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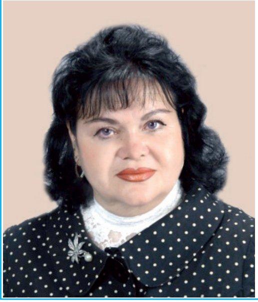
Content

AGE CHANGES OF BLOOD MICROCIRCULATION IN STUDENTS AND SPORTSMEN UNDER THE INFLUENCE OF PHYSICAL TRAINING



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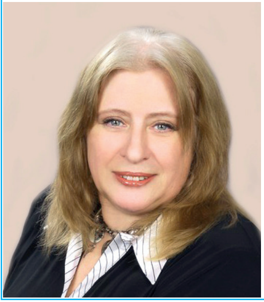

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Age specific features of blood microcirculation reactivity in students and athletes (freestyle wrestling at the level of candidates for a master of sports) are studied for 18 to 21 years under the influence of a dosed physical training. Significant differences in the values of the most parameters characterizing the microcirculation of blood at rest were observed between the 4 age groups under examination, both in students and athletes with different levels of the microcirculation index, and it was shown that the contribution of active modulations of the blood flow to the formation of its profile is more important. Regular exercise changes the age dependence of the level of muscle tissue perfusion, as well as the amplitude of blood flow fluctuations in tissues. Essential differences in the effect of physical training on the effectiveness of microcirculation in students and athletes have been established, depending on the value of the microcirculation index. The results indicate the need to take into account the hierarchy of regulatory mechanisms in the selection of the intensity of physical training, as well as the possibility of a targeted effect on respiratory-pulse modulation in the microvasculature and, consequently, on their ratio, by means of dosed physical training.

Key words: *microcirculation, dosed physical training, laser Doppler flowmetry, students, sportsmen.*

Вивчено вікові особливості реактивності мікроциркуляції крові у студентів і спортсменів (вільна боротьба на рівні кандидатів у майстри спорту) 18-21 року під впливом дозованого фізичного навантаження. Виявлено суттєві відмінності у величинах більшості параметрів, що характеризують мікроциркуляцію крові в стані спокою, між обстежуваними чотирма віковими групами як у студентів, так і у спортсменів з різними рівнями показника мікроциркуляції, і показано, що внесок активних модуляцій кровотоку в формування її профілю є більш істотним. Регулярні заняття спортом змінюють вікову залежність рівня перфузії м'язової тканини, а також амплітуду коливань кровотоку в тканинах. Встановлено суттєві відмінності впливу фізичного навантаження на ефективність мікроциркуляції у студентів і спортсменів у залежності від величини показника мікроциркуляції.

Отримані результати вказують на необхідність врахування ієрархії регуляторних механізмів при підборі інтенсивності фізичних навантажень, а також на можливість цілеспрямованого впливу на респіраторно-пульсові модуляції в мікроциркуляторному руслі і, отже, на їх співвідношення, за допомогою дозованих фізичних тренувань.

Ключові слова: *мікроциркуляція, дозоване фізичне навантаження, лазерна допплерівська флоуметрія.*

Introduction.

The change in the functions of the cardiovascular system under the influence of muscular activity attracts the attention of physiologists, physicians and specialists in the field of physical culture and sports. Sport penetrates into the life of the world's population and especially the young people deeper. Often sports are considered by researchers as a stress factor. The urgency of the problem of the effect of physical exercises on the human body increases. The elucidation of the physiological patterns of this effect becomes an important scientific task (Barabanov, 2004; Bykov, 2005).

The modern scientific direction was formed as a division of physiology, which studies the active state of the organism, as well as the problems of medical control in physical exercises and sports (Ivanova, 2011; Ryvkin, Andrianova, Pobedinskaya, 2005; Bollinger, Yanar, Hoffmann, Franzeek, 1993). The study of the physically active organism allowed to distinguish the features of physiological and pathological shifts in the work of the circulatory system in the trained persons in comparison with the untrained (Gurov, Ryzhakin, 2015; Novikov, 1992; Pautkin, Samsonov, Antonyuk, 2007).

