ORIGINAL ARTICLE

PECULIARITIES OF VASOR-REGULATING FUNCTIONS OF THE VASCULAR ENDOTHELIUM IN ADAPTATION OF THE YOUTH BODY TO SYSTEMATIC PHYSICAL LOADS

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ABSTRACT
The aim: To analyze the features of changes in the functional state of the vascular endothelium of handball players in the dynamics of the training process, at different levels of the body's hypoxic state.
Materials and methods: Theoretical methods, the method of Corretti et al. with the use of high-resolution ultrasound, Fisher test with the calculation of the Fisher criterion and the Bland-Altman method. The study of the vasomotor function of the vascular endothelium was carried out of young men 18-20 y.o., who did not go in for sports and which were systematically played handball. The brachial artery diameter, maximum linear blood flow velocity, volumetric blood flow velocity were registered in the state of relative rest after artificially created reactive hyperemia.
Results: The primary results obtained showed that in the process of long-term adaptation to systematic muscular work, a pronounced vasodilation effect was observed. Subsequent analyze of changes in the functional state of the vascular endothelium of young sportsmen during the macrocycle preparation different levels of the body's hypoxic state manifested the following. The young men-athletes had more pronounced vasodilation effect, the values of the linear and volumetric blood flow velocity both in the state of relative rest and at the peak of the artificially created hyperemia were significantly higher than in the young men, who did not go in for sports.
Conclusions: Suggested that the systematic muscular work contributes to a significant intensification of the oxidation pathway of nitric oxide formation from L-arginine with the participation of endothelial NO-synthase.

KEY WORDS: vasodilation effect, linear blood flow velocity, volumetric blood flow velocity, reactive hyperemia, handball

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INTRODUCTION
The process of adaptation of the body of athletes to physical loads of significant volume and intensity is accompanied by significant adaptive morphological and functional rearrangements of the leading physiological systems and the cardiovascular system, in particular [1-3].

Numerous studies have indicated that the organism adapted to physical activity is characterized by certain morphological changes in the heart and blood vessels (myocardial hypertrophy, the increase in the volume of cardial cavities and major vessels, etc.) [4,5], as well as functional changes in the blood circulatory system (sports bradycardia, sinus arrhythmia, increased cardiac output, etc.) [6,7]. The researchers also draw attention to the possible consequences of COVID-19 for athletes, including general cardiac complications of this disease; agreed recommendations for returning to sports after COVID-19; and international guidelines for the treatment of cardiac pathology that might result from COVID-19 [8,9].

In recent years, the attention of a number of authors has been drawn to the state of the vascular endothelium, which ensures an increase in the linear and volumetric blood flow velocity, and the optimal form of the relationship between the processes of vasoconstriction and vasodilation, thereby the most adequate level of the functional state of the cardio-vascular system [10,11]. Scientists have shown the relationship between cardiovascular morbidity and lifelong exercise patterns [12]. It has been proven that elite athletes have a lower risk of cardiovascular and cancer, live longer than the general population [13].

Groups of specialists have established that disorder of the functional state of the vascular endothelium is one of the main causes of a number of pathological conditions (hypertension, coronary heart disease, endothelial dysfunction, atherosclerosis, etc.) and can be observed under the influence of extreme environmental factors on the organism [14,15]. Taking into account the fact that physical activity is rightly considered as a sufficiently strong external stimulus for any organism, it can be assumed that there are certain adaptive features in the functional state of the vascular endothelium of persons who systematically perform muscle work of significant volume and intensity

[16]. So a number of scientists have proved that frequent exercise modifies the lipid profile, inhibits the production of pro-inflammatory and pro-apoptotic cytokine TNFα, increases nitric oxide production via endothelial nitric oxide synthase (eNOS) [17]. In addition, Gomes, Casella-Filho, Chagas, & Tanus-Santos have reported that physical activity decreases both oxidative stress and the circulating concentrations of endogenous inhibitors of NOS [18].

