Amerta Nutrition
e-ISSN: 2580-1163 (Online)
p-ISSN: 2580-9776 (Print)
Pibriyanti et al. | Amerta Nutrition Vol. 9 Issue 3 (September 2025). 486-495

RESEARCH STUDY
English Version
OPEN ACCESS

Correlation of Sleep Quality and Diet Quality with Hemoglobin Levels in Adolescent Girls

Korelasi Kualitas Tidur dan Kualitas Diet dengan Kadar Hemoglobin pada Remaja Putri

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ARTICLE INFO

Received: *18-11-2024*
Accepted: *14-05-2025*
Published online: *12-09-2025*

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DOI:
10.20473/amnt.v9i3.2025.486-495

Available online at:
https://e-journal.unair.ac.id/AMNT

Keywords:
Iron Deficiency Anaemia, Nutrition Intake, Sleep Quality, Adolescent Girls, Haemoglobin

ABSTRACT

Background: Iron deficiency is a common health issue among adolescent girls, mainly due to poor eating habits and inadequate sleep. The prevalence of anemia in this group remains high, ranging from 40% to 88%.
Objectives: This study aimed to examine the relationship between nutritional intake, diet quality, and sleep quality with hemoglobin levels among adolescent girls.
Methods: A cross-sectional study was conducted with 80 adolescent girls aged 15–19 years, selected from a population of approximately 230 adolescent girls in Ponorogo. Hemoglobin levels were measured using the Easy Touch GCHB instrument via capillary blood sampling. Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Nutritional intake was evaluated using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), and diet quality was measured with the Diet Quality Index (DQI). Multinomial logistic regression analyzed the relationships between nutritional intake, sleep quality, and hemoglobin levels.
Results: The study found that 50% of participants had normal hemoglobin levels, 42.5% had mild anemia, and 7.5% had moderate anemia. The mean hemoglobin level was 13.8, the average diet quality score was 57.47, and the mean sleep quality score was 7.33. Poor nutritional intake increased the risk of mild anemia by 20.32 times (OR=20.320, 95%CI=3.12-41.55, p-value=0.004). Moderate sleep quality increased the risk of mild anemia by 22.93 times (OR=22.932, 95%CI=2.91-182.55, p-value=0.013).
Conclusions: Interventions to improve nutritional intake and sleep quality are essential for adolescent girls, as these factors are strongly associated with iron deficiency in this group.

INTRODUCTION

Rapid developments in physical, emotional, and psychological characteristics are generally observed during adolescence, which is a critical phase of growth and development. During this phase, adolescents, particularly females, are highly vulnerable to unhealthy lifestyle habits, including poor sleep patterns and inadequate diet quality. This often occurs due to academic pressures, the desire to achieve an ideal body image, and high social demands, which cause aspects of health, such as sleep and nutrition intake, to be frequently overlooked. The understanding of adequate nutritional intake is important to be disseminated, as recommended by the World Health Organization (WHO)[1] and the Indonesian Ministry of Health, which emphasized the importance of adequate iron intake for adolescent girls to prevent iron deficiency anemia.

The National Health and Nutrition Survey by the CDC[2], shows that about 73% of adolescents have sleep disturbances and 50% do not meet the recommended daily nutrient intake. Sleep deprivation contributes to a variety of health problems, including anemia, emotional instability, and impaired growth. Studies show that individuals with inadequate sleep have a 1.5-2.5 times greater risk of anemia than those with adequate sleep, with prevalence reaching 20-40%[3] depending on age group and gender[4] depending on age group and gender[5].

Poor quality sleep can disrupt the regulation of appetite hormones, which tends to encourage the consumption of foods high in sugar and fat[6]. An unbalanced diet, especially one low in iron and magnesium, also inhibits the production of the hormone melatonin, which is essential in regulating sleep. Furthermore, poor sleep can affect iron metabolism and

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hemoglobin synthesis, ultimately increasing the risk of anemia and mood disorders due to neurotransmitter imbalances[7].

Adolescent girls are physiologically more prone to anemia due to iron loss during menstruation. This risk is exacerbated by inadequate nutritional intake and sleep disturbances that impact hemoglobin production. Adequate sleep and a good diet contribute positively to academic performance, body image and physical activity. Conversely, sleep deprivation and poor diet create a negative cycle that worsens nutritional status and overall health[2,3].

