calls for urgent action through effective nutrition programs in the schools.

Conclusion: The associations between anemia, working memory, and malnutrition in elementary school children have been established. There is an urgent need for school-based nutrition programs.

Keywords: Working memory, Anemia, Nutritional status, Elementary school children, Cognitive function.

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1. INTRODUCTION

Working memory is essential for learning and academic achievement and is important for children's development [1]. It is defined as the capacity to temporarily store and manage intricate information and perform cognitive tasks [2]. Recent studies found that one's nutrition, specifically anemia and iron deficiency, can negatively affect cognitive functions and working memory in children in the school-age range [3, 4].

Iron Deficiency Anemia (IDA) remains a major public health issue in developing countries, and school-age children account for about 25% of the total population with this deficiency [5]. In Indonesia, the anemia prevalence rate among school-age children ranges from 20% to 40%, which is a moderate to severe public health issue according to WHO guidelines [6]. Iron is necessary for the synthesis of some neurotransmitters and myelination, as well as for brain metabolism, so it is important for working memory and learning [7, 8].

Various studies have proven the relationship between anemia and cognitive performance, but the research focused on working memory is scarce [9]. Deficits in working memory are detrimental to educational success because it is the building block of skills necessary for reading and understanding texts, solving mathematical problems, and learning in general [10]. The link between anemia and working memory is particularly important when working in the elementary setting because of the importance of cognitive growth and learning [11].

The relationship between nutritional status and cognitive performance is complex and multifaceted, which requires thorough research in order to implement effective strategies [12]. This study, taking into account nutritional status, aims to analyze the relationship bet-ween working memory deficits and anemia in elemen-tary school children. Both anemia and cognitive deficits are highly common and avoidable, which makes under-stan-ding their relationship very important for developing strategies to improve public health, educational systems, and anemia levels in children in developing countries. There is a significant amount of childhood anemia in these regions, which makes the study of these relationships critical.

2. MATERIALS AND METHODS

This cross-sectional study was conducted between May and August 2023 at two public elementary schools in urban Jakarta, Indonesia. The schools were selected from middle-income neighborhoods to represent typical urban elementary schools in the capital city, with approval from the Medical and Health Research Ethics Committee of Universitas Muhammadiyah Prof. Dr Hamka No. 03/23.05/02515. The study population comprised elementary school students from grades 3-5, with a total of 335 students selected using purposive sampling. Written informed consent was obtained from the parents/-guardians of all participants, and students with severe illnesses or those who had taken iron supplements within the past month were excluded from the study.

Anthropometric measurements were conducted with height measured using a microtoise with participants standing barefoot. Height-for-age z-scores (HAZ) were calculated using the WHO AnthroPlus software, and short stature was defined as HAZ < -2 SD. Blood hemoglobin levels were measured using a non-invasive hemoglobinometer (Masimo Spot-Check Rad-67™ Pulse CO-Oximeter®), and anemia was defined according to WHO age-specific criteria (Hb < 11.5 g/dL for children 5-11 years; < 12.0 g/dL for children 12-14 years).

Working memory was evaluated using the Indonesian version of the Working Memory Rating Scale (WMRS), a standardized teacher-rated scale consisting of 20 items assessing behavioral indicators of working memory in classroom settings. Classroom teachers completed the assessment, with each item scored on a four-point scale (0-3), where higher scores indicated greater working memory difficulties. A total score of over 60 demonstrated moderate deficits in working memory, while a score over 70 showed severe deficits in working memory. The scale showed excellent internal consistency as evidenced by a 0.959 Cronbach's alpha. The WMRS was chosen for this study owing to its ecological validity for working memory assessment in real-life classroom situations, validation for use in the Indonesian context, and the ability to assess working memory in its behavioral forms that affect academic performance. WMRS, unlike laboratory cognitive tests, assesses everyday working memory function, as observed by the teacher from their regular student interactions, thereby providing a deeper assessment of working memory in real-life educational situations than the cognitive tests [13].

