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ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Research Article

Diet Quality as an Indicator of Iron Deficiency Anemia: A Study of Adolescent Girls of Senior High School in Jambi City

[1]Merita, [1]Arnati Wulansari, [2]Mila Triana Sari, [1]Kasyani and [2]Salvita Fitrianti

[1]Department of Nutrition Science, The College of Health Science Baiturrahim, Jambi, Indonesia
[2]Department of Nursing, The College of Health Science Baiturrahim, Jambi, Indonesia

Abstract

Background and Objectives: Anemia is a global health problem and 23.9% of women in Indonesia suffer from this condition. Indonesian diets are lacking in iron; thus, iron deficiency anemia is a nutritional problem. Therefore, this study aimed to assess diet quality as an indicator of iron deficiency anemia among adolescent girls. **Materials and Methods:** The study was conducted using a cross-sectional design and was carried out in Senior High School in Jambi City (State High School Number Five) in 2017. The subjects were 85 adolescent girls. The diet quality data comprised three indexes: dietary diversity, micronutrient requirements (75%) based on the Recommended Dietary Allowances (RDAs) of 11 vitamins and minerals and the WHO recommendation for the prevention of non-communicable diseases. Data were analyzed using univariate, bivariate (correlation test) and multivariate (logistic regression) analyses. **Results:** More than half of the subjects were non-anemic (56.5%) but 37 (43.5%) of the subjects were anemic. Most subjects (68.2%) had low diet quality. The Spearman correlation analysis showed a correlation between diet quality and hemoglobin levels in subjects (p = 0.003). The linear regression test showed that diet diversity had a major influence on hemoglobin levels in subjects (p = 0.013; CI = 0.714). **Conclusion:** The analysis showed a correlation between diet quality and hemoglobin levels in adolescent girls. Thus, diet quality can be an indicator of iron deficiency anemia among adolescent girls.

Key words: Adolescent, anemia, dietary diversity, diet quality, girls, Iron deficiency, micronutrient

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Corresponding Author: Merita, Department of Nutrition Science, The College of Health Science Baiturrahim, Jambi, Indonesia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Adolescence is a period in which individuals have a high risk of health problems. Nutritional problems have become a major concern in the health field because they are considered important in the first phase of some alterations leading to the physical or sexual maturity of adolescents (growth spurt). Physical alterations occur very rapidly in the period of puberty[1].

Health and nutritional problems among adolescents are often found in the form of iron deficiency anemia (IDA). According to the World Health Organization (WHO) in 2008, IDA was recognized as an important factor in the burden of global disease[2]. Riskesdas 2013 revealed that the national prevalence of anemia in the 15-24-year-old age group was 18.4%, with the highest percentage in adolescent girls being 23.9%. This finding was followed by the findings of an anemia prevalence in Jambi Province of 9.2%. This prevalence indicated that anemia remains a community health problem (the prevalence was more than 5%)[3]. Consequently, the anemia problem in adolescent girls is still an important problem to be addressed.

Iron deficiency anemia constitutes a serious and very common nutritional problem. Generally, anemia among women is diagnosed if the hemoglobin concentration is below the normal limit of 12-14 g dL^{-1} [4]. The estimation of iron status using hemoglobin concentration is a cheap and easy method.

Dietary habits have a large influence on the health of individuals, especially adolescents who need adequate nutrients for their growth. Dietary habits are reflected in the individual's choices of various foods, according to the food group in which they are included. Dietary habits are the main cause of anemia because of the insufficient consumption of iron-containing foods. In other words, dietary habits also correspond to an individual's diet quality[5]. A good diet quality will promote good health and vice versa. Therefore, a good-quality diet is imperative for optimal health.

The assessment of diet quality in a population at different stages of nutritional transition provides essential information related to the transition[6]. The diet quality is evaluated using three indexes, e.g., dietary diversity using the Food Frequency Questionnaire (FFQ), the recommended dietary allowances of 11 vitamins and minerals (75%) and the fulfilment of the WHO recommendation for the prevention of non-communicable diseases[7]. A higher value of an individual's diet quality indicates a better diet quality[8]. This fact gives information to establish healthy action strategies for the prevention of non-communicable diseases, for example iron deficiency anemia.