Anemia, which occurs due to low hemoglobin levels, inhibits the distribution of oxygen to the body's tissues, thereby impairing various vital functions[8]. Although many factors play a role, diet quality is the main factor that strongly correlates with hemoglobin levels[9]. Adolescent girls often go on extreme diets or restrict food consumption, leading to deficiencies in essential nutrients such as iron[9,10]. Research by Gurnani in 2019 shows that a poor diet, especially one low in iron-rich foods such as red meat, green vegetables, and beans, negatively affects hemoglobin production. In addition to iron, vitamin B12 and folic acid deficiencies also interfere with the process of red blood cell formation and aggravate anemia[11].

Sleep quality also affects hemoglobin levels through physiological mechanisms such as immune system regulation, oxidative stress management and hormonal balance. Exposure to blue light from electronic devices such as cell phones and tablets at bedtime decreases melatonin production and disrupts circadian rhythms, thus impacting sleep duration and quality. Disrupted sleep can impair iron metabolism and increase red blood cell destruction (hemolysis), which in turn lowers hemoglobin levels[12].

Data shows that iron deficiency anemia is one of the major health problems for adolescent girls. About 24% of the world's population suffers from anemia, with a higher prevalence in women of reproductive age (29.9%) and children (39.8%)[13,14]. In Indonesia, the 2018 Riskesdas data noted that 48.9% of adolescent girls with anemia had iron intake below the recommended nutritional adequacy. This condition has a direct impact on academic performance, causes chronic fatigue, and increases susceptibility to infections[15].

While many studies have examined the effect of diet quality on anemia, there are limited studies on the relationship between sleep quality and hemoglobin levels, especially among adolescents. A study from the International Journal of Adolescent Health found that 60% of adolescent girls on extreme diets had lower than normal hemoglobin levels. A survey by Astuti in 2017 showed that 65% of adolescents slept less than the recommended duration (7-9 hours per night), which contributed to an increased risk of iron deficiency (OR=2.3; 95%CI=1.8-2.9), suggesting that adolescents with insufficient sleep duration were 2.3 times more likely to experience iron deficiency compared to those who slept enough[16]. Teenage girls' diets often lack iron, which is necessary for the formation of hemoglobin. There are two possible causes for this, namely the desire to maintain a slim figure or ignorance about a balanced diet. Lack of consumption of foods high in iron can drastically lower hemoglobin levels and increase the risk of anemia, which is a hallmark of a poor diet[10,17].

Good sleep quality has important benefits, including more balanced hormone regulation, reduced oxidative stress, as well as improved erythropoiesis processes. Conversely, poor sleep quality increases oxidative stress, disrupts circadian rhythms, and accelerates red blood cell destruction[18,19]. Therefore, poor sleep quality may exacerbate the risk of anemia, especially in adolescent girls who also face nutritional challenges.

Physiologically, there is a proven positive correlation between iron intake and hemoglobin levels. In addition, sleep quality plays a role in supporting hemoglobin metabolism and synthesis indirectly through its influence on circadian rhythms and hormonal balance[19,20]. However, until now, not many studies have specifically examined the relationship between sleep quality, nutrient intake, and hemoglobin levels in adolescent girls. Based on this background, this study aims to examine the relationship between sleep quality, diet quality, and blood hemoglobin levels in adolescent girls. This study aims to provide a scientific basis for designing interventions that can improve adolescent health, especially in preventing and treating iron deficiency anemia through a healthy nutrition and sleep quality approach.

METHODS

Study Design and Data Collection

A cross-sectional study design was used to observational investigate the relationship between sleep quality, nutrient intake, diet quality, and hemoglobin levels among adolescent girls. Respondents consisted of a group of adolescent girls aged 15-19 years, selected from one of the senior high schools in Ponorogo through cluster random sampling with a total population of 230 adolescent girls. This population was chosen due to the high risk of anemia, as shown by previous studies. The sample size required to meet the research standards followed the following sample size formula:

$$n = \frac{Z^2 \times p \times (1-p)}{d^2}$$

Notes:
Z = 1.96 which is the standard value for a 95% confidence level, indicating that the estimated results have a 95% chance of reflecting the true state of the population.
p = 0.5 as the assumption of maximum variation, used to optimize estimation in situations where the true proportion is unknown.
d = 0.12 which represents a precision of 88%, indicating an acceptable margin of error in sample estimation[21,22].

