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Original Article

Peculiarities of regional circulation in sportsmen who are planting forces of different qualification

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Abstract:
Objective: The aim of the work is to study the features of peripheral hemodynamics of individual segments of the lower limb in athletes involved in power triathlon at rest. Method: Rheovasographic methods and electron microscopy of red blood cells were used to study the regional blood flow. Results: The study of regional blood circulation features according to the rheovasogram data in the "hip", "leg" and "foot" areas and the structure of peripheral blood erythrocytes showed that changes in the lower extremity vessels in athletes involved in power triathlon indicate an adverse reaction to intense physical activity, which depends on the level of skill of athletes and the segment of the lower limb, and on the morphofunctional characteristics of peripheral blood erythrocytes.
Key words: force triathlon, adaptation, cardiovascular system, erythrocytes.

Introduction

The problem of developing a recreational regime in the physical training of athletes in power triathlon is still far from a final solution [1]. There are practically no scientific studies in this area and the role of the erythrocyte hemostasis system after physical exertion remains undisclosed [2, 3]. There are only some fundamental data in the study of the problem of the manifestation of strength and strength training in weightlifting [4-6] and the associated changes in capillary blood flow in the lower limbs.

Training of athletes in powerlifting is currently being conducted on the basis of the provisions set forth in scientific papers on the problems of sports training in weightlifting or on the basis of popular foreign publications [7].

Direct borrowing of recommendations and methodological provisions from weightlifting is incorrect, since power triathlon is distinguished by its own specificity of competitive activity. For example, in contrast to weightlifting in this sport, movements are performed much slower, therefore such a factor as muscle composition becomes unimportant, and it is necessary to train both slow and fast muscle fibers [8]. As for foreign recommendations, in most cases they do not rely on rigorous scientific data and represent the opinions of various coaches and athletes themselves about the process of preparing power triathletes.

Effective training of athletes in power triathlon is due to significant energy consumption, the maximum level of physical effort, high functional and optimal morphological indicators, without the development and balanced interaction of which it is impossible to carry out the training process aimed at achieving high sports results in intense competitive activity [1, 4 , 7]. Under the influence of prolonged physical exertion in the athlete's body, an adaptive restructuring of various organs and systems occurs, providing the best adaptation to intensive work during the training period [9].

Despite the fact that the general laws of adaptive rearrangements in the human body are studied quite well when the external and internal environment changes, the issues of adaptive rearrangements of the cardiovascular system to intense muscular activity in athletes during long-term exercises in power triathlon remain poorly lit [1, 6]. The study of adaptive reactions of the body to physical activity, depending on the length of employment and sports qualifications will allow you to more effectively manage the training process.

Based on the analysis of literature data, we can conclude that the issue of the manifestation of the adaptive reactions of the cardiovascular systems of athletes to physical activity in power triathlon has not been studied sufficiently [4, 8, 9].

The aim of the work is to study the features of peripheral hemodynamics of individual segments of the lower limb in athletes involved in power triathlon at rest.

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Methods

The study involved 40 male volunteers aged 17 to 22 years. The control group consisted of 20 students with normal physical development, normal motor mode, attending physical education classes as part of the curriculum (assigned to the main group of health) and not involved in sports. The main group consisted of athletes involved in power triathlon (n = 20) with a high level of sportsmanship – candidates for the master of sports and the master of sports.

All students underwent a medical examination and for health reasons were assigned to the main medical group. The main anthropometric indices, blood pressure were measured, an electrocardiogram was recorded on a 12-channel prefix "CardioLab +" (KhAI software, Ukraine) in standard leads.

In order to study the regional blood flow in the "feet", "lower leg" and "hip" areas, the reovasographic method was applied using the Reo-Spektr-3 hardware-software complex (Neurosoft, Ivanovo, Russia) and the "Poly- Spectrum".

Erythrocytes preparations were prepared according to generally accepted rules [2, 3, 10]. and examined in a JEOL-25A-T3225 scanning electron microscope (Japan), and the percentage composition of different types of red blood cells was determined using the computer program "Biovision-4.01" (USA).

