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The Effect of Caffeine Consumption Habits and Sleep Quality on Hemoglobin Levels in Adolescent Girls

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ABSTRACT

Adolescent girls are particularly vulnerable to anemia as they undergo rapid growth during puberty, which increases their iron requirements to support this growth. Several factors contribute to the occurrence of anemia, including the habitual consumption of iron-inhibiting substances such as caffeine and poor sleep quality. This study aimed to investigate the effects of caffeine consumption habits and sleep quality on hemoglobin levels among adolescent girls aged 15-18 at SMAN 8 Malang. The research design employed an analytical approach with a cross-sectional method. The sampling technique used was two-stage clustering random sampling. Data collection involved the use of the SQ FFQ and PSQI questionnaires, as well as the Point of Care Testing (POCT) method for hemoglobin level analysis, which was analyzed using Spearman rank correlation and logistic regression tests. The results of the Spearman rank correlation test revealed a relationship between caffeine consumption habits and hemoglobin levels (p-value = 0.000 < 0.05), sleep quality and hemoglobin levels (p-value = 0.005 < 0.05), and no relationship between caffeine consumption and sleep quality (p-value = 0.646 > 0.05). The logistic regression test showed a significant effect of caffeine consumption habits and sleep quality on hemoglobin levels in adolescent girls (significant value 0.000 < 0.05).

Keyword : Caffeine; Sleep Quality; Hemoglobin Levels

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INTRODUCTION

Anemia is a condition where the number of erythrocytes falls below the normal threshold, which serves the essential functions of binding and transporting oxygen throughout the body. Anemia continues to be a public health issue worldwide, particularly in developing countries (1–5). When erythrocyte levels are too low, the blood's function of transporting oxygen to body tissues is compromised (6). Anemia is frequently observed among the younger generation, with adolescent girls

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being one of the groups most susceptible to iron deficiency anemia (7–9). Research conducted by the WHO (2015) indicates that the prevalence of anemia among adolescent girls is 29%. In developing countries, the prevalence among adolescent girls (aged 10 to 18) is 41.5%. Indonesia is a developing country where the prevalence of anemia among the young generation remains high. According to Riskesda data from 2013, the prevalence of anemia among girls over the age of 15 is 22.7% (10). Furthermore, Riskesdas data (2018) show an increase in the prevalence of anemia among adolescent girls aged 15-24, from 6.9% in 2007 to 32.0% in 2018. In 2018, 27.2% of adolescent girls in Indonesia experienced a 6.9% increase in anemia prevalence over the last 11 years, a rate higher than that of young males. These data indicate that three to four out of ten adolescent girls in Indonesia suffer from anemia (10).

Anemia in adolescent girls can lead to various negative impacts on health and quality of life, including reduced immunity, concentration difficulties, decreased learning focus, impaired fitness, and productivity (11). Other studies have shown that anemia in adolescents can also hinder growth and increase susceptibility to infections (12). Additionally, anemia in adolescents may contribute to mood swings and emotional well-being disturbances (13,14). One of the reasons adolescent girls are particularly vulnerable to anemia is due to iron deficiency. The relatively high iron requirements in adolescent girls are attributed to menstruation, growth, and the maturation of the reproductive system (7–9,15). Other causes of anemia in adolescents include poor dietary patterns due to dieting, resulting in inadequate iron intake, parasitic infections, consuming tea or coffee immediately after meals, oversleeping, vitamin C deficiency, and economic factors (16–18).

Inhibitors of iron absorption include caffeine, tannins, oxalates, and phytates found in soy products, tea, and coffee. It has also been proven that the more frequent and closer the consumption of tea after a meal, the greater the risk of anemia (19). Caffeine can inhibit iron absorption and also has diuretic effects and reduces calcium absorption in the kidneys (20). Moreover, caffeine can affect health by increasing blood pressure, causing rapid heartbeats, nervousness, headaches, tension, irritability, and insomnia (21). Sleep problems or insomnia are one of the factors that affect hemoglobin levels in the blood. Sleep disorders lead to decreased sleep quality due to ongoing oxidative stress, which if sustained for more than 12 hours accelerates the lysis of red blood cells, reducing hemoglobin levels and causing anemia (22).

