

Intercorrelations among Hemoglobin Level, Physical Fitness, and Cognitive Score in Adolescent Girls: A Cross Sectional Study in Banggai District, Indonesia

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ABSTRACT

Iron deficiency anemia in adolescent girls can cause decreased concentration, cognitive levels and fitness. In the long term it will have an impact on low productivity and school achievement. This study aims to analyze the correlations between hemoglobin level, physical fitness and cognitive score in Anemic adolescent girls. The research design was cross-sectional, with a sample of adolescent girls aged 12–18 years (n=139). Iron status was determined by hemoglobin levels using Hemocue. Cognitive function was measured using the Culture Fair Intelligence Test (CFIT), memory scores using the Intelligenz Structure Test (ITS), and physical fitness based on the predicted VO2max using the Bleep Test. Correlation analysis uses Pearson correlation analysis. The research results showed that overall 58.3% of students experienced anemia, of which 64.1% experienced mild anemia and 32.1% experienced moderate anemia. The average value of hemoglobin levels in respondents was 11.6 mg/dl. The mean predicted VO2 max is 25.3 kg/m² and kognitif score 81,02 and memori score 11,01. Pearson's test results showed that there was a significant positive correlation between hemoglobin levels and predicted VO2 max ($r = 0.28, p < 0.05$) and memori score ($r = 0.31, p < 0.05$). There was a weak correlation between hemoglobin levels and kognitif score ($r = 0.17, p = 0.053$). **Conclusion:** There is a significant relationship between hemoglobin levels and physical fitness and cognitive function. Therefore, an intervention program is needed to increase Hb levels in adolescent girls

Keywords: Anemia, Hemoglobin level, Physical Fitness, kognitif, Adolescent girl.

INTRODUCTION

Anemia due to iron deficiency is a nutritional disorder indicated by low levels of hemoglobin in the blood.¹ Anemia affects 1.62 billion people in the world, especially in developing and developed countries. Iron deficiency is the cause of 50% of cases of anemia worldwide and represents a global health problem.² The prevalence of anemia in Indonesia among women of childbearing age (15–49 years) increased from 21.6% in 2018 to 22.3% in 2019.³ The female adolescent group is at a higher risk of iron deficiency anemia. Adolescent girls experience rapid growth, increased nutritional requirements,⁴ iron loss due to menstruation.⁵

The impact of anemia is quite significant on adolescent health. Lack of hemoglobin due to anemia limits oxygen transport in the blood, causing reduced physical and mental capacity as well as other health risks.⁶ Anemia in adolescents will cause a decrease in fitness levels which will have an impact on low productivity and sports performance.⁷ In addition, iron deficiency also causes reduced attention, decreased memory and school attendance, which ultimately affects school performance in adolescents.^{8,9}

Several previous studies have investigated the importance of iron in cognitive function and found links between iron deficiency, diet and changes in psychological development and cognitive function.^{10,11,12} Experimental studies in animals and

humans suggest that iron deficiency has the potential to cause cognitive impairment, with damage to mitochondria brain as the basis for these changes. Cognitive disorders, including those associated with impaired attention, intelligence and sensory perception, emotion and behavior and are generally associated with iron deficiency anemia.¹¹

Several studies explain a significant relationship between iron deficiency and physical activity, including decreased work capacity in children,¹³ and decreased endurance and performance in completing tasks.^{5,14} The decrease in physical activity is caused by a decrease in iron stores and hemoglobin (Hb) concentration, thereby reducing the availability of oxygen to the tissues and the work of the heart.¹⁵ In research conducted by *Wati et al.* proves that an athlete who has high hemoglobin levels has good endurance or VO2max.¹⁶

Although several studies have confirmed a significant relationship between hemoglobin concentration and cognitive impairment,^{15,17,9} other studies have not shown a significant relationship between anemia or decreased Hb levels and cognitive function.^{18,5} Likewise, the relationship between hemoglobin and physical fitness, several studies show that hemoglobin levels have no effect on VO2max values,¹⁹ hemoglobin levels remain stable in untrained adults, but there is an increase in VO2max of 10% after 40 days of regular exercise or certain physical activities.²⁰

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These different results became the basis for researchers to examine the correlation between Hb levels and physical fitness and cognitive function in young women. The aim of this research is to determine the correlation between Hb levels and physical fitness and cognitive function in adolescent girls in Banggai Regency.

