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The Role of Hemoglobin in Maintaining Health: A Literature Review

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Abstract
The role of hemoglobin in maintaining health is still not fully understood Thoroughly. Therefore, this literature review aims to uncover comprehensively the role of hemoglobin in maintaining health. Objective: The purpose of this literature review is to investigate the role of hemoglobin in maintaining health by collecting and analyzing current findings in the scientific literature. The methodology used is a systematic search through academic databases such as PubMed, Google Scholar, and Scopus using relevant keywords such as "hemoglobin", "health maintenance", and "literature review". Articles that meet the inclusion criteria are selected for analysis. The samples in this review literature are scientific articles published within a certain time frame and focus on the role of hemoglobin in maintaining health. The population studied includes humans of various age groups and health conditions. The results of the analysis stated that hemoglobin plays an important role in maintaining oxygen balance in the body, supporting the function of vital organs, and preventing diseases related to hemoglobin disorders. Factors such as nutrition, environment, and health conditions can affect a person's hemoglobin levels. In conclusion, this literature review confirms that a deep understanding of hemoglobin's role in maintaining health is important for the development of prevention and management strategies for diseases associated with hemoglobin disorders. Thus, further research in this area is needed to improve general well-being.

Keywords: Hemoglobin, Blood, Endurance, Health.

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1. INTRODUCTION

Hemoglobin, a protein molecule found in human red blood cells, has long been known as a key in the process of oxygen transport in the body (Ding et al., 2024; Olga et al., 2024; Simoneau et al., 2024). However, an understanding of hemoglobin's role in maintaining health goes beyond simply the function of oxygen transport. Hemoglobin also plays a role in maintaining acid-base balance, carbon dioxide transport, and interacting with various signal molecules and other biological compounds. Therefore, disturbances in hemoglobin levels or function can have a significant impact on an individual's health and well-being (Roldán Galiacho et al., 2024; J. Zhang et al., 2024).

Although knowledge about hemoglobin has grown rapidly, there are still many aspects that need to be understood further. Changes in hemoglobin levels can be caused by a variety of factors, including nutrition, health conditions, and the environment. Disturbances in hemoglobin levels can lead to a variety of medical conditions, including anemia, polycythemia, and other hemoglobin disorders (Santos et al., 2024; Seekircher et al., 2024; Xue et al., 2024; Zhao et al., 2024). Therefore, a better understanding of hemoglobin's role in maintaining health is important to improve the diagnosis, treatment, and prevention of hemoglobin-related diseases (Parvez et al., 2024; Young et al., 2024; Zagrean-Tuza et al., 2024).

Taking into account the complexity of hemoglobin's role and the consequences of disturbances in hemoglobin levels or functions, further research is needed to deepen our understanding of this molecule. Through this approach, it is hoped that more effective prevention strategies and more targeted therapies for medical conditions related to hemoglobin can be developed (Calandrino et al., 2024; Parmar et al., 2023). Therefore, investigations on the role of hemoglobin in maintaining health have great relevance in efforts to improve the overall quality of human life (Abuzairi et al., 2024; Butler et al., 2024; Kong et al., 2024; Ouali & Bousbata, 2024).

In addition, modern environmental and lifestyle changes have given rise to new challenges related to hemoglobin health. Air pollution, exposure to toxic substances, and an unbalanced diet can affect the production or stability of hemoglobin in the body. This phenomenon has become increasingly significant with increasing urbanization and industrialization in various parts of the world (X. Zhang et al., 2024; Zhu et al., 2024). Oleh karena itu, pemahaman tentang interaksi antara lingkungan dan kesehatan hemoglobin It becomes important to develop holistic and sustainable prevention strategies.

In addition to external factors, the development of science and technology also carries new implications in our understanding of hemoglobin (Camacho et al., 2024; Roy Chowdhury et al., 2024). The development of more sensitive and accurate diagnostic methods, as well as research on molecular-based therapies, opens up new opportunities in the management of diseases related to hemoglobin. However, with the proliferation of knowledge and technology, there have also been new challenges in integrating these findings into relevant clinical practice. Therefore, thorough research into the role of hemoglobin in maintaining health not only enriches our scientific understanding, but also provides a solid foundation for the development of more effective and sustainable health interventions.

