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Comparative Study of Hemoglobin Levels: Adolescents in The Highlands and Lowlands of Blitar Regency, East Java

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ABSTRACT

Introduction. Indonesia's geographical area appears to be separated into two regions: highlands and lowlands. Highlands impact hemoglobin levels. Because of the decreased partial pressure of oxygen and the body's acclimatization response, being at a high altitude results in hypoxia. In order to adjust to low oxygen levels, hemoglobin levels rise. This study aimed to compare hemoglobin levels using the hemoglobin POCT test among teenagers residing in the lowlands of Blitar Regency, East Java**. Methods**. Purposive sampling is used in the research method, which employs a cross-sectional approach. The sample is chosen using inclusion and exclusion criteria**. Results**. With an average hemoglobin level of 14.6833 g/dl, teenagers in the Highlands had normal hemoglobin levels for up to five of them (42%), and abnormal hemoglobin levels for seven of them (58%). The average hemoglobin level among teens in the lowlands was 12.2333 g/dl, with three (25%) and nine (75%) having normal levels. Using the Independent T-Test, the data analysis revealed a significant value of 0.038 <0.05. **Conclusion.** Hemoglobin levels of adolescents who live in the highlands of Semen Village RT. 03 RW. 04 had an average hemoglobin level of 14.6833 g/dl, and hemoglobin levels in adolescents who lived in the lowlands of Sutojayan Village, RT. 01 PC. 04 with an average hemoglobin level of 12.23 g/dL and a significance value of 0.038.

1. Introduction

A plateau is defined as a flat area of land situated at an altitude of more than 200 meters above sea level. It typically refers to an extensive plain located in high or mountainous regions. In contrast, lowlands are broad expanses of land lying between 0 and 200 meters above sea level, generally characterized by relatively flat terrain. The soil layer in lowland areas tends to be horizontally stratified and is commonly found along coastal regions, though it may also occur inland. In Indonesia, the classification of natural landscapes into lowlands and highlands is based primarily on altitude. Lowlands, situated below 200 meters above sea level, typically experience higher temperatures ranging from 24°C to 32°C and are associated with hotter environments. Highlands, located above 200 meters, are characterized by cooler temperatures ranging from 23°C to 28°C and tend to have a more humid climate. Sutojayan Village—located at an altitude of 170 meters above sea level—was categorized as a lowland area, while Semen Village—located at 700 meters above sea level—was classified as a highland area.[1-3]

Highlands have lower oxygen levels than lowland areas. This causes a person to experience a lack of oxygen (hypoxia). The hypoxia state greatly affects the physiological changes in hemoglobin values at high altitudes due to the occurrence of erythropoiesis. Erythropoiesis is the process of forming the hormone erythropoietin in the kidneys. Baroreceptors in the renal tubules and erythropoietin will stimulate the bone marrow to produce red blood cells. An increase in erythropoietin levels is followed by an increase in red blood cell levels and an increase in hemoglobin levels in the blood when hypoxia occurs in the body.[4] These stages are achieved by an increase in the amount of 2,3 diphosphoglycerate (2,3-DPG) as a compensation for the body's transport and oxygen

perfusion. 2,3-DPG is a substance in erythrocytes that acts as an allosteric regulator of oxygen and hemoglobin affinity (HbO2). An increase in 2,3-DPG will decrease the affinity of oxygen and hemoglobin so that oxygen release from the blood and oxygen perfusion into tissues occurs.[5] In all aspects of acclimatization, indigenous people living in the highlands are superior to those who move from the lowlands. The acclimatization process in indigenous people starts from birth or is equivalent to 10 years of living in the highlands.[2]

Hemoglobin (Hb) levels and lung capacity are influenced by differences in partial oxygen pressure (PO_2) between lowland and highland areas.[6] Geographical location is one of the key factors affecting blood hemoglobin levels. In high-altitude regions, reduced oxygen availability stimulates the production of hemoglobin to meet the body's oxygen demands, which explains the typically higher Hb levels observed in highland populations.[7] Conversely, low hemoglobin levels can impair blood circulation and negatively impact overall health.[8]