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Therefore, the estimated minimal required sample size was:

$$n = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.12^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0144}$$

$$n = \frac{0.9604}{0.0144} = 66.69$$

$$n \approx 67 \text{ responden}$$

To anticipate missing data, this study used an additional percentage for missing data of 20%, so that the sample size used was 80 respondents. The eligibility criteria for participants to become respondents were determined based on factors that could affect hemoglobin levels and sleep quality, and avoid bias in the results of the study. Inclusion criteria include:

1) Adolescent girls aged 15-19 years, who are vulnerable to anemia due to physiological and dietary changes;
2) Willingness to participate in the study by providing informed consent, either independently or through the consent of parents or guardians, in accordance with the ethics of research on underage subjects;
3) No chronic diseases that may affect hemoglobin levels and body metabolism, such as heart disease, tuberculosis, or HIV/AIDS, in order to control for confounding factors in data analysis;
4) Not having menstruation or pregnancy at the time of participation, as these conditions can significantly affect hemoglobin levels and cause fluctuations that do not reflect the normal condition of the respondents.

Variables and Measurements

Hemoglobin levels were measured using the Easy Touch GCHB instrument, which requires a small blood sample from the respondent's finger. The blood sample was taken by pricking the left middle finger, and the hemoglobin level was recorded. Hemoglobin levels were categorized as: “normal” (>12 g/dL), ‘mild anemia’ (>10-12 g/dL), ‘moderate anemia’ (>7-10 g/dL), and ‘severe anemia’ (7 g/dL or less) according to WHO standards for adolescent girls.

Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI), a standardized questionnaire that has been internationally validated to assess various aspects of sleep. The PSQI includes seven main components: sleep duration, sleep latency (time taken to fall asleep), sleep efficiency, sleep disturbances, sleep medication use, daytime dysfunction due to sleep disturbances, and subjective sleep satisfaction. Each component is scored between 0 to 3, and then summed into a total score with a range of 0 to 21. A higher total score indicates poorer sleep quality[23].

Based on the PSQI total score, sleep quality can be categorized into three levels: 1) Good sleep quality (score 1-5), indicating quality sleep with little or no disturbance; 2) Moderate sleep quality (score 6-10), indicating some sleep disturbances, but still within tolerable limits; and 3) Low sleep quality (score >11), indicating significant sleep disturbances[23]. Nutritional intake was assessed using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ)[24], which is a survey method that identifies an individual's eating habits over a period of time (last 1-3 months). The instrument assesses the frequency of consumption of various food groups with a focus on iron-rich foods, fruits, vegetables, and protein, which play an important role in hemoglobin production and overall body health[24].

Meanwhile, nutrient intake data was categorized based on the percentage of adequate energy and nutrient intake compared to the Nutrient Adequacy Rate (RDA), with the following categories: 1) Adequate (70%-100%) indicates adequate nutrient intake in accordance with recommendations; 2) Insufficient (<70%) indicates nutrient intake that does not meet daily needs; 3) Excessive (>100%) indicates consumption that exceeds daily nutrient requirements. Meanwhile, the Diet Quality Index (DQI)[25] is used to evaluate the overall diet quality based on variety, adequacy, moderation, and balance. The DQI score was calculated based on an instrument with separate questions from the SQ-FFQ with a range of 0-100 points, then categorized as follows: 1) High diet quality (80-100 points) indicates a healthy and balanced diet; 2) Moderate diet quality (60-79 points) indicates a fairly good diet but still requires improvement; 3) Low diet quality (<60 points) indicates a diet that is less balanced and poses a health risk[26].