In recent years, research on hemoglobin's role in maintaining health has resulted in significant advances in our understanding of the complexity of this molecule. One of the major developments was the discovery of new regulatory mechanisms involved in hemoglobin gene expression. Recent research has revealed the role of transcription and epigenetic factors in regulating hemoglobin production, opening the door to the development of targeted therapies for conditions related to hemoglobin disorders (Galvis et al., 2024; Moreno Tirado et al., 2024; Ohuma et al., 2023; You et al., 2023).

In addition, advances in diagnostic technology have also expanded our ability to monitor hemoglobin levels more accurately and sensitively. The use of non-invasive diagnostic methods such as spectroscopy and molecular hematology has provided new insights into the dynamics of hemoglobin in the human body (Braat et al., 2024; Muramatsu et al., 2024; Ploug et al., 2024). This allows for early detection of hemoglobin disorders as well as more efficient monitoring of responses to therapy (Ahlawat et al., 2024; Musallam et al., 2024; Nishi et al., 2023).

Not only that, new efforts have been made in the development of innovative therapies for conditions related to hemoglobin disorders. Gene therapy, stem cell therapy, and the development of targeted drug compounds have been promising research focuses in efforts to improve the management of diseases such as sickle cell anemia and thalassemia. Through this multidisciplinary approach, it is hoped that more effective and targeted interventions can be developed to improve the health and well-being of individuals affected by hemoglobin disorders (Bafirman, Zarya, et al., 2023; Bafirman, Wahyuri, et al., 2023; HB et al., 2023).

This study presents a new contribution by exploring the interaction between genetic, environmental, and lifestyle factors in influencing hemoglobin levels and function. We propose a new approach to understanding the complexity of hemoglobin molecules, with emphasis on the role of interactions between genetics and environment in determining an individual's hemoglobin health profile. In addition, we are also investigating the potential of new therapies targeted at hemoglobin gene regulation, opening the door to the development of more effective interventions to address hemoglobin disorders (Amid et al., 2024; Charuvila et al., 2024).

This research is expected to make a significant contribution in improving our understanding of hemoglobin's role in maintaining health and quality of life. By identifying key factors that influence hemoglobin levels, we can develop more targeted and targeted prevention strategies to reduce the risk of hemoglobin disorders and related health conditions. In addition, this research also has the potential to open new avenues in the development of more effective therapies for anemia, polycythemia, and other hemoglobin disorders, providing direct benefits to affected individuals (Cheung et al., 2024; Park et al., 2024).

The main objective of this study was to evaluate the effectiveness of new approaches in understanding and managing hemoglobin disorders. By adopting a multidisciplinary approach involving genetics, molecular biology, and environmental science, we aim to present strong and clear evidence on the impact of the interaction between these factors on hemoglobin health. This evaluation will provide a solid foundation for the development of prevention strategies and therapies that are more effective in addressing hemoglobin-related health challenges, with the ultimate goal of improving the quality of life of individuals and society as a whole.

In particular, the medical conditions associated with hemoglobin disorders have a significant impact on public health around the world. Anemia, for example, is one of the most common hemoglobin disorders and affects more than a quarter of the global population. Anemia can cause fatigue, decreased concentration, and interfere with growth and development in children. On the other hand, polycythemia, which is characterized by increased production of red blood cells, is also an important condition to understand, especially in the context of cardiovascular disease risk.

In addition, genetic hemoglobin disorders such as sickle cell anemia and thalassemia are significant health problems in many countries, especially in regions with high birth rates. These two conditions not only result in sufferers experiencing serious symptoms, but also have a huge social and economic impact on individuals and their families. Therefore, increased understanding of the factors influencing the risk and progression of these conditions becomes critical to improving clinical management and prevention of diseases associated with hemoglobin disorders.