METHOD

The research design in this study was observational analytical with a cross-sectional approach. Target The population in this study were adolescent girls aged 12-18 years in Luwuk Banggai Regency, Central Sulawesi. There were 139 samples that met the inclusion and exclusion criteria. The sampling technique in this research used a simple random sampling method. The data used is primary data. Data collection was carried out by assessing physical fitness as assessed by VO2max using the Bleep Test, assessing cognitive function using the Culture Fair Intelligence Test (CFIT), memory scores using the Intelligenz Structure Test (ITS). Determination of student hemoglobin is carried out by health workers at the school health center by taking blood samples via finger prick using a hemocue (Hemocue HB 201⁺).²⁴

Data analyses were done employing version Statistical Package for Social Sciences Programs (SPSS). The normality test is The Shapiro-Wilk test was carried out on each data and a correlative test was carried out between the independent variable and the dependent variable using the Pearson correlation test with a p-value or significance level of $p < 0.05$. This study received ethical approval from the Ethics Commission of the Faculty of Public Health, Hasanuddin University, with Protocol Number: 1816/UN4.14.1/TP.01.02/2023.

RESULTS AND DISCUSSION

In this study, 139 research subjects were collected from 13 middle and high schools in the Banggai district. The characteristics of this research subject are all listed in table 1.

The characteristics of the research subjects showed that most of the adolescent girls (55.4%) were aged 12–15 years. The majority of subjects' fathers and mothers had basic education (67.6% and 79.1%) and there were (8.6%) fathers, (5.8%) mothers who had no education. The majority of subject fathers worked as farmers, 77.8%, and 73.4% of mothers did not work. There were 71.4% of subjects with normal nutritional status, 8.6% with less nutritional status and 17.3% who were overweight. The majority of subjects suffer from anemia as much as 58.3%, low fitness level as much as 54.7%, cognitive score below average as much as 71.2% and cognitive ability as much as 66.2% with moderate memory.

Table 2 shows the results of measuring hemoglobin levels, physical fitness scores (VO2Max), cognitive and memory ability scores and nutritional status z scores (BAZ) of research subjects. The measurement results showed that the average hemoglobin (Hb) level was 11.6 ± 1.19 mg/dl, the total oxygen capacity (VO2Max) was 25.3 ± 2.64 kg/m2, the subject's cognitive ability score was $81.02 \pm 13, 82$, memory ability score 11.01 ± 4.33 and Z Score (BAZ) value of the subject's nutritional status -0.15 ± 1.82 .

Table 3 shows a significant relationship between hemoglobin levels and total oxygen capacity VO2 max ($p=0.001$, $r=0.28$), which means that the greater the value of the subject's hemoglobin level, the greater the value of VO2Max. The correlation found was a positive correlation with moderate correlation strength ($r=0.28$). Furthermore, the results of the study also showed a significant relationship between hemoglobin levels and memory ability scores ($p=0.000$, $r=0.31$), with a moderate positive correlation ($r=0.31$), which means that the greater the subject's hemoglobin level value, the greater the memory ability score. subject.

Furthermore, a significant correlation was found between hemoglobin levels and cognitive scores, the direction of the correlation was positive

Table 1: Characteristics of Adolescent girl.