A preliminary study by the Malang City Health Office showed that 34% of adolescent girls suffer from anemia. Among all the Community Health Centers in Malang City, the Arjowinangun Community Health Center has the highest anemia rate among adolescent girls, followed by the Dinoyo Community Health Center, which ranks second in terms of anemia prevalence in Malang City with 333 cases of anemia among high school girls, amounting to 33 percent. Therefore, the researcher is interested in conducting a study on the impact of coffee consumption and sleep quality on hemoglobin levels in adolescent girls aged 15-18 years at SMAN 8 Malang, located in the Dinoyo District.

METHODS

This study used a quantitative data analysis design using a cross-sectional method, collecting data simultaneously from October 2023 to June 2024. The sampling for this research was conducted using a two-stage clustering random sampling method. The sampling technique utilized was probability sampling, where the type of sampling in this study involved simple random sampling. In the initial sampling stage, the population consisting of 207 adolescent girls aged 15-18 years at SMAN 8 Malang was selected based on inclusion criteria, resulting in 160 respondents who were present and willing to participate. From these 160 respondents, a further selection was made according to exclusion criteria, such as respondents who were menstruating or ill at the time of data collection, yielding 135 respondents. From these 135 respondents, the second stage involved dividing them into two cluster samples: a cluster of anemic adolescent girls and a cluster of non-anemic adolescent girls. There were 72 anemic girls and 63 non-anemic girls identified, after which sampling was performed from each cluster according to the calculated sample size of 34 samples per cluster using the simple random sampling method. The sampling was carried out by drawing lots within each cluster sample.

The primary data sources used were directly obtained from female Class XI students aged 15-18 years at SMAN 8 Malang through questionnaire techniques and hemoglobin level measurements. The questionnaires used in this study were the PSQI and SQ-FFQ, designed to collect direct data on caffeine consumption habits and sleep quality from willing respondents. Hemoglobin (Hb) levels were measured using the Point of Care Testing (POCT) method, which aimed to determine whether respondents were anemic. Data analysis was conducted in three stages: first, univariate analysis described the data collected throughout the research process, both general data and specific data related to caffeine consumption habits, sleep quality, and hemoglobin levels. Second, bivariate analysis was performed to test the relationships between independent and dependent variables, using the Spearman rank correlation test in this study. Third, multivariate analysis involved logistic regression to examine the relationships between the caffeine consumption habits and sleep quality of adolescent girls and their hemoglobin levels.

RESULT

Table 1. Distribution of Respondents Based on Age, Compliance with Iron Supplement Consumption, Caffeine Intake and Sleep Quality of Adolescent Girls at SMAN 8 Malang

Characteristics	Frequency (f)	Presentation (%)
Age of Respondent		
16 years	21	30.9
17 years	46	67,6
18 years	1	67,6
Iron Supplement Consumption		
Regular	3	4.4
Sometimes	18	26.5
Rarely	47	69.1
Age of Respondent		
Within Recommended Limits	58	85.3
Above Recommended Limits	10	14.7
Sleep Quality		
Good	7	10.3
Poor	61	89.7

Based on Table 1, the majority of respondents are 17 years old, totaling 46 students (67.6%), and rarely consume iron supplements, accounting for 47 students (69.1%), 34 students (50%) were not anemic and 34 students (50%) were anemic, with the lowest hemoglobin level recorded at 8.40 g/dl and the highest at 15.50 g/dl. The majority had caffeine intake within the recommended limits, totaling 58 students (85.3%), with the lowest caffeine intake being 11 mg/hr and the highest 221 mg/day. Poor sleep quality was reported by 61 students (89.7%), with the lowest PSQI score being 1 (good) and the highest 18 (poor).

Table 2. Relationship Between Caffeine Consumption Habits and Sleep Quality in Adolescent Girls at SMAN 8 Malang

Caffeine Consumption	Sleep Quality				Total		*p-value*	Rho (Correlation Coefficient)
	Good		Poor					
	f	%	f	%	n	%		
Within Recommended Limits for Children and Adolescents (≤ 100 mg/day)	7	12	51	88	58	100	0.646	0.057
Above Recommended Limits for Children and Adolescents (> 100 mg/day)	0	0	10	100	10	100		
Total	7		61		68	100		

A Significance value (p-value) > 0.05, specifically 0.646, indicates that there is no relationship between caffeine intake and sleep quality. Poor sleep quality is one of the risk factors for physiological and psychological issues.