At the same time, the problem of relatively more subtle physiological mechanisms that provide the optimal form of adaptation of the athletes' circulatory system to training and competitive loads is practically has not studied. It is obvious that knowledge of these mechanisms can provide both an effective form of control over the current functional state of the cardiovascular system of athletes, and a targeted impact on the process of adaptation of the whole organism to physical loads of increased volume and intensity [19].

THE AIM

Aim of the study: to analyze the features of changes in the functional state of the vascular endothelium of handball players in the dynamics of the training process, at different levels of the body's hypoxic state.

MATERIALS AND METHODS

Within the framework of this study, the study of the vasomotor function of the endothelium was carried out of 39 young men between 18-20 years of age. All of them were divided into two groups: the control group, which included 28 young men who did not go in for sports, and the main group (11 young men), the representatives of which were systematically played handball for 10 years (ZTR handball team (Zaporizhzhia, Ukraine)). The registration of the parameters of ultrasound examination of the young men of the main group was carried out at the end of the preparatory period (EPP), the middle of the competitive period (MCP) and at the end of the competitive period (ECP).

Informed consent was obtained from each patient included in the study. The study has been approved by the Institutional Ethics Committee, complied with all relevant national regulations and institutional policies, followed the tenets of the declaration of Helsinki, and has been approved by the authors' institutional review committee.

The study was carried out according to the method of Corretti et al. [20] with the use of high-resolution ultrasound using a Siemens ultrasound apparatus at the functional diagnostics department of the city hospital № 7 in Zaporizhzhia. During the examination, using this method, the brachial artery diameter (Dp, mm), maximum linear blood flow velocity (Vmax, ml/s) and volumetric blood flow velocity (Vvol, l/min) were registered in the state of relative rest and after artificially created reactive hyperemia. The postocclusive vasomotor response of the brachial artery was assessed in accordance with the values of the relative increase in these parameters (in % to the initial values of Dp, Vmax, and Vvol) are shown in Fig. 1.

During the study, the following methods were used: a systematic approach, biblical semantic and medical statistical methods. We have evaluated the significance of the differences among the samples using the Fisher angular transformation criterion φ*, which is determined by the formula:

$$\varphi^* = (\varphi_1 - \varphi_2) * \sqrt{\frac{n1 * n2}{n1+n2}},$$

where φ_1 – an angle corresponding to a higher percentage share (V1)

$$\varphi_1 = 2*\arcsin(\sqrt{V1}),$$

where φ_2 – an angle corresponding to a smaller percentage share (V_2)

$$\varphi_2 = 2*\arcsin(\sqrt{V2}),$$

where n_1 – the number of observations in the sample 1;
where n_2 – the number of observations in the sample 2.

Also, we have used the Blend-Altman method with the calculation of the common error (T, %) to compare two measurements, each of which led to a certain error in the measurements.

RESULTS

Table I shows the results of a comparative analysis of the studied parameters which characterize the vascular-motor function of the vascular endothelium, which were recorded in the control group (CG) and main group (MG). As can be seen from the given data (Table I), statistically reliably higher values of the above parameters were characteristic of young men-athletes. Thus, they had significantly higher than in the control, Dp values in a state of relative rest, after artificially created hyperemia and, as a consequence, significantly more pronounced vasodilation effect.

The results of the comparative analysis of the values of the linear and volumetric blood flow velocity fully confirmed the presented materials. It turned out that both in the state of relative rest and at the peak of the artificially created hyperemia, the Vmax and Vvol values recorded in the main group were significantly higher than in the control group. In this regard, the advantage of handball players in terms of the relative increase in these parameters.

The results obtained made it possible to state that in the process of long-term adaptation to regular muscular work, there is a significant optimization of the vasoregulatory function of the vascular endothelium, meaning to ensure a pronounced vasodilation effect.

In connection with the above saying, it looked quite natural to analyze the peculiarities of changes in the functional state of the vascular endothelium of young sportsmen in the dynamics of the training process, with various combinations of training and competitive physical loads and, as a consequence, different levels of the body's hypoxic state.

In accordance with the materials presented in Table II, the statistically significant Dp values in the state of relative rest and at the peak of hyperemia of the examined young men-athletes were recorded in the middle of the competitive period. At the same time, it was at this stage of the training process that the lowest values of ΔDp were noted, which, as is known, characterizes the degree of vasodilation effect of the vascular endothelium.

