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Original article

Title: The Association Between Tea and Coffee Consumption and Hemoglobin Levels in Female Adolescents: A Cross-Sectional Study

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Running Title: The Impact of Polyphenol-Rich Drinks on Hemoglobin Levels in Female Adolescents: A Cross-Sectional Study

Abstract:

Objective: This study investigated the association of tea and coffee consumption habits on hemoglobin levels in female adolescents in Madiun City, East Java, Indonesia.

Materials and Methods: A cross-sectional study was conducted among 1,575 female students in junior and senior high schools. Tea and coffee consumption habits were assessed through interviews, and hemoglobin levels were measured using the HemoCue Hb301. The Kruskal-Wallis test was used to analyze the association between tea and coffee consumption and hemoglobin levels.

Results: The study found a significant difference in mean hemoglobin levels between groups with different tea and coffee consumption habits ($p\text{-value} < 0.001$). The mean hemoglobin concentration was 12.82 ± 1.42 g/dL, with a total anemia prevalence of 22.5%. The average tea consumption was 1.84 ± 2.40 cups per week, and the average coffee consumption was 0.95 ± 2.04 cups per week. The study suggests that frequent consumption of tea and coffee may contribute to lower hemoglobin levels.

Conclusion: This study highlights the importance of awareness about the association of tea and coffee consumption on hemoglobin levels among female adolescents.

Keywords: anemia, coffee consumption, female adolescents, hemoglobin levels, tea consumption

Introduction

Indonesia continues to face the “triple burden of malnutrition,” which includes overnutrition, undernutrition, and micronutrient deficiencies, with a high prevalence of anemia, specifically indicating the problem of micronutrient deficiency^{1,2}. Anemia is a public health concern that accounts for a majority of nutritional problems and is principally caused by iron deficiency³. Hence, worldwide, iron-deficiency anemia is the most prevalent nutritional deficiency disorder⁴. General causes of iron deficiency include inadequate dietary iron levels, insufficient dietary iron absorption, and blood loss⁵. Iron is needed in all body cells and is fundamental to physiological processes, such as the formation of hemoglobin and enzyme function⁶. Without adequate iron, these processes can be disrupted. Tannins are polyphenolic compounds found in high amounts in certain beverages, such as coffee and tea, which are potent inhibitors of non-heme

iron intestinal absorption⁷⁻⁹. In controlled studies, ingestion of 200 ml of black tea with a test meal resulted in a 21% reduction in iron absorption compared with warm water in premenopausal Indian women. Subsequent investigations have demonstrated similar inhibitory effects, with iron absorption reductions ranging from approximately 10% to 50%, depending on the concentration of tannins, volume of tea consumed, and the iron content and composition of the accompanying meal. Higher tannin concentrations or repeated tea consumption further increase inhibition, while enhancers such as ascorbic acid or milk can lessen the effect. Variability in absorption across individuals and studies (1–50%) reflects differences in iron homeostasis regulation¹⁰. Although theoretically tea and coffee consumption may influence hemoglobin levels, earlier studies have reported inconsistent findings, with some demonstrating an association¹¹⁻¹⁴ and others showing no relationship¹⁵⁻¹⁸.

In recent years, there have been growing concerns about the increased consumption of polyphenol-rich drinks, including coffee and tea, particularly among adolescents¹⁵. Indonesia is no exception, with more than 50% of adolescents reportedly consuming coffee or tea, and peer influence identified as the dominant factor driving consumption^{16,17}. According to the World Health Organization, the adolescent age group is defined as between 10 and 19 years¹⁸. This period is characterized by rapid physical, psychological, and cognitive development. This is a vulnerable period in the human lifecycle for the development of nutritional anemia¹⁹, and Indonesian adolescents are among the hardest hit²⁰. Data from the 2018 Indonesian Basic Health Research (Riset Kesehatan Dasar, Riskesdas), conducted by the Ministry of Health, indicate that one in two pregnant women and approximately three to four in ten female adolescents experience anemia²¹. Due to blood loss during menstruation and increased iron needs during growth, adolescent females of reproductive age suffer from a lack of iron, resulting in iron-deficiency anemia^{22,23}. Anemia, the most marked consequence of iron deficiency, is characterized by a reduction in the blood's oxygen-carrying capacity. This can lead to symptoms, such as fatigue, weakness, and reduced work capacity. In some instances, behavioral disturbances and impaired performance in cognitive tasks can occur. This, in turn, may lead to poor academic performance²⁴. This can also impact the future when adolescents reach reproductive age, potentially leading to adverse maternal and neonatal outcomes. The adversity and impact of maternal anemia is vulnerability to preterm birth and low birth weight babies, in addition to various other gestational complications, such as the risk of

miscarriages, intra-uterine growth retardation, increased susceptibility to infection, and postpartum hemorrhage^{25,26}. In lower-middle-income countries, anemia is a major cause of child and maternal mortality²⁷.