Table 3. Relationship Between Sleep Quality and Hemoglobin Levels in Adolescent Girls at SMAN 8 Malang

Sleep Quality	Hemoglobin Level				Total		p-value	Rho (Correlation Coefficient)
	Not Anemic		Anemic					
	f	%	f	%	n	%		
Good: ≤ 5	7	100	0	0	7	100	0.005	0.339
Poor: > 5	27	44.3	34	55.7	61	100		
Total	34		34		68	100		

A significance value (p-value) < 0.05, specifically 0.005, indicates that there is a relationship between sleep quality and hemoglobin levels, with a moderate correlation strength observed with a rho of 0.339. This falls within the correlation strength criteria of 0.26 – 0.50, suggesting a moderate positive relationship, indicating that better sleep quality is associated with higher hemoglobin levels.

Table 4. Relationship Between Caffeine Consumption Habits and Hemoglobin Levels in Adolescent Girls at SMAN 8 Malang

Caffeine Consumption	Hemoglobin Level				Total		*p-value*	Rho (Correlation Coefficient)
	Not Anemic		Anemic					
	f	%	f	%	n	%		
Within Recommended Limits for Children and Adolescents (≤ 100 mg/day)	34	58.7	24	41.3	58	100	0.000	0.538
Above Recommended Limits for Children and Adolescents (> 100 mg/day)	0	0	10	100	10	100		
Total	34		34		68	100		

A Significance value (p-value) < 0.05, specifically 0.000, indicates that there is a strong relationship between caffeine intake and hemoglobin levels, with a correlation strength rho of 0.538. This falls within the correlation strength criteria of 0.51 – 0.75, suggesting a strong positive relationship, indicating that appropriate caffeine consumption is correlated with normal hemoglobin levels.

Table 5. Hypothesis Test F Results in the Omnibus Test of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	24.713	2	.000
	Block	24.713	2	.000
	Model	24.713	2	.000

Based on Table 5, a significance value of 0.000, which is less than 0.05, indicates there is a simultaneous effect of caffeine consumption habits and sleep quality on the hemoglobin levels of adolescent girls aged 15-18 years at SMAN 8 Malang.

DISCUSSION

Based on the results of the study, it shows that the majority of students had caffeine intake within the recommended limits and poor sleep quality. Caffeine is a natural substance found in various foods, beverages, nutritional supplements, and prescription medications (23). It has numerous effects on health and the body, including impacts on the cardiovascular system, respiratory system, kidneys, and smooth muscles, as well as mood, memory, alertness, physical activity, and cognition (24). Data on safe consumption and safe dosages for children are still limited, although some sources suggest that the recommended limit for children and adolescents should not exceed 100 mg per day or 2.5 mg/kg per day (21). Sleep is an essential part of daily routine; without sleep, humans cannot create and maintain brain functions that enable learning activities and the creation of new memories, and it becomes more difficult to concentrate and respond quickly (25). Adolescents aged approximately 12-18 years require 8 to 9 hours of healthy sleep duration. Adolescents with insufficient sleep may experience depression, poor concentration, and poor academic performance (26).

The result of the study indicates that there is no relationship between caffeine intake and sleep quality. Caffeinated drinks and foods are not the primary cause of poor sleep quality among adolescents; however, other factors contribute to poor sleep quality in this group, including poor sleep hygiene, insomnia (27), adolescents with symptoms of depression, social anxiety, and stress which are associated with poor sleep quality (28,29), and the use of digital and social media at bedtime or during the night which impacts both sleep duration and quality (30–32). Other research also suggests that nutrition and physical activity significantly affect sleep quality. It is noted that consuming foods rich in tryptophan, serotonin, and melatonin can enhance sleep quality (33,34).

Contrary to some studies that have shown caffeine to impact sleep patterns and quality, especially when consumed excessively. Side effects include headaches, tremors, agitation, sleep disturbances, insomnia, excessive anxiety, fatigue, and lack of energy, as well as nausea and vomiting (35,36). Caffeine can stay in the body for 2 to 10 hours, but can last up to 20 hours depending on exogenous and endogenous factors, The absorption process of caffeine that occurs in the stomach and intestines is fast and effective, and side effects can occur 30 minutes after consumption (37). The timing of caffeine consumption can also significantly affect sleep quality, daily caffeine consumption in the morning and evening shows no significant disturbance to the structure of nighttime sleep or to the sleep quality of individuals who are subjectively healthy and do not have sleep disorders. However, caffeine consumed at bedtime or during the evening can prolong sleep latency, reduce sleep duration, and shorten deep sleep phases. The frequency of caffeine intake is a much more critical factor in its impact on sleep (38).