Modern literary data show that the work of the circulatory system in sports is different from healthy people who do not go in for sports systematically. These differences can be detected both at rest and during physical exertion. The microcirculation channel department remains the most difficult for research. The possibility of testing microcirculation has expanded over the past 10 years due to laser Doppler flowmetry (LDF) (Karpman, Belotserkovsky, Lubina, 1994; Kozlov, Morskov, Kishko, 1995; Stolyarov, 2013; Kramer, Dijkstra, Bast, 1993). A large list of not yet clarified mechanisms of microcirculation and regulation of microcirculatory blood flow requires further study. The circulatory features of people of different ages under the influence of physical exertion against the background of varying degrees of fitness of the organism are not studied (Ivanova, 2011; Ismaru, 1981; Kozlov, Mach, Sidorov, 2000; Makolin, 1999).

The purpose of this study was to study the age-related differences in the reactivity of microcirculation in students and athletes aged 18-21 under the influence of physical activity.

Materials and methods of research.

To achieve the goal, 260 male students aged 18-21 were examined. 130 of them were engaged in freestyle wrestling at the level of candidates for master of sports. Participants of this group will be called «athletes» in our text in the future. Another group of 130 people were students who did not go in for sports systematically. The participants of this group will be called «students» here in our work. In each of these groups, subgroups according to age were identified (Table 1).

All students and athletes were examined in a state of relative physiological dormancy and after dosed physical exertion (hereinafter «load»).

Table 1

Distribution by groups of surveyed students and athletes depending on age

Age	athletes surveyed number	students surveyed number
18 years	35	40
19 years	30	35
20 years	30	30
21 years	35	30

Indices of microcirculation were evaluated with the help of LDF. The basis for the method is the non-invasive sounding of tissues by a monosromatic signal and the subsequent analysis of the frequency spectrum of the reflected signal. The researchers used the device LAKK-01 (NPP, Lazma, Russia). The sensor of the device consists of three microfibers. One of them is used to deliver a laser beam to the tissue under investigation. The other two fibers take the light reflected from the tissues. The depth of the muscle tissue studied depended on the wavelength of the laser source and did not use 1 mm (red radiation – λ = 632 nm) (Sidoryak, 2016). This method allows you to record periodic fluctuations in tissue perfusion (Sidorov, Chemeris, Krasikov, 2001; Shahanova, Koblev, Grechishkina, 2010).

The LDF signal was recorded on the ventral surface 4 of the finger of the left hand of the subject at rest in the prone position so that the area measured was at the level of the heart. The duration of the LDF-gram recording was 2 minutes. Analysis of LDF-grams was performed in accordance with the Instruction manual (Kozlov, Morskov, Kishko, 1995; Lukyanova, Antipkin, Chernyshov, Vykhovanets, 2002).

The following data were determined for the analysis.

1) Characteristics of tissue flow – the microcirculation parameter (PM), which is a function of the concentration of erythrocytes in the investigated tissue volume (Ner) and their average velocity. The value of PM

is the level of perfusion of a unit volume of tissue per unit time and is measured in relative units (perfusion units – pf.):

$$(V_{av}): PM = N_{er} \times V_{av};$$

2) "σ" is the mean square deviation (MSD) of the amplitude of the blood flow oscillations from the arithmetic mean value – is also measured in pF. units and characterizes the temporal variability of microcirculation or fluctuations in the flow of erythrocytes, referred to in microvascular semantics as a fluke;

3) "Kv" is the coefficient of variation (Kv = δ / M × 100%), which indicates the relationship between variability of perfusion (flax) and average perfusion in the probed tissue site (Kozlov, Morskov, Kishko, 1995; Kolchinskaya, 1990).

All subjects were further divided into two subgroups according to the results of the determination of the main indicator. Thus, in persons of the first subgroup, the PM index was limited to 0.5-10 pov. units, and in persons of the second subgroup – in the range of 12-25 pf units.

When analyzing the amplitude-frequency spectrum, the contribution (in%) of the physiologically most significant changes in blood flow to the power of the entire spectrum of the LDF-gram was determined:

1) low-frequency oscillations (ALF), caused by the activity of smooth muscle cells in the arterioles (vasomotions);

2) high-frequency oscillations (AHF), caused by periodic changes in pressure in the venous section of the bloodstream during respiration;

3) pulse oscillations (ACF) synchronized with the cardiorhythm [Johnson, Rowell, Appl., 1975].

