EFFECTS OF PHYSICAL EXERCISE ON BLOOD RHEOLOGY

https://doi.org/10.56238/sevened2025.001-020

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ABSTRACT
Several cellular processes and interactions are mediated across membranes. For optimal functioning, cell membranes must have stability and functionality, properties that depend on their degree of fluidity. Both extreme and insufficient fluidity are undesirable characteristics that affect cell physiology and can contribute to the loss of stability and consequent acceleration of membrane destruction, leading to cell destruction. Erythrocytes are a good model for studying the stability of biological membranes for their convenience, as it is easy to monitor their lysis. The environment in which erythrocytes are found in the blood is a decisive factor in determining the composition and fluidity of the cell membrane. This environment can be altered by diet, exercise, and various diseases. Hemorology is understood as the study of the flow and components of blood in the micro and macrocirculation. Regular physical exercise promotes hemorheological adaptations in the blood, such as changes in the aggregation, deformability, and fluidity of erythrocytes, in order to improve efficiency in the collection, transport, and delivery of oxygen to tissues. Studying physical exercise in relation to hemorheology is important to determine the ability of cells to transport and transfer oxygen to tissues. Understanding the effects of physical exercise on hemorheology should encompass distinct analyses of acute and chronic alterations.

Keywords: Physical exercise. Cells. Osmotic stability. Hemorology.

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INTRODUCTION

Erythrocytes are a good model for studying the stability of biological membranes for their convenience, as it is easy to monitor their lysis. In addition, properties such as changes in the composition and behavior of their membranes can be reflected in cells in the body (De Freitas et al., 2008; Lemos et al., 2011). The environment in which erythrocytes are found in the blood is a decisive factor in determining the composition and fluidity of the cell membrane. This environment can be altered by diet, exercise, and various diseases (De Freitas et al., 2010; De Arvelos et al., 2013).

Hemorheology is understood as the study of the flow and components of blood in the micro- and macrocirculation. This branch of research also investigates the physiological or pathological factors and situations that influence blood flow (Brun et al, 2007; Copley, 1990). Among these factors are the elements that make up blood, deformability and the physical properties of blood and erythrocytes, such as viscosity, rigidity and stability. There is a growing body of clinical and experimental data clearly indicating that blood flow behavior is the determining factor for adequate tissue perfusion (Baskurt ; Meiselman, 2003).

Regular physical exercise promotes hemorrheological adaptations in the blood, such as changes in the aggregation, deformability, and fluidity of erythrocytes, in order to improve efficiency in the collection, transport, and delivery of oxygen to tissues (Brun 2002; Brun et al 1998).

Studying physical exercise in relation to hemorheology is important to determine the ability of cells to transport and transfer O2 to tissues. Understanding the effects of physical exercise on hemorheology should encompass distinct analyses of acute and chronic alterations. Physical activity promotes improvements in physical and mental health, these changes are related to the volume, intensity, type, duration of exercise, and level of physical fitness of the individual (Connes et al, 2004; Yalcin et al., 2003; De Souza Junior et al., 2025).

This study aims to carry out a narrative review on acute and chronic hemorheological changes caused by physical exercise.

MATERIALS AND METHODS

This study was based on a review of the LILACS / BVS, MEDLINE / PUBMED, EMBASE, ScienceDirect, and Scopus databases. The keywords used were "hemorheology" and its English counterparts, "hemorheology". The exclusion criteria were: articles published before 1980 and those referring to diseases, 2142 articles were found.

After reading the titles of the articles, it was noted that some of them were repeated and others did not meet the criteria of this study. A total of 100 articles were selected for reading the abstract, and those that did not relate to the purpose of this study were excluded. After reading the abstracts, 32 articles were selected that met the criteria initially proposed and were read in full.

RESULTS AND DISCUSSION

ACUTE HEMORRHEOLOGICAL CHANGES DUE TO EXERCISE

The main alterations of acute exercise in hemorheology are increased stiffness, increased viscosity and decreased deformability of erythrocytes (Wood et al 1991). These alterations are related to changes in body fluids, due to the increase in the concentration of circulating cells and the production of metabolites (Yalcin et al., 2003).

