nutrición clínica y Dietética Hospitalaria

Artículo Original

Nutr Clín Diet Hosp. 2025; 45(1):334-345
DOI: 10.12873/451musfira

The relationship of chronic malnutrition to adolescent girls' cognition in Indonesia: A systematic review

MUSFIRA, Veni HADJU

Department of Nutrition Science, Faculty of Public Health, Hasanuddin University, Indonesia.

Recibido: 5/diciembre/2024. Aceptado: 21/febrero/2025.

ABSTRACT

Background: Chronic malnutrition, including chronic energy deficiency, stunting, and anemia, significantly impacts cognitive development in adolescent girls in Indonesia.

Objective: A systematic review was conducted to examine the relationship between chronic undernutrition and cognitive function.

Method: In this systematic use the PRISMA framework. Studies from the past 10 years, including cross-sectional or cohort observational quantitative designs, were analyzed using Loney's critical appraisal tool. From an initial 781 articles, 13 met the inclusion criteria.

Result: Findings revealed anemia as a key factor affecting cognitive function and learning, with reduced hemoglobin levels linked to poor concentration, problem-solving, and academic performance ($p<0.05$). Anemic adolescents were 3 to 37 times more likely to exhibit poor learning outcomes (75%-92.5% low performance). Stunted adolescents had lower MMSE scores (median = 24, $p = 0.013$) and IQ (<84) compared to their non-stunted peers. The combination of anemia and stunting may exacerbate cognitive deficits, though research on this interaction is limited.

Conclusion: Anemia was identified as having the most pronounced impact on cognitive function, highlighting the need for targeted interventions to prevent and manage anemia, improve academic performance, and enhance the quality of life of adolescent girls. Further research is recommended to establish causal relationships and inform effective policy strategies.

KEYWORDS

Chronic Energy Deficiency, Stunting, Anaemia, Intelligence.

INTRODUCTION

Adolescent girls' nutritional issues are multifaceted and include anaemia, stunting, and chronic malnutrition, including Chronic Energy Deficiency (CED). Their academic potential and future productivity are at risk due to these nutritional problems, which have a significant impact on cognitive development in addition to physical health[1]. The 2018 Basic Health Research report, which revealed that the prevalence of CED among adolescent girls reached 23.6%, underscores the serious challenge Indonesia faces in this regard. Nearly one in four teenage girls still suffer from persistent energy deficits, according to the 2023 Indonesian Health Survey (IHS), which showed a modest decrease to 21.4% despite five years of interventions[2].

Surprisingly, among ASEAN nations, Indonesia has one of the lowest average cognitive levels. Indonesia's average cognitive score of 78.5 placed it 130th out of 199 countries in the 2022 World Population Review, below its neighbours Malaysia (87.6), the Philippines (81.6), and Laos (81.0). Given the strong correlations between poor cognitive performance and undernutrition, poor educational quality, early marriage, and other sociocultural factors, this emphasises the urgent need for effective interventions[3].

CED inhibits physical growth and brain development, which are essential for optimal cognitive function. A study showed that adolescents with CED have lower academic

Correspondencia:
Veni Hadju
phunhas@gmail.com

performance compared to those who are well-fed. Energy deficiency affects concentration, memory and critical thinking skills, all of which are important for academic success. Inadequate height or stunting also occurs in adolescent girls, resulting from chronic malnutrition during the growing years, which leads to impaired growth and brain development. Additionally, stunting has a major impact on both physical stature and brain development and is frequently caused by chronic malnutrition during growth phases[4]. Stunted adolescents typically have lower IQs, less capacity for learning, and worse academic results. Long-term health hazards, such as a higher chance of developing chronic illnesses as an adult, are also linked to stunting[5].

According to the 2023 IHS, anaemia, another common problem, affects about 24.1% of Indonesian adolescent girls, which is only marginally less than the 26.4% prevalence in 2018. Iron deficiency is the main cause of anaemia, which lowers oxygen delivery to the brain and affects cognitive function and academic performance[6]. Research has shown that a discernible drop in IQ scores is linked to even a 1 g/dL drop in haemoglobin levels. Likewise, it has been demonstrated that stunting reduces IQ scores by a number of points, highlighting its negative effects on cognitive ability[7].

Stunting, anaemia, and CED are all linked to one another, forming a vicious cycle. Anaemia, which is often caused by iron deficiency, leads to fatigue, decreased concentration, and poor cognitive performance. Iron is an important component in haemoglobin, which transports oxygen throughout the body including the brain. Lack of oxygen in the brain impairs cognitive function and decreases learning ability. Children with anaemia perform lower in cognitive tests and have lower academic scores. These three conditions are interrelated and exacerbate each other, creating a chain cycle that is difficult to break[8]. Given that Indonesia, the world's fourth most populous nation, is currently experiencing its demographic "golden period," it is imperative that the quality of its human resources be maximised. In addition to improving their academic and cognitive performance, addressing adolescent girls' malnutrition will have a significant impact on the social and economic advancement of the country[9].

This study aims to further examine the impact of chronic malnutrition in adolescent girls in Indonesia on their cognitive levels. With a better understanding of the relationship between CED, stunting, anaemia and cognitive development, more effective interventions can be formulated to improve the nutritional status and cognitive development of adolescent girls in Indonesia. This study also aims to identify which malnutrition conditions have the most significant impact on adolescent girls' cognition, so that health and nutrition programmed can focus on the most critical areas. Thus, appropriate interventions can be designed to break the cycle of malnutrition and improve the academic potential and quality of life of young Indonesians.

