DOI: 10.46300/91011.2022.16.12 Volume 16, 2022

Functional reaction of the cardiovascular system to irritation of vestibular receptors in students engaged in different types of martial arts

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Received: May 19, 2021. Revised: November 21, 2021. Accepted: December 14, 2021. Published: January 3, 2022.

Abstract. Regular dosed physical activity in all cases has a tonic and healing effect on a person. Feasible muscle activity helps to improve the function of the heart, lungs, blood vessels and the nervous system. In martial arts, the reactivity of the vestibular apparatus is of great importance, providing the flow of information about the current position of the body in space, the success of movement in it and maintaining the stability of the posture due to the effective redistribution of muscle tone. Purpose of the work: to find out the dependence of the reaction of the cardiovascular system to the arising vestibular irritation in different types of martial arts. Martial arts classes help to increase the degree of vestibular stability. The statokinetic stability is very pronounced and increases in the course of hand-to-hand combat, which has a lot of moments with different severity of angular accelerations. The peculiarities of motor activity in any kind of martial arts inevitably affect the peculiarities of the reaction to the test with a change in the position of the head.

Keywords: **boxing, cardiovascular system, hand-to-hand combat, irritation of vestibular receptors, karate, vestibular system.**

I. Introduction

RECENTLY in the world as a result of a decrease in the general physical activity of the population, there has been a general weakening of the health status of people of different ages. Currently, only about 20% of the population is engaged in physical culture and sports in the world. In this regard, the problem of low physical development of young people, especially students, is becoming increasingly acute [1]. The real volume of their muscle activity does not give them full physical development and significant health improvement. The situation is complicated by the fact that among university students, the number of people who avoid significant physical exertion and have various deviations in health is gradually increasing [2].

A significant part of young people, especially in cities, do not always live in environmentally friendly conditions. As a result of various social and economic problems, a significant number of young people experience prolonged psycho-emotional and social stress, which further worsens their health [3]. For this reason, the purposeful use of the powerful health-improving potential of physical culture and sports to preserve the health of the entire population and especially young people in the course of their education and professional development becomes very urgent. With their help, it is possible to massively achieve longevity, form a healthy psychological climate in the social environment, and reduce primary morbidity and the number of cases of disability [4, 5].

The leading stage of the physical development of the population is rightly considered the educational stage of life, when the necessary professional skills are mastered, which are required for their consistent practical application in the course of work [6]. High attention to physical training among young people during their studies at the university is associated with the possibility with their help to significantly increase the level of their health and physical fitness, to create conditions for interesting leisure time [7]. Under the conditions of a difficult demographic situation and the presence of economic difficulties associated with high morbidity, intensification of production and the growth of requirements for the state of physical health and professional training of workers, it seems very reasonable and effective to increase the physical activity of young people [8]. These measures are able to increase labor productivity, improve the well-being of the population and provide the foundations for sustainable socio-economic development [9]. In this regard, long-term regular physical culture and health-improving classes among students in excess of the volume of the standard educational course of physical culture acquire great importance [10].

The general health-improving effect of increasing muscle activity in adolescence is associated with the intensification of adaptation processes to it throughout the body, significantly increasing their overall resistance to any influences from the external environment [11]. A serious role in adaptation to the influence of physical activity is played by the heart, which in many respects limits the state of oxygen supply to all functioning organs. Under conditions of regular training, the biological capabilities of the heart increase, the volume and speed of blood flow increase, which leads to an increase in the level of oxygen delivery to all cells of the body [12].

Physical activity, when properly dosed, always has a tonic and revitalizing effect on the body [13]. Muscular feasible regular activity ensures the optimization of the work of the heart, lungs, blood vessels and analyzers [14]. With any physical activity, the vestibular apparatus bears a great load and is of leading importance in ensuring the success of motor activity due to the realization of a clear orientation of the body in space and effective redistribution of muscle tone [15]. The biological importance of the vestibular apparatus is associated not only with its participation in the implementation of the movement of the body and its parts in space, but also with its connection with many autonomic systems and, first of all, with the hemocirculation system [16]. In this regard, the assessment of the functional connections of the vestibular apparatus and the cardiovascular system is of great importance for determining the general physical condition and the level of fitness of a physical cultured and an athlete [17].

Purpose of the study: to find out the reactions of the cardiovascular system to emerging vestibular different types of martial arts.