Characteristic	N (139)	%
Age		
12-15 y	77	55.4
16-18 y	62	44.6
Father's education		
None	12	8.6
Primary School	94	67.6
Secondary School	27	19.4
University	6	4.3
Mother's education		
None	8	5.8
Primary School	110	79.1
Secondary School	19	13.7
University	2	14.4
Father's occupation		
Farmer	108	77.8
Self Employed	10	7.1
Employee	14	10.1
Other	7	5.0
Mother's occupation		
Farmer	32	23.0
Self Employed	2	14.4
Employee	3	2.2
Not working	102	73.4
Nutritional Status (BAZ)		
Underweight	12	8.6
Normalweight	103	74.1
Overweight	24	17.3
Anemia classification		
Anemic	81	58.3
Non Anemic	58	41.7
Physical Fitness		
Low	63	45.3
Midle	76	54.7
Kognitif		
Mean above	99	71.2
Mean	40	28.8
Memori		
Low	47	33.8
Midle	92	66.2

Table 2: Data Description of Hemoglobin, VO2max, Score Kognitif, and Z Score.

Variable	N	Minimum	Maksimum	Mean	SD
Hb (mg/dl)	139	7.0	14.4	11.6	1.19
VO2Max (kg/m2)	139	19.2	31.4	25.3	2.64
Score Kognitif	139	50	117	81.02	13.82
Score Memori	139	2	21	11.01	4.33
Z Score (BAZ)	139	-3.45	2.72	-0.15	1.28

Table 3: Correlation of Hemoglobin and Vo2Max, Kognitif, Memori and ZScore with Control Age and Mother's education.

	Pearson Correlation	
	<i>p</i>	<i>r</i>
VO2Max (kg/m2)	0.001*	0.28
Score Kognitif	0.053	0.17
Score Memori	0.000*	0.31
Z Score (BAZ)	0.674	0.04

*statistically significant, $p < 0.005$

with a weak correlation strength ($p=0.053$ $r=0.17$), which means the subjects' hemoglobin levels tended to influence the subjects' cognitive scores. Meanwhile, regarding the relationship between hemoglobin levels and the Zscore value, there was no significant relationship between

the two ($p=0.674$, $r=0.04$), meaning that the subject's hemoglobin level did not affect the Zscore value of the subject's nutritional status.

DISCUSSION

Hb and VO2Max

Hemoglobin is an erythrocyte protein whose function is to transport oxygen from the lungs to be distributed to all body tissues so that it can be released during expiration. When there is an iron deficiency, the body cannot produce enough hemoglobin. Lack of hemoglobin production reduces the oxygen supply in the blood enough so that the body does not get oxygen. This is what causes iron deficiency anemia sufferers to become easily tired, weak, even short of breath and affect their physical activity.²¹ VO2max is the maximum volume of oxygen (O2) that a person can consume per minute and is usually related to body mass. Therefore, the unit of measurement for VO2max is ml/kg/minute.⁶ A high VO2max will make the body have a large supply of oxygen. Physiologically, the greater the Hb or carrier, the more O2 that can be captured. and conversely, the process of removing CO2 as oxidation residue will also be easier and faster.

Our research found a correlation between hemoglobin levels and vo2max scores, which means that the greater a person's hemoglobin level, the greater the person's vo2max scores. These results are in line with research conducted previously by Wati *et al* which stated that there is a relationship between hemoglobin levels and VO2max, it is proven that an athlete who has high hemoglobin levels has good endurance or VO2max.⁶ Other research states that the variables HB and VO2max have positive relationship.^{22,23,24} There is research that analyzes the relationship between vital lung capacity and VO2max by carrying out a test or walking test for 6 minutes, it was found that when the hemoglobin level is below normal, the oxygen level in the blood is also lower, and vice versa. Normal hemoglobin levels lead to more optimal oxygen transport processes into the tissues.¹⁴

These findings also confirm the concept that physical fitness is positively related to the overall capacity of hemoglobin in red blood cells to carry oxygen in circulation to heart and skeletal muscle. In addition, previous studies also reported that some physically active individuals may experience anemia due to iron deficiency,^{24, 25, 26} because hemoglobin is consumed by pathological reactions to excessive exercise, fitness Physical exercise can also be reduced⁹ with low or moderate intensity exercise, where the body usually uses oxygen to produce energy.²⁷