The long-term impact of addressing chronic nutritional problems in adolescent girls will have far-reaching positive impacts. Healthy and cognitively well-developed adolescents will have a greater chance of success in their education and career, which in turn will contribute to the economic and social development of the country. Therefore, it is important for governments, health institutions and communities to work together to implement effective and sustainable nutrition programmed to address CED, stunting and anaemia among adolescent girls.

METHODS

A systematic review using narrative analysis was conducted to explore the nutrition and dietary habits of adolescent girls in Indonesia. The review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a comprehensive and structured approach[10].

Options

Articles were included if they met the following criteria: (1) cross-sectional surveys, descriptive studies, baseline data from intervention studies, or other relevant observational research; (2) published between 2014 and 2024; (3) written in English or Bahasa Indonesia; (4) focused on adolescent girls in Indonesia aged 10 to 19 years; and (5) addressed topics such as severe energy deficiency (SEZ), stunting, anemia, and their cognitive impacts on adolescent girls.

Literature Search Strategy

The search strategy involved identifying English-language journal articles using keywords related to prevalence, adolescents, Indonesia, chronic malnutrition, stunting, and anemia, combined with the Boolean operator AND to refine results. For Indonesian-language databases, equivalent or translated terms were applied to ensure consistency.

Document Screening

The literature search, initiated on August 8, 2024, included three English-language databases (Scopus, ProQuest, and PubMed) along with four Indonesian-language journals indexed by the Indonesian Ministry of Research and Technology. Articles published from 2014 to 2024 were reviewed based on their titles, abstracts, and full-text content focusing on human participants. Additionally, grey literature was explored through a customized Google search and resources from Indonesian government bodies, NGOs, and UN organizations. Relevant materials were carefully assessed to confirm their eligibility

Data Collection

Data from the selected studies were systematically recorded in a structured template, including information on the author and publication year, study design, sample size, reported health conditions, participants' age, location (e.g., district, city), nutritional status, chronic energy deficiency, stunting, anemia, and the type of literature (e.g., journal article, report). Due to variations in study designs and outcomes, a narrative approach was used to synthesize the findings.

Study Appraisal

The selected studies underwent quality and bias assessment using a tool adapted from Loney et al. This tool evaluated full-text articles based on three main criteria: research method validity (up to six points), result interpretation (one point), and result applicability (one point), as shown in Table 1. Studies with a score of six or higher were included. To maintain rigor and reliability in the systematic review, the PRISMA checklist (prisma-statement.org) was used as a guiding framework, as depicted in Fig. 1.

Table 1. Critical appraisal process using Loney et al Critical appraisal of the health research literature[21]

No.	Title of article (authors)	Critical appraisal								Score
		Random sample or whole population	Unbiased sampling frame	Adequate sample size (>100)	Measures were the standard	Outcomes measured in an unbiased fashion	Adequate response rate (70%), refurse described	CI, subgroup analysis	Study Subjects described	
1	Different Results of Cognitive Impairment Screening in Adolescent Aged 10-12 Years with Normal and Short Stature in Pangandaran District Rodman Tarigan, et al (2017)[12]	Y	Y	Y	Y	Y	N/A	N/A	Y	6
2	Intercorrelations among Haemoglobin Level, Physical Fitness, and Cognitive Score in Adolescent Girls: A Cross-Sectional Study in Banggai District, Indonesia Risma Risma, Veni Hadju, et al (2024)[13] (13)	N	N	Y	Y	Y	N/A	Y	Y	6
3	Associations of Knowledge, Attitude, and Practices towards Anaemia with Anaemia Prevalence and Height-for-Age Z-Score among Indonesian Adolescent Girls Rina Agustina, et al (2021)[14]	Y	Y	Y	Y	Y	N/A	Y	Y	7
4	Analysis of the Relationship between Anaemia and Learning Performance among Adolescent Girls at Madrasah Aliyah Negeri (MAN) 1 Gorontalo Siti Rahasia K Baderan, et al (2024)[15]	Y	Y	Y	Y	N/A	N/A	Y	Y	6
5	The Relationship between Anaemia and Learning Achievement of Students at Bina Insani Junior High School" Pratiwi Retno Ayu, et al (2017)[16]	Y	Y	N	Y	N/A	N/A	Y	Y	5
6	The Relationship between Anaemia and Learning Achievement of Students at SMP Negeri Kelila, Mamberamo Tengah Regency in 2018 Jenny Anna Siauta, et al (2018)[17]	Y	Y	N	Y	Y	N/A	Y	Y	6

Y= yes, N= no, N/A= information not available in the paper.