Microcirculatory bed is a link between arterial and venous vessels. The rhythms of erythrocyte flow fluctuations in the microcirculation system are influenced both by inflow pathways – arterial or active modulation of tissue flow fluctuations, and on the side of the outflow tracts, passive modulation of fluctuations (Kolchinskaya, 1990; Sidoryak, 2016).

The obtained data made it possible to evaluate the passive and active components of microcirculation regulation. The active mechanism is caused by the myogenic and neurogenic activity of precapilar vasomotors (ALF / M) and basal vascular tone (δ / ALF).

The passive regulatory mechanism includes blood flow fluctuations synchronized with the cardiac rhythm (ACF / δ) and fluctuations synchronized with the respiratory rhythm (ANF / δ). The ACF index is the maximum amplitude of blood flow oscillations in the range of 50-60 vibrations / min. (0,8-1,5 Hz). Indicator ANF – the maximum amplitude of fluctuations of a blood flow in a range of 12-24 fluctuations / mines. (0.2-0.4 Hz).

The ratio of active and passive blood flow modulations was represented as the index of floxemia or the index of efficiency of microcirculation (IEM), which indicates the efficiency of perfusion of a unit volume of tissue per unit time (Barkhatov, 2013; Kolchinskaya, 1990).

Statistical processing of the data was carried out using the Microsoft Ecxel 2003 program using the criterion t of the Student's criterion. The data are presented as the mean ± mean error (M ± m), because, due to a significant array of the obtained digital material, and also in accordance with the Shapiro-Wilkie criterion, the obtained data fit into the normal distribution law (Lukyanova, Antipkin, Chernyshov, Vykhovanets; 2002). Differences between mean values were considered statistically significant at $p < 0.05$.

Results and discussion.

The obtained results indicate the following. First of all, attention is drawn to the presence of significant differences in the values of the majority of parameters characterizing the microcirculation of blood at rest, between the subjects of the 4 age groups, both students and athletes of the I and II subgroups (Table 2, 3).

Comparing the value of the microcirculation index for students and athletes of different ages, i.e. the level of perfusion of a unit of tissue volume per unit of time, at rest, it should be emphasized that changes in PM were spasmodic.

The most intensive perfusion was observed in 19-year-old students of the II-nd subgroup, 21-year-old students of the I-st subgroup, as well as 18-year-old athletes of the I-st subgroup and 21-year-old athletes of the II-nd subgroup.

Consequently, regular exercise changes the age-related dependence of the level of perfusion of muscle tissue. The same conclusion can be reached when assessing the time variability of microcirculation (flax), which characterizes the magnitude of blood flow fluctuations in tissues, and the coefficient of variation (although the maxima of these parameters fall on other age periods) (see Table 2, 3).