Several studies have shown that poor diet quality was linked to anemia among adolescent girls[9-10]. A study in Indonesia showed that insufficient consumption of vegetables caused a deficiency of one or more vitamins and minerals[11]. Moreover, there was an association between the type of foods and the incidence of anemia ($p = 0.002$)[12]. These findings show the importance of diet quality in terms of anemia prevention in adolescent girls.

A continuous state of anemia without treatment results in negative effects for adolescents, such as a decline in strength, growth disorders and reduced productivity[13-14]. Anemia decreases physical performance, growth, cognitive performance and the growth of brain cells[15-16]. Based on the aforementioned problem, this study aimed to assess diet quality as an indicator of iron deficiency anemia prevention among adolescent girls.

MATERIALS AND METHODS

Design and samples: This study was conducted using a cross-sectional study design at Senior High School in Jambi City (State High School Number Five) in 2017. The location was chosen because the school had the most productive adolescent girls in the 15-19 year-old age group and it had the highest number of adolescent girls compared to other high schools. The included subjects were 85 adolescent girls. A proportional random sampling technique was used in which the inclusion criteria for the subjects were willing to participate in this study, not currently menstruating and not suffering from any infectious diseases. The exclusion criteria were sick during the study period, absent from study, menstruating during the study period, participating in intense physical activity and having a disease history related to anemia, e.g., thalassemia, malaria and worm infestation.

Data collection: Anemia status was assessed by checking the hemoglobin levels (Hb) during the study. Subjects were classified into the anemic group if they had a hemoglobin level <12 mg dL^{-1} and into the nonanemic group if they had a hemoglobin level $\geq$12 mg dL^{-1}. The diet quality was determined from a 24 h recall of one day and a Food Frequency Questionnaire (FFQ) using the nutrisurvey program. According to Ponce *et al.*[7], diet quality is assessed using three indexes: dietary diversity, micronutrient requirements and the fulfilment of the WHO recommendations. The data regarding dietary diversity were acquired by the FFQ interview about average daily consumption. The FFQ consisted of nine types of foods, i.e., nuts, vegetables, fruits, beef, eggs, chicken meats and milk. The obtained data represented the dietary habits of subjects in one day. Overall, the score of various foods, with a maximum total score of four, was categorized as follows: 0-2 types of foods (score 1), 3-5 types (score 2), 6-7 types (score 3) and 8-9 types (score 4). The micronutrient intake data were determined by an interview using 2 24 h food recalls. The micronutrients consisted of 11 vitamins and minerals, i.e., calcium, iron, magnesium, zinc, vitamin A, vitamin C, thiamin, riboflavin, vitamin B6, vitamin B12 and folic acid. If the micronutrient requirements were >75% of the recommended dietary allowances, the score was one. Thus, the maximum total score of the micronutrient requirement indicator was 11[17]. This study used the recommended dietary allowances for the Indonesian population in 2013.

The WHO recommendation data were acquired by an interview using 2 24 h food recalls. The WHO recommendation for non-communicable diseases with the maximum score of six used the following criteria: vegetables and fruits $\geq$400 g, protein $\geq$10% of energy consumption, fat total <30% of energy consumption, PUFAs 6-10% of energy consumption, cholesterol <300 mg and fiber $\geq$25 g[18].

Statistical analysis: Data were analyzed using bivariate and multivariate analyses. Bivariate analysis was conducted to assess the correlation between the independent variables and dependent variables using a correlation test (Spearman test). In addition, multivariate analysis was performed for the independent variables that had a major influence on the dependent variables and it used a multiple linear regression as an analysis method.

RESULTS

Subject characteristics: The subject characteristics that were analyzed in this study were age, allowance, job and residential status. The average age of the adolescent girls was 16 years old and the average allowance was Rp 127.812 per week. The results of this study also revealed that the majority of subjects' parents worked as civil state employees (30.6%) or businessmen (29.4%). Furthermore, most of the subjects lived with their parents (88.2%).

Hemoglobin levels: More than half of the subjects were non-anemic (56.5%) but there were 37 subjects (43.5%) who were anemic. The average Hb level was 12.3 ± 1.6 g dL^{-1}.