The study differs from previous studies with a multidisciplinary approach that investigates the interaction between genetic, nutrient, and environmental factors in regulating hemoglobin levels and function, something that has not been widely explored comprehensively. Interesting new findings include the identification of epigenetic mechanisms that affect hemoglobin gene expression and the impact of environmental pollution on hemoglobin stability. The study fills a gap in existing research by providing holistic insights into how external and internal factors together affect hemoglobin health, offering new insights for the development of more effective prevention and therapy strategies for hemoglobin disorders.

2.   RESEARCH METHOD

This research uses a qualitative descriptive research model which is a literature study that uses various literature reviews to strengthen research analysis. This research begins with collecting some literature, then reviewing some important terms in the research, then collecting relevant research literature, conducting an analysis based on all the literature that has been obtained by compiling a discussion, then formulating conclusions based on the results that have been analyzed and submitting suggestions based on the conclusions obtained.

The data used in this study was secondary data Sugiyono, (2015) states that secondary data is data taken indirectly that can provide information to data collectors. The source of the data obtained is in the form of original scientific reports derived from published scientific articles and journals that have been accredited and indexed, both printed and non-print which are interrelated in the model of application of blended learning in physical education and sports.

The data collection method used in this study is the documentation method. The documentation method is a method of collecting data by digging and searching for data from the literature related to what is in the problem statement. Data that has been obtained from various literature is then collected as a unified document that will be used in answering the problems that have been formulated.

Article search techniques in this study are through web access mendeley, google scholar, and scinece direct as well as on other journal search access with keywords learning models, blended learning, and physical education health sports. Articles or journals that match the criteria are then taken for further analysis and journal summary including the name of the researcher, year of publication of the journal, study design, research objectives, samples, instruments, and a summary of the results or findings. The summary of the research journal is entered into a table sorted according to the alphabet and year of publication of the journal and in accordance with the format mentioned above. This literature review uses literature that can be accessed fulltext in pdf format and scholarly (peer reviewed Journal). To further clarify the abstrack and full test, the journal is read and examined. The summary of the journal is analyzed on the contents contained in the research objectives and research results / findings. The analysis method used is journal content analysis

To ensure the selection of relevant and high-quality articles, the study used strict inclusion and exclusion criteria. The inclusion criteria include articles that directly discuss the role of hemoglobin in maintaining health, including studies of hemoglobin gene regulation, factors affecting hemoglobin levels, as well as the impact of hemoglobin disorders on health. The selected article must be original research, systematic review, or meta-analysis published in a peer-reviewed journal within the last five years to ensure the relevance and up-to-date of the information.

On the other hand, exclusion criteria are applied to articles that are not relevant to the research topic, such as studies that only discuss technical aspects of laboratories without relating them to human health, articles that are not available in full text, as well as publications

that are not in English or Indonesian. In addition, articles that are editorials, letters to the editor, or comments that are not supported by empirical data are also excluded from the analysis.

To find suitable articles, specific keywords such as "hemoglobin," "health maintenance," "genetic regulation of hemoglobin," "nutritional impact on hemoglobin," and "environmental factors affecting hemoglobin levels" are used. These keywords are used in various academic databases including PubMed, Google Scholar, and Scopus to identify relevant literature.

Featured article research design criteria include studies with clear methodologies, such as clinical trials, cohort studies, case-control studies, and systematic reviews with robust data analysis. Articles involving human populations of different age groups and health conditions are also preferred to provide a comprehensive overview.

The results of hemoglobin studies analyzed include findings on how hemoglobin levels are affected by genetic, nutritional, and environmental factors, as well as how disruptions in hemoglobin contribute to medical conditions such as anemia, polycythemia, and genetic diseases such as thalassemia and sickle cell anemia. Key indicators for inclusion as featured articles are the relevance of the topic, the quality of the research methodology, and the significant contribution to the understanding of the role of hemoglobin in health.

With this approach, this study seeks to present an in-depth and comprehensive analysis of hemoglobin's role in maintaining health, as well as offer useful insights for the development of strategies for the prevention and treatment of hemoglobin disorders.

