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Hematologic health and athletic performance: exploring the role of anemia. A systematic review of clinical studies

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ABSTRACT

Introduction

Anemia is a widespread hematological disorder characterized by low hemoglobin levels, which reduce the blood's capacity to deliver oxygen to tissues. Iron deficiency, its leading cause, is essential for hemoglobin synthesis, myoglobin function, and energy production. While anemia can manifest in various forms, its impact on athletic performance remains a subject of ongoing research. Given the increasing prevalence of anemia among athletes, especially in endurance sports, understanding its effects on physical performance is essential for developing effective training and treatment approaches.

Aim of the study

The aim of the study was to analyze the impact of anemia on the physical performance of athletes, the effectiveness of iron supplementation and differences in the response to anemia in various sports groups.

Materials and methods

The article was created based on the PubMed and Cochrane databases. The literature was analyzed using the fallow keywords: anemia, athletes, sport, physical performance, hemoglobin, exercise tolerance, oxygen delivery.

Results

Anemia, particularly iron deficiency, significantly limits athletes' physical performance, especially in endurance sports where oxygen transport is crucial. Treatment with iron supplementation improves performance, but an individualized approach considering factors like gender, age, and sport type is necessary.

Conclusion

Effective diagnosis and treatment of anemia can enhance athletic performance. Regular hematological monitoring, personalized dietary strategies, and appropriate iron supplementation are recommended. Educating athletes, coaches, and medical staff on anemia prevention is essential for optimizing training and performance.

Keywords: anemia, athletes, sport, physical performance, hemoglobin, exercise tolerance, oxygen delivery.

Introduction

Anemia is one of the most common hematological disorders worldwide, characterized by a decrease in hemoglobin concentration, which leads to reduced blood capacity to transport oxygen to tissues. Although anemia can occur in various forms, its impact on an athlete's body, particularly in the context of physical performance, remains an intensively studied issue. Physical performance, understood as the ability to sustain prolonged effort, depends on the effective delivery of oxygen to skeletal muscles, and its reduction due to anemia can lead to deterioration in sports results. Iron deficiency, being the main cause of anemia, plays a crucial role in athletes' lives. Iron is essential for hemoglobin synthesis, myoglobin function, and energy production in mitochondria [1,2].

Due to the increasing number of anemia cases among athletes, especially those engaged in endurance disciplines, understanding the impact of this disorder on physical performance is crucial for effective training planning and treatment. Anemia can lead to decreased exercise tolerance, reduced aerobic capacity, accelerated fatigue, and an increased risk of injury. It is worth emphasizing that the impact of anemia on an athlete's performance depends on many factors, such as the severity of anemia, the type of sport practiced, as well as the applied treatment and medical interventions.
The aim of this systematic review is to analyze available clinical studies on the impact of anemia on athletes' physical performance, the effectiveness of iron supplementation, and differences in response to anemia in various sports groups.

Epidemiology of anemia in sports
Anemia is a significant health problem in the athlete population, and its prevalence varies significantly depending on gender, sports discipline, and other individual factors. Studies show that anemia affects 2% to 29% of athletes, with women (23%) being much more susceptible than men (9%) [3,4]. Groups of athletes particularly at risk of anemia include those practicing long-distance running, gymnastics, cycling, and other sports that require maintaining low body weight [2,3].

Impact of anemia on physical performance
Anemia, especially resulting from iron deficiency, significantly affects athletes' ability to achieve high physical performance. This is due to mechanisms involving reduced oxygen availability for tissues and limited energy production in mitochondria. The negative effects of anemia are particularly visible in two key areas: aerobic endurance and muscle strength and power.