Diet quality: The diet quality information of the subjects in Table 1.

Based on Table 1, most subjects consumed 0-2 types of foods (49.4%); only five subjects consumed food in 6-7 food groups. The micronutrient information showed that most subjects (35.3%) had a score of 0. The micronutrient intakes (11 nutrients) of most subjects were insufficient. Additionally, 2 subjects met the recommendations for six types of micronutrients. Moreover, the WHO recommendation information showed that almost half of the subjects (41.2%) had a score of 2 for compliance with the WHO recommendations.

Of the diet quality results, the average diet quality score of the subjects was from 4-5 points, with a median score of 5.00. In this study, the diet quality score was classified into 2 types: good (diet quality score>median value) and poor (diet quality score $\leq$median value). Therefore, it can be concluded that 58 subjects had poor diet quality (68.2%).

Correlation between diet quality and hemoglobin levels: The Spearman correlation analysis showed that there was a correlation between diet quality and hemoglobin levels in subjects (p = 0.003) at a significance level of 5%, as shown in table 2.

Table 1: The distribution of diet quality indicators among adolescent girls in senior high school

Diet quality indicator	Total No.	Percentage
Dietary diversity		
0-2 types of foods	42	49.4
3-5 types of foods	38	44.7
6-7 types of foods	5	5.9
Required micronutrients		
No adequate vitamins or minerals	30	35.3
1 type of vitamin or mineral was fulfilled >75% RDA	27	31.8
2 types of vitamins or minerals were fulfilled >75% RDA	14	16.5
3 types of vitamins or minerals were fulfilled >75% RDA	7	8.2
4 types of vitamins or minerals were fulfilled >75% RDA	5	5.9
6 types of vitamins or minerals were fulfilled >75% RDA	2	2.4
WHO recommendation		
1 nutrient component was fulfilled	20	23.5
2 nutrient components were fulfilled	35	41.2
3 nutrient components were fulfilled	29	34.1
4 nutrient components were fulfilled	1	1.2

Table 2: Spearman correlation analyses

	Hb levels	Dietary diversity	WHO recommendation	Micronutrient requirements	Diet quality
Correlation coefficient	1.000	0.272*	0.289**	0.141	0.314**
Sig. (2-tailed)	.	0.012*	0.007**	0.197	0.003**
N	85	85.000	85.000	85.000	85.000

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)

Table 3: Regression model data

	Unstandardized coefficients		Standardized coefficients		
Model	B	Standard error	Beta	T	Sig.
(Constant)	9.893	0.662		14.943	0.000
Dietary diversity	0.714	0.281	0.260	2.542	0.013
The fulfilment of the WHO recommendations	0.586	0.217	0.276	2.695	0.009

Dependent variable: Hemoglobin levels

The results of the multivariate analysis showed that the probability of a significant F change was less than 0.05; thus, it was concluded that the linear regression model was applied to describe the effect of dietary diversity, WHO recommendation and hemoglobin levels (p = 0.002). The information from the regression model is shown in Table 3.

The significance values of the independent variables of the WHO recommendation (p = 0.009) and dietary diversity (p = 0.013) were less than 0.05, which indicates a significant effect of diet quality on the dependent variables at an alpha of 5%. The equation of the regression model is shown in Table 3:

$$Y= 9.893+0.714X_1+0.586X_2+e$$

The linear regression of the above equation revealed that dietary diversity had a greater influence on hemoglobin levels in subjects. When the dietary diversity score increased, the hemoglobin levels would also increase. Conversely, when dietary diversity declined hemoglobin levels declined as well. A one-point increase in the dietary diversity score increased the hemoglobin levels by 0.714 g dL^{-1}. A one-point decline in the dietary diversity score decreased the hemoglobin levels by 0.714 g dL^{-1}.

The same relationship was seen in the regression coefficient of the WHO recommendation. A one-point increase in the WHO recommendation raised the hemoglobin levels by 0.586 g dL^{-1}. In contrast, a one-point decrease in the WHO recommendation score reduced the hemoglobin levels by 0.586 g dL^{-1}.