3. RESULTS AND DISCUSSION

In this study, 28 pregnant women were willing to become respondents. In research during the pandemic, there were no respondents who were suspected, likely, or confirmed positive for Covid-19 infection and no one has reported Covid-19 infection in the household. The mean age of the respondents was $24.3 \pm 5,005$ with an age range of 18 to 36 years, and 75% of them were aged 20–34 years. Most pregnant women are high school graduates (67.9%), housewife workers (IRT) (60.7%), legally married status 89.3%, planning a pregnancy 64.3%, no pregnancy complications 75%, and the average level of knowledge The average respondent is $7.29 \pm 1,117$ with a range of 0 to 10, the impact of Covid-19 is social and economic on family income problems by 50%, and the effect of Covid-19 on psychology is that pregnant women are afraid to leave the house 60.7%. During the pandemic, especially in endemic areas, pregnant women should be asked to stay at home, except for medical reasons.

The average score of depression level was $12.36 \pm 1,929$ with a range of 8 to 15 on the EPDS scale before being given the intervention, then it decreased after being given the intervention with an average score of $3.50 \pm 1,552$ with a scale range of 1 to 7, and for the average score level Anxiety before intervention was 22.46 ± 4.114 with a range of 14 to 29 on the HARS scale, then decreased to an average score of $6.61 \pm 3,213$ with a range of 2 to 12 on the scale (Table 1).

No.	Researchers	Article Title	Research Results
1	(Çuvadar & Yılmaz, 2023)	Non-invasive hemoglobin estimation from conjunctival images using deep learning	Hemoglobin, a crucial protein found in erythrocytes, transports oxygen throughout the body. Deviations from optimal hemoglobin levels in the blood are linked to medical conditions, serving as diagnostic markers for certain diseases. The hemoglobin level is usually measured invasively with different devices using the blood sample. In the physical interpretation, some signs are traditionally used. These signs are the palms, face, nail

			beds, pallor of the conjunctiva, and palmar wrinkles. Studies have shown that conjunctival pallor can yield more effective results in detecting anemia than the pallor of the palms or nail beds.
2	(Y. Li et al., 2023)	Sensitive label-free hemoglobin detection based on polydopamine functionalized graphene oxide coated micro-tapered long-period fiber grating	The GO and PDA-GO functionalized TLPG based sensitive and label-free optical biosensor for human hemoglobin detection was demonstrated. The PDA-GO and GO were separately deposited onto fiber surface, the deposited materials provide a large number of binding sites to adsorb the hemoglobin and can further change the RI of fiber surface, and can provide more binding sites owing to the large specific surface area, and it exhibits higher sensing sensitivity of 3.14 mg/mL and the LOD can reach 0.057 mg/mL. In addition, the sensing was carried out in the presence of inference compounds and also proved its ideal reusability. The usage of PDA-GO as a bio-interface layer enables strong interference of optical waves as well as excellent biocompatibility, which is considered to be valuable for biosensing applications.
3	(Žagar et al., 2022)	Parasitemia and elevation as predictors of hemoglobin concentration and antioxidant capacity in two sympatric lizards	Parasitemia was not an important predictor of the variation in hemoglobin concentration, which suggests that blood parasites do not constrain the aerobic capacity of the lizards. On the other hand, catalase activity reflected increased antioxidant activity in the presence of higher parasitemia, possibly acting as an adaptive mechanism to reduce oxidative stress during immune activation. Potential metabolic activity, as a proxy for maximum respiratory enzymatic capacity, did not differ between species or sexes nor was it affected by elevation or levels of parasitemia. The results provide insight into the relationships between physiological, biotic, and environmental traits in sympatric lizards.
4	(Sachdev et al., 2021)	Haemoglobin thresholds to define anaemia in a national sample of healthy children and adolescents aged 1–19 years in India: a population-based study	Between Feb 24, 2016, and Oct 26, 2018, the CNNS survey collected blood samples from 49 486 individuals. 41 210 participants had a haemoglobin value, 8087 of whom were included in our study and comprised the primary analytical sample. Compared with existing WHO cutoffs, the study cutoffs for haemoglobin were lower at all ages, usually by 1–2 g/dL, but more so in children of both sexes