Table 1 continuation. Critical appraisal process using Loney et al Critical appraisal of the health research literature[21]

No.	Title of article (authors)	Critical appraisal								Score
		Random sample or whole population	Unbiased sampling frame	Adequate sample size (>100)	Measures were the standard	Outcomes measured in an unbiased fashion	Adequate response rate (70%), refurse described	CI, subgroup analysis	Study Subjects described	
7	Relationship between Nutritional Status and Haemoglobin Level with Learning Achievement of Students of SMA Negeri 14 Palembang Manuntun Rotua, et al (2018)[18]	Y	Y	N	Y	Y	N/A	Y	Y	6
8	The Study of Nutrient Intake and Adolescent Girls' Quality of Life in a Rural Area of Indonesia Puspa Sari, et al (2022)[19]	Y	Y	Y	Y	Y	N/A	Y	Y	7
9	Factors Affecting Anaemia Status in Adolescent Girls Mulianingsih, M et al (2021)[20]	Y	Y	N	Y	Y	N/A	Y	Y	6
10	Anaemia among Adolescent Girls in West Java, Indonesia: Related Factors and Consequences on the Quality of Life Puspa Sari, et al (2022)[21]	Y	Y	Y	Y	Y	N/A	Y	Y	7
11	Iron Deficiency Anaemia and Associated Factors Among Adolescent Girls and Women in a Rural Area of Jatinangor, Indonesia Puspa Sari, et al (2022)[22]	Y	Y	Y	Y	Y	N/A	Y	Y	7
12	Understanding the pubertal, psychosocial, and cognitive developmental trajectories of stunted and non-stunted adolescents: protocol of a multi-site Indonesian cohort study Bernie Endyarni, et al (2024)[23]	Y	Y	Y	Y	Y	N/A	Y	Y	7
13	Relationship between anaemia, stunting and intelligence level among adolescent girls aged 13-15 years in South Galesong District, Takalar Regency, 2022, Susi Susanti, Veni Hadju (2023)[24]	Y	Y	Y	Y	Y	N/A	N/A	Y	6

Y= yes, N= no, N/A= information not available in the paper.

Nutrition Status

The nutritional status of adolescent girls can be classified into various categories. Chronic undernutrition is identified when their daily energy intake falls below the recommended caloric needs for their age and level of activity. Stunting is defined by a height below 150 cm, which is considered inadequate for their age. Anemia is diagnosed when their blood hemoglobin (Hb) level is less than 12 g/dL.

RESULTS

Results

The search identified 781 articles from reputable international and national journals, with 234 full-texts screened after duplicate removal. Following exclusions for access restrictions, title suitability, and content relevance, 13 articles included in the analysis.

Chronic Energy Deficiency (CED) and cognitive function. A study by Tarigan R, Mulyani S, Sari P, et al. (2017) in