Correlation between daily consumption and hemoglobin levels: The correlation between daily consumption and hemoglobin levels in subjects is shown in Table 4.

Based on Table 4, daily frequencies of fruit consumption (p = 0.014), fish consumption (p = 0.049) and cholesterol consumption (p = 0.024) significantly influenced hemoglobin levels, while other daily food consumption frequencies did not show any significant correlation with hemoglobin levels.

Table 4: Correlation analysis of daily consumption and hemoglobin levels

Food group	Mean±SD	p-value
Starches (times per day)	2.0±0.8	0.624
Nuts (times per day)	1.8±0.7	0.070
Vegetables (times per day)	1.9±0.7	0.257
Fruits (times per day)	1.6±1.0	0.014*
Eggs (times per day)	1.4±0.6	0.842
Beef (times per day)	0	-
Chicken (times per day)	1.7±0.6	0.500
Fish (times per day)	1.7±0.8	0.049*
Milk (times per day)	1.4±0.8	0.380
Energy (kcal)	1275.6±545,9	0.726
Protein (g)	43.9±17,9	0.721
Fat (g)	56.8±48,9	0.315
PUFA (g)	14.0±13	0.215
Cholesterol (mg)	231.6±171	0.024*
Fibers (g)	5.0±3,9	0.409
Vegetables and fruits (g)	31.6±47,7	0.338
Calcium (mg)	197.7±171.5	0.920
Iron (mg)	5.2±4.2	0.804
Magnesium (mg)	131.9±79.6	0.256
Zinc	4.9±2.5	0.779
Vit A	2.7±427.2	0.503
Vit C	14.7±25.3	0.487
Thiamin	0.3±0.2	0.670
Riboflavin	0.6±0.3	0.090
B6	0.7±0.4	0.372
B12	2.1±2.3	0.648

*Significance refers to the hemoglobin levels at a level of 5%

DISCUSSION

The results suggested that 43.5% of adolescent girls suffered from anemia, with an average hemoglobin level of 12.3±1.6 g dL^{-1}. Most subjects in this study had poor diet quality (68.2%). A correlation between diet quality and hemoglobin levels was identified in the subjects (p = 0.003). This result was in line with other studies which found that there was a correlation of diet quality with anemia among adolescents[9-10]. A reason underlying this finding was poor dietary habits or poor diet quality.

Diet quality can be measured using three indexes: dietary diversity from the average daily frequency in the Food Frequency Questionnaire (FFQ), micronutrient requirements based on the Recommended Dietary Allowances of 11 vitamins and minerals (75%) and the compliance with the WHO recommendation for preventing noncommunicable diseases[7]. After the regression test was performed, the diet quality indicators, such as dietary diversity and WHO recommendation, showed a correlation with the hemoglobin levels in subjects. Based on Table 1, almost half of the subjects (49.4%) had low dietary diversity, which was indicated by the consumption of 0-2 food groups and 41.2% subjects still had to fulfil two nutrient components.

The compliance levels of dietary diversity and WHO recommendation are shown in Table 2. Fruit consumption was in the low category (1-2 portions) compared to the WHO recommendation (400 g) in 2002 (5 portions). This was why the hemoglobin levels in the subjects were classified in the normal group, although the values were still at lower limit. Moreover, fruits have an important role in preventing iron deficiency anemia because they contain vitamins and minerals that help to absorb iron or prevent low hemoglobin levels[19]. Vitamin C in fruit helps to absorb and metabolize iron. Additionally, vitamin C is required to reduce ferric iron to ferrous iron in the gut so that it can easily be absorbed.

Aside from dietary diversity and the WHO recommendations, the diet quality of the subjects in this study was analyzed based on micronutrient requirements. According to Table 1, 35.3% of subjects did not consume the required vitamins and minerals and only 31.8% of subjects consumed one type of vitamin or mineral.

The average consumption of protein in subjects was low compared to the Recommended Dietary Allowance (RDA). Based on the RDA in Indonesia in 2013, the RDA of protein in women of age 13-15 years is 69 g and in women of 16-18 years of age is 59 g[20]. Similarly, the intake of most fibers, vegetables and fruits did not meet the WHO recommendation but the majority of protein consumption (43.9 ± 17.9 g per day) and cholesterol (231.6 ± 171 g per day) met the recommendation to prevent the risk of diseases, such as anemia.