A single 24-hour food recall questionnaire was used to assess dietary intake, administered by trained nutri-tionists. The percentage of the Indonesian Recommended Dietary

Allowances (AKG) by age and sex was used to calculate nutrient adequacy. The following cut-off points were used to classify nutrient adequacy: energy and carbohydrates are adequate at <70% AKG and are considered inadequate at ≥70% AKG, and for protein, it was considered adequate at <80% AKG and inadequate at ≥80% AKG, and for fat, it was adequate at <70% AKG and considered inadequate at ≥70% AKG [14].

The data was analyzed using SPSS version 25.0. Descriptive analyses are shown as frequencies, percentages, means ± standard deviation, or medians with ranges. Analyses at a single variable level were performed using Pearson's correlation coefficient, the Student's t-test, the Mann-Whitney U test, and Chi-square tests, as appropriate for the characteristics of the data. Multi-variable logistic regression was used to assess the relationships and to obtain Odds Ratios (OR) and 95% Confidence Intervals (CI) for potential confounders of age, gender, and socio-economic status. To reduce bias, all measurements were conducted using standardized procedures, validated instruments, and trained assessors.

3. RESULTS

3.1. Participant Characteristics

Table **1** illustrates information collected from 335 elementary school children who took part in the study. The participant sample spanned across 3 different grades: 3rd grade (119 parti-cipants, 35.5%), 4th grade (113 parti-cipants, 33.7%), and 5th grade (103 participants, 30.7%). The study also had a slight male majority, with 174 (51.9%) males and 161 (48.1%) females. The participants' ages ranged from 9 to 12 years, with 10 years as the average. In the assessment, 19.7% of participants were identified as having anemia, and 22.1% were found to have working memory deficits. Additionally, 5.4% of parti-cipants were assessed and found to have short stature (Table **2**).

Table 1. Characteristics of respondents (N=335).

Variable	n (%)	Median (min-max)
Grade Level	-	-
Grade 3	119 (35.5)	-
Grade 4	113 (33.7)	-
Grade 5	103 (30.7)	-
Gender	-	-
Male	174 (51.9)	-
Female	161 (48.1)	-
Age (years)	-	10 (9 – 12)

The relationship between clinical parameters and working memory status is presented in Table **3**. Our analysis revealed significant relationships between clinical parameters and working memory status. For height-for-age status, 44.4% of children with short stature had compromised working memory compared to 20.8% of those with normal stature (p=0.035, OR=3.04, 95% CI: 1.15-8.01). Mean hemoglobin levels were significantly lower in students with compromised working memory (12.1±1.1 g/dL) compared to those with normal working memory (12.4±0.9 g/dL, *p*=0.035). While 28.8% of anemic children showed compromised working memory compared to 20.4% of non-anemic children, this difference was not statistically significant (p=0.194).

Table 2. Clinical and nutritional characteristics of elementary school children (N=335).

Variable	Category	n (%) or Mean ± SD
Working Memory Rating Scale (WMRS)	Normal	261 (77.9)
	Deficit	74 (22.1)
Height-for-Age Z-score (HAZ)	Normal	317 (94.6)
	Short stature	18 (5.4)
Hemoglobin Status	Mean Hemoglobin (g/dL)	12.3 ± 1.0
Anemia Status	Normal	269 (80.3)
	Anemic	66 (19.7)
Nutritional Intake (% RDA)	-	Mean ± SD
Energy	-	92.4 ± 20.5
Carbohydrate	-	80.6 ± 22.4
Protein	-	50.9 ± 19.4
Fat	-	46.5 ± 14.7
Nutritional Adequacy Status	-	n (%)
Energy	Adequate	241 (71.9)
	Inadequate	94 (28.1)
Carbohydrate	Adequate	123 (36.7)
	Inadequate	212 (63.3)
Fat	Adequate	0 (0)
	Inadequate	335 (100)
Protein	Adequate	0 (0)
	Inadequate	335 (100)

Abbreviation: RDA: Recommended Dietary Allowance.

Table 3. Relationship between clinical parameters and working memory status (N=335).

