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Physiological Changes in the Body of Adolescent Students Who Started Swimming Lessons

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Abstract

The state of erythrocytes fully reflects the level of functional capabilities of the body and can be considered a reliable marker of its general condition. The study was carried out on 32 healthy young men who had low stable physical activity for a long time and started swimming training in the pool 3 times during the week. The control group consisted of 38 healthy young men who, over the past 5 years, regularly went in for swimming 3 times a week. Standard hematological and statistical methods for performing scientific research were applied. After six months of swimming training in the blood of beginner swimmers, a normalization of the number of metabolites of arachidonic acid, a reduction in the composition of erythrocytes of cholesterol molecules and lipid peroxidation products, and an increase in the content of phospholipids in them was noted. In the blood of beginner swimmers, there was an increase in the number of erythrocytes with a normal shape, and a significant decrease in the number of erythrocytes with a changed shape was achieved. For the boys of the control group, who had been swimming for a long time, it turned out to be characterized by a high content of unchanged erythrocytes in the blood and the optimum of their biochemical parameters. It can be assumed that regular swimming lessons already after six months provide significant positive dynamics of the surface properties of erythrocytes in the blood, which significantly improves the implementation of microcirculation and intensifies metabolism throughout the body.

Keywords: Adolescence, Sports, Swimming, Exercise, Erythrocytes, Erythrocyte membrane

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Introduction

In modern society, weak muscle activity is becoming more and more common in all categories of the population (Filippov & Petrov, 2015; Bespalov *et al.*, 2018). This contributes to a significant health weakness (Drapkina & Shepel, 2015; Kotova *et al.*, 2017). This pattern has long been noticed in all age groups and a relationship was found between poor physical fitness and the risk of developing various dysfunctions (Skoryatina & Zavalishina, 2017; Zavalishina, 2018a). In the case of detraining, even at a young age, the functional activity of all internal organs weakens, the foundation for the appearance of various diseases is created, and the overall resistance of the body decreases (Zavalishina, 2018b; 2018c). Stably low muscle activity also contributes to the accelerated progression of any existing pathology and the rapid appearance of any of its complications (Tkacheva & Zavalishina, 2018a; Zavalishina, 2018d).

Consistently low daily physical activity quickly leads to a violation of the main hematological parameters (Carrizzo *et al.*, 2013). Under these conditions, there is a violation of several biochemical parameters of plasma and a weakening of the functions of blood cells (Zavalishina, 2018e; 2018f). Even at a young age, poor physical fitness is accompanied by a deterioration in the microrheological characteristics of the blood, leading to the appearance of hypoxia in the internal organs (Zavalishina, 2018g). The resulting apparent oxygen deficiency weakens biosynthetic processes in all tissues of the body (Zavalishina, 2018h; Belousova *et al.*, 2021). A situation is created that leads to the appearance of a widespread spasm of arterioles, which further weakens the blood supply to the body (Tkacheva & Zavalishina, 2018b).

In the case of long-term preservation of weak muscle activity in the body, conditions are formed for an excessive increase in blood pressure with the risk of developing arterial hypertension (Tkacheva & Zavalishina, 2018c; Zavalishina, 2018i). In addition, with weak physical activity, as a rule, the properties of the most numerous cell population, erythrocytes, are violated. If this situation is created, even at a young age, the risk of somatic pathology becomes especially high (Vorobyeva *et al.*, 2018; Zavalishina, 2018j). Due to the high danger to the body from prolonged low muscle activity, it is necessary to continue the search for effective approaches to get out of the state of physical inactivity with simultaneous optimization of hematological characteristics, especially in physically untrained young men. The purpose of the study is to establish changes in the surface characteristics of the erythrocyte membrane in physically untrained young men who have begun systematic swimming lessons.

Materials and Methods

A study group was taken under observation, which included 32 young men, with an average age of 20.7±0.5 years. All observed during the life did not experience regular significant muscle loads. After enrollment in the study, they voluntarily began regular swimming training 3 times a week. The duration of one swimming session was not shorter than 40 minutes. The control group included 38 clinically healthy young men with an average age of 19.7±0.9 years. The control group regularly visited the pool at least three times a week over the past three years. The duration of each swimming session was at least 40 minutes for one visit to the pool.

In the course of the study, by enzyme immunoassay using a kit released by Enzo Lifescience (USA), the level of thromboxane B_2 in blood plasma and the amount of 6-keto-prostaglandin F1α in it were evaluated. In the membrane structures of erythrocytes after the standard washing procedure and standard resuspension of erythrocytes, the amount of cholesterol contained in erythrocytes was determined using a set of reagents manufactured by Vital Diagnosticum (Russia). In washed and resuspended erythrocytes, the amount of phosphorus was determined, which made it possible to determine the total amount of phospholipids present in their membranes (Kolb & Kamyshnikov, 1982). The level of lipid peroxidation in erythrocytes was monitored after they were washed and resuspended in saline. For this purpose, the level of malondialdehyde and the number of acyl hydroperoxides in their suspension were recorded using traditional methods (Volchegorskiy *et al*., 2000).