To combat the rising prevalence of anemia among adolescent girls in Indonesia, the Indonesian government carries out a yearly anemia screening for students in 7th and 10th grade and distributes iron tablets to target groups aged 10-18, grades 5-12, to be consumed once a week²⁸. This serves as an initial step in prevention through specific protection and early diagnosis of potential anemia occurrences²⁹. Given that coffee and tea consumption may contribute to iron-deficiency anemia, reducing the occurrences of anemia in Indonesia requires a better understanding of this potential risk factor. Moreover, the inconsistent findings of previous studies highlight the need for further research. Therefore, this research aimed to determine the association between tea and coffee consumption and hemoglobin levels among female adolescents, as well as to identify consumption patterns associated with varying hemoglobin levels.

Materials and Methods

Study Design and Sampling Method

This research is an analytic observational study with a cross-sectional design, employing a census sampling method.

Participants

The study was conducted at all junior high schools and senior high schools within the work area of the Banjarejo Primary Healthcare Center (Puskesmas) in Madiun City, East Java, Indonesia, concurrently with the government's annual anemia screening for female students in grades 7 and 10, carried out by the Primary Healthcare Center (Puskesmas). A total of 2,391 female students across 20 schools, including 8 junior high schools and 12 senior high schools, were screened. The inclusion criteria for participants were female students in 7th and 10th grade within the work area of the Banjarejo Primary Healthcare Center (Puskesmas). A total of 1,575 participants were included in this study after applying the exclusion criteria: female students who were absent during the health screening examination, vegetarians, menstruating, taking iron supplements more than once a week, and attending special needs schools.

Variables and Data Collection

The independent variables of this study are coffee and tea consumption habits, while the dependent variable is hemoglobin levels. An interview regarding tea and coffee consumption habits was conducted to determine how many glasses or cups of coffee and tea are consumed per week. The results were categorized as follows: <3 (rarely), 3-5 (sometimes), and >5 (often). Capillary hemoglobin levels were measured using the HemoCue Hb301, which can measure hemoglobin levels from 0 to 25.6 g/dL. The research team visited each school within the work area of the Banjarejo Primary Healthcare Center (Puskesmas) over the course of two months. The interview was carried out by a team of doctors, and the capillary blood sample for hemoglobin level testing was taken by a laboratory attendant from the Banjarejo Healthcare Center.

Statistical Analysis

The data collected were analysed using the Statistics Package for the Social Sciences (SPSS) for Windows 10 software. Descriptive statistics were applied to assess the distribution of all variables in the analysis. In this study, before conducting statistical testing, the normality and homogeneity of the data were first determined to identify the appropriate analytical test. In the normality test, it was found that the data distribution was not normal; hence, a non-parametric test was used, the Kruskal-Wallis test.

Ethical Consideration

This study was approved by the Ethics Commission of the Faculty of Medicine, Hang Tuah University, letter number: No.E/006/UHT.KEPK.03/II/2025 . Participation in the study was entirely voluntary. The data obtained were strictly used for this research only, and all the participants' identities were anonymized.

Results

A total of 1,575 participants were analyzed; the findings are presented below. Table 1 shows the distribution of tea consumption habits among the research sample, with 117 students drinking tea often (7.4%), 330 students drinking tea sometimes (21.0%), and 1,128 students drinking tea rarely (71.6%), with a mean consumption of 1.84 ± 2.40 cups per week. Table 2 shows the distribution of coffee consumption habits among the research sample, with 58 students drinking

coffee frequently (3.7%), 150 students drinking coffee sometimes (9.5%), and 1,367 students drinking coffee rarely (86.8%), with a mean of 0.95 ± 2.04 cups per week.