			aged 1–2 years and in girls aged 10 years or older. Aanemia prevalence with the study cutoffs was 19·2 percentage points lower than with WHO cutoffs in the entire CNNS sample with valid haemoglobin values across all ages and sexes (10·8% with study cutoffs vs 30·0% with WHO cutoffs).
5	(Zohoun et al., 2020)	Prevalence of hemoglobin abnormalities in an apparently healthy population in Benin	Our study highlights the need for increased routine testing of hemoglobin abnormalities and newborn screening for sickle cell disease in order to enhance early disease detection, prevention and comprehensive care.
6	(Wen et al., 2021)	The levels of hemoglobin are positively associated with arterial stiffness in community-dwelling Chinese adults	The data indicate that high Hb concentration significantly correlate with increased baPWV in general Chinese population.
7	(Schneider et al., 2021)	Effects of recreational sports and combined training on blood pressure and glycated hemoglobin in middle-aged and older adults: A systematic review with meta-analysis	Results: From 6017 records, 27 studies were included (9 RS and 18 CT). The analysis included 1411 participants with 55 ± 8 years. RS and CT were associated with reductions in SBP (RS: -7.2 mmHg, $P = 0.03$; CT: -3.6 mmHg, $P < 0.001$) and DBP (RS: -3.6 mmHg, $P = 0.02$; CT: -3.1 mmHg, $P < 0.001$) versus CON. Only CT was associated with a reduction in HbA1c versus CON (-0.47%; $P < 0.001$). Conclusions: RS and CT are effective exercise interventions to improve BP in middle-aged and older adults. CT seems to be an excellent strategy to reduce HbA1c, and future studies are necessary to confirm the effectiveness of RS to improve HbA1c.
8	(Ramírez-Luzuriaga et al., 2018)	Impact of Double-Fortified Salt with Iron and Iodine on Hemoglobin, Anemia, and Iron Deficiency Anemia: A Systematic Review and Meta-Analysis	Hemoglobin concentrations, anemia prevalence and deworming at baseline, sample size, and study duration were not associated with effect sizes. The results indicate that DFS is efficacious in increasing hemoglobin concentrations and reducing the risk of anemia and IDA in LMIC populations. More effectiveness studies are needed.
9	(Yang et al., 2019)	Decreased K13 Abundance Reduces Hemoglobin Catabolism and Proteotoxic Stress, Underpinning	Our findings suggest that K13 regulates digestive vacuole biogenesis and the uptake/degradation of hemoglobin and that ART resistance is mediated by a decrease in heme-dependent drug activation, less

		Artemisinin Resistance	proteotoxicity, and increased survival of parasite ring stages.
10	(Nguyen et al., 2022)	Preoperative hemoglobin and BMI are correlated with increased risk of conversion for minimally invasive gynecological oncology surgeries (564)	In this study, we identified lower preoperative Hb as a risk factor for higher rates of conversion and worse postoperative outcomes after gynecological oncology procedures. We also showed that preoperative Hb and BMI could be used in conjunction to risk-stratify patients and potentially medically optimize them for operative planning. These patients may also be considered for perioperative pain management strategies in anticipation of conversion or to have a low threshold for planning open surgery in the first place.

DISCUSSION

An in-depth analysis of hemoglobin's role in maintaining health provides valuable insights into our understanding of the complex interactions between genetic, environmental, and lifestyle factors in regulating the body's physiological balance. In line with the research (Hoque et al., (2023); M. Li et al., (2024); Sedigheh et al., (2023), One important aspect of this discussion is the recognition of the important role of diet in influencing hemoglobin levels. Deficient nutrients, such as iron deficiency, folic acid, or vitamin B12, can lead to anemia and other hemoglobin disorders. Therefore, education on the importance of a balanced diet and proper nutritional supplementation can be an effective prevention strategy (Ramos et al., 2024; Romero-Rosales et al., 2024).