Previous research by Beall et al.[9] reported that the Tibetan population living at 3,800 meters above sea level had average hemoglobin concentrations 3.5–3.6 g/dL lower than the Aymara population, who reside at an altitude of 4,065 meters above sea level and had average Hb levels approximately 3.5 g/dL higher. Similarly, a study by Marlinda Sakti[8] found that individuals in lowland areas (32 meters above sea level) had an average Hb level of 12.2 g/dL, whereas those in highland regions (1,100 meters) exhibited higher levels, averaging 14.1 g/dL. In another study by Waani et al., individuals in Rurukan Village had higher average Hb levels (15.53 g/dL) compared to those in Paslaten Village (14.84 g/dL).[10]

Hemoglobin concentration serves as a laboratory biomarker commonly used to assess the prevalence of anemia.[8] A hemoglobin deficiency may result in impaired tissue oxygenation and disruption of circulatory function.[1] Preliminary observations conducted in December 2021 involving 12 adolescents—6 residing in highland areas and 6 in lowland areas—revealed that adolescents in highland regions had average hemoglobin levels of 14.9 g/dL, which exceeded the normal reference range. In contrast, adolescents in lowland areas exhibited average Hb levels of 12.4 g/dL, remaining within normal limits. Given these findings, this study was designed to investigate anemia prevalence among adolescents, using hemoglobin levels as a screening parameter. The research, entitled *"Comparison of Hemoglobin Levels in Adolescents Living in the Highlands and Lowlands of Blitar Regency, East Java"*, was conducted in RT 03 RW 04, Semen Village (highland area), and RT 01 RW 04, Sutojayan Village (lowland area).

2. Methods

This study employed a cross-sectional design with purposive sampling. Participants were adolescents aged 18 to 21 years who were born and raised in the study area and were in good health at the time of data collection. Individuals were excluded if they were menstruating during data collection, had a history of chronic illnesses such as cardiovascular disease or anemia, or had other hematologic disorders. Based on these criteria, a total of 24 participants—12 from RT 01 RW 04 Sutojayan Village (lowland area) and 12 from RT 03 RW 04 Semen Village (highland area)—were selected for inclusion in the study. Hemoglobin levels were measured using the amperometric method, which determines hemoglobin concentration based on changes in electrical potential generated by chemical interactions between the blood sample and a test strip. Measurements were taken using the Easy Touch GCHB Point-of-Care Testing (POCT) device. POCT was selected due to its ease of use, portability, and high accuracy, as demonstrated by a coefficient of variation (CV) of 0.04, indicating strong precision (CV < 0.05). Reliability testing was conducted using Cronbach's Alpha, analyzed via IBM SPSS Statistics 25, in accordance with the method described by Ghozali in Fanani.[12] Hemoglobin levels were measured directly in all participants, and the data were analyzed using the independent t-test and the Shapiro-Wilk test for normality and homogeneity. This study received ethical approval from the Ethics Committee of the Bhakti Wiyata Institute of Health Sciences, Kediri City, on February 19, 2022, under certificate number 40/FTMK/EP/II/2022.

3. Results

Based on Table 1, it is known that the sample of adolescents living in the highlands is 12 adolescents, with 5 adolescents (42%) females and 7 adolescents (58%) males. The sample of adolescents living in the lowlands is 12 adolescents with the gender of 6 adolescents (50%) females and 6 adolescents (50%) males. Based on Table 2, it is known that the sample of adolescents living in the highlands is 12 adolescents, with 4 adolescents (33%) aged 18 years, 5 adolescents (42%) aged 19 years, 2 adolescents (17%) aged 20 years and 1 person aged 21 years (8%). Meanwhile, the adolescents living in the lowlands is 12 adolescents, with the age of 18 years (33%), the age of 19 years as many as 2 teenagers (17%), the age of 20 years as many as 3 teenagers (25%) and the age of 21 years as many as 3 people (25%).

Table 1. Characteristics of adolescents by gender

Gender	Highlands		Lowland	
	Number of teenagers	%	Number of teenagers	%
Female	5	42	6	50
Male	7	58	6	50
Total	12	100	12	100

Table 2. Characteristics of adolescents by age

Age	Highlands		Lowland	
	Number of teenagers	%	Number of teenagers	%
18 Year	4	33	4	33
19 Year	5	42	2	17
20 Year	2	17	3	25
21 Year	1	8	3	25
Total	12	100	12	100

Table 3. Characteristics of adolescents based on BMI

BMI classification	Highlands		Lowland	
	Number of teenagers	%	Number of teenagers	%
Skinny	2	17	4	33
Normal	9	75	7	58
Overweight	1	8	1	8
Obese	0	0	0	0
Total	12	100	12	100

Table 4. Distribution of hemoglobin levels in adolescents living in highlands and lowlands