Variables	Compromised Working Memory	Normal Working Memory	p value	OR (95% CI)
Height-for-Age	-	-	**0.035***	3.04 (1.15 - 8.01)
Short stature	8 (44.4%)	10 (55.6%)	-	-
Normal stature	66 (20.8%)	251 (79.2%)	-	-
Hemoglobin levels	12.1±1,1	12.4±0.9	**0.035***	-
Anemia Status	-	-	0.194	1.57 (0.85 - 2.89)
Anemic	19 (28.8%)	47 (71.2%)	-	-
Normal	55 (20.4%)	214 (79.6%)	-	-

Note: *Statistically significant at $p < 0.05$.

Table 4. Comparison of nutrient intake between anemic and non-anemic students.

Nutrients Intake (% RDA)	Anemic	Non-anemic	*p*-value
Total energy	85.2 (23 - 163)	83.5 (22 - 175)	0.758
Carbohydrate	36.5 (31 - 94)	41.5 (31 - 94)	0.109
Fat	47.4 (44 - 48)	46.3 (44 - 48)	**0.010***
Protein	46.3 (40 - 64)	52.6 (40 - 64)	**0.010***

Note: *Statistically significant at $p < 0.05$.

The analysis of two groups of students, anemic and non-anemic, who were students at the same level of total energy intake and had the same total energy intake and total energy intake (Table **4**). Total energy intake was the same for both groups (anemic: 85.2%, range 23-163%; non-anemic: 83.5%, range 22-175%; p=0.758), and the total carbohydrate intake was similar for both groups (anemic: 36.5%, range 31-94%; non-anemic: 41.5%, range 31-94%; p=0.109). Students with anemia had higher fat intake (47.4%, range 44-48%) compared to non-anemic students (46.3%, range 44-48%; p=0.010) and lower protein intake (46.3%, range 40-64%) compared to non-anemics (52.6%, range 40-64%; p=0.010).

4. DISCUSSION

4.1. Working Memory and Anemia

Our analysis showcased significant constructive engagements regarding malnourished elementary school children and their cognitive development. Our study revealed that among the total anemic participants, 29% exhibited clinically significant deficits in working memory. This event suggests that working memory may be particularly susceptible to iron deficiency. This effect was displayed in our analysis of hemoglobin levels; on average, children who had working memory deficits exhibited lower levels (12.1 ± 1.1 g/dL) versus those who had no deficits (12.4 ± 0.9 g/dL, p = 0.035), which shows that small changes in cognitive function could be attributed to differences in cognitive function [15, 16].

The plausible theory regarding the fundamental explanatory assumptions holds that iron deficiency affects the construction of specific neurotransmitters and the myelination of the central nervous system [17, 18]. particularly the working memory, which is the ability to both mentally hold onto and manipulate information, appears to be in the domain of the central nervous system, which is in the domain of loss of oxygen to the brain and the consequent changes in neurotransmitters. Our various studies and analyses indicated that working memory is in the domain of iron status among children, and that cognitive development among school-age children is in the domain of working memory [21].

4.2. Anthropometric Status and Working Memory

Our study results that, compared to their peers, children with short stature had working memory scores that were more than three times as likely to be low (OR = 3.04, 95% CI: 1.15-8.01), indicating the impact of chronic malnutrition on cognitive development. This impact is reported in other works [22, 23] and indicates low levels of nutrition in early life and less developed brains.

The combined phenomena of short stature and hemoglobin deficiency, in relation to working memory deficits, point to a more intricate case of both chronic and acute malnutrition's impact on cognitive development. Even though both relationships were statistically significant, it is important to state that not all nutritionally deficient children experienced working memory difficulties. This cognitive outcome variability is likely due to the timing and degree of nutrition deficiency and during development, compensatory influences [24].