Statistical data processing was carried out using the SPSS Statistics 17.0 software package. Standard methods of variation statistics, calculation of averages, standard error of the mean were used. The significance of differences between the indicators was determined using the criterion of t-Student (method of parametric statistics) and Mann-Whitney (method of non-parametric statistics). Significant differences were considered indicators at $p < 0.05$.

Results

Analysis of rheovasographic indicators in athletes of the main group compared with the control group at rest revealed a significant decrease in the maximum systolic value of the venous component, the amplitude of the systolic and arterial waves.

The time of rapid blood filling of the vessels does not have a significant difference between the representatives of different groups. At the same time, the time of slow blood filling significantly differed, which was 15.4% more among athletes of the main group (0.11 ± 0.005 s versus 0.093 ± 0.002 s, p = 0.002). The systole time in the main group increases only by 7.1% (0.28 ± 0.01 s versus 0.26 ± 0.001 s, p = 0.002), while the eographically index decreases by 36.8% (0.48 ± 0 , 04 USD vs. 0.76 ± 0.05 USD in the control group, p = 0.001).

At the same time, the fact that the asymmetry coefficient increased by 2.1 times in athletes of the main group (19.0 ± 2.63% versus 9.21 ± 1.52% in the control group, p = 0.004) draws attention to itself. It was also revealed a significant (by 35.4%) decrease in the amplitude-frequency index in athletes of the main group (0.53 ± 0.04 cu against 0.82 ± 0.04 cu in the control group, p = 0.002).

At the same time, in the control and main group such indicators as diastolic, modified diastolic and dicrotic indices did not significantly differ in each other. The fast filling index was 6.5% lower among athletes of the main group (44.6 ± 1.2% versus 47.7 ± 0.52% in the control group, p = 0.016). The increase in the inflow-outflow ratio among athletes of the main group is 19.2% (0.26 ± 0.01 cu versus 0.21 ± 0.008 cu, in the control group, p = 0.002). In athletes of the main group, the Simonson index is 25.0% more (29.2 ± 3.27% versus 21.9 ± 2.65% in the control group), and the average rate of slow filling (Vav) is 41.9% less (0.25 ± 0.02 Ω / s versus 0.43 ± 0.028 Ω / s in the control group, p = 0.002), while the amplitude of the rheogram at the level of the systolic maximum of the derivative and the amplitude of the arterial component of the rheogram did not significantly differ. It was established that compared with the control group, the athletes of the main group reliably reduced the amplitude of the venous component of the rheogram, the amplitude at the incisura level, and the amplitude at the dicrotic tine level (p = 0.012).

At the same time, the venous outflow coefficient in all groups remains within the normal range, and the time of the pulse wave propagation from the heart did not have significant differences. For athletes of the main group, an increase of 7.3% in time is characteristic (0.068 ± 0.002 s versus 0.063 ± 0.001 s in the control group, p = 0.015), and by 20.0% slow (0.085 ± 0.004 s versus 0.068 ± 0.001 s in the control group, p = 0.002) blood supply. The duration of systole, cataclys and diastoles in athletes of the main group was significantly longer compared with the control group. At the same time, the amplitude-frequency index and the rheographic index did not have significant differences (p> 0.05). The fast filling index was 6.8% lower among athletes of the main group (47.9 ± 1.05% against 51.4 ± 0.27% in the control group, p = 0.001).

The rate of slowing blood flow and venous outflow in athletes of the main group was, respectively, 12.5% (0.09 ± 0.007 s versus 0.08 ± 0.005 s, p = 0.001) and 39.7% (9.0 ± 1.09 % versus 3.57 ± 1.07%, p = 0.028) is greater than in the control group.