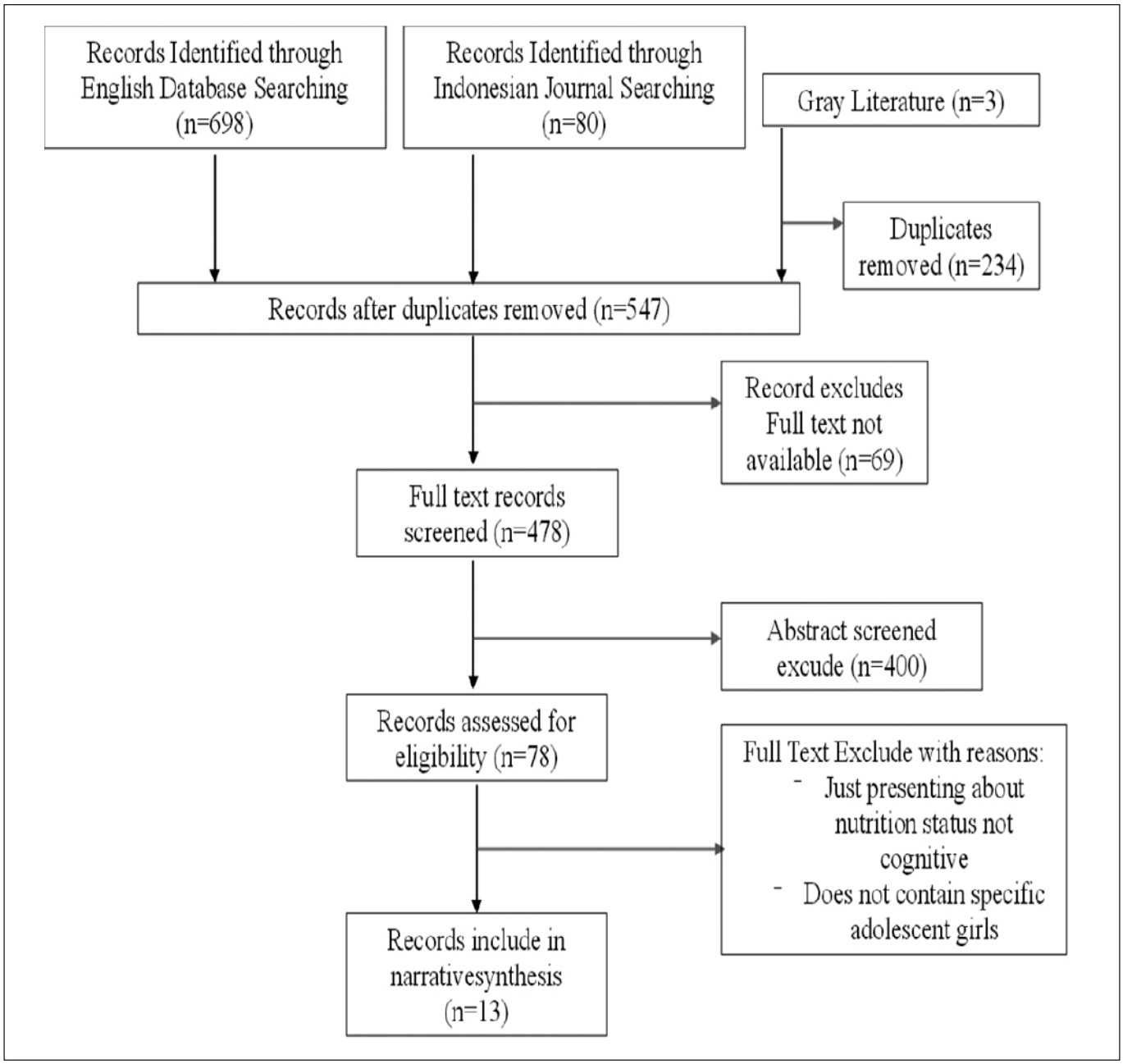

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Flow Diagram

rural Bandung found that nutritional intake, particularly carbohydrates, vitamin C, and fat, had a positive correlation with physical health which is directly related to optimal cognitive function. This study indicated that chronic energy deficiency can reduce the cognitive scores of adolescent girls with a significant correlation coefficient ($r = 0.15$, $p < 0.05$), which suggests that chronic energy deficiency can inhibit cognitive and learning abilities. In contrast, Risma R, Hadju V, et al. (2024) in rural Jatinangor found that CED had a greater impact on physical than cognitive aspects, where socioeconomic factors and overall nutritional intake had more influence on quality of life than cognitive function itself. Both studies agree that a balanced nutritional intake plays an important role in supporting cognitive function, but they differ in highlighting how much impact CED has on cognitive decline. The study by Agustina R, Syamsul R, et al. (2021) emphasised iron deficiency and carbohydrate as important factors, while the study by Baderan SRK, Nugroho R, et al. (2024) emphasised a holistic approach of social and economic factors[12-15].

Stunting and cognitive function. Stunting has a significant effect on reducing cognitive ability in adolescent girls.

Table 2. Studies included in the literature review based on level of study

Peer-reviewed literature							
No.	**Author**	**Study Type**	**Journal**	**Sample (Size)**	**Specific location**	**Nutrition Status**	**Results**
1	Rodman Tarigan (2017)	Cross-Sectional	American Journal of Clinical Medicine Research	Adolescent girls 10-12 years (n=144)	Pangandaran Regency, West Java, Indonesia	Stunting	The median MMSE score of adolescents with short height was 24 (range 14-30), while that of adolescents with normal height was 27 (range 9-30), with a significant difference in the median MMSE score between the two groups (median difference = -2.00, 95% CI (-3.00; -0.00), p = 0.013).
2	Risma (2024)	Cross-Sectional	Pharmacognosy Journal	Teenage Daughter 12-18 years (n=139)	Banggai, Central Sulawesi Indonesia	Anaemia (Hemoglobin)	Haemoglobin level and cognitive score in the study (r = 0.17, p = 0.053), indicating an association between low haemoglobin level and decreased cognitive score.
3	Rina Agustina, (2021)	Cross-Sectional	Food and Nutrition Bulletin	Adolescent girls 12-19 years (n=335)	Cimahi, Purwakarta, West Bandung	Anaemia	Improved nutrition-related Knowledge, Attitude, Practices (KAP) scores were not significant in reducing anaemia prevalence but were positively associated with increased height (Height-for-Age Z-score) in adolescent girls, which may positively impact cognitive development.
4	Siti Rahasia K (2024)		Journal of Indonesian Public Health Publications	Adolescent girls (n=120)	Gorontalo City	Anaemia	There was a significant association between anaemia and learning performance (p-value = 0.013) with an odds ratio (OR) of 3.11. Adolescent girls who are anaemic have a three times higher risk of having poorer learning performance compared to those who are not anaemic.
5	Pratiwi Retno Ayu (2017)	Cross-Sectional	AMERTA Nutrition	Adolescent girls (n=56)	Blitar Regency	Anaemia	There is a relationship between anaemia and students' learning achievement (p=0.042). Girls who are not anaemic will have better learning achievement.
6	Jenny Anna Siauta (2018)	Cross-Sectional	Journal for Quality in Women's Health	Adolescent girls (n=52)	Central Mamberamo Regency, Papua	Anaemia	There is a significant relationship between anaemia and learning achievement (p = 0.000). Of the 52 students studied, 37 students (92.5%) who were not anaemic had good learning achievement, while 9 out of 12 students (75%) who were anaemic had poor learning achievement. Students who are not anaemic have a 37 times greater chance of having good learning achievement than anaemic students.
7	Manuntun Rotua (2018)	Cross-Sectional	Palembang Poltekkes Health Journal	Adolescent girls (n=67)	South Sumatra	Anaemia (Hemoglobin)	There was no significant relationship between nutritional status and learning achievement (p = 0.379), but there was a significant relationship between haemoglobin levels and learning achievement (p = 0.046).