In the blood of the observed young men, the number of erythrocytes with a discoid shape and the number of erythrocytes with any variant of an altered shape were evaluated. This was done using standard light-phase contrast microscopy.

The entire study group was examined three times: when taken under observation, after three months, and after six months of systematic swimming lessons. The control group was examined once at the start of the study. Mathematical processing of the digital results of the study was carried out by calculating the Student's t-test.

Results and Discussion

In the blood of physically untrained young men, the levels of arachidonic acid metabolites were found to be significantly different from the control values. The content of thromboxane B_2 in their blood exceeded the concentration in the control by 30.0% ($p<0.01$), while the amount of 6-keto-prostaglandin $F_{1\alpha}$ was 17.1% lower than the control level ($p<0.05$) **(Table 1)**.

Initially, in the composition of erythrocyte membranes in individuals included in the study group, the cholesterol content was higher than in the control by 19.5%, and the level of total phospholipids in them was inferior to the control level by 11.9% ($p<0.05$). In physically inactive young men, the initial levels of acyl hydroperoxides and malondialdehyde were higher than the control values by 45.0% and 43.5%, respectively.

Table 1. Dynamics of indicators during the study

Hematological indicators	Swimming loads, n=32, M±m			Control group, n=38, M±m
	start of classes	3 months of classes	6 months of classes	
The content of total phospholipids in erythrocytes, μmol/10^{12} erythrocytes	0.67±0.012 p<0.05	0.70±0.016 p<0.05	0.75±0.005 p1<0.05	0.75±0.014
Cholesterol content in erythrocytes, μmol/10^{12} erythrocytes	1.04±0.016 p<0.05	0.95±0.017 p<0.05	0.87±0.006 p1<0.05	0.86±0.012
6-keto-prostaglandin $F_{1\alpha}$ in blood plasma, pg/ml	84.7±0.49 p<0.05	91.6±0.38 p<0.05	98.3±0.41 p1<0.05	99.2±0.26
Thromboxane B_2 in blood plasma, pg/ml	182.8±0.47 p<0.01	169.3±0.54 p<0.05	142.1±0.42 p1<0.01	140.6±0.41
Malondialdehyde in erythrocytes, nmol/10^{12} erythrocytes	1.88±0.009 p<0.01	1.53±0.014 p<0.05	1.33±0.011 p1<0.01	1.31±0.027
The content of acyl hydroperoxides in erythrocytes, D_{233}/10^{12} erythrocytes	4.06±0.014 p<0.01	3.47±0.010 p<0.01	2.87±0.018 p1<0.01	2.80±0.012
The number of irreversibly changed red blood cells, %	9.0±0.14 p<0.01	4.6±0.09 p<0.01 p1<0.05	1.1±0.11 p1<0.01	1.0±0.08

The number of reversibly changed erythrocytes, %	13.9±0.16 p<0.01	12.4±0.16 p<0.01 p1<0.05	9.4±0.08 p1<0.01	9.2±0.15
The number of discoid erythrocytes, %	77.1±0.37 p<0.05	83.0±0.31 p<0.05	89.5±0.30 p1<0.05	89.8±0.24

Note: the p-reliability of differences between the study group and the control group: p_1 - reliability of changes in indicators in representatives of the study group during the observation process.

At the very beginning of the observation, in the boys of the study group, the content of erythrocytes with the optimal form in the blood turned out to be less than in the control by 16.4% ($p<0.05$) **(Table 1)**. At the same time, the level of erythrocytes in their blood, which had a disturbing shape to varying degrees, was higher than the level in the control by 51.1% for reversible disorders and by 9.0 times for irreversible disorders ($p<0.01$).

In the case of regular swimming lessons in the blood of beginner athletes, the imbalance in the levels of arachidonic acid metabolites was noted. By the end of the observation in the blood of the swimmers of the study group, it was possible to note a decrease in the content of thromboxane B_2 by 28.6% ($p<0.01$). This was accompanied by an increase in the amount of 6-keto-prostaglandin $F_{1\alpha}$ in their blood by 16.0% ($p<0.05$).

After six months of systematic swimming training in the composition of erythrocyte membranes in young athletes, a decrease in the amount of cholesterol by 19.5% and an increase in the total level of phospholipids in their membranes by 11.9% ($p<0.05$) were noted. At the same time, in the study group, by the end of our observation, a decrease in the levels of lipid peroxidation products was noted in erythrocytes: acyl hydroperoxides by 41.5% and malonic dialdehyde by 41.3%.