Data Analysis

Data were analyzed using univariate and bivariate methods. Univariate methods were used to summarize the distribution of key variables (hemoglobin level, sleep quality, nutrient intake and diet quality) through frequency and percentage tables, then visually illustrate the correlation of cross tabulation within variables. The bivariate method was used to assess the relationship between the independent variables (sleep quality, nutrient intake and diet quality) and the dependent variable (hemoglobin level) using multinomial logistic regression. Odd ratios (OR) with 95% confidence intervals were calculated to estimate the strength of association. p-value<0.05 was considered statistically significant for all analyses. Statistical analysis was performed using SPSS software.

Ethical Considerations

This study was conducted in compliance with applicable research ethical principles, including respect for participants' rights, data confidentiality, and informed consent. Ethical clearance was obtained from the Research Ethics Committee of Dr. Moewardi Hospital with approval number 019/I/HREC/2024 on January 5, 2024, as a form of legality and legitimacy of the study implementation. All participants, including those under 18 years of age through the consent of their guardians, have provided written informed consent after receiving an adequate explanation of the objectives, procedures, and their right to participate voluntarily or withdraw at any time without consequence.

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RESULTS AND DISCUSSIONS

This table provides an overview of the variation in observed characteristics of the respondents, which include factors that may affect hemoglobin levels, such as sleep and diet patterns. This information is important to understand the relationship between these factors and the nutritional status and blood health of adolescent girls.

Table 1. Frequency distribution of characteristics including age, sleep quality, nutrient intake, diet quality and hemoglobin level of adolescent girls

Variable	Frequency (n)	Percentage (%)	Mean
Age			16.1
Sleep Quality			
Good	19	23.8	
Moderate	26	32.5	57.47
Poor	35	43.8	
Nutrition Intake			
Adequate intake	35	43.8	
Deficient intake	15	18.8	
Excess intake	30	37.5	
Diet Quality			
High	1	1.3	7.33
Moderate	52	65.0	
Low	27	33.8	
Hemoglobin Level			
Normal	40	50.0	
Mild Anemia	34	42.5	13.18
Moderate Anemia	6	7.5	
Severe Anemia	0	0.0	

The data presented in table 1 reveals a picture of sleep quality, nutrient intake, diet quality, and hemoglobin levels of a group of individuals, with a mean age of 16.1 years. While 43.8% reported good sleep, most (56.3%) still experienced moderate to poor sleep. 37.5% of individuals had excess nutrient intake, while 18.8% suffered from deficiencies, indicating a persistent dietary imbalance. Only 1.3% had a high-quality diet, with 33.8% reporting a poor diet, although 65.0% maintained a moderate diet. Meanwhile, Half (50.0%) of individuals had normal hemoglobin levels, but 42.5% had mild anemia, and 7.5% had moderate anemia.