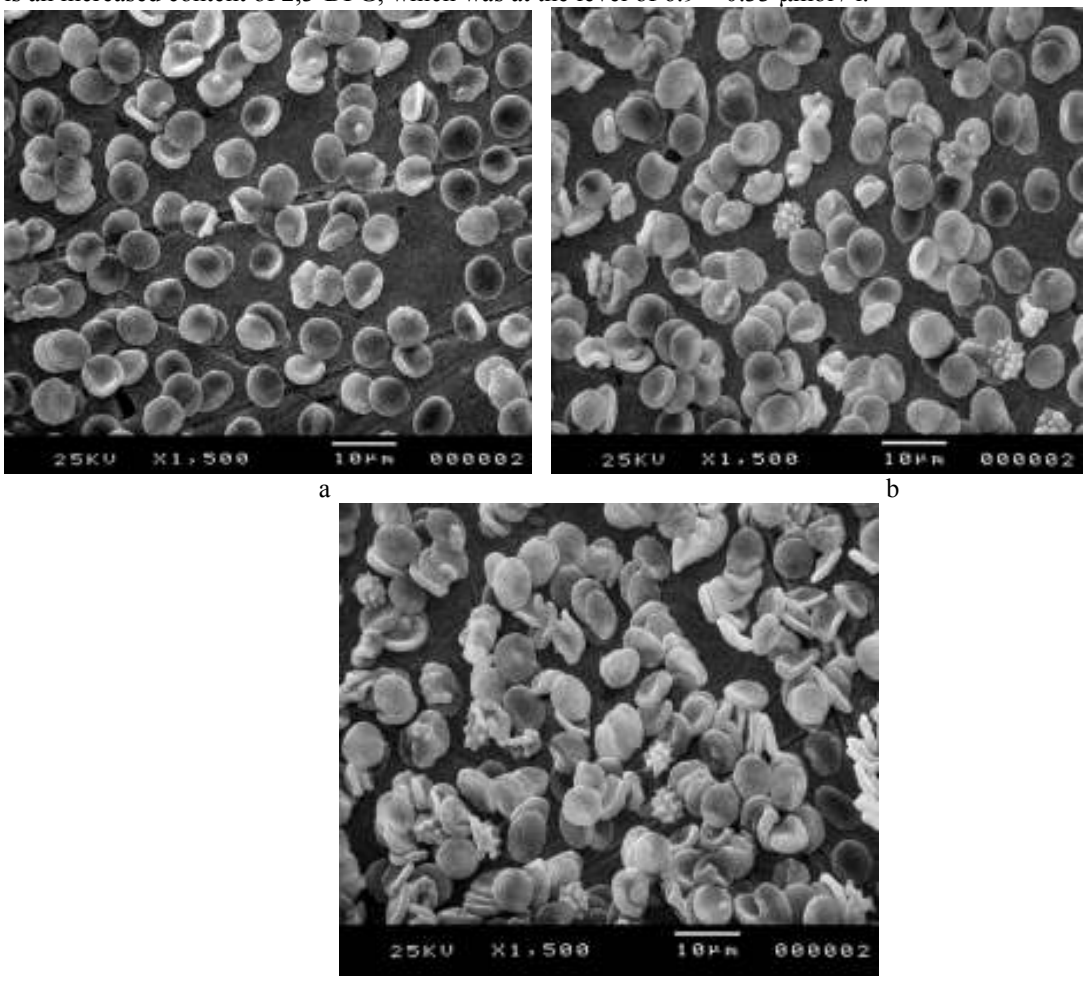
A comparative analysis of the foot rheovasography indices showed that the amplitudes of the rheogram at the level of the systolic maximum, the arterial component, and the venous component of the rheogram did not significantly differ in both groups. However, the amplitude at the level of incisura and dicrotic prong was significantly lower, by 47.4% (0.031 ± 0.0005 Ohms versus 0.052 ± 0.0005 Ohm in the control group, p = 0.004) and 23.6% (0.012 ± 0, respectively). 0002 ohms vs. 0.015 ± 0.0001 ohms in the control group, p = 0.011).

It was established that the time of slow blood filling in athletes of the main group increases by 23.3% (0.074 ± 0.004 s versus 0.06 ± 0.003 s in the control group, p = 0.001). The duration of dikroty significantly increased by 63.6% (0.36 ± 0.02 s vs. 0.22 ± 0.02 s in the control group, p = 0.001).