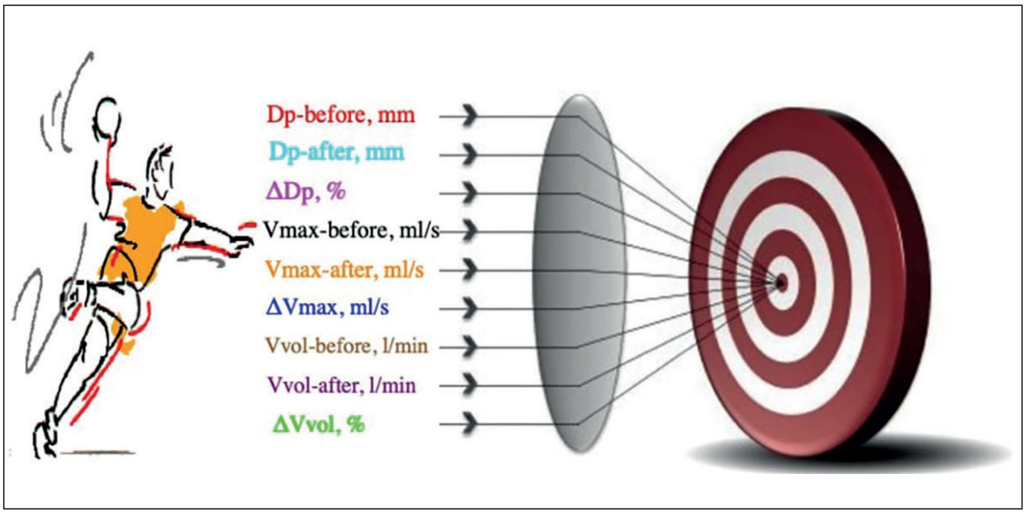

Fig. 1. The values indicators of young men.

Table I. Values indicators of young men before and after the test with reactive hyperemia

Indicators	CG (n=28)	MG (n=11)	F (2,9)	T
Dp-before, mm	0,34±0,006	0,40±0,01*	26,47	5,1
Dp-after, mm	0,40±0,007	0,49±0,004*	124,62	4,7
ΔDp, %	18,80±0,97	23,18±0,72*	13,15	4,2
Vmax-before, ml/s	27,83±0,68	32,83±0,61*	29,96	3,5
Vmax-after, ml/s	38,25±0,85	47,19±0,45*	86,40	3,7
ΔVmax, ml/s	38,17±2,69	44,10±2,32*	2,99	4,2
Vvol-before, l/min	1,30±0,02	1,42±0,01*	28,80	5,3
Vvol-after, l/min	3,21±0,08	3,78±0,03*	44,51	4,0
ΔVvol, %	147,75±6,09	167,19±2,14*	9,07	3,3

* – $p < 0.05$

Table II. The values indicators of young men in the main group before and after the test with reactive hyperemia at various stages of the training process

Indicators	EPP (1)	MCP (2)	ECP (3)	F_{1-2} (3,07)	F_{3-2} (3,07)	F_{3-1} (3,07)
Dp-before, mm	0,40±0,01	0,43±0,01*	0,39±0,01•	4,50 (5,1)	8,00 (5,3)	0,50 (6,1)
Dp-after, mm	0,49±0,004	0,51±0,005*	0,47±0,004•*	9,76 (4,2)	39,0 (4,2)	12,50 (5,2)
ΔDp, %	23,18±0,72	18,40±1,01*	20,04±2,22	14,85 (3,7)	0,45 (5,9)	1,81 (6,0)
Vmax-before, ml/s	32,83±0,61	35,05±0,61*	32,76±0,52•	6,62 (5,3)	8,16 (4,7)	0,01 (6,7)
Vmax-after, ml/s	47,19±0,45	48,33±0,43	46,71±0,78•	3,35 (5,9)	3,31 (5,8)	0,28 (5,8)
ΔVmax, ml/s	44,10±2,32	38,17±2,05*	42,82±2,78	3,67 (5,4)	1,81 (6,2)	0,12 (6,4)
Vvol-before, l/min	1,42±0,01	1,44±0,01	1,39±0,01•*	2,00 (4,7)	12,50 (4,7)	4,50 (5,3)
Vvol-after, l/min	3,78±0,03	3,80±0,02	3,74±0,02•	0,31 (5,6)	4,50 (4,8)	1,23 (6,1)
ΔVvol, %	167,19±2,14	163,39±2,03	169,76±2,16•	1,66 (5,8)	4,62 (5,1)	0,71 (6,4)