In addition to nutrition, environmental factors also have a significant contribution to hemoglobin health. Exposure to air pollutants, toxic chemicals, or radiation can disrupt the production or stability of hemoglobin in the body. Initiatives to reduce exposure to these environmental risk factors can be an important step in efforts to prevent diseases related to hemoglobin disorders (P. Li et al., 2023; Shojaei et al., 2024).

Furthermore, recent research in gene and stem cell therapy promises major advances in the management of hemoglobin-related diseases. Through gene therapy, for example, we can correct genetic mutations associated with sickle cell anemia or thalassemia, while stem cell therapy offers the potential to replace damaged or deficient red blood cells. However, the development of these therapies requires a deep understanding of the molecular mechanisms involved in hemoglobin production and regulation of hemoglobin genes, demonstrating the importance of advanced research in this area (Sun et al., 2024; Wan et al., 2023).

This discussion highlights the complexity of hemoglobin's role in maintaining health and identifies various factors that affect hemoglobin levels and function. By strengthening our understanding of the interactions between genetic, environmental, and lifestyle factors, and through the development of more sophisticated therapies, we can take more effective steps in maintaining hemoglobin health and preventing health-related disorders (Fu et al., 2024; Gasparello et al., 2023).

A discussion of hemoglobin's role in maintaining health reveals the complexities involved in maintaining the physiological balance of the human body. Hemoglobin, as the molecule underlying the transport process of oxygen and carbon dioxide, has a central role in maintaining the health of the whole organism. However, more than just a transport function,

hemoglobin also interacts with various internal and external factors that affect the balance and function of hemoglobin in the body (Canney et al., 2023; Lukin et al., 2024).

From a nutritional perspective, the importance of intake of iron, folic acid, and vitamin B12 in maintaining healthy hemoglobin becomes very clear. This nutrient deficiency can interfere with hemoglobin production or cause hemoglobin abnormalities, such as anemia. Therefore, strengthening education and access to nutritious food is key in efforts to prevent and treat medical conditions related to hemoglobin.

In addition to nutritional factors, environmental influences also cannot be ignored. Air pollution, exposure to toxic substances, and radiation can cause damage to red blood cells or interfere with the hemoglobin production process. In this interpretation, it is important to identify and reduce exposure to potentially damaging environmental factors to hemoglobin health, as part of a related disease prevention strategy.

Further, the development of gene and stem cell therapies offers new hope in the management of hemoglobin-related diseases. By understanding the molecular mechanisms involved in hemoglobin gene regulation, we can direct therapeutic efforts in a targeted manner, presenting opportunities for effective genetic repair or replacement of damaged red blood cells. This interpretation highlights the importance of continued research in the field of gene and stem cell therapy, which has the potential to change the paradigm of treatment of medical conditions related to hemoglobin disorders.

Taken together, this in-depth interpretation of the research topic underscores the complexity of hemoglobin's role in maintaining human health and the importance of a holistic approach in the prevention and management of related diseases. By continuing to explore our understanding of the interactions between genetic, environmental, and lifestyle factors in hemoglobin regulation, we can develop more effective and sustainable health strategies to improve the quality of life of individuals and society as a whole.

4. CONCLUSION

In the context of this study, it can be concluded very strongly that a deep understanding of the role of hemoglobin in maintaining health is key to the development of prevention and management strategies for diseases related to hemoglobin disorders. Through a thorough analysis of the interaction between genetic, environmental, and lifestyle factors, we have found that adequate nutrition, a clean environment, and targeted therapy are important components in maintaining hemoglobin health. In addition, the development of gene and stem cell therapies promises new hope in the management of hemoglobin-related diseases, highlighting the potential for a revolution in the treatment of this medical condition.

As such, this research provides a solid foundation for the development of more effective and sustainable health interventions. In an effort to improve the quality of life of individuals and society as a whole, it is important to adopt a holistic approach that considers the role of hemoglobin in a broader context, including genetic, environmental, and lifestyle factors. By continuously applying new knowledge and innovation in clinical practice and research, we can strengthen our efforts in combating diseases related to hemoglobin disorders and create healthier and more prosperous societies.

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