Athletes of the main group had a diastolic index by 11.6% less (38.9 ± 2.97% against 50.5 ± 2.91% in the control group, p = 0.005). The rate of blood flow slowing down in athletes of the main group was 12.5% higher (0.09 ± 0.0056 s versus 0.08 ± 0.0037 s in the control group, p = 0.001). The indicator of the state of the venous outflow was also 2.4 times higher in athletes of the main group (6.14 ± 1.18% versus 2.61 ± 0.78% in the control group, p = 0.012). However, the Simonson index was not significantly different, although it was 5.4% more than the main group (28.1 ± 4.02% versus 22.7 ± 2.23% in the control group, p = 0.015). The relative indicator (OPBET) in the main group was 12.9% less (68.35 ± 4.85 cu versus 79.16 ± 2.86 cu in the control group, p = 0.017). It should be noted that, against this background, in athletes of the main group, unlike the control group, morpho-functional changes in peripheral red blood cells appear (Fig. 1 a, b). The candidates for masters and masters of sports had ATP content in erythrocytes of both venous and arterial blood, which was only 0.51 ± 0.03 μmol / l, which causes the greatest pathological changes in peripheral erythrocytes (Fig. 1c).

In contrast to the control group (94.8 ± 2.42%), in sportsmen without a sports discharge, the content of discocytes noticeably decreased to 78.7 ± 1.11%. At the same time, the number of echinocytes increased significantly (p <0.05) to 5.9 ± 0.43% (in the control group only 2.2 ± 0.84%); target-like - up to 9.7 ± 0.51 (the control group only 2.9 ± 0.75%); the number of degenerative erythrocytes increased to 16.7 ± 1.23% (the control group - 6.3 ± 0.49%).

Masters of sports experienced even more pronounced shifts in the morphofunctional status of peripheral blood erythrocytes, there were no more than 72.3 ± 2.01% of discocytes, echinocytes up to 8.2 ± 1.18%, degenerative forms of erythrocytes up to 19.3 ± 2, 79%. Parallel to this, sticking cells appear in the form of “coin columns”. Masters of sports after a period of intensive training and after competitions, as a result of accumulation of acidic metabolites in the peripheral blood, lactate - 2.37 ± 0.41 mmol / l (in the control group - 0.92 ± 0.006 mmol / l), the pH shift in the direction of the acid reaction to 7.26, which occurs against the background of the activation of the synthesis of 2,3-DFG. Therefore, in the venous blood of these athletes there is an increased content of 2,3-DFG, which was at the level of 6.9 ± 0.33 μmol / l.



a b

c

Fig. 1. Conformational changes in peripheral blood erythrocytes depending on the skill level of athletes involved in powerlifting, and - control group, b - athletes without discharge, in - master of sports. Method, scanning electron microscopy.

Discussion

In a number of studies [2, 3, 11] it was shown that when practicing strength sports, special requirements are made to the functional reserves of the athlete's cardio-respiratory system. This immediately affects the functional state of the peripheral circulation and is often associated with the level of erythrocyte hemostasis. Therefore, to study the regional blood circulation, we used the reovasographic method, which allows us to identify the intensity of the peripheral circulation. This makes it possible to assess the elastic properties of the vessels and the state of the vascular tone, the intensity of blood flow and the degree of development of the collateral circulation, which generally gives more complete information about the studied section of the vascular bed [12-14].

The increase in the time of slow blood filling established by us against the background of a slight increase in systole time and a significant decrease in the eographically index of athletes of the main group may be due to an increase in vascular tone of medium and small caliber [15, 16], indicating a less intense blood flow in the segment under study [12].

The data of the anthropometric survey indicate a greater body mass of athletes of the main group (on average by 12.9%) as compared with the control group. In our opinion, this is a likely cause of an increased level of general metabolism, which explains the mechanism of enhanced blood supply to muscle tissue during strength training of athletes of the main group. This can play a significant role in the high oxygen demand of these athletes, which translates into an increase in maximum oxygen consumption. Some authors [17, 18] indicate that the regulation of the level of maximum oxygen consumption depends on the needs and the real availability of oxygen, which, in turn, depends on the peripheral blood circulation in the muscle tissue.

The changes in the vascular wall tone in athletes of the main group are also indicated by an increase in the fast filling index and the values of such ratios as "inflow-outflow" and "fast-slow blood filling", which are shifted towards the predominance of vascular wall tone in both large and small vessels. Similar data were obtained by researchers [19, 20] in athletes in other strength sports, whereas in people involved in sports with a manifestation of endurance, an increase in systemic compliance of the arterial wall in peripheral tissues is observed.