Table 2

Changes in microcirculation parameters in students

Options	18 years		19 years		20 years		21 years	
	1	2	1	2	1	2	1	2
I subgroup								
PM, pf. units	1,70 ±0,05	6,45 ±0,77**	3,70 ±0,01	5,55 ±0,32*	2,14 ±0,01	3,85 ±0,18*	6,93 ±0,35	12,47 ±0,24**
MSD	0,83 ±0,07	1,45 ±0,07*	0,94 ±0,02	1,74 ±0,01*	1,37 ±0,01	2,88 ±0,06*	1,92 ±0,07	1,50 ±0,06*
Kv, %	100,72 ±7,07	50,23 ±5,29**	25,44 ±0,16	30,53 ±6,18	64,05 ±0,01	77,50 ±2,46*	88,39 ±1,22	8,58 ±0,71**
relative units	0,20± 0,001	0,14± 0,002*	0,19± 0,001	0,13± 0,002*	0,08± 0,002	0,10± 0,001*	0,10± 0,002	0,12± 0,001
relative units	0,39± 0,011	0,55± 0,016*	0,33± 0,012	0,60± 0,010**	0,34± 0,008	0,37± 0,009	0,34± 0,014	0,32± 0,010
II subgroup								
PM, pf. units	12,29 ±0,29	15,48 ±0,61*	24,27 ±0,01	16,94 ±0,67*	16,49 ±0,58	15,17 ±0,36*	16,57 ±0,41	14,25 ±0,38*
MSD	1,04 ±0,05	0,84 ±0,02*	2,63 ±0,06	2,13 ±0,01*	1,99 ±0,07	1,83 ±0,02*	2,76 ±0,01	1,83 ±0,02*
Kv, %	7,98 ±0,23	3,80 ±1,05*	12,23 ±0,79	14,68 ±7, 24	12,44 ±0,59	13,56 ±2,77	5,65 ±0,36	6,24 ±0,26*
relative units	0,26± 0,002	0,22± 0,001*	0,08± 0,001	0,10± 0,003	0,10± 0,001	0,11± 0,002	0,14± 0,001	0,13± 0,001
relative units	0,33± 0,010	0,63± 0,012*	0,24± 0,009	0,29± 0,010*	0,39± 0,010	0,46± 0,011*	0,34± 0,014	0,42± 0,010*

Notes: 1 – control values; 2 – values after exercise; * – differences are reliable;
** – the differences are significant between the values before and after the load (p <0.01).

Table 3

Changes in microcirculation parameters in sportsmen

Options	18 years		19 yaers		20 yaers		21 years	
	1	2	1	2	1	2	1	2
I subgroup								
PM, pf.units	17,76± 0,73	23,04± 0,42*	10,03 ±0,71	17,85 ±0,74*	6,69 ±0,35	23,76 ±1,46**	9,96 ±0,42	13,34 ±0,24*
MSD	1,22± 0,11	2,26± 0,15*	0,84 ±0,01	2,13 ±0,02*	1,52 ±0,01	2,43 ±0,03*	1,14 ±0,05	1,10 ±0,02
Kv, %	7,04± 0,98	8,94± 0,74*	8,34 ±0,51	11,84 ±0,80*	25,52 ±0,78	10,63 ±0,15**	12,12 ±0,84	12,91 ±0,31
relative units	0,18± 0,002	0,13± 0,004**	0,41± 0,010	0,08± 0,002**	0,11± 0,004	0,13± 0,002	0,11± 0,003	0,13± 0,001
relative units	0,42± 0,010	0,38± 0,003**	0,31± 0,001	0,30± 0,001	0,26± 0,003	0,41± 0,003*	0,41± 0,015	0,43± 0,001
II subgroup								
PM, pf.units	17,76± 0,73	23,04± 0,42*	15,84 ±0,28	20,48 ±0,48*	18,01 ±0,04	18,84 ±0,82	20,87 ±0,72	13,98 ±0,44*
MSD, pf. units	1,22± 0,11	2,26± 0,15*	1,74 ±0,02	0,98 ±0,03*	1,83 ±0,02	1,55 ±0,04*	1,65 ±0,04	4,45 ±0,07*
Kv, %	7,04± 0,98	8,94± 0,74	10,75 ±0,34	6,45 ±0,38*	10,64 ±0,28	7,44 ±0,22*	9,93 ±0,01	40,34 ±0,98**
relative units	0,18± 0,002	0,13± 0,004*	0,10± 0,004	0,13± 0,002	0,11± 0,004	0,19± 0,003*	0,11± 0,003	0,09± 0,001*
relative units	0,42± 0,010	0,38± 0,003*	0,51± 0,011	0,41± 0,009*	0,38± 0,001	0,54± 0,013*	0,57± 0,001	0,24± 0,002**

Notes: 1 – control values; 2 – values after exercise; * – differences are reliable;
** – the differences are significant between the values before and after the load (p <0.01).

The most important value in the diagnosis of changes or disorders of microcirculation is the analysis of the relationship between the mechanisms of active and passive modulation of tissue blood flow. The active mechanism of blood flow modulation is mainly due to two factors: myogenic and neurogenic activity of precapillary vasomotors and microvascular tone. Considering the myogenic and neurogenic activity of precapillary vasomotors, it can be noted that it underwent significant changes depending on the age of students and athletes surveyed at rest (see Table 2, 3). The same conclusion can be reached in the analysis of respiratory pulsatile blood flow fluctuations, i.e. passive mechanism of modulation of blood flow. In this case, it is necessary to emphasize the following fact.