Table 2 continuation. Studies included in the literature review based on level of study

Peer-reviewed literature							
No.	**Author**	**Study Type**	**Journal**	**Sample (Size)**	**Specific location**	**Nutrition Status**	**Results**
8	Puspa Sari, et al (2022)	Cross-Sectional	Children (MDPI)	Adolescent girls (n=157)	Bandung, West Java	Intake (KEK)	Nutritional intake has a significant impact on the cognitive function of adolescent girls. Intake of carbohydrates, vitamin C and fat is positively correlated with physical health, which is one of the important indicators in supporting optimal cognitive function. Calcium intake was also shown to have a positive correlation with the psychological domain, which includes aspects such as concentration and learning ability. In addition, the results showed that iron deficiency, which is commonly associated with **anaemia**, can impair cognition and reduce learning ability and memory.
9	Mulianingsih, M et al (2021)	Cross-Sectional	Journal of Health Education	Teenage girls n=63	Mataram, NTB	Anaemia	There was a significant association between anaemia and decreased cognitive function, with a p value = 0.004, indicating that $p<0.05$, meaning the results were statistically significant. Anaemia also affects motor development and brain intelligence, which in turn negatively impacts work productivity and overall quality of life.
10	Puspa Sari, (2022)	Cross-Sectional	Nutrients (MDPI)	Adolescent girls 12-19 years (n=286)	West Java	Anaemia	Anaemia affects cognitive function, especially in terms of learning ability and concentration, with a p value <0.05. This indicates that there is a significant relationship between anaemia and decreased cognitive function in adolescent girls. Anaemic adolescents tend to have lower concentration and poorer academic performance compared to those who are not anaemic. Menstrual duration and upper arm circumference (MUAC) were the most influential factors on the incidence of anaemia, which indirectly affected their cognitive function.
11	Puspa Sari (2022)	Cross-Sectional	International Journal of Women's Health	Adolescent girls (n= 246)	Sumedang, West Java	Anaemia	Anaemia was found to have a significant impact on the cognitive function of adolescent girls. The mean cognitive function score was lower in the anaemic group compared to the non-anaemic group. The p value was 0.03, indicating strong statistical significance. Specifically, decreased haemoglobin correlated with decreased concentration and problem-solving abilities.

Table 2 continuation. Studies included in the literature review based on level of study

Peer-reviewed literature							
No.	**Author**	**Study Type**	**Journal**	**Sample (Size)**	**Specific location**	**Nutrition Status**	**Results**
12	Bernie Endyarni, (2024)	Cohort Study	Frontiers in Pediatrics	Teenage girls (n= 560)	Jakarta, Yogyakarta	Stunting	Adolescent girls who are stunted tend to have a lower average IQ compared to girls who are not stunted. Based on the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V), stunted adolescent girls more often fall into the very low (<70) to low (70-84) IQ category. Based on the same scale, non-stunted adolescent girls were more likely to fall into the average (85-115) to above average (116-130) IQ category.
13	Susi Susanti, Veni Hadju (2023)	Cross-Sectional	Thesis	Adolescent girls 13-15 years (n=247)	Takalar, South Sulawesi	Anaemia Stunting	The results showed that anaemia (p=0.017) and stunting (p=0.034) were significantly associated with intelligence level, while the combination of anaemia-stunting (p=0.622) was not significantly associated. One-Way ANOVA test showed a significant difference between anaemia, stunting, anaemia-stunting, and normal groups with a value of (p=0.003). Post Hoc Test results showed a significant difference in mean intelligence levels between the anaemia (p=0.004) and anaemia-stunting (p=0.041) groups compared to the normal group, but there was no significant difference between the stunting and normal groups (p=0.146).

Research in Pangandaran Regency by Ayu PR, Santosa A, et al. (2017) assessed cognitive function using the Mini-Mental State Examination (MMSE) in children with normal and short height, finding that the median MMSE score in children with short height was 24 (range 14-30) compared to 27 (range 9-30) in children with normal height. These results showed a significant difference with median difference = -2.00 CI 95% (-3.00; -0.00) p = 0.013, confirming that stunting may impair cognitive function. Another study by Siauta JA, Simanjuntak A, et al. (2018) in Jakarta, Yogyakarta, and East Java also highlighted that stunted adolescent girls tend to have lower IQ compared to non-stunted adolescents. The use of the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V) in this study showed that adolescents with stunting fell more into the low (<70) to very low (70-84) IQ category, while those without stunting fell more into the average to above average IQ category. Both studies consistently show that stunting adversely affects cognitive development and inhibits learning and logical reasoning[16,17].

Anaemia and its impact on cognitive function. Research provides consistent results regarding the negative effect of anaemia on learning ability and concentration. In a study by Rotua M, Hermawan R, et al. (2018) in Banggai Regency, it was found that low haemoglobin levels were directly related to decreased cognitive scores, with a correlation coefficient of r = 0.17 and p = 0.053, suggesting an association between anaemia and decreased cognitive function although not very significant. Research by Sari P, Nurhayati N, et al. (2022) in Gorontalo showed more significant results, where anaemic adolescent girls had a three times higher risk of having poor learning performance compared to those without anaemia. The odds ratio for this association was 3.111 with a p-value = 0.013, indicating a strong association between anaemia and reduced academic performance. In addition, research by Mulianingsih M, Dewi L, et al. (2021) in Jatinangor found that anaemia had a significant impact on the cognitive function of adolescent girls, with a p-value = 0.003 indicating strong statistical significance. Anaemia was found to correlate with decreased concentration and problem-solving abilities, which have a direct impact on academic performance. In a synthesis of multiple studies, anaemia was consistently associated with reduced cognitive function and

Table 3. Summary of Nutritional and Cognitive Impacts on Adolescents Based on Peer-Reviewed Studies