	Altitude	Hb value description	Frequency (n)	%	Average
Hemoglobin levels	Highland	Normal	5	42%	14,6833
		Abnormal	7	58%	
	Lowland	Normal	3	25%	12,2333
		Abnormal	9	75%	

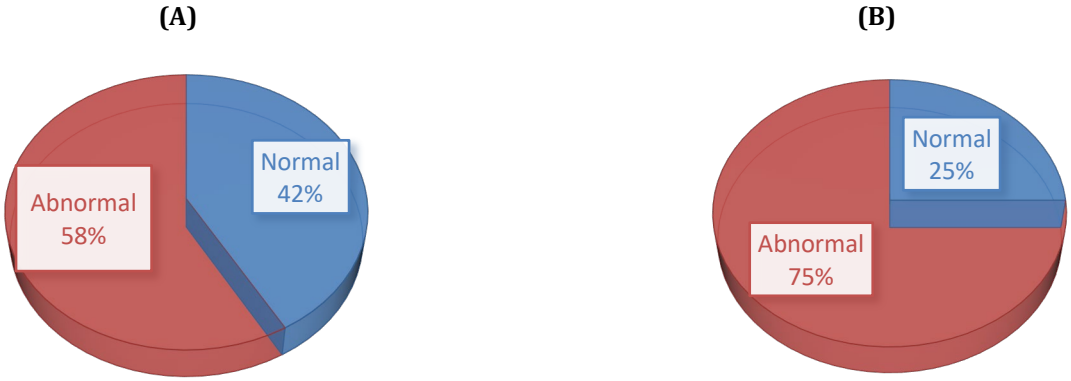

Figure 1. Hemoglobin levels in adolescents living in the highland (A), and hemoglobin levels in adolescents living in lowlands (B)

Based on Table 3, it is known that the sample of adolescents living in the highlands with the characteristics of skinny BMI is 2 adolescents (17%), normal BMI as many as 9 adolescents (75%), overweight as many as 1 teenager (8%) and obese (0%). Meanwhile, the sample of adolescents living in the lowlands with the characteristics of skinny BMI is 4 adolescents (33%), normal BMI 7 adolescents (58%), overweight 1 adolescents (8%), and no adolescents with obese (0%).

According to the aforementioned findings, a sample of teenagers living in the highlands had an average hemoglobin level of 14.6833 g/dl, whereas adolescents living in the lowlands had an average hemoglobin value of 12.2333 g/dl. Although hemoglobin levels remained within normal ranges, adolescents living in the highlands had an average hemoglobin level that was greater than adolescents living in the lowlands.

The Shapiro-Wilk test was used to determine the normality of the hemoglobin level data in the individuals. The significance of the hemoglobin levels in the highland and lowland teenagers was 0.316 and 0.959, respectively.

4. Discussion

In this study, the average hemoglobin level of adolescents living in highlands was 14.6 g/dl, while the average hemoglobin level of adolescents living in lowlands was 12.2 g/dl. The average hemoglobin level of adolescents living in the highlands was higher than that of adolescents living in the lowlands. In adolescents without anemia and with adequate nutritional status, the food consumed contains all the essential nutrients required by the body. As a result, there is a balance between nutrient intake and the body's nutritional needs.[9,16]

The findings of this study contradict study by Waani et al., which discovered that those who lived in highlands had lower hemoglobin levels than those who lived in lowlands.[11] Because of the pattern of adaptation to altitude at certain intervals, a 2019 study by Inayati et al. found no variation in the hemoglobin levels of East Lombok residents depending on the area's height, with the highest position being 1140 meters above sea level.[13] There are differences in hemoglobin levels in each individual because they are influenced by various factors, such as height, weight or BMI, nutritional adequacy, socioeconomic factors, smoking habits, chronic infectious diseases, alcohol consumption, physical activity, and dehydration.[13]

a. BMI factors and nutritional adequacy

Based on the questionnaire data that has been analyzed, there is an influence of BMI or body weight with hemoglobin levels. Low hemoglobin levels are found in adolescents with varying body mass indexes. Adolescents living with obesity and anemia in the highlands were as many as 1 teenager (8%), and in the lowlands as many as 3 adolescents (25%). This is due to a decrease in iron absorption in adipose tissue due to the accumulation of fat cells and an increase in hepcidin levels, which inhibits the absorption of iron in enterocytes and iron release so that iron metabolism is disturbed, and anemia occurs.[14]