Based on hemoglobin concentration, anemia was classified as mild, moderate, and severe. The cut-off values for the hemoglobin concentration of non-pregnant women—non-anemic, mild, moderate, and severe—were ≥ 12 g/dL, 11.0–11.9 g/dL, 8.0–10.9 g/dL, and < 8 g/dL, respectively¹¹. As depicted in Table 3, 1,221 students were not anemic (77.5%), 211 students had mild anemia (13.4%), 133 students had moderate anemia (8.4%), and 10 students had severe anemia (0.6%). Table 4 shows that the mean hemoglobin concentration of 1575 female adolescents was 12.82 ± 1.42 , which is considered non-anemic based on the WHO cut-offs, with the lowest hemoglobin level at 6.70 and the highest at 16.70.

The Kruskal-Wallis test was used to analyse the effect of tea and coffee consumption on hemoglobin because the hemoglobin concentration data, as well as the tea and coffee consumption habits, showed non-normal distribution, as indicated in Table 5. The Kruskal-Wallis test showed a significant difference in mean hemoglobin levels between the groups that consume tea rarely and sometimes (p-value < 0.001), as well as between the groups that consume tea rarely and often (p-value < 0.001). However, there was no significant difference in mean hemoglobin levels between those who consume tea sometimes and often (p-value 0.310), as shown in Table 6. This finding aligns with that of coffee: no significant difference was found between those who consume coffee sometimes and often (p-value 1.00), as shown in Table 7.

Discussion

Our research data analysis found a difference in the average hemoglobin levels between groups with 'rarely' and 'sometimes' tea-drinking habits, as well as between 'rarely' and 'frequently' tea-drinking habits. However, no difference was found in the average hemoglobin levels between those with 'sometimes' and 'frequently' tea-drinking habits. This finding is the same for coffee-drinking habits. These findings suggest that hemoglobin levels decrease once intake reaches ≥ 3 cups per week, but no further reduction occurs beyond this threshold, indicating the absence of a dose–response relationship above 3 cups per week. The data shows that 28.4% of female students have a habit of drinking tea more than twice a week, and 13.2% have a habit of drinking coffee more than twice a week.

Association between tea and coffee drinking habits and hemoglobin levels:

Our study found an association between tea and coffee drinking habits and hemoglobin levels. This finding is consistent with previous studies that showed a relationship between lower hemoglobin levels and an increased frequency of coffee and tea consumption¹¹⁻¹⁴. However, there are also studies that state otherwise, indicating no relationship between hemoglobin levels and tea and coffee drinking habits^{28,30-32}. Conflicting findings across studies may arise from a range of methodological and contextual differences. Variations in study design, sample characteristics, and measurement methods for hemoglobin and beverage consumption can lead to divergent outcomes. Differences in the timing of tea or coffee intake relative to meals and in the polyphenol content of beverages may also influence results, but are not consistently controlled. Differences in sample size, statistical power, and susceptibility to recall or selection bias further affect study conclusions. Moreover, environmental and cultural variations may also underlie the inconsistent findings reported in the literature.

There has been an increasing trend in the consumption of coffee and tea, especially among adolescents¹⁵. The rise in coffee consumption is largely due to the need to stay alert because of school workloads³³. Whereas tea has traditionally been a typical drink for Indonesians during meals³⁴. Furthermore, nowadays, it is easy to purchase readily accessible packaged beverages at convenience stores and vending machines, and there is a growing number of cafes, coffee shops, and tea houses where adolescents often hang out³⁵.

The strength of this study lies in its large sample size, which enhances the accuracy and representativeness of the findings for the target population. Additionally, interviews were conducted to reduce potential misunderstandings when answering the researcher's questions. This study has several limitations that should be acknowledged. Important potential confounders, including dietary iron intake, menstrual characteristics, body mass index, and socioeconomic status, were not measured and may fully account for the observed findings, thereby precluding causal inference and potentially explaining the associations in their entirety. The cross-sectional design also limits the ability to draw causal inferences between tea and coffee consumption and hemoglobin levels. Excluding participants who reported consuming iron tablets more frequently than the government-recommended once-weekly regimen may have influenced the results.