1. Aerobic endurance
Anemia causes a reduction in oxygen transport capacity, which is particularly important in endurance sports. VO2max values, an indicator of the body's maximum aerobic capacity, decrease proportionally to the reduction in hemoglobin levels [2,4]. Research results indicate that anemia causes a 3% to 6% decrease in VO2max in athletes with low ferritin levels (<20 µg/L) [5,6]. In the context of endurance sports, such as long-distance running or cycling, the time to complete exercise tests was 1% to 19% longer in athletes with anemia compared to their healthy peers. Low hemoglobin content reduces the ability to transport oxygen to muscles, which limits the effectiveness of oxidative mechanisms in mitochondria, resulting in poorer energy utilization by muscles [2,6].

2. Muscle strength and power
Anemia also affects muscle strength and power. Studies on athletes practicing strength sports have shown that anemia can reduce anaerobic power by up to 9%, especially in individuals with very low iron levels. Deficiency of this element impairs ATP regeneration, the main source of energy during intense physical efforts, resulting in a decrease in the muscles' ability to perform quick and intense contractions.

Anemia can reduce the muscles' ability to perform quick and intense contractions due to reduced oxygen availability. This is crucial in sports such as sprinting, weightlifting, or contact sports. Muscles with limited oxygen supply are more susceptible to fatigue, leading to a decrease in performance. This effect is particularly noticeable in disciplines requiring precise coordination, such as gymnastics or climbing.

3. Specifics for particular age groups and sports disciplines

The impact of anemia on physical performance varies depending on age and type of sports discipline. In studies conducted on youth athletes, anemia often correlated with low body weight and growth delay. In children and adolescents, the demand for iron increases due to the need to increase blood volume, hemoglobin mass, and the development of lean body mass during the growth period. For girls, an additional factor increasing this demand is the onset of menstruation. This makes them more susceptible to anemia, especially in sports requiring high endurance effort [2,3].

Anemia has a more noticeable impact on disciplines requiring prolonged aerobic effort. The greatest impact was observed in endurance disciplines, such as long-distance running, swimming, or cycling, where oxygen demand is highest [5,6]. In strength sports, the effects of anemia are less pronounced, although still noticeable in the form of reduced muscle strength and endurance [2].

Role of iron supplementation

1. Effectiveness of supplementation

Iron supplementation plays a crucial role in improving physical performance in athletes. The improvement in aerobic capacity results from increased oxygen transport capacity by hemoglobin and the efficiency of oxidative processes occurring in mitochondria [1,2].

The introduction of supplementation in athletes with anemia related to iron deficiency, especially in cases of ferritin deficiency (<30 μg/L), showed a significant improvement in performance parameters, such as VO2max, which increased by 6% to 15% after using doses of 100 mg daily for a period of 6-8 weeks [5].

Studies suggest that iron supplementation may also benefit athletes with low ferritin levels but without anemia. In these individuals, an improvement in time trial results, such as a 5 km run, was observed in the range of 2% to 20% [2,5].

Supplementation is particularly effective in endurance sports, such as long-distance running, swimming, or cycling. During periods of intense training, when iron demand is highest, adequate supplementation of its deficiencies can significantly improve performance and delay the onset of fatigue [2,4].

Moreover, iron supplementation can affect athletes' well-being, reducing the feeling of chronic fatigue and improving regenerative abilities, which is crucial in maintaining training intensity [2,4].

2. Side effects and limitations

Despite many benefits, iron supplementation may be associated with certain limitations and side effects. The most common complaints are gastrointestinal symptoms, such as nausea, bloating, constipation, or diarrhea, which may discourage athletes from continuing supplementation [2,3,5].

An alternative to oral supplementation is intravenous iron administration, which allows for faster results. However, this method requires strict medical supervision [6].

Increased levels of hepcidin, a hormone regulating iron metabolism, after intense physical effort can block iron absorption from the gastrointestinal tract, which reduces the effectiveness of supplementation, especially if supplementation occurs at an inappropriate time [1,2].

Advances in the development of drugs lowering hepcidin expression or neutralizing its action may contribute to the development of effective therapies for treating anemia in athletes in the future. These therapies may include antibodies against hepcidin, BMP modulators, as well as drugs acting on regulatory pathways of erythropoiesis and inflammation [1].