The main factors responsible for the change of fluids in the body as a result of physical exercise are: redistribution of red cells in the vascular bed; contraction of the spleen to increase the release of circulating red blood cells (Convertino et al 1988), increased concentration of proteins in plasma; water loss via sweat and breathing for thermoregulation; water entry into muscle cells (Stephenson; Kolka, 1988).

These physiological modifications occur to meet the high oxygen demand by the muscles and to regulate homeostasis at the time of exercise. The reflexes of these changes in the blood are increased viscosity and lower flow resistance. Notably in red blood cells, changes in membrane properties, an increase in rigidity and decrease in deformability and cell volume are observed (Wardyn et al, 2008).

Both maximal and submaximal acute exercise increase blood viscosity, this change is dependent on: plasma viscosity, hematocrit, and structural parameters associated with cell aggregation and rigidity. The increase in plasma viscosity is related to the changes involved with the alteration of body fluids and the concentration of proteins in the plasma (Mairbaurl et al 2013).

Some associations are clear, as the increase in hematocrit is proportional to the increase in the ability to carry oxygen. However, with the increase in hematocrit, there is also an increase in viscosity and resistance of blood flow, which decreases the delivery of oxygen to the tissues. This complex relationship means that there must be an ideal hematocrit value in which the oxygen delivery capacity to the tissues is the maximum possible (Baskurt, O. K., Meiselman, 2003).

Although the hematocrit value increases during exercise, the restoration of its value is rapid and often the increase is not evidenced after exercise. An uncommon rheological alteration to be observed is the increase in the aggregation of erythrocytes. This increase is associated with an increase in the concentration of proteins in plasma, such as albumin and fibrinogen. The presence of aggregates can impair the normal distribution of red blood cells and flow dynamics in the microcirculation, leading to inadequate oxygen transfer to tissues (Vandewalle et al., 1988).

Other studies have concluded that in vitro lactate increases the deformability of red blood cells in trained subjects and decreases it in untrained subjects. This result suggests that well-trained individuals, such as endurance athletes (long-duration aerobic exercise), have red blood cells that are more resistant to the action of lactate, showing that erythrocytes are influenced by lactate according to the level of physical fitness (Connes et al 2004).

Oxidative stress is another factor that impairs the deformability of erythrocytes. Stress is induced by the increase in the production of free radicals during exercise. The deformability of red blood cells after a 5 km run. A reduction in deformability was found associated with changes in cell shape, with an increase in the number of echinoid cells and a high rate of hemolysis. Along with these alterations, an increase in the concentration of malondialdehyde within the red cells was observed, as a result of lipoperoxidation, since that metabolite is the product of the peroxidation of polyunsaturated fatty acids (Yang et al., 1995).

Another factor that alters deformability during exercise is the amount of water inside the red blood cell. About 62% of the cell content is water. Most of this molecule is "bound" to other molecules in the cell and to a lesser extent (25%) "free" within the erythrocyte. The percentage of "bound" water molecules is associated with deformability and oxygen transport. During acute exercise, the total amount of water does not change in the erythrocyte or decreases slightly, but the percentage of "free" water increases leading to a smaller amount of "bound" water, with the effect of decreasing deformability (Baskurt et al., 2007).

Regarding all the acute hemorheological alterations reported, the alteration in deformability is the most important factor to be evaluated, because variations in this cell property result in modifications in the blood flow in the capillaries. In addition, lower deformability may limit blood perfusion (Yalcin et al., 2003).

Together, these results indicate that physical exercise acutely promotes an increase in blood viscosity. This behavior is a result of the combined effects of increased plasma viscosity and decreased red cell deformability. These changes can impair microcirculation and therefore the release of oxygen to working muscles (Connes et al 2013).

It is important to highlight that the reported hemorrheological changes are adaptive physiological modifications that occur during the performance of most exercises and do not imply greater risks for the individual. Presumably, such changes are easily controlled with hydration during training (El-Sayed et al., 2005).

Recent studies have shown the importance of the erythrocyte in releasing nitric oxide (NO) together with the vascular endothelium contributes to vasodilation and greater deformability of erythrocytes during exercise, since the nitrosylation of cytoskeletal proteins in the erythrocyte membrane seems to improve its deformability (Grau et al., 2013).

