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Dr. Shashi Kanaujia
Assistant Professor, Department of Physical Education, University of Lucknow, Uttar Pradesh, India

Aditya Pratap Yadav
Research Scholar, Department of Physical Education, University of Lucknow, Uttar Pradesh, India

Corresponding Author:
Dr. Shashi Kanaujia
Assistant Professor, Department of Physical Education, University of Lucknow, Uttar Pradesh, India

Effects of exercise intensity on hemoglobin levels in Athletes: A study on perceived effort and blood adaptations

Shashi Kanaujia and Aditya Pratap Yadav

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Abstract
This study examines the relationship between exercise intensity and hemoglobin levels in athletes, focusing on perceived effort and physiological blood adaptations. Hemoglobin plays a critical role in oxygen transport, directly influencing endurance and performance. By analyzing various training intensities, this research explores how different levels of exertion impact hemoglobin concentrations and overall athletic adaptation. The study follows a 12-week training program, measuring hemoglobin variations across different exercise intensities. The results indicate that high-intensity exercise promotes significant hemoglobin adaptations, while moderate and low-intensity training have lesser impacts. This research provides valuable insights for athletes, coaches, and sports scientists in optimizing training regimens.

Keywords: Hemoglobin, exercise intensity, athletes, oxygen transport, blood adaptations, perceived effort

Introduction
Exercise intensity significantly affects cardiovascular and hematological parameters, including hemoglobin levels. Hemoglobin is essential for oxygen transport, and its adaptation to training can influence athletic performance. This study aims to investigate how varying exercise intensities impact hemoglobin levels, considering both acute and chronic adaptations in athletes. Previous studies have suggested that high-intensity training enhances erythropoiesis (Smith *et al*., 2020; Brown *et al*., 2018) [9, 2], while excessive endurance training may lead to hemolysis (Jones & Taylor, 2017) [5]. Understanding these mechanisms can help optimize training strategies for athletes in endurance and strength-based sports.
Hemoglobin is a protein found in red blood cells responsible for oxygen transport. The ability of the body to increase hemoglobin levels is critical for endurance sports such as marathon running, cycling, and long-distance swimming (Sawka *et al*., 2021) [8]. Training at different intensities has been associated with varied erythropoietic responses, depending on the stress imposed on the body. While moderate exercise is known to maintain stable hemoglobin levels, high-intensity interval training (HIIT) has shown the potential to enhance erythropoiesis by stimulating erythropoietin (EPO) production (Neufer *et al*., 2016) [7]. This study aims to evaluate these effects using a controlled experimental design.

Methodology
A cohort of 60 competitive athletes from endurance and strength-based sports participated in this study. They were divided into three groups based on exercise intensity: low-intensity (n=20), moderate-intensity (n=20), and high-intensity training (n=20). The training interventions were designed to match real-world athletic practices:

- **Low-intensity group:** Engaged in steady-state cardio at 50-60% of maximum heart rate (MHR) for 45 minutes per session, four times a week.
- **Moderate-intensity group:** Trained at 70-80% MHR, combining steady-state and interval workouts for 60 minutes, four times a week.
- **High-intensity group:** Performed HIIT at 85-95% MHR, with repeated short bursts of maximum effort, lasting 30-40 minutes per session, five times a week.

Hemoglobin levels were measured before, during, and after the 12-week training period using a hematology analyzer (Beckman Coulter DxH 900). Perceived exertion was recorded using the Borg Rating of Perceived Exertion (RPE) scale (Borg, 1982) [1]. Additional hematological parameters such as hematocrit and red blood cell count were also assessed to provide a comprehensive understanding of blood adaptations.

Results

Findings indicate a correlation between exercise intensity and hemoglobin adaptations. High-intensity training groups showed an average hemoglobin increase of 7.2% (±1.3), suggesting erythropoietic stimulation. Moderate-intensity exercise exhibited stable hemoglobin levels with a slight increase of 2.4% (±0.8), while low-intensity training resulted in minimal changes of 0.9% (±0.5). Perceived exertion scores correlated with hemoglobin fluctuations, with higher RPE values (15-18) associated with greater hematological adaptation. These findings align with previous research by Jacobs *et al*. (2019) [4], which demonstrated similar erythropoietic responses to high-intensity training.

Furthermore, the red blood cell count (RBC) and hematocrit levels increased significantly in the high-intensity group (6.5% and 5.8%, respectively), while moderate-intensity training showed modest increases (2.2% and 1.8%). The low-intensity group experienced negligible changes, confirming that a higher workload stimulates greater erythropoietic adaptation.

Discussion

The results suggest that high-intensity exercise promotes erythropoiesis, likely due to increased oxygen demand and subsequent physiological stress (Sawka *et al*., 2021) [8]. This adaptation may benefit endurance athletes by improving oxygen transport efficiency. However, excessive high-intensity training could lead to hemolysis (Neufer *et al*., 2016) [7], necessitating careful monitoring of training loads. Moderate-intensity training appears to maintain stable hemoglobin levels without excessive physiological strain, making it a viable option for maintaining endurance without the risk of overtraining.

The study also highlights the role of erythropoietin (EPO) in blood adaptation. EPO, a hormone released in response to hypoxia, stimulates red blood cell production. High-intensity training has been shown to increase EPO secretion, leading to a subsequent rise in hemoglobin concentration (Friedmann *et al*., 2005; Montero *et al*., 2017) [3, 6]. This mechanism explains why elite endurance athletes often train at high intensities or at altitude to maximize hematological benefits (Sawka *et al*., 2021) [8].

Despite these benefits, there are potential risks associated with high-intensity training. Prolonged and excessive HIIT can cause oxidative stress and hemolysis, leading to iron depletion and anemia (Jones & Taylor, 2017) [5]. Therefore, proper recovery and nutrition strategies, such as iron supplementation and adequate hydration, should be considered to mitigate these risks.

Conclusion

Exercise intensity plays a crucial role in hemoglobin adaptation among athletes. High-intensity training enhances hemoglobin concentration, improving oxygen transport and endurance capacity. Moderate-intensity training helps maintain stable hemoglobin levels, while low-intensity training induces minimal changes. Understanding the optimal training intensity for maximizing hematological benefits can help athletes and coaches optimize performance while preventing overtraining-related complications. Future studies should explore long-term adaptations and the impact of altitude training on hemoglobin levels.

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