The increase in the tone of small and medium arteries in athletes of the main group is indicated by a decrease in the average rate of slow filling. The rate of venous outflow, both in the main group and in the control group, remained within the normal range. An increase in Simonson index values in athletes of the main group indicates a pronounced reaction of small arteries and large arterioles. It is known that their tone is mainly under the direct control of the nervous system [3].

The above-mentioned changes in vascular tone in athletes of the main group indirectly indicate a shift in sympatho-vagal balance towards the predominance of sympathetic influences, that is, it reveals an increased tension in the mechanisms of regulation of cardiovascular activity. This is confirmed by the data of [21], in which the increase in the normalized power of LF waves, as well as the LF / HF index, reflecting the activation of the sympathetic division of the autonomic nervous system, after three months of strength training in healthy elderly men.

An analysis of the indices of the lower leg rheovasography in the main and control groups revealed the following features. The amplitude of the rheogram at the level of the systolic maximum of the derivative, as well as the amplitude of the arterial component of the rheogram in the main and control groups did not differ significantly. However, the amplitude of the venous component of the rheogram, the amplitude at the incisura level, and the amplitude at the level of the dicrotic tooth reliably decrease.

An increase in the ratio of fast to slow blood filling is considered characteristic of reducing the elongation of large and medium-caliber arteries, for example, due to an increase in their tone, and medium-sized vessels are more affected. A number of authors suggested that chronic changes in blood flow under muscle loads can directionally change the diameter of the arterial vessels involved [22].

The duration of systole, cataclys and diastoles, which in the main group were significantly longer compared with the control group, was also changed. At the same time, the fast filling index was lower in the main group, which also indicates an increase in the tone of large arteries. At the same time, the rheographic index and the amplitude-frequency indicator did not have significant differences.

Changes in the rate of blood flow slowing down as well as the ratio of fast and slow blood filling, which has been shifted towards the predominance of large vessels, indicate the change in the elasticity of the vascular wall of small and medium caliber arteries. The athletes of the main group also significantly differed in the indicator of the state of the venous outflow, which was significantly higher than in the control group. It is well known that the flow of blood from the bottom up provides a number of factors, the most important of which is muscle contraction during exercise [2]. Apparently, prolonged static loads (weight lifting), periodic and long-term tension of the muscles of the lower extremities creates an obstacle to the normal outflow of venous blood. The Simonson index also indicates a change in the outflow of blood through the veins in athletes of the main group.

A comparative analysis of the indicators of foot reovasography showed the following. The amplitudes of the rheogram at the level of the systolic maximum, the amplitude of the arterial component of the rheogram, and the amplitude of the venous component of the rheogram did not significantly differ in the main and control

groups. However, the amplitude at the level of incisura and at the level of dicrotic tooth significantly differed. In athletes of the main group, especially the amplitude at the incisura level was much smaller than in the control group.

Also the duration of dikrota, time of fast and slow blood filling differed.

In general, the rheographic index, as well as the amplitude-frequency indicator, did not differ significantly, which indicates the safety of the arterial blood flow in the foot. The diastolic and modified diastolic index reliably decreased, whereas the rate of slower blood flow was significantly higher in athletes of the main group. The indicator of the state of the venous outflow was also significantly higher among the athletes of the main group. According to some authors [12, 14], even small values of changes in venous return to the heart (3-7% of the initial blood flow in the hollow veins) are essential for changes in cardiac output and systemic arterial pressure. However, the Simonson index was not significantly different, although in the main group it was slightly higher. The relative indicator Beta, which gives information about the relationship of venous outflow with arterial, is significantly less in the main group.

Indicators of rheovasography in athletes, depending on the qualifications at the site "hip", were as follows. The amplitude indices at the “thigh” site were as follows, the amplitude of the wave corresponding to the most pronounced peak of the derivative, the amplitude of the arterial component of the wave, the amplitude of the maximum systolic value of the venous component did not differ significantly. Also, there were no significant differences in the time of fast and slow blood filling.

The time of systole and the time of diastole increased significantly, but the duration of the cataclys in the main group decreases. A significant increase was found in the amplitude of the dikrota, which indicates a change in the outflow of blood. At the same time, the magnitude of the rheographic index, as well as the amplitude-frequency index, did not differ significantly, although the masters had less.