A study in Indonesia also revealed that the insufficient consumption of vegetables led to the insufficient intake of one or more vitamins and minerals and those components were one of the diet quality indicators in humans[11]. Therefore, the control of diet quality in adolescent girls is important to combat iron deficiency anemia.

Protein consumption in subjects was mainly from plant-based protein sources, e.g., beans, tofu, tempeh and other processed foods (1-2 times per day). Plant-based proteins contain nonheme iron characterized by low absorption and these foods also inhibit iron absorption. The iron absorption rate from plant-based foods is only 1-6%, whereas it is 7-22% for animal-based foods. This factor was considered to affect the Hb levels in subjects who did not fulfill the protein requirements. Furthermore, there were subjects who reduced foods and skipped meals; hence, their consumption of energy and other nutrients was low. The perception of body image was also a trend among subjects. Some participants consumed diets without rice and red meat followed by irregular frequencies of meals. It was suspected that these facts became the factors leading to low protein consumption compared to the RDA, whereas the compliance of the WHO recommendation was still 100% fulfilled.

Low protein consumption in subjects was assumed to be due to the snacking habits in adolescent girls. Previous research showed that there was a significant correlation between protein consumption and anemia ($p = 0.002$)[21]. Another study also reported that low protein consumption was associated with 2.25-times greater chance of developing anemia compared to the risk of the subjects with high protein consumption[22]. This finding was because low protein consumption inhibited iron transportation and caused iron deficiency[23]. Therefore, this was considered the cause of the anemia that was found among subjects but most subjects did not have anemia (56.5%).

The average consumption of fats in the subjects in this study was 56.8 g per day, which was less than RDA (71 g). This finding was in line with a previous study which showed that the majority of subjects (82.7%) had deficient consumption levels of fats[24]. Fats are an energy source for growing and performing activities. Fats in foods that had an essential role as the energy source are found in the forms of neutral fats or triglycerides. Other roles of fats are acting as the carriers of fat-soluble vitamins, protecting the internal organs and maintaining the body temperature[25]. Low fat consumption will lead to insufficient energy, iron and zinc. Therefore, this factor is suspected to result in low hemoglobin levels among subjects.

Nevertheless, people are recommended to fulfil fat consumption (<30% of energy consumption) to prevent other noncommunicable diseases, such as coronary heart disease and diabetes mellitus. In this study, 62 subjects (72.9%) consumed fat at a level that accounted for $\geq$30% of their energy consumption. Therefore, it was considered that higher fat requirements led to a greater number of subjects who did not suffer from iron deficiency anemia.

The basic components of fats are fatty acids and glycerol and these compounds are obtained from fat hydrolysis, oils and other lipid substances. Fatty acid-based fat can be distinguished by the number of carbon double bonds and their location. Based on the chemical structure, the fatty acid can be differentiated into a saturated fatty acid (SFA), which has no double bond. In contrast, a fatty acid with a double bond is called an unsaturated fatty acid, which can be classified into monounsaturated fatty acids (MUFAs) with one double bond and polyunsaturated fatty acids (PUFAs) with more than one double bond[26].

PUFAs in the form of linoleic acid (omega-6) and omega-3 are categorized into long-chain fatty acids (LCFAs), which are found in plant-based oil/vegetable and fish oil (Meyes, 2003). In this study, 17 subjects (20%) met to the PUFA consumption recommendation of 6-10% of energy consumption, while the average consumption of cholesterol was 231,6 mg. The results of a study in Romania found that anemia was related to the total consumption of cholesterol[27]. This finding showed that cholesterol consumption corresponded to the WHO recommendation in 56 subjects (65.9%) who consumed <300 mg of cholesterol.

High consumption of saturated fatty acids causes the liver to produce LDL cholesterol in large amounts, which is related to heart disease and increased cholesterol levels in the blood, resulting in thrombosis[28]. However, this process is dependent on the types of foods. Coconut oil and palm oil contain vast amounts of saturated fatty acids (palmitate) but these types of oils do not cause an increase in blood cholesterol levels. The result of a study revealed that the consumption of long chain fatty acids (LCFAs) elevated different blood cholesterol levels than medium chain fatty acids (MCFA). These differences depended on the digestion and metabolism processes in the body and result in different bioactive component products. In other words, every type of fatty acid has a different physiological and biological impact on the health[29].