Adolescents who have a BMI below normal with anemia living in highlands as many as 2 adolescents (17%) and in lowlands as many as 2 adolescents (17%). This is due to the lack of nutritional intake in the body so that nutritional needs in the body, such as the need for iron are not met. One of the most important components in the formation of hemoglobin levels is iron, with a lack of iron intake in the body will cause a reduction in red blood cell-forming materials, so that the oxygen supply cannot be carried out by red blood cells so that anemia occurs.[13] In this study, the effect of nutritional intake in the face of hemoglobin levels was also obtained. Adolescents with a normal BMI who live in the highlands are 9 adolescents (75%), and adolescents in the lowlands as many as 5 adolescents (42%) with normal nutritional status. In adolescents without anemia and with adequate nutritional status, the food consumed contains all the essential nutrients required by the body. As a result, there is a balance between nutrient intake and the body's nutritional needs.[13]

Based on research data, there were 2 adolescents (17%) who lived in lowlands who had good nutritional status, BMI 18.5 - 25.0, and anemia. This condition may result from inadequate intake of nutrient-rich foods, particularly those containing iron. Adolescents who frequently consume fast food or junk food may experience reduced nutrient absorption, which can interfere with hemoglobin synthesis and impair oxygen transport in the blood, ultimately leading to anemia.[5]

b. Physical activity factor

Based on the results of the questionnaire that has been analyzed, there is an influence between physical activity and hemoglobin levels. A total of 8 adolescents (67%) living in the highlands were engaged in strenuous physical activities, including participation in multiple sports-related extracurricular activities, foraging for livestock along hilly terrains, and assisting their parents with agricultural work.[11]

c. Alcohol consumption factors

Low hemoglobin levels in adolescents with alcohol consumption in adolescents living in highlands as many as 3 adolescents (25%) and adolescents who consumed alcohol living in highlands as many as 3 adolescents (25%). This may occur because alcohol affects hematopoiesis indirectly through its metabolic effects. One such effect is the inhibition of heme synthesis, which leads to reduced hemoglobin production. In addition, nutrient deficiencies associated with alcohol consumption may directly interfere with the proliferation and polymerization of cellular elements in the bone marrow, thereby contributing to decreased hemoglobin levels.[2]

d. Smoking habit factors

Based on the research data, there is an influence of smoking habits on hemoglobin levels. The results of this study are in line with research conducted by Zukefeli which stated that there was an increase in blood hemoglobin levels in smokers. A total of 5 adolescents (41.7%) who live in the highlands smoke and 4 adolescents (33.3%) who live in the lowlands, have high hemoglobin levels.[15] The increase in hemoglobin in smokers is caused by exposure to carbon monoxide contained in cigarettes and has a great affinity for hemoglobin, making it easier to bind to each other to form carboxyhemoglobin, an inactive form of hemoglobin. As a result, hemoglobin cannot bind oxygen to be released into various tissues, so it

will cause tissue hypoxia. The body will compensate for the decrease in oxygen levels by increasing hemoglobin levels.[6]

e. Water consumption

Based on the research, there is an effect of water consumption with hemoglobin levels. Adolescents who live in highlands who tend to have high hemoglobin levels as many as 4 adolescents (33.3%) is also caused by a lack of water consumption. Cool temperatures may reduce the sensation of thirst in adolescents, leading to decreased water intake, even though the body still requires adequate hydration. Insufficient fluid intake can affect blood plasma volume. When fluid intake increases and the body's hydration needs are met, plasma volume rises, which may initially dilute hemoglobin concentration. However, with proper hydration, hemoglobin levels tend to stabilize and return to normal physiological ranges.[7]

The limitations of this study include a small sample size and limited availability of measurement tools. It is hoped that future research can be conducted on a larger population and across a broader range of altitudes to enable more accurate comparisons of hemoglobin levels.

5. Conclusion

In conclusion, adolescents living in highland areas tend to have higher hemoglobin levels compared to those living in lowland areas. This difference may be influenced by several factors, including altitude of residence, nutritional status, lifestyle habits such as smoking and alcohol consumption, levels of physical activity, and water intake. These findings highlight the importance of considering environmental and behavioral factors in assessing hemoglobin levels and the risk of anemia among adolescents.

6. Author Contribution

The M.P was in charge of preparing the research and then processing the results until writing the article manuscript, while the A.P and M.P.P helped in the research and revision of the article.

7. Acknowledgements

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