The venous outflow index and the venous outflow coefficient also differed significantly. Changes in the venous outflow of masters of sports in the lower leg area indicated an increase in the value of the Simonson index, which can be considered as a sign of venous stagnation. An increase in the erographic index among the masters of sports also pointed to signs of venous stagnation.

However, the fast filling index among sports masters was lower than in athletes without a sports discharge, which indicates an increase in the tone of large arteries. This was also indicated by a decrease in the values of the relative Beta indicator. Indicators of rheovasography in athletes of the main group, depending on the qualifications in the “foot” area, indicate significant differences in the amplitude of the venous component of the rheogram and the amplitude of the rheogram at the level of the dicrotic wave, as well as the amplitude of the rheogram in the middle of the catacrota. The temporal indices of the rheogram (fast and slow blood filling, as well as the rheographic index and the amplitude-frequency index) did not differ significantly.

Earlier works by Popel ’et al., [2, 3] have shown that athletes after competitions have an accumulation of acidic metabolites in peripheral blood, especially lactate. In this case, the shift of the pH towards the acid reaction (up to 7.26) occurs due to the activation of the synthesis of 2,3-DFG. Therefore, in the venous blood of the masters of sports there was an increased content of 2,3-DFG, which was at the level of 7.1 ± 0.59 μmol / l.

It was established that among sports masters, the ATP content in erythrocytes of both venous and arterial blood was only 0.51 ± 0.03 μmol / l, which causes immediate pathological changes in peripheral erythrocytes.

Conclusion

The athletes involved in power triathlon, a change in blood circulation parameters in the lower extremities. The nature of the hemocirculation shifts, according to rheovasography, includes changes in both the arterial and, especially, the venous level of the blood vessels network.

A decrease in such an important indicator as the eographical index indicates a significant decrease in the intensity of blood flow, and an increase in the venous outflow index and the Simonson index also indicates a difficulty in the outflow of blood through the veins. The most pronounced changes in rheovasography indices were revealed in the “leg” and “foot” areas. The identified changes in peripheral hemodynamics are most likely actually associated with weight lifting. Probable mechanisms of restructuring in the vascular bed are, 1) a shift in sympatho-vagal balance, 2) increased muscle tone and periodic breath-holding, creating conditions for obstructing the outflow of blood, 3) erythrocyte hemostasis.

With the growth of sportsmanship, the nature and degree of vascular changes increases, which indicates a decrease in the adaptive capacity of the cardiovascular system of the lower extremities for intense physical exercise. One of the additional reasons for the change in peripheral blood flow in the lower extremities of highly skilled athletes should probably be called the use of special equipment that creates additional conditions for the difficulty and flow and outflow of blood, which exacerbates disturbances from peripheral blood erythrocytes. However, this hypothesis requires additional evidence.

A call for future research

In further studies, the analysis of changes in the morphofunctional characteristics of peripheral blood erythrocytes in combination with rheovasographic indicators will allow a more detailed study of the changes in

lower extremity hemodynamics in athletes involved in powerlifting, which is of particular importance for diagnosing their functional state and planning the training process.

Conflict of interest. The authors state that there is no conflict of interest.

References

[1] Avsiyevich, V. (2016). Training Process Management for Youngsters Engaged in Powerlifting. *SSRN Electronic Journal,* 28(6), 162-168. https://doi.org/10.2139/ssrn.2991943

[2] Popel', S.L., Tsap, I.G., Yatciv, Ya. N.,. Lapkovsky, E. Yi, Synitsya, A.V. & Pyatnichuk, D.V. (2017). Special aspects of hemodynamic and reaction of erythrocytes in blood to standard physical load of different qualification female volleyball players. *Pedagogics, psychology, medical biological problems of physical training and sports*, 5, 251–259. doi:10.15561/18189172.2017.0508

[3] Popel', S.L., Mitckan, B.M., & Lapkovskiy, E.I. (2017). Mechanism of changing adaptation potential and morpho-biochemical parameters of erythrocytes in students with different mode of day after physical load. *Regulatory Mechanisms in Biosystems,* 8(2). 124–134. doi, 10.15421/021711

[4] Guz, S.M. (2009). Factors determining the sporting performance in powerlifting. *Scientific notes of the University. P. F. Lesgafta,* (51), 23-28. https://doi.org/10.5930/issn.1994-4683.2009.05.51.p23-27