The possible connection between cognitive function and anthropometric status is likely due to the long-term effects of chronic under-nutrition, which stunts brain development. Detected changes in malnutrition during the period of brain development evidenced regional changes in the brain and in the regions that perform core functional activities of memory and executive function [25]. This underlines the need for an integrated focus on school-aged children's management of both acute and chronic malnutrition, coupled with early and sustained monitoring of cognitive and nutritional function.

4.3. Protein and Nutritional Adequacy

It is particularly disconcerting that all participants show universal inadequacies in fat and protein intake (100%), which highlights the multitudinous concerns surrounding our study population. Previous researchers similarly found Indonesian children to have widespread deficiencies in similar micronutrients [26, 27]; however, the universal inadequacies within our study's participants are particularly concerning. Numerous studies have documented insufficient access to animal protein and protein-rich foods, and the prevailing practice of carbohydrate-based consumption, coupled with the prevailing low-socioeconomic food purchasing ability [28], likely explains the indisputable protein deficits. The cross-study inadequacies of protein intake and anemia likely have far-reaching impacts on the protein deficit, especially for neurotransmitter synthesis and neural growth [12]. Your study revealed that anemic participants had a statistically significant lower protein intake (46.3% *vs* 52.6%, p = 0.010), which is similar to other studies reporting that lower protein intake is associated with reduced iron bioavailability/dietary protein [29]. The dual problems of anemia and lower protein intake likely exert a serious, compounded adverse effect on cognitive development [30], perpetuating a cycle of nutritional deficiencies and reduced learning ability. This suggests that improving protein intake is associated with reduced anemia and enhanced cognitive ability [31], which is best achieved through school-based nutrition programs that prioritize protein and nutrition education for children's caretakers.

4.4. Fat Intake and Cognitive Development

The concern regarding the universally low fat intake documented in the study should consider the established effects of dietary fat, especially Polyunsaturated Fatty Acids (PUFAs), on the brain development and functioning of children [32, 33]. Recent studies of fat intake in children across 33 countries show that low fat intake is a global phenomenon; 88% of children aged 1-3 years do not consume enough total fat [34]. This is also the case for Indonesian children, whose median total fat intake is only 26.7% of total energy, which is still below the recommendation [35].

The positive effect of dietary fat and cognitive performance is now more recognized. Studies show that dietary fat has positive, significant correlations with several measures of cognitive performance in children, particularly reaction time and cognitive flexibility [36]. Polyunsaturated fatty acids, more specifically omega-3 fatty acids like Docosahexaenoic Acid (DHA), are crucial for fluidity of neural membranes and synaptic plasticity and are important for neurotransmitter activity [37, 38]. The combination of inadequate fat intake and the iron deficiency anemia present in the study population may multiplicatively adversely affect working memory and cognitive development.

Considering public health, there is a need for more integrated approaches to the problems associated with the deficiency of certain fats. School feeding programs can improve the provision of important micronutrients and macronutrients, including the healthy fats that children need. One systematic review and meta-analysis of school feeding programs in low and middle-income countries showed that these programs had a positive effect on the education and health of school-aged children and adolescents, which indicates the potential of school feeding programs for nutritional interventions. Combining local agriculture with Home Grown School Feeding programs has the potential to improve the economic situation of the local community, as well as the nutritional quality of school meals. It would be relevant for further research to use randomized controlled trials to examine school- and community-based interventions to improve children's fat intake in Indonesia.

4.5. Public Health Implications

The numbers we found for anemia (19.7%) and working memory deficits (22.1%) in our sample exemplify a significant public health concern. Our findings stress the need to design and implement integrated school-based nutrition programs aimed at eliminating iron deficiency and improving overall nutrition. The combined presence of these conditions is likely to erode academic and developmental outcomes even further.

School-based nutrition programs can integrate micronutrient supplementation, dietary diversification, and nutrition education. A life course approach to Iron Deficiency Anemia (IDA) advocating integrated strategies across multiple life stages was proposed by Sungkar *et al.* This approach posits that nutritional measures taken during the school-age years will immediately address existing gaps but will also instill healthy dietary practices that will carry into later life, thereby disrupting the multigenerational transmission of poor nutrition and cognitive deficits. Past successful interventions illustrate that integrated strategies that simultaneously target nutritional and cognitive outcomes yield positive improvements in academic performance and in the overall development of children.