The main function of red blood cells in exercise is to transport O2 from the lungs to the tissues and deliver metabolically produced CO2 to the lungs for expiration. Hemoglobin also contributes to the buffering capacity of the blood, and the release of ATP and NO from red blood cells contributes to vasodilation and increases blood flow to working muscles. These functions require an adequate number of red blood cells in circulation. The normal amount of Hb per blood volume increases the amount of O2 that can be transported approximately 70-fold, to meet normal tissue O2 requirements. Therefore, increasing the amount of Hb will also increase the amount of O2 that can be sent to the tissue.

Hb and Kognitif dan Memori

One of the important functions of the brain is cognitive function, namely the function of digesting information or the ability to gain knowledge through learning, experience and feelings. One aspect of cognitive function is memory. Cognitive function is the most important function in a person's learning process.²⁵ Memory is the ability to encode, store, present, control, and then recall information and past experiences in the human brain.²⁶

Our research found a correlation between hemoglobin levels and cognitive scores and memory scores, which means that the greater

a person's hemoglobin level, the greater the person's cognitive and memory scores. This is in line with research^{9,15,17} which found that there was a relationship between the incidence of anemia and cognitive abilities in female adolescents. From the results of this experiment, it was found that if hemoglobin levels were normal, cognitive abilities would also be good.

Hemoglobin consists of Fe (iron) and alpha, beta, gamma and delta chains (globin polypeptides). Low hemoglobin levels in the body indicate iron levels in the body are very low and almost depleted. If the body's Hb decreases, the body's condition is very risky for anemia because hemoglobin levels decrease.⁹

Adequate iron for the body is one of the requirements for nerve health. Iron deficiency can cause abnormalities in three brain domains, namely a decrease in dendritic structure and an increase in glutamate and GABA in the hippocampus, nerve hypomyelination and changes in the metabolism of monoamine neurotransmitters (dopamine). It was further explained that iron deficiency has a significant effect on abnormalities in the development of the dendritic structure which results in failure of efficient synapses in the hippocampus area which functions as a place of learning and memory.^{28,29,30} The latest information also states that iron is beneficial for the development of the brain's hippocampus. The hippocampus is a part of the brain that plays a role in regulating memory storage.³¹

Hemoglobin is an important molecule in the body that is used as a means of transporting oxygen throughout the body. Without hemoglobin, oxygen in the lungs will not be able to be transported and will result in insufficient or insufficient oxygen levels in each cell of the body and brain.²¹ An insufficient supply of oxygen throughout the body results in a lack of fuel that will be produced. , because oxygen is one of the ingredients in making ATP, where ATP will be used in all activities of the body's organs, including the brain.³²

The direct effect of anemia on cognitive disorders is the disruption of oxidative metabolism in the brain. This disruption of oxidative metabolism results in increased oxidative stress which directly affects brain function, resulting in a decrease in cognitive function.^{33,34} Sementara Efek tidak langsung anemia pada fungsi kognitif yakni pada kondisi kadar hemoglobin yang rendah akan terjadi penurunan asupan oksigen ke otak. Meanwhile, the indirect effect of anemia on cognitive function is that in conditions of low hemoglobin levels there will be a decrease in oxygen intake to the brain. By decreasing oxygen intake into the brain, it will affect the ability to remember (memory), the ability to work and the brain's speed of thinking so that its function in general becomes disrupted.²⁷

CONCLUSION

Our research concluded that the average hemoglobin level of participants was in the normal category (11.6 g/dL). Fitness levels based on VO2max predictions show average results (25.3 ml/kg/minute). Based on cognitive and memory scores, the average scores were 81.02 and 11.01 respectively. There is a significant relationship between hemoglobin levels and fitness levels based on predictions of VO2max, cognitive and memory scores. Therefore, an intervention program is needed to increase Hb levels in adolescent girls.

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