CHRONIC HEMORHEOLOGICAL CHANGES DUE TO EXERCISE

It is interesting to note that rheological properties are altered as a result of chronic exercise. There is a correlation between increased aerobic capacity and blood viscosity. Thus, plasma viscosity, hematocrit, aggregation and stiffness of erythrocytes are lower in athletes when compared to sedentary individuals (El-Sayed, 2005).

There are several adaptations provided by exercise that lead to improvement in hemorology. The main ones are: increased plasma and blood volume; modification in the properties of erythrocytes; increased cell turnover rate; change in body composition; greater oxidation of fats. After hours of physical exercise, there is an increase in plasma volume, which represents a reverse response of hyperviscosity, resulting in an "auto-hemodilution". The increase in plasma volume is accompanied by a decrease in hematocrit and plasma proteins. With the regular practice of physical exercise, this process becomes constant and the blood of active individuals and athletes becomes more diluted when compared to sedentary people (Brun et al., 2007).

The first positive adaptation is increased deformability. The improvement in this property is related to the increase in plasma volume, the increase in the percentage of water within the erythrocyte, the increase in the cell renewal rate, and the decrease in the rigidity of the erythrocyte membrane (Connes et al., 2013).

In addition to the increase in the percentage of total water within the erythrocyte, there is an increase in the percentage of "on" water and a decrease in the percentage of free water. This modification contributes immensely to an improvement in the deformability of erythrocytes (Peyreigne, 1998). A hematological adaptation promoted by exercise is the increase in cell renewal that contributes to the improvement of the hemorrheological properties of the blood. Exercise is an important effective factor in the stimulation of erythropoies (Schmidt et al., 1988).

The mechanisms used to repair these damages, which are responsible for the stimulation of erythropoiesis, such as: hypoxia; hormonal action; higher rate of hemolysis; greater oxygen demand for active tissues. Exposure to hypoxia situations occurring during exercise is a stimulus for erythrocyte production. The hormonal action of cortisol and catecholamines releases reticulocytes from the bone marrow and possibly stimulates erythropoiesis which is also stimulated by growth hormone and insulin-like growth factors that are elevated during exercise (Mairbaurl, 2013).

The higher speed of cell renewal due to the regular practice of physical exercise is closely related to the higher rate of intracellular hemolysis (Deitrick, 1991). During physical exercise, there is an intensification of hemolysis and the related mechanisms change according to the type of activity performed. In the case of exercises that involve impact with the ground, there is traumatic destruction of circulating erythrocytes in the microvessels of the foot region due to impact with the ground.

In addition to traumatic mechanical damage, an increase in hemolysis is also evidenced in exercise that has no impact (Robinson et al., 2006). In this case, hemolysis can happen due to compression of erythrocytes in the microcirculation during the rapid contraction of large muscles. The age of the erythrocytes is another factor involved in hemolysis. The older the cell, the less resistant it becomes to trauma and, consequently, the greater the chance of being lysed (Bartosz, 1991; Waugh et al 1992).

Allied to the higher rate of hemolysis that occurs during exercise is the body's greater need for oxygen. To meet this demand, more efficient cells must be recruited (Smith, 1995; Szygula, 1990). Young erythrocytes have different rheological properties than old ones. They are more deformable, more fluid, and less aggregatable, thus being more efficient at transporting oxygen (Mairbaurl, 2013).

Circulating erythrocytes are less rigid in response to chronic physical exercise. This change is a reflection of the decrease in weight and LDL cholesterol and the increase in HDL cholesterol (El-Sayed, 2005). The changes in circulating lipids are reflected in the change in the lipid composition of the membranes, which helps to increase their fluidity. Regular exercise alters the metabolism of lipids, there is a higher rate of oxidation of these molecules, reducing the levels of triglycerides and LDL cholesterol in the circulation. Weight loss also occurs, which contributes to the breakdown and increased deformability of erythrocytes (Brun et al, 2011).

CONCLUSION

The training contributes to the decrease in the concentration of all parameters known to alter the rheology of the blood. All rheological adaptations in response to regular training are to facilitate O2 transfer and tissue oxygenation, which results in improved performance.

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