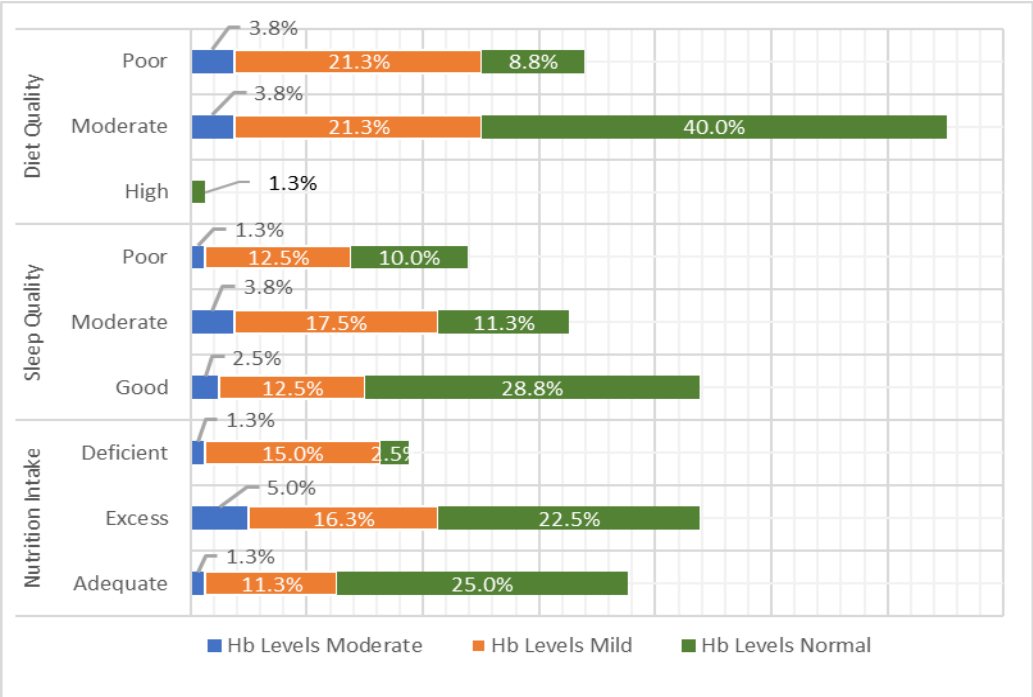

Figure 1. Cross-comparison of Hb levels by Nutrition Intake, Diet Quality and Sleep Quality

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Based on Figure 1 descriptively, no individual with high dietary quality had moderate or mild anemia status (0%). Mild to moderate levels of anemia were experienced by respondents with moderate and low diet quality, although the proportion of respondents with normal Hb was highest (40%) in respondents with moderate diet quality. Based on sleep quality, the distribution of respondents tended to be even, but respondents with good sleep quality had the highest proportion of normal Hb (28.8%). The comparison of Hb levels based on nutrient intake shows that both deficiency and excess nutrient intake can have a negative impact on hemoglobin levels. This mechanism can be explained through the role of key nutrients in hemoglobin synthesis and oxygen transportation in the body. Iron, as the main component of hemoglobin, plays an important role in the formation of red blood cells. Iron deficiency inhibits hemoglobin production, which can lead to iron deficiency anemia. Excess of certain nutrients, such as protein or certain micronutrients, can disrupt metabolic balance and cause oxidative stress, which also impacts the quality of red blood cells[27]. In contrast, individuals with normal Hb levels tended to have a better overall nutritional balance, with a higher proportion maintaining adequate nutrition (25.0%), but also tended to have excess nutritional intake (22.5%). This is supported by Sutaryono's research in 2024[28] which states that a balanced nutritional intake supports the production of erythropoietin, a hormone that stimulates the formation of red blood cells in the bone marrow, as well as increasing the efficiency of iron absorption in the gut.

Meanwhile, individuals with mild Hb levels were more likely to experience moderate (17.5%), and poor (12.5%) sleep quality, suggesting an association between inadequate hemoglobin levels and sleep disturbances. On the other hand, individuals with normal Hb levels tended to have good sleep quality (28.8%), with a small percentage reporting poor sleep quality (10,0%). Participants who had moderate Hb levels tended to have moderate sleep quality (3.8%) compared to the other groups. This indicates that stable hemoglobin levels contribute to optimal oxygen supply to the brain, supporting more regular and quality sleep patterns.

Table 2 shows the likelihood of having "moderate" anemia or "mild" anemia (compared to the reference category, "normal" hemoglobin level) based on predictors such as nutrient intake, diet quality, and sleep quality index. In nutrient intake, it was significant for both mild and moderate anemia, especially for those in the adequate nutrient intake category). In the nutrient deficient intake group, the probability of having mild anemia was 20.320 times higher than the reference group, and this result was statistically significant (p-value=0.004). Diet quality showed extreme effects, especially for Low Diet Quality, the probability of having mild anemia was very high (Exp(B)=45,034,628,230), with a highly significant p-value (p-value<0.001). Meanwhile, Sleep quality also had a significant impact, especially for Medium sleep quality index, which showed a strong correlation between better sleep quality and lower likelihood of anemia.