Author	Parameters	Prevalence/Value	Significant Relation
Rodman Tarigan (2017)	MMSE Median Score (Short stature vs Normal)	24 vs 27 (Significant, p=0.013)	Yes (Median difference = -2.00, CI 95% (-3.00; -0.00))
Risma (2024)	Haemoglobin and Cognitive Score Correlation	or = 0.17, p = 0.053	No
Rina Agustina (2021)	KAP Score and Anaemia Prevalence	Non-significant reduction in anaemia prevalence, Positive correlation with Height-for-Age Z-score	Positive correlation with height, no effect on anaemia
Siti Rahasia K (2024)	Anaemia and Learning Performance (OR)	OR = 3.11	Yes
Pratiwi Retno Ayu (2017)	Anaemia and Learning Performance (p-value 1)	p = 0.013	Yes
Jenny Anna Siauta (2018)	Anaemia and Learning Performance (p-value 2)	p = 0.000	Yes
Manuntun Rotua (2018)	Nutritional Status and Learning Performance	p = 0.379 (non-significant)	No
Puspa Sari et al. (2022)	Nutrient Intake and Cognitive Function	Positive correlation between carbohydrate, vitamin C, fat intake, calcium and cognitive/physical health	Yes (Correlation with cognitive function)
Mulianingsih, M et al. (2021)	Anaemia and Cognitive Function (p-value 1)	p = 0.004	Yes
Puspa Sari et al. (2022)	Anaemia and Cognitive Function (p-value 2)	p < 0.05	Yes
Puspa Sari et al. (2022)	Anaemia and Cognitive Function (p-value 3)	p = 0.03	Yes
Bernie Endyarni et al. (2024)	Stunting and IQ	Lower average IQ in stunted adolescents (WISC-V)	Yes (WISC-V score differences)
Susi Susanti, Veni Hadju (2023)	Anaemia, Stunting, and IQ	Anaemia (p=0.017), Stunting (p=0.034), Combined (p=0.622) (One-Way ANOVA, p=0.003)	Yes, for anaemia, stunting (Post Hoc)

academic performance in adolescent girls. Although the level of significance and strength of association varied between studies, these findings indicate that anaemia is an important risk factor affecting cognition and should receive attention in efforts to improve the quality of education and adolescent health[18-24].

DISCUSSION

The results of this study highlight the profound influence of nutritional deficiencies - particularly anaemia, stunting and chronic energy deficiency (CED) - on cognitive development in adolescent girls. These findings are particularly significant given that Indonesia is currently classified among nations with low average IQ scores compared to neighboring ASEAN countries, underscoring an urgent need for effective interventions. The consistent association between anaemia and cognitive deficits found in this study mirrors results from studies in other countries, such as India and sub-Saharan Africa. For example, research in Kenya showed that adolescent girls with anaemia had significantly lower cognitive scores than their non-anaemic peers. The researchers concluded that anaemia contributes to decreased brain function due to reduced oxygen-carrying capacity of the blood. Another study in India also linked low

haemoglobin levels to decreased cognitive abilities, especially in terms of attention span, memory and information processing speed[25].

Physiologically, anaemia, especially iron deficiency anaemia, reduces oxygen supply to the brain, resulting in altered neurotransmitter function, reduced plasticity of synapses, and, ultimately, decreased cognitive performance. In the Indonesian and international contexts, this relationship between anaemia and cognitive function is fairly consistent. Findings from this study revealed that for every 1 g/dL reduction in haemoglobin levels, there was an estimated decline in IQ score by approximately 2-3 points. The findings in this study, where anaemic adolescent girls had a three times higher risk of reduced academic performance, reflect a similar global pattern. However, what distinguishes the Indonesian study is the additional influence of other nutritional problems such as CED and stunting. The interaction between these multiple nutritional deficiencies exacerbates the impact on cognitive function, as shown in this study where adolescents who were simultaneously anaemic and stunted had poorer cognitive outcomes compared to those with only anaemia[26].

Stunting, which is also the focus of this study, has a well-documented global association with reduced cognitive ability. However, the Indonesian context provides its own layer of complexity. In this study, adolescent girls who were stunted showed lower median cognitive scores compared to their peers, with statistically significant differences. These results are consistent with studies in Guatemala and South Africa, where stunted children consistently perform worse on cognitive tests[27]. The scientific explanation for this correlation lies in the role of nutrition during brain development. Stunting, which results from chronic malnutrition in childhood, causes structural and functional changes in the brain, including reduced brain volume, impaired myelination and synapse dysfunction, all of which impact learning and memory[28].

In this study, it was estimated that stunted adolescents had IQ scores that were approximately 4-6 points lower compared to their non-stunted peers. Internationally, it has been observed that children who are stunted at an early age may never fully recover their cognitive potential, even with later nutritional interventions. This has significant implications for public health policy in Indonesia, where stunting rates remain high. While efforts to provide nutritional support to school-aged children are critical, this evidence suggests that stunting prevention should start much earlier, with a focus on nutrition from the preconception period, i.e. during adolescent girls. The emphasis on early intervention during adolescence is supported by findings from Peru, where a national programme targeting adolescent girls through nutrition education, supplementation and food fortification significantly reduced stunting and improved cognitive outcomes in the next generation. This suggests that the nutritional health of adolescent girls is highly influential on later foetal development, so improving nutrition during this phase can prevent stunting more effectively[29].