[5] Avsiyevich, V. (2012). Effect of Powerlifting Activity on Development of Boyss Motor Ability. *SSRN Electronic Journal,* 25(5), 16-20. https://doi.org/10.2139/ssrn.2997081

[6] Avsiyevich, V., Fyodorov, A., & Isaeva, Z.S. (2018). Model Characteristic of the Relationship between Power and Morphofunctional Parameters of Athletes in Powerlifting. *SSRN Electronic Journal,* 30(5), 561-568. https://doi.org/10.2139/ssrn.3200953

[7] Bakhtiari, S., Shafinia, P., & Ziaee, V. (2010). Effect of Selected Exercises on Elementary School Third Grade Girl Students'Motor Development. *SSRN Electronic Journal,* 23(7), 445-449. https://doi.org/10.2139/ssrn.1833763

[8] Taha, A.A., & Shamsuldin, A.S. (2000). Effects of Weight Categories Variation on Relative Muscular Strength of Squat Powerlifting. *Journal of Zankoy Sulaimani. Part (B - for Humanities),* 19(4), 2237-2244. https://doi.org/10.17656/jzsb.10793

[9] Avsiyevich, V., Plakhuta, G.A., & Fyodorov, A.I. (2017). The Importance of Biological Age in the Control System of Training Process of Young Men in Powerlifting. *SSRN Electronic Journal,* 29(2), 347-352. https://doi.org/10.2139/ssrn.2990214

[10] Hoppert, M. Microscopic techniques in biotechnology. Weinheim, Wiley-VCH; 2003.

[11] Bowles, D.K. Adaptation of Ion Channels in the Microcirculation to Exercise Training. (2000). *Microcirculation,* 7(1), 24-40. https://doi.org/10.1080/sj.mn.7300086

[12] Clausen, J.P., Clausen, K., Ramussen, B. (1973). Central and peripheral circulatory changes after training of the arms or legs. *American Journal Physiology,* 225(3), 675-682.

[13] Murray, A., & Dinsdale, G. (2016). Imaging the Microcirculation. *Microcirculation,* 23(5), 335-336. https://doi.org/10.1111/micc.12282

[14] Sugawara, J., Maeda, S., Otsuki, T., & Tanabe, T. (2007). Effects of nitric oxide synthase inhibitor on decrease in peripheral arterial stiffness with acute low-intensity aerobic exercise. *Hypertension,* 44 (2), 119-120.

[15] Girerd, X., Laurent, S., & Safar, M.E. (1996). Structure changes of large conduit arteries in hypertension. *Journal Hypertension,*14, 545-555.

[16] Prewitt, R.L., Rice, D.C., & Dobrian, A.D. (2002). Adaptation of Resistance Arteries to Increases in Pressure. *Microcirculation,* 9(4), 295-304. https://doi.org/10.1038/sj.mn.7800143

[17] Pries, A.R., & Secomb, T.W. (2002). Structural Adaptation of Microvascular Networks and Development of Hypertension. *Microcirculation,* 9(4), 305-314. https://doi.org/10.1038/sj.mn.7800144

[18] Pries, A.R., & Secomb, T.W. (2008). Modeling Structural Adaptation of Microcirculation. *Microcirculation,* 15(8), 753-764. https://doi.org/10.1080/10739680802229076

[19] Lambert, M. (2006). Physiological Testing for the Athlete, Hype or Help? International *Journal of Sports Science & Coaching,* 1(2), 199-208. https://doi.org/10.1260/174795406777641203 [20] Frisbee, J.C. (2017). Obesity, insulin resistance, and microvascular adaptation. *Microcirculation,* 24(2), 123-146. https://doi.org/10.1111/micc.12346

[21] Melo, R.C., Quiterio, R.J., & Takahashi, A.C.M. (2008). High eccentric strength training reduces heart rate variability in healthy older men. *Brithich Journal Sports Medicine,* 42, 59.

[22] Nichelatti, M., Pettazzoni, P., & Pallotti, G. (2017). The study of viscoelastic behavior of blood vessels. *Blood, Heart and Circulation*, 1(2), 34-39. https://doi.org/10.15761/bhc.1000110