Table 2. Parameter estimation based on multinominal logistic regression test results

Hemoglobin Levels[a]	Factor Groups	Std. Error	p-value	Coefficients
Moderate Anemia	Intercept	1.628	<0.001	
	Defficient-Nutritional Intake	1.754	0.098	18.148
	Adequate-Nutritional Intake	1.358	0.046	15.080
	Excess-Nutritional Intake			
	Poor-Diet Quality	1.032	<0.001	37688887.067
	Moderate-Diet Quality	<0.001		5915706.339
	High-Diet Quality			
	Poor-Sleep Quality Index	1.405	0.365	3.566
	Moderate-Sleep Quality Index	1.266	0.013	22.932
	Good-Sleep Quality Index			
Mild Anemia	Intercept	0.859	<0.001	
	Defficient-Nutritional Intake	1.048	0.004	20.320
	Adequate-Nutritional Intake	0.745	0.051	4.280
	Excess-Nutritional Intake			
	Poor-Diet Quality	0.656	<0.001	45034628.232
	Moderate-Diet Quality	<0.001		8308416.454
	High-Diet Quality			
	Poor-Sleep Quality Index	0.768	0.034	5.088
	Moderate-Sleep Quality Index	0.864	0.003	13.313
	Good-Sleep Quality Index			

[a]) Reference category=normal Hb level
[b]) Parameter is assigned a value of zero because it is not required or does not make an additional contribution
*) Significant with a tolerable error rate<0.05

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Table 3. Likelihood ratio results

Model	Factors	Chi-Square	df	p-value
1	Intercept	.000	0	-
	Nutritional Intake	14.209	4	0.007
	Diet Quality	9.423	4	0.051
	Sleep Quality Index	14.279	4	0.006
2	Intercept Only			
	Final	34.894	12	<0.001

*) Significant with a tolerable error rate<0.05

Based on the multinomial logistic regression test results (Table 3), nutritional intake and sleep quality showed strong and statistically significant relationships with the dependent variable (p-value<0.05), while diet quality was at the limit of statistical significance (p-value>0.05). The Log -2 likelihood for the final model, which included the predictors (e.g., nutrient intake, diet quality, sleep quality), was 34.89. This indicates that the final model, which includes the predictors, provides a much better fit to the data compared to the intercept-only model. The very low p-value (0.001) indicates that the variables included in the final model (nutritional intake, diet quality, sleep quality, or other) collectively have a meaningful and statistically significant effect on the outcome.

This study shows that anemia is caused by various factors, especially in adolescent girls who experience menstruation, rapid growth, and lifestyle that can worsen diet and sleep patterns. Nutritional factors are commonly identified as the main determinants of hemoglobin levels. This study is in line with previous studies, emphasizing the importance of consuming iron-rich foods to maintain normal hemoglobin levels. Adolescents who have an insufficient or excessive diet tend to increase the risk of moderate anemia[29,30]. The Studi by Kumar,et al in 2020[18] also showed that adolescent girls have twice the risk of anemia compared to boys due to a combination of biological factors and inadequate diet. In addition, rapid hormonal changes during puberty may also affect iron metabolism, exacerbating the risk of anemia[29,30].

In addition, proportionate nutrient intake is essential to prevent iron deficiency anemia. As optimal dietary intake in this study has been shown to reduce the prevalence of anemia. Based on the results of this study, either deficiency or excess nutrient intake can disrupt the body's nutritional homeostasis, affecting hemoglobin synthesis[31]. This is because hemoglobin synthesis depends on the availability of iron, folate and vitamin B12, which support red blood cell formation in the bone marrow. Deficiency of these nutrients can inhibit hemoglobin production, while iron overload can disrupt homeostasis and cause oxidative stress[32]. Fingdings Chaundary in 2019[31] support this statement, where his study showed that adequate dietary intake in both quantity and quality contributes to reducing the prevalence of anemia by providing iron and essential micronutrients such as folate and vitamin B12. Imbalances in nutrient intake, whether in the form of deficiency or excess, can disrupt iron homeostasis and inhibit hemoglobin synthesis. Therefore, nutrition education among adolescent girls is an important aspect, focusing on the consumption of iron-rich foods, such as red meat, liver, spinach, and beans, which are indispensable during periods of increased physiological demand[33].

While diet quality did show some association with anemia, its statistical significance was borderline in this study. The results suggest that moderate to high diet quality lowers anemia rates, possibly by providing a greater variety of nutrients that support hemoglobin synthesis and overall health. This highlights the need for a comprehensive strategy for dietary intervention, where adolescents are urged to eat a variety of foods high in nutrients rather than concentrating solely on iron consumption[29,34,35]. While diet quality did show some association with anemia, its statistical significance was borderline in this study. The results suggest that moderate to high diet quality lowers anemia rates, possibly by providing a greater variety of nutrients that support hemoglobin synthesis and overall health. This highlights the need for a comprehensive strategy for dietary intervention, where adolescents are urged to eat a variety of foods high in nutrients rather than concentrating solely on iron consumption[11,36].