Students taking extra iron likely had pre-existing anemia. Excluding them removes the population most relevant to beverage-hemoglobin relationships. This introduces selection bias toward healthier participants, potentially weakening any true association. In addition, categorizing beverage intake solely by the number of cups or glasses without standardizing volume or accounting for brand and preparation methods may have introduced measurement error, which could bias the results toward the null. Moreover, polyphenol content varies substantially across beverage brands and preparation styles³⁶⁻³⁹. This variability was not assessed; such differences could confound the findings if, for example, anemic participants were more likely to consume lower-tannin beverages. A 240 mL cup versus a 500 mL tumbler represents approximately a two-fold difference in polyphenol exposure. If beverage intake was categorized solely by the number of cups, without standardizing volume, substantial exposure misclassification may have occurred. Individuals classified as consuming 3 cups per week could have markedly different actual polyphenol intake depending on the cup size used.

Recommendations for further research:

Future researchers should conduct tests on female students with anemia, specifically examining their erythrocyte index through a complete blood test, serum iron, and peripheral blood smear to identify whether the anemia is due to iron deficiency or another cause. Additionally, future studies could explore the timing of tea and coffee consumption in relation to the last meal, as consuming these beverages close to or with food may impact the absorption of iron from the meal. Future studies are recommended to account for any potential confounding factors in the limitations in order to improve the accuracy of the observed associations.

Conclusion

This study highlights the significant association between tea and coffee consumption habits and hemoglobin levels in female adolescents. These findings suggest that hemoglobin levels decrease once tea and coffee intake reaches ≥ 3 cups per week, but with no further reduction occurring beyond this threshold, indicating the absence of a dose-response relationship above 3 cups per week, which emphasizes the need for awareness and education regarding the potential impact of these beverages on iron status. Health promotion efforts, including both conventional school-based education and modern digital dissemination, are recommended to increase awareness

about anemia and its contributing factors among female adolescents. Confirmatory studies with rigorous dietary assessment are needed before implementing interventions.

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Conflict of Interest

The authors declare no conflict of interest.

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Table 1 The distribution of tea consumption habits among adolescent girls

Classification Tea	
	Frequency
Often	117 (7.4%)
Sometimes	330 (21.0%)
Rarely	1128 (71.6%)
Total	1575 (100.0%)

Table 2 The distribution of coffee consumption habits among adolescent girls

Classification Coffee	
	Frequency
Often	58 (3.7%)
Sometimes	150 (9.5%)
Rarely	1367 (86.8%)
Total	1575 (100.0%)

Table 3 The distribution of hemoglobin concentration classification of the research sample

Classification Hemoglobin	
	Frequency
Non Anemic	1221 (77.5%)
Mild Anemia	211 (13.4%)
Moderate Anemia	133 (8.4%)
Severe Anemia	10 (0.6%)
Total	1575 (100.0%)

Table 4 The distribution of hemoglobin concentration of the research sample

Hemoglobin	
Mean	12.8183
Median	13.0000
Mode	13.00
Std. Deviation	1.41943
Minimum	6.70
Maximum	16.70

Table 5 Kolmogorov-Smirnov normality test

Tests of Normality			
Kolmogorov-Smirnov ^a			
	Statistic	df	Sig.
Hemoglobin	0.079	1573	0.000
Tea	0.221	1573	0.000
Coffee	0.330	1573	0.000

a= Lilliefors Significance Correction

Table 6 The Kruskal-Wallis test for tea consumption habits and hemoglobin

Classification	N	Mean	Kruskal-Wallis	p-value	Pairwise Comparison
Tea		Rank	H (df=2)		(Adj. Sig.)
Often	117	513.76	142.767	<0.001	Often vs Sometimes: 0.310
Sometimes	330	593.43			Often vs Rarely: <0.001
Rarely	1128	873.37			Sometimes vs Rarely: <0.001
Total	1575				

df= degree of freedom, Adj. Sig.= adjusted significance

Table 7 The Kruskal-Wallis test for coffee consumption habits and hemoglobin

Classification Coffee	N	Mean Rank	Kruskal-Wallis H (df=2)	p-value	Pairwise Comparison (Adj. Sig.)
Often	58	578.66	45.594	<0.001	Often vs Sometimes: 1.000
Sometimes	150	594.09			Often vs Rarely: <0.001
Rarely	1367	818.16			Sometimes vs Rarely: <0.001
Total	1575				

df= degree of freedom, Adj. Sig.= adjusted significance