* – $p < 0.05$ compared with the end of the PP; • – $p < 0.05$ compared to the middle of the CP. The values of the total error (T, %) are shown in brackets

Almost the same data were obtained for the linear and volumetric blood flow velocity. It turned out that despite the higher values of Vmax and Vvol in the state of relative rest and at the peak of hyperemia in the middle of the competition period, the lowest values of the relative increase in these parameters were recorded precisely at this stage of the experiment.

The fact of the almost complete restoration of the values of Dp, Vmax and Vvol in a state of relative rest, at the peak of hyperemia, the values of ΔDp, ΔVmax and ΔVvol, recorded at the end of the competitive period, to the values of these indicators observed in the examined young athletes at the end of the period also was quite interesting.

DISCUSSION

Currently, the assessment of the functional state of athletes of various specializations and qualifications is carried out mainly on the basis of the analysis of the results of their medical and biological examination using traditional methods of functional diagnostics (electrocardiography, rheography, plethysmography, etc.) [21-24]. These methods make it possible to determine only the integral parameters of the circulatory system, which do not fully characterize the real functional state of this system.

The results obtained in the course of the study, which made it possible to determine the existence of specific physiological mechanisms of adaptation of the cardiovascular system of the body of athletes to physical activity (an increased level of the functional state of the vascular endothelium and connected with this – vasodilation effect) are consistent with the opinion of a number of the researchers regarding the need to study the main mechanisms of providing muscle activities in the process of adaptation of the body to physical loads of significant volume and intensity [25]. Although periodically there are some debates about the effect of exercise on cardiovascular disease [26] and whether high volumes of exercise accelerate the development of coronary atherosclerosis [27].

The results of the study, taking into account the well-known concepts that the vasodilation function of the vascular endothelium is provided mainly by increased synthesis of nitric oxide (NO) [28-30], suggest that the systematic muscular work contributes to a significant intensification of the oxidation pathway of NO formation from L-arginine with the participation of endothelial NO-synthase (eNOS).

In connection with the above mentioned, it can also be assumed that a decrease in the vasodilation effect of the vascular endothelium in the middle of the competitive period, characterized by a prolonged combination of high physical loads of a training-competitive orientation, and requiring a significant mobilization of the body's functional reserves, is also associated with a decrease in the activity of the non-oxide pathway of NO formation from L-arginine. A longer combination of training and competitive loads (the end of the competitive period) contributes to the formation of a certain stable form of adaptation to conditions of oxygen deficiency and, as a consequence, optimization of the oxidation pathway of NO synthesis, and, ultimately, the functional state of the vascular endothelium.

This conclusion is of great practical importance, since opens up the possibility of a targeted influence on the synthesis of nitric oxide, then on the state of the vascular endothelium and increasing the vasodilation function of blood vessels by using drugs of a non-doping nature, in particular, the plant extract of ecdysterone. In turn, an increase in the vasodilation function of the vascular endothelium contributes to a significant activation of the arterial and peripheral blood flow, a more intensive supply of nutrients to working muscles, the removal of metabolic products and a pronounced increase in the physical performance of the body.

CONCLUSIONS

The materials of the study made it possible to state a rather high role of the vascular endothelium in ensuring the adaptation of the body of young men 18-20 years old to systematic physical loads of significant volume and intensity.

In our opinion, the obtained materials are not only a certain addition to the available theoretical information on this problem, but can serve as the basis for the development of appropriate physiological measures aimed at increasing physical performance and general optimization of the functional state of the body.

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The Authors declare no conflict of interest.

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