This study also found that in addition to nutrient intake and diet, sleep quality also has a significant influence on hemoglobin levels. Poor sleep quality has been associated with an increased risk of mild to moderate anemia[37]. This is because adolescents who experience poor sleep may be more susceptible to anemia due to disrupted biological rhythms and increased oxidative stress, which can lead to reduced red blood cell production and accelerated hemolysis. However, the observed association between sleep deprivation and anemia highlights the need to consider lifestyle factors beyond diet when addressing Iron Deficiency Anemia in this population[38,39]. Based on studies Cheng et al. in 2024[40] dan Yusufu in 2023[41], sleep disturbances were shown to affect hemoglobin levels through physiological pathways such as decreased melatonin production, circadian rhythm disruption and oxidative stress. These studies confirm that poor sleep quality is not just an additional symptom, but also a major contributor to the incidence of anemia, especially in physiologically vulnerable adolescent girls. This is also supported by Chun et al in 2021[42] and McWilliam in 2024[43], who showed that digital lifestyles and poor dietary patterns create a negative cycle for sleep health and iron metabolism.

The effects of sleep and nutrient intake on hemoglobin levels suggest that addressing anemia in adolescent girls requires an integrated approach. While both factors independently contribute to the risk of anemia, their combined effect can worsen the condition.

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Adolescents who experience poor sleep and an unbalanced diet are at high risk of anemia. This emphasizes the need for multifaceted public health programs that promote healthy eating and sleeping habits in addition to addressing other lifestyle factors to lower the prevalence of anemia[29,44,45]. A study by Zhang et al. in 2020 showed that poor sleep quality was associated with low hemoglobin levels in adolescent girls, which may worsen the anemia condition. Poor sleep quality can affect overall health, including increasing the risk of anemia, especially in adolescent girls. Inadequate sleep or poor quality sleep can disrupt various physiological processes of the body, including iron metabolism and red blood cell production. Lack of sleep can reduce the body's ability to absorb iron effectively, which in turn can lead to iron deficiency and potentially trigger anemia. In addition, poor sleep can worsen the condition of anemia by disrupting the balance of hormones that play a role in blood formation, such as erythropoietin[46].

Despite the results provided by this study, some limitations should be considered. A broader area-based population might limit the generalizability of potential studies[47,48]. Cross-sectional methods may also reduce the ability to explain deeper causative relationships within variables, and future longitudinal studies are needed to better understand the temporal relationships between sleep, nutrition, and anemia[49,50]. In addition, self-reported measures of sleep and food intake may introduce bias, and objective measures would improve the reliability of the findings. The effects of other confounding factors, such as stress, socioeconomic status, and physical activity levels, which may further influence the risk of anemia should be investigated in future studies.

CONCLUSIONS

There is an association between nutrient intake, diet quality, sleep quality, and hemoglobin levels The findings of this study highlight the important role of maintaining a balanced diet and improving sleep quality in preventing iron deficiency anemia among adolescent girls. To effectively reduce anemia rates in this vulnerable group, interventions focused on promoting healthier dietary habits and lifestyles are needed. In addition, strategic prevention should prioritize encouraging balanced nutrition and better sleep quality to support optimal hemoglobin levels and overall health during adolescence.

ACKNOWLEDGEMENT

Thanks are due to Universitas Darussalam Gontor and the Faculty of Health Sciences for their full support as the main institution providing resources and facilities for this publication. The assistance provided was instrumental in the smooth running of the publication, from the planning stage to completion.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

All authors have no conflict of interest in this article. The authors received no funding for this research.

AUTHOR CONTRIBUTIONS

KP: lead author/project leader; DI, IS, AYD, IM, LL: contributed to data collection and organization; DAA: conducted data analysis and interpretation, and managed the use of statistical software for analysis.

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