Thus, from the discussion above, it can be concluded that consuming food or beverages containing caffeine is one of the factors that can influence sleep patterns or quality, but it is not the primary or dominant factor that can cause poor sleep quality, as many factors cause adolescent girls to have good or poor sleep quality. Caffeine will have a dominant impact on sleep quality if consumed excessively and before bedtime.

Test Results of the Relationship between Sleep Quality and Hemoglobin Levels in Adolescent Girls at SMAN 8 Malang show that there is a relationship between sleep quality and hemoglobin levels, with a moderate correlation strength. The function of sleep is to heal and repair the human body (22), including through recovery processes that promote protein synthesis, such as Hemoglobin (39). Sleep helps reduce the body's energy expenditure. During sleep, particularly in deep sleep phases, the body's

temperature drops, and the brain's glucose (sugar) requirements decrease. This means that the brain requires much less energy during sleep, using up to twice as little glucose compared to when awake (34). Thus, the biological processes occurring during sleep impact how sleep duration affects everyone, with shortened sleep duration disturbing these processes, one of which is the formation of hemoglobin, thereby increasing the likelihood of reduced hemoglobin levels more than usual (40).

It is explained that reducing sleep duration can disrupt the metabolism of body cells, including the metabolism of hemoglobin breakdown. Insufficient sleep increases energy expenditure, which must be balanced with proper nutrition to restore the energy needed for metabolism and the repair of damaged body cells (41,42). In studies with animal models suffering from insomnia, short sleep duration has been shown to reduce the number of red blood cells produced in the body because the growth and differentiation of erythroid progenitor cells are inhibited, thus suppressing erythropoiesis in the bone marrow (43).

Insufficient sleep has been shown to result in fluctuations in blood hemoglobin levels, suggesting that the blood system, in this case, hemoglobin and hematocrit, can change as a result of sleep deprivation (44). Another study indicates that an individual's sleep duration positively correlates with hematocrit levels, which is the proportion of red blood cells in the blood, as well as hemoglobin levels. Analytical results reveal that sleep can increase hematocrit and hemoglobin levels. Additionally, the influence of sleep duration on hematocrit and hemoglobin appears more pronounced in males than in females, though further research is needed. Adequate sleep can therefore help improve red blood cell levels across various age groups (39).

However, previous research indicates that there are many factors causing anemia in adolescent girls besides sleep patterns, such as menstrual patterns, diet, physical activity, and health history (45). Intake, awareness, and distribution of blood supplements are contributing factors to the development of low Hb levels in adolescent girls (46). Consequently, it can be concluded that sleep quality is related to hemoglobin levels, where if adolescent girls have poor sleep quality, they are likely to have lower Hb levels than normal. However, if they have a normal menstrual pattern, good nutritional intake, and consume iron supplements, sleep quality will not significantly affect the reduction of hemoglobin levels because adolescent girls will have iron reserves for the biosynthesis of red blood cells, namely hemoglobin.

This study shows that there is a strong relationship between caffeine intake and hemoglobin levels. A crucial health issue among adolescents currently is nutrient deficiency, with the most common worldwide being iron deficiency anemia (1,47). One of the causes of iron deficiency anemia in adolescents is the consumption of foods and beverages containing caffeine, tannins, oxalates, and phytates. Caffeine is one substance that can inhibit the absorption process of iron (1,17). It is one of the most commonly consumed stimulants by children and adolescents, typically found in coffee, tea, energy drinks, chocolate, and carbonated beverages (34,48). Additionally, caffeine has diuretic effects and reduces calcium absorption in the kidneys (20).

Research indicates that caffeine may be recommended for adolescents with specific conditions such as ADHD and prematurity apnea; however, its use is not advised for healthy children or adolescents, particularly at moderate to high doses, due to potential physiological changes. Furthermore, recommendations for caffeine consumption for children and adolescents should not exceed 100 mg per hour or 2.5 mg/kg per day (21).