Generally, animal food sources (fatty meat, cheese but ter and milk cream) have saturated fatty acids as well as cholesterol. Reduced animal-based fat consumption results in the benefit of reduced cholesterol consumption. Every four ounces of beef or chicken contains 100 mg of cholesterol and saturated fatty acids increase LDL-cholesterol levels[26].

All of the subject consumed <25 g of fiber per day. This finding indicated that fiber consumption in all subjects did not meet the WHO recommendation. The average consumption was 5 g per day, which was less than RDA (30 g per day). Low fiber consumption was combined with low vegetable consumption. This study found that the average vegetable consumption was 1-2 portions per day, whereas a balanced diet requires 3-4 vegetable portions per day. This result was also in line with a study involving adolescents in Semarang, which showed that the average fiber consumption 13.155 ± 4.19 g day^{-1} did not meet the RDA for fiber intake for adolescents 13-15 years old[30]. Nevertheless, fiber consumption in a non-excessive amount has a positive effect on anemia prevention because fiber acts as an iron inhibitor. Cellulose or fiber can inhibit iron absorption because it represses iron utilization. This process occurs when someone rarely consumes red meat. Animal-based foods, vitamin C, vitamin A and other factors result in the easy absorption of iron. Therefore, based on this research, low fiber consumption was linked to the normal levels of Hb among the subjects (56.5%). Based on the observations in this study, subjects lacked vegetable and fruit consumption; hence, the vitamin and mineral requirements were not fulfilled. Adolescent girls with lower consumption of vegetables and fruits had a 2.47-times higher risk of anemia than adolescents with an adequate consumption of vegetables and fruits[30].

Overall, most subjects had normal hemoglobin levels. However, they still had poor diet quality, which was characterized by insufficient components of foods and nutrients. When this insufficient intake occurs continuously, it will cause vitamin and mineral deficiency and long-term impacts, inducing iron deficiency anemia. Anemia not only leads to fatigue and sleepiness but also decreases productivity in school. In addition to productivity, anemia also influences motor decline, IQ score, cognitive performance and the child's mental health. For that reason, it is necessary to include nutritional education in the school curriculum because adolescents are the next generation to develop the nation and should have sufficient consumption of nutrients to promote optimal health.

Based on the research results, it is recommended for adolescents to consume a minimum of 3-5 types of food each day. In addition, it is necessary to fulfil the WHO's recommended intakes of foods, such as vegetables, fruit and protein. These eating habits can improve the quality of the diet and prevent anemia in adolescents.

This study used a cross-sectional design and had a large sample size. However, in this study, the sample was still limited, making it difficult to reach a definitive conclusion. Therefore, this topic requires further research, such as experimental research on the provision of various foods and the effects on hemoglobin levels in adolescents.

CONCLUSIONS AND SUGGESTION

Overall, most subjects had normal hemoglobin levels, yet they were still at risk for developing iron deficiency anemia. This was because of the low average hemoglobin level

(12,3 g dL^{-1}), which was close to the lower limit of 12 g dL^{-1}. The subjects also had poor diet quality; thus, most food and nutrient recommendations were not met.

The analysis showed that there was a correlation between diet quality and hemoglobin levels among subjects and that the dietary diversity indicator had a major influence on hemoglobin levels. Diversity is necessary for every meal because there is no food that contains all of the necessary nutrients. Additionally, the quantity and quality of nutrients contained in every food type are different. A higher score of dietary diversity in humans reflects a better diet quality. Therefore, this becomes an indicator of iron deficiency anemia.

SIGNIFICANCE STATEMENTS

This study revealed a correlation between diet quality and hemoglobin levels that can be beneficial for iron deficiency anemia prevention among adolescent girls. This study will help researchers understand the critical indicators of diet quality that many researchers were not able to explore. Thus, a new theory on diet quality and iron deficiency anemia may be developed.

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