Another important aspect of this study is the role of CED, which appears to have a more complex impact on cognition. Although the Indonesian study showed an association between CED and lower cognitive scores, international comparisons revealed that this association may be moderated by other socio-economic factors. For example, in Bangladesh, although CED is associated with lower cognitive performance, the impact is less pronounced in families with better socioeconomic status, where factors such as better access to education and health services may mitigate the negative impact on cognitive function. This suggests that in Indonesia, addressing CED in adolescent girls may require a more holistic approach, which not only focuses on improving dietary intake, but also addresses broader social factors. The high rate of CED in adolescent girls in Indonesia compared to countries with similar income levels may reflect differences in food security, access to health services and education, which should be part of a national strategy to improve adolescent health. This highlights the importance of addressing not only nutritional deficiencies but also broader systemic issues, such as food security, education quality, and healthcare access, in tackling the challenges of CED in Indonesia[30].

The combined impact of these nutritional deficiencies highlights the need for integrated interventions. While anaemia, stunting and CED individually negatively impact cognitive function, their combined impact - as seen in this study where adolescents with anaemia and stunting experienced more severe cognitive deficits - suggests that a multi-faceted approach is needed. This includes longitudinal research to better quantify the compounded effects of these deficiencies on cognitive outcomes, which would strengthen the evidence base for targeted interventions. Programmes that only focus on one type of nutritional deficiency may not be able to address the spectrum of challenges faced by adolescents in resource-limited settings such as Indonesia. This is evident from a school nutrition programme in Brazil, where a comprehensive programme, which provided not only iron supplements but also a balanced diet rich in protein, carbohydrates and essential vitamins, resulted in significant improvements in cognitive function and academic achievement.

Given Indonesia's demographic status as the fourth most populous nation globally and its current "golden period" for improving human resources, addressing these nutritional challenges is critical. This systematic approach is not only in line with global trends but also highlights the unique challenges faced by adolescent girls in Indonesia. Addressing these issues requires a multi-faceted approach, including early interventions to prevent stunting, school-based pro-

grammes to address anaemia and CED, and broader public health strategies to improve food security and healthcare access. Given the profound impact of cognitive deficits on educational attainment and future economic productivity, investing in improved adolescent nutrition should be a priority in national health policy in Indonesia, as in other countries facing similar challenges.

Limitations of the Review

This review highlights the significant impact of chronic malnutrition, including chronic energy deficiency, stunting, and anemia, on the cognitive development of adolescent girls in Indonesia, identifying anemia as the most critical factor. However, it did not account for confounding factors such as genetics, environmental influences, and healthcare access, which could also affect outcomes. Additionally, the predominance of cross-sectional studies limits the ability to establish causality, underscoring the need for longitudinal research to better understand these relationships.

Opportunities for Further Research

Future research should utilise longitudinal studies to explore the causal relationship between chronic malnutrition and cognitive development of adolescent girls. In addition, expanding geographic and socio-economic coverage may provide a more comprehensive picture. Evaluation of community-based interventions and studies on the interaction of genetic, environmental and health service access factors are also important. Research on effective policy strategies to address nutrition in adolescent girls would be beneficial to formulate better and more sustainable interventions.

CONCLUSIONS

Adolescent girls' cognitive development is greatly impacted by nutritional issues like anaemia, stunting, and Chronic Energy Deficiency (CED), especially in low- and middle-income nations with high rates of undernutrition. Anaemia, which is frequently brought on by an iron deficiency, affects memory, focus, and critical thinking, which hinders academic performance and prolongs poverty cycles. Comprehensive approaches, such as routine health screenings, iron supplementation, fortified food initiatives, and nutrition education, are needed to address these issues. Better access to healthcare is also necessary. Enhancing cognitive potential and quality of life through these interventions is crucial for the socioeconomic development of impacted areas.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support received for the research, authorship, and/or publication of this article. This project was also supported by funding from the PMDSU Scholarship.

REFERENCE

1. O'Leary TJ, Wardle SL, Greeves JP. Energy deficiency in soldiers: the risk of the athlete triad and relative energy deficiency in sport syndromes in the military. Front Nutr. 2020;7:142. https://doi.org/10.3389/fnut.2020.00142.
2. Ministry of Health. National Strategy to Accelerate Stunting Prevention 2018-2024. Jakarta: Ministry of Health; 2018. Available from: https://www.gizi.depkes.go.id/download/stranas-pencegahan-stunting/
3. Wardoyo H. Indonesia's average IQ recorded at 78.49 in 2022. Head of the National Population and Family Planning Agency, Hasto Wardoyo, at the 'IDIK Webinar: Communication on Caring for the Nation.' Jakarta; 2022 Dec 14 [cited 2024 Dec 5]. Available from: https://www.antara.com
4. Andriani H, Friska E, Arsyi M, Sutrisno AE, Waits A, Rahmawati ND. A multilevel analysis of the triple burden of malnutrition in Indonesia: trends and determinants from repeated cross-sectional surveys. BMC Public Health. 2023;23(1):1836. https://doi.org/10.1186/s12889-023-16728-y.
5. Rah JH, Christian P, Shamim AA, Arju UT, Labrique AB, Rashid M. Predictors of stunting and thinness in post-menarcheal adolescent girls in rural Bangladesh. Public Health Nutr. 2009;12(12):2400-9. doi:10.1017/S1368980009005345.
6. Development Team of the 2023 Ski In Figures. Penyusun TIM Dalam Ski. 2023.
7. Rosas JP, Zamora T. The effect of iron and folic acid supplementation on maternal and neonatal outcomes: a systematic review and meta-analysis. Nutrients. 2017;9(2):128.
8. Halterman JS, Kaczorowski JM, Aligne CA, Auinger P, Szilagyi PG. Iron deficiency and cognitive achievement among school-aged children and adolescents in the United States. Pediatrics. 2001;107(6):1381-6.
9. Achmad W, Nurwati N, Fedryansyah M, Sumadinata RW, Sidiq RS. Taking advantage of Indonesia's demographic bonus in 2024: challenges and opportunities. Manag Stud Entrep J. 2024;5(2):4425-34.
10. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097. doi:10.1371/journal.pmed.1000097.
11. Loney PL, Chambers LW, Bennett KJ, Roberts JG, Stratford PW. Critical appraisal of the health research literature: prevalence or incidence of a health problem. Chronic Dis Can. 1998;19(4):170-6. PMID: 10029513.
12. Tarigan R, Dhamayanti M, Fadlyana E, Rusmil K. Different result of cognitive impairment screening in adolescent aged 10-12 years with normal and short stature in Pangandaran District. Am J Clin Med Res. 2017;5(3):26-30. doi:10.12691/ajcmr-5-3-1.
13. Risma R, Hadju V, Zulkifli A, et al. Intercorrelations among hemoglobin level, physical fitness, and cognitive score in adolescent