It should be emphasized that in all groups of subjects IEM was> 1.0, therefore, regardless of the fitness of the organism or the effect of physical activity, the leading effect on blood microcirculation is exerted by active mechanisms, i.e. myogenic and neurogenic activity of precapillary vasomotors, which determine vascular tone (Vikulov, Drattsev, Melnikov, Alekhin, 2009). Despite this, passive mechanisms of regulation of microcirculation, namely, cardiac and respiratory fluctuations, play an important role in physical activity, because it is due to the function of the respiratory and cardiovascular systems that adequate provision of the body with oxygen is ensured.

The ratio of cardiac and respiratory floxemias affecting blood microcirculation, and making it possible to diagnose both microcirculation disorders and evaluate the prevalence of these or other mechanisms of its regulation (Barkhatov, 2013), practically all students and athletes surveyed (except for 19-year-old athletes I subgroup) was <1.0. Consequently, the contribution of respiratory modulations to the formation of a capillary blood flow profile is more significant, and the contribution of cardiac modulation to the limiting ability of adaptive responses. And the intensive physical load, in both untrained and trained young people of different ages, smoothing the age-related fluctuations of this indicator, in most cases even more increases the contribution of the respiratory rhythm of fluctuations.

Such dynamics at the level of blood microcirculation confirms the formed idea that during training, the limiting link limiting the energy supply of the oxygen request of the organism and promoting the development of hypoxia of the load with pronounced secondary tissue hypoxia is the circulation, and not the function of external respiration (Kolchinskaya, 1990). This feature, in our opinion, indicates, firstly, the need to take into account the hierarchy of regulatory mechanisms in selecting the intensity of physical exertion, and second, the possibility of a targeted effect on respiratory-pulse modulation in the microcirculatory bed and, consequently, on their relationship with using metered physical training.

It should be emphasized that microcirculation among students and athletes in the age aspect varies abruptly, and the age group differences are marked by significant differences in blood microcirculation between the I and II subgroups. However, it is impossible to reveal a clear pattern of changes in parameters, which, apparently, can be conditioned with individual features of the organism of the subjects surveyed in the process of ontogenetic development and the formation of physiological functions (Golubeva, Golubev, 2010).

Conclusions.

The presence of significant differences in the values of the majority of parameters characterizing the microcirculation of blood at rest, between the subjects of 4 age groups, both in students and in athletes with different levels of the microcirculation index.

Regular exercise changes the age dependence of the level of perfusion of muscle tissue, as well as the amplitude of fluctuations in blood flow in tissues.

Myogenic and neurogenic activity of precapillary vasomotors undergoes significant changes depending on the age of students and athletes who are examined at rest. The same conclusion can be reached in the analysis of respiratory pulsatile blood flow fluctuations and passive mechanism of modulation of blood flow.

The ratio of active and passive mechanisms that affect blood microcirculation – an index of the effectiveness of microcirculation – was almost 1.0 in all students and athletes tested. Consequently, the contribution of active modulation of blood flow to the formation of microcirculation profile is more significant.

The intensive physical load, both in untrained and in trained young people of different ages, smoothes the fluctuations in the ratio of cardiac and respiratory mechanisms of microcirculation fluctuations and in some cases enhances the role of the respiratory rhythm of fluctuations.

Significant differences in the effect of exercise on the effectiveness of microcirculation in students and athletes, depending on the value of the microcirculation index. In persons with hyperemic type of microcirculation, regular physical training contributes to the formation of compensatory mechanisms at the level of the capillary bed, which are realized by increasing the efficiency of microcirculation in response to intense loads; in untrained persons, such mechanisms are not formed, and in response to physical exertion, the effectiveness of microcirculation decreases, which may lead to a decrease in efficiency. In students and athletes with mesoemic type of microcirculation, the age-related adaptive or disadaptive reaction of the described type is not formed.

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