Contrary to other studies, which showed that 98.7% of other factors influence hemoglobin levels. Discussions explained that respondents had a good diet with sufficient iron sources and consumed caffeine-containing foods about 1-2 hours after eating (49). Caffeine is rapidly absorbed in the small intestine within less than one hour and quickly diffuses into other tissues (48). The duration of coffee's effect varies depending on consumption, for instance, in adults it lasts 3-5 hours, in children under six months it can last up to 24 hours, in pregnant women about 7 to 8 hours, and in smokers, it is the shortest at 2 to 3 hours (50). Additionally, anemia can be managed through various methods including lifestyle changes, such as dietary adjustments, meeting iron requirements or using erythropoiesis-stimulating agents, and maintaining good sleep patterns to facilitate recovery by promoting protein synthesis, including Hemoglobin (39).

Therefore, it can be interpreted that the way adolescent girls consume caffeine has both positive and negative impacts. The negative impact includes a decrease in hemoglobin levels due to caffeine acting as an inhibitor of iron absorption, depleting iron reserves in adolescent girls, potentially leading to anemia. However, caffeine consumption may not affect hemoglobin levels if an individual has adequate iron absorption for red blood cell production and sufficient iron stores, especially if women consume a variety of sources. Caffeine should ideally be consumed 1 to 2 hours after eating and within the recommended amounts.

There is a simultaneous effect of caffeine consumption habits and sleep quality on the hemoglobin levels of adolescent girls aged 15-18 years at SMAN 8 Malang. Caffeine can affect hemoglobin levels both directly and indirectly. Directly, caffeine can inhibit the absorption of iron in the body (1) because it is rapidly absorbed (51) into the bloodstream from the gastrointestinal tract (stomach and intestines), with side effects occurring within 30 minutes (37) and peak blood caffeine levels typically reached one hour after consumption (52). Therefore, it is advised not to consume caffeine 1-2 hours after eating as it can impede iron absorption.

Caffeine can have positive effects such as reducing fatigue and enhancing mood, alertness, concentration, and overall well-being. However, it can also have negative health impacts including increased blood pressure, heart rate, nervousness, headaches, tension, irritability, and both the quality and quantity of sleep (21,37,53). Insomnia, defined as insufficient sleep due to difficulties falling asleep, staying asleep, or waking up too early (54), can significantly affect the quality and duration of a person's sleep (55). Ultimately, in such cases, sleep disorders occur, supported by the theory that sleep problems lead to poor sleep quality, persistent oxidative stress if lasting more than 12 hours, faster erythrocyte lysis than expected, low hemoglobin, and anemia (22).

According to research on the relationship between sleep deprivation and erythrocyte membrane stability mediated through lipid profile changes (56), there is constant variation in the erythrocyte population in the blood due to ongoing erythrocyte production and degeneration processes (57). It is clarified that erythrocyte circulation exhibits fluctuations not only influenced by the biological clock but also by the sleep-wake cycle and light/dark cycles. Furthermore, studies have shown that workers who average less than six hours of sleep per day have a higher erythrocyte count but lower hemoglobin concentration (56).

Based on the results of the data analysis, there is a simultaneous influence of caffeine consumption habits and sleep quality on the hemoglobin levels of adolescent girls aged 15-18 years at SMAN 8 Malang. It is advised for adolescent girls to regulate their intake to not exceed the recommended limit of 100 mg/day and to avoid consuming caffeine-containing foods and beverages at night before bedtime.

Additionally, maintaining a sleep pattern of 8-9 hours per day, creating a comfortable sleeping environment, and avoiding gadget use before bedtime are recommended for better sleep quality and overall health.

CONCLUSION

Based on the research conducted with adolescent girls aged 15-18 years at SMAN 8 Malang from May 15–17, 2024, the following conclusions can be drawn: the average hemoglobin level was 11.66 g/dL, with the lowest level at 8.40 g/dL and the highest at 15.50 g/dL. Out of 68 respondents, 58 girls (85.3%) consumed caffeine within the recommended limits, and 10 girls (14.7%) exceeded the recommended limits, with an average caffeine intake of 66.39 mg/day, the lowest intake being 11 mg/hr and the highest 221 mg/day. As for sleep quality, 7 girls (10.3%) had good sleep quality, while 61 girls (89.7%) had poor sleep quality. Therefore, the hypotheses were addressed as follows: there was no relationship found between caffeine consumption habits and sleep quality about hemoglobin levels; there was a relationship between sleep quality and hemoglobin levels; there was a relationship between caffeine consumption habits and hemoglobin levels; and there was an influence of caffeine consumption habits and sleep quality on hemoglobin levels in adolescent girls at SMAN 8 Malang.

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