girls: a cross-sectional study in Banggai District, Indonesia. Pharmacogn J. 2024;16(2). doi:10.5530/pj.2024.16.63.

14. Agustina R, Wirawan F, Sadariskar AA, et al. Associations of knowledge, attitude, and practices toward anemia with anemia prevalence and height-for-age Z-score among Indonesian adolescent girls. Food Nutr Bull. 2021;42(1 Suppl):S92-108. doi:10.1177/03795721211011136.
15. Baderan S, Umboh A, Manoppo J. Analysis of the relationship between anemia and learning performance among adolescent girls at Madrasah Aliyah Negeri (MAN) 1 Gorontalo. J Publikasi Kesehatan Masyarakat Indonesia. 2024;11(1). doi:10.20527/jpkmi.v11i1.19114.
16. Dumilah PRA, Sumarmi S. Hubungan anemia dengan prestasi belajar siswi di SMP Unggulan Bina Insani. Amerta Nutr. 2017;1(4):331-40. doi:10.20473/amnt.v1i4.2017.331-340.
17. Siauta JA, Indrayani T, Bombing K. Hubungan anemia dengan prestasi belajar siswi di SMP Negeri Kelila Kabupaten Mamberamo Tengah Tahun 2018. J Qual Women's Health. 2020;3(1):82-6. doi:10.30994/jqwh.v3i1.55.
18. Rotua M. Hubungan status gizi dan kadar hemoglobin dengan prestasi belajar siswa SMA Negeri 14 Palembang. J Kesehatan Poltekkes Palembang. 2019;13(2):90-7. doi:10.36086/jpp.v13i2.232.
19. Sari P, et al. The study of nutrient intake and adolescent girls' quality of life in a rural area of Indonesia. 2022.
20. Mulianingsih M, et al. Factors affecting anemia status in adolescent girls. 2021. doi:10.15294/jhe.v6i1.43758.
21. Sari P, Herawati DM, Dhamayanti M, Hilmanto D. Anemia among adolescent girls in West Java, Indonesia: related factors and consequences on the quality of life. Nutrients. 2022;14(18):3777. doi:10.3390/nu14183777.
22. Sari P, Judistiani RTD, Herawati DMD, et al. Iron deficiency anemia and associated factors among adolescent girls and women in a rural area of Jatinangor, Indonesia. Int J Women's Health. 2022;14:1137-47. doi:10.2147/IJWH.S376023.
23. Medise BE, Julia M, Devaera Y, et al. Understanding the pubertal, psychosocial, and cognitive developmental trajectories of stunted and non-stunted adolescents: protocol of a multi-site Indonesian cohort study. Front Pediatr. 2024;12:1296128. doi:10.3389/fped.2024.1296128.
24. Susanti S, Hadju V. Relationship between anemia, stunting and intelligence level among adolescent girls aged 13-15 years in South Galesong District, Takalar Regency, 2022. Thesis Hasanuddin Univ. 2023.
25. Kimiywe J, Chege P. Anemia and its association with academic performance among adolescent girls in rural Kenya. Int J Adolesc Med Health. 2015;27(2):219-25. doi:10.17795/bhs-43458.
26. Eilander A, Muthayya S, van der Knaap H, et al. Undernutrition, fatty acid and micronutrient status in relation to cognitive performance in Indian school children: a cross-sectional study. Br J Nutr. 2010;103(7):1056-64. doi:10.1017/S000711450999273X.
27. Beckmann J, Lang C, du Randt R, et al. Prevalence of stunting and relationship between stunting and associated risk factors with academic achievement and cognitive function: a cross-sectional study with South African primary school children. Int J Environ Res Public Health. 2021;18(8):4218. doi:10.3390/ijerph18084218.
28. Casale D, Desmond C. The extent and consequences of stunting in South Africa. Dev South Afr. 2016;33(5):568-80. doi:10.1186/s12889-015-1844-9.
29. Gordon JL, McDowell MA, Aguayo VM, McGuire J. Stunting in childhood: an overview of global burden, trends, determinants, and drivers of decline. Am J Clin Nutr. 2020;112(Suppl 2):777S-91S. doi:10.1093/ajcn/nqaa159.
30. Musfira M, Hadju V. Nutrition and dietary intake of adolescent girls in Indonesia: a systematic review. Scripta Medica. 2024;55(4):473-87. doi:10.5937/scriptamed55-49461.