As a result of systematic swimming training in the blood of persons included in the study group, there was an increase of 16.1% in the content of erythrocytes-discocytes **(Table 1)**. By the end of the observation, this was accompanied by a decrease in the content in their blood of erythrocytes with a reversibly changed shape by 47.8% and erythrocytes with an irreversibly changed shape by 8.2 times.

In developed countries, the use of muscle effort in the process of labor activity is in little demand, and diseases associated with physical inactivity are already quite common (Zavalishina, 2020a). At the same time, modern science recognizes that low physical activity leads to the formation of several dysfunctions and the risk of any pathology (Karpov *et al*., 2020). It becomes clear that maintaining the physical health of the body throughout its life is impossible without regular physical activity (Zavalishina, 2018k). They are necessary for the long-term maintenance of the main morphofunctional indicators of the body at a high level.

It is recognized that long-term maintenance of a low level of muscle loads leads to the appearance of violations of the main blood parameters and especially the microrheological properties of erythrocytes. Activation of lipid peroxidation in the structures of erythrocyte membranes contributes to their negative rearrangements and a significant weakening of their functions (Zavalishina, 2020b). This situation is exacerbated by the formation of changes in the lipid composition of erythrocyte membranes under conditions of hypodynamia, which impairs their functioning and inhibits the passage of erythrocytes through small-caliber vessels (Zavalishina, 2018l). In this regard, the discovered violations of the level of phospholipids and the level of cholesterol in erythrocyte membranes can be considered very negative biologically (Karpov *et al*., 2021). The current situation worsens the state of the lipid bilayer of erythrocyte membranes and reduces the functionality of erythrocyte membrane proteins due to the upcoming violations of their secondary and tertiary structure. These changes can have an extremely negative effect on the permeability of the outer membrane of erythrocytes, affecting the transport of ions and plastic substances through it (Zavalishina *et al*., 2021a).

An increase in the number of erythrocytes in the blood with structural changes that have arisen reversibly or irreversibly leads to an increase in the process of their aggregation in the blood and inhibition of microcirculation in all microvessels.

There is information indicating that with weak physical activity in the vessels, the synthesis of regulatory molecules that are significant for the rheology of blood cells is weakened. This situation, as a rule, is accompanied by an increase in the blood of substances that have a proaggregant effect (Vorobyeva *et al*., 2020). The study carried out confirmed this point of view. So initially in the blood of the examined young men, there was a high level of the metabolite of thromboxane and a reduced content of the metabolite of its antagonist - prostacyclin. This formed a clear imbalance between the production of arachidonic acid in the blood plasma (Makurina *et al*., 2020). This situation significantly aggravated the disturbances in the rheological properties of a significant part of erythrocytes that formed under these conditions, inhibiting the movement of blood through the vessels and weakening metabolism throughout the body (Zavalishina *et al*., 2021b).

To comprehensively improve the body of physically untrained young men who had weak muscle activity for a long time, the authors strongly recommended that they go swimming three times a week. In the course of swimming lessons in the erythrocytes of these young men, there was a decrease in the content of products of the process of peroxidation of lipid molecules (Fayzullina *et al*., 2020). This was accompanied by the normalization of the lipid composition of erythrocyte membranes. This was indicated by the normalization of the number of phospholipid and cholesterol molecules in the erythrocyte membranes achieved in young swimmers. The achieved changes created conditions for optimizing the morphofunctional status of erythrocytes (Zavalishina *et al*., 2021a). An important mechanism of the achieved effect may be the development of normalization of the degree of permeability of erythrocyte membranes and the maintenance of the optimum of the protein cytoskeleton of erythrocytes (Zavalishina 2021c; Zavalishina *et al*., 2022).

With systematic training in the blood of young swimmers, an increase in the number of erythrocytes with a normal discoid shape occurred. Apparently, in the young men who increased their muscle activity, through regular swimming, the content of erythrocytes in their blood decreased steadily. This created conditions for the weakening of the phenomena of erythrocyte aggregation in their blood, which additionally increased the blood supply to all internal organs and increased physical capabilities (Mikhaylova *et al*., 2021).

Conclusion

In the case of weak muscle activity in the blood, the level of erythrocytes that have a changed shape increases. At any age, this can significantly reduce the efficiency of tissue hemocirculation. In young men who had initially low physical activity and who started regular swimming training, a significant weakening of lipid peroxidation occurred in the structures of erythrocytes and their lipid composition improved. In the course of swimming lessons in the blood of beginner young swimmers, the content of unchanged erythrocytes and their altered varieties returned to normal. Achieved under conditions of regular swimming loads, the normalization of hematological characteristics taken into account contributed to a significant general strengthening of the body of physically untrained young men.

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