While our study on nutritional status and cognitive function in elementary school children has revealed important findings, it has also identified potential areas for future research. The cross-sectional design has documented sufficient evidence for associating memory and nutrition, and this research can be expanded through longitudinal designs, so as to describe and analyze relationships in time across constructs. A 24-hour dietary recall documented useful population-level estimates of nutritional intake. In future research, it would be useful to have multiple dietary recalls to assess individual dietary intake more accurately and to include a food frequency questionnaire to analyze micronutrient intake. The assessment of working memory employed significant standardized tools, providing empirical evidence to support the assessment of other cognitive domains. Given the findings of the study, additional research would include longitudinal studies to assess developmental trajectories; implementation studies of targeted nutritional interventions;

advanced cognitive assessments; expanded dietary assessment approaches; studies on micronutrient interactions; and studies on the provision of additional cognitive domains. These research studies will reinforce the evidence and will be of great help in designing effective strategies to address the nutritional and cognitive needs of school-aged children.

There are some limitations in this research work. A cross-sectional research design captured associations between anemia and working memory deficits at one time. The purposive sampling of two Jakarta schools imposes limitations on generalizing findings to other Indonesian populations. Longitudinal research is required to assess the temporal relationship between nutritional status and cognitive development. Moreover, research studies employing different nutrition assessment methods, comprehensive cognitive assessments, beyond hemoglobin level cognitive tests, teacher evaluations, and varied research populations from both rural and urban locations in Indonesia would yield better studies on the nutrition and cognition relationship of school-aged children. The sample size of 335 participants and statistical power showed more than sufficient power to recognize effect sizes of moderate and over; however, certain patterns did not reach statistical significance. The effect size in working memory groups' level hemoglobin average of 0.3 g/dL demonstrates a meaningful, clinically significant difference; both statistical and clinical significance should be considered.

CONCLUSION

There are substantial correlations between the nutritional status and the performance in working memory of elementary school-aged children in Indonesia. It was found that 19.7% of the students were found to be anemic, and 22.1% of the students were found to have working memory deficits. It was also found that anemic children were more likely to exhibit working memory deficits that were found to be clinically important. Furthermore, it was found that children with short stature were 3 times more likely to have working memory deficits. This emphasizes the effect of long-term malnutrition on the cognitive development of children. This study also found poor patterns of nutritional intake. For example, anemic children had a significantly lower protein intake of 46.3% compared to 52.6% of the Recommended Dietary Allowance (RDA) and a higher fat intake of 47.4% compared to 46.3% RDA compared to non-anemic children. This emphasizes the interconnection between nutritional status and cognitive function. Therefore, it can be concluded that school-based nutrition programs, as a remedy for iron deficiency and low nutritional intake, should be implemented in elementary schools throughout Indonesia to enhance the cognitive performance and academic achievement of schoolchildren.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: N.F.M., R.W.B., T.S., and K.R.D.: Contributed to the conceptualization and design of the study; R.W.B., T.S., K.R.D., E.T., and D.P.: Performed data analysis and interpretation; R.W.B., T.S., K.R.D., and E.T.: Prepared the original draft; and N.F.M., R.W.B., T.S., K.R.D., E.T., and D.P.: Responsible for reviewing and editing the manuscript. All authors have read and agreed to the published version of the manuscript.

LIST OF ABBREVIATIONS

WMR	=	Working Memory Rating Scale
IDA	=	Iron Deficiency Anemia
HAZ	=	Height-for-Age Z-scores
AKG	=	Indonesian Recommended Dietary Allowances
WHO	=	World Health Organization
OR	=	Odds Ratio
CI	=	Confidence Interval
RDA	=	Recommended Dietary Allowance
SD	=	Standard Deviation

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of UHAMKA with approval number 03/23/05/02515.

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent was obtained from all subjects involved in the study.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, R.W.B., on special request.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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