Long-term use of iron supplements, especially without regular monitoring of its levels, can lead to an excess of this element in the body. This condition is toxic and can cause liver damage and metabolic disorders [2].

3. Recommendations for athletes

To maximize the benefits of iron supplementation, it is recommended to regularly monitor ferritin and hemoglobin levels in high-risk athletes, such as those practicing endurance sports. For athletes experiencing absorption problems, it is advisable to combine supplementation with a diet rich in heme iron (meat, poultry), non-heme iron (legumes, green vegetables), and vitamin C, which supports its absorption [2,3,6].

It is recommended to take iron supplements on an empty stomach to increase their absorption, taking into account the temporary effect of hepcidin after exercise [2].

Differences between groups of athletes

1. Endurance disciplines

Athletes practicing endurance disciplines, such as long-distance running or cycling, are particularly susceptible to iron deficiencies and related effects of anemia. Iron loss can result from many factors, including exercise-induced hemolysis, gastrointestinal microbleeding caused by intense physical effort, and iron losses through sweat [3,4,6].

Intense and prolonged effort leads to an increase in hepcidin levels, which reduces iron absorption from the gastrointestinal tract. This phenomenon is particularly problematic during periods of intense training when iron demand is especially high [1,2].

Studies have shown that iron supplementation in this group of athletes brings the most noticeable benefits, improving performance indicators such as VO2max, and delaying the onset of fatigue [2,5].

2. Strength disciplines

Athletes in strength disciplines, such as weightlifting, bodybuilding, or wrestling, less frequently experience iron deficiencies because their training generates less endurance load, and iron losses through hemolysis or sweat are less significant [2,4].

Anemia causes a reduction in anaerobic capacity and maximum strength, which makes it difficult to achieve optimal results. Iron deficiencies in this group can also slow down muscle regeneration after intense training sessions, which translates into longer breaks between training units [6].

Greater muscle mass may increase the demand for iron for myoglobin synthesis, a protein responsible for storing oxygen in muscles. However, the risk of iron deficiencies remains lower than in endurance athletes [2].

Iron supplementation in this group is less common but may be recommended in cases of intense strength training, combined with limited iron intake in the diet [2].

3. Team sports

In team sports, such as football or basketball, anemia can significantly affect both physical and mental performance. Studies indicate that reduced levels of hemoglobin and ferritin translate into poorer concentration, extended reaction time, and increased feeling of fatigue during competition [3,4,7].

In these disciplines, the risk of iron deficiency may increase in the case of intense endurance training or combination with strength training [2,3].

Conclusions

Anemia, especially resulting from iron deficiency, is a significant factor limiting the physical performance of athletes in various disciplines. Its impact on aerobic parameters, strength, and regenerative processes is particularly noticeable in endurance sports, where oxygen demand is higher, and the efficiency of its transport is crucial.

Studies have shown that iron deficiency in athletes is associated with reduced muscle ability to utilize oxygen. Low ferritin levels worsen aerobic capacity, even in the absence of full anemia, which indicates the importance of monitoring iron levels in athletes.

Treatment of iron deficiency improves performance, especially in endurance athletes. However, an individual approach to diagnosis and treatment is necessary, taking into account gender, age, type of sport practiced, and lifestyle.

Taking action to diagnose and treat anemia can significantly improve sports results and training quality. Therefore, it is recommended to:

1. Conduct regular hematological tests, including monitoring ferritin and hemoglobin levels, for high-risk athletes.
2. Personalize dietary interventions, taking into account sources of heme iron, non-heme iron, and vitamin C.
3. Consider iron supplementation, tailored to individual needs, including oral or intravenous forms, depending on the degree of deficiency and health condition.
4. Educate coaches, athletes, and medical personnel in the field of anemia prevention.

In conclusion, anemia is a health problem that requires a comprehensive approach, including both diagnosis and appropriate treatment. Effective intervention in terms of supplementation and diet can improve sports results and overall training quality for athletes.

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