II. Material and Methods

The study was approved by the local ethics committee of the Russian State Social University on September 15, 2017 (Protocol No. 9). The study was conducted on the basis of the Russian State Social University, Moscow, Russia.

Clinically healthy athletes, a total of 78 male athletes (22.5 ± 1.3 years), regularly engaged in various types of martial arts for a period of not less than five years: boxing (26 people), karate (24 people), hand-to-hand combat (28 people) with a sports qualification not lower than a candidate for master of sports of Russia.

The control group consisted of clinically healthy students (21.2±1.1 years), experiencing regular physical activity only in academic physical education classes (18 people).

Assessment of the reaction of the cardiovascular system to vestibular influences was carried out using the traditional rotational test according to the method of V.I. Voyacheka. The heart rate and blood pressure figures recorded before and after the rotational test were used to determine the characteristics of the reaction of the cardiovascular system to it. To change the composition of the excited receptors located in different semicircular canals of the vestibular apparatus, rotation was used under conditions of tilting the head to the left and to the right (5 rotations in 10 s). To enhance the severity of the effect of rotation on the vestibular apparatus, the time of the test during the study was doubled (10 rotations for 20 s).

Statistical processing of the results obtained in the work was carried out using the Student's test using the standard Excel for Windows 10 software package.

III. Research Results and Their Discussion

The initial value of heart rate in boxers, karate fighters and hand-to-hand fighters was normal and amounted to 63.7 ± 0.62; 60.1 ± 0.70 and 58.5 ± 0.58 beats / minute, respectively. In the control group, the value of the heart rate was slightly higher (69.7 ± 0.99 beats / minute), but it was also within the normal range.

The main reaction of the heart rate indicator to the emerging vestibular load in athletes and in the control group was its increase. Only 5% of athletes had a decrease in the value of the heart rate. At the same time, this type of reaction was completely absent among boxers. The presence of a decrease in the value of the heart rate in the case of vestibular irritation in karate and hand-to-hand fighters, even in a small percentage of cases, was considered as a manifestation of the high level of fitness of their heart and vestibular apparatus associated with the peculiarities of training in these sports.

In the course of the main variant of the Voyachek test, an increase in the size of heart contractions was noted in boxers by 3.7±0.72 beats / minute, in karate fighters by 3.0±0.67 beats/minute, in hand-to-hand fighters by 2.0±0.28 beats/ minute. At the same time, in the control group, this indicator changed by 5.5±0.62 beats / minute ($p<0.01$).

The peculiarities of the reaction of the heart of athletes, also associated with the position of their head during the rotation test, were noted. These features are due to the fact that the reaction of the heart when the body rotates when the head is tilted to the right and left may differ. Table 1 shows the changes in heart rate in the case of the test in conditions of head tilt to the right, slightly lower than in the course of head tilt to the left. Differences were obtained in the magnitudes of reactions in all sports, which were small, but had reliability. This difference is due to the fact that in the sports considered, the right hand and the right shoulder girdle in right-handers (there were the bulk of the subjects) in the course of performing the bulk of sports actions to a greater extent ensure their effectiveness and optimal position in the head space required for a normal level muscle tone [18,19]. For this reason, the adaptation of the vestibular apparatus in relation to rotational loads occurs to a greater extent in the case of an inclination of the head to the right. Apparently, in all martial arts this takes place, but to a different extent. Obviously, this change in the position of the head is most characteristic of hand-to-hand combat, in connection with which a minimal reaction of the heart rate to its rotation is achieved in conditions of different head positions (2.4±0.20 beats / minute).

Apparently, due to the most "dense" direct contact with the enemy with a high saturation of movements in hand-to-hand fighters with elements of rotation, they develop the highest adaptation of the heart reaction to the existing elements of training and competitive activity [20,21].

Table 1. Dynamics of an increase in heart rate in athletes at different head positions during vestibular load

Observation groups	**Dynamics of growth of heart rate under load in the form of 5 rotations in 10 seconds, M±m**	
	tilt to the left	tilt to the right
Control group (n = 18), beats / minute	6.8±0.62	5.7±0.51 $p_2<0.01$
Boxers (n = 26), beats / minute	4.9±0.42 $p<0.01$ $p_1<0.01$	3.8±0.36 $p<0.01$ $p_1<0.01$ $p_2<0.01$
Karate practitioners (n = 24), strokes / minute	4.2±0.27 $p<0.01$ $p_1<0.05$	2.3±0.22 $p<0.01$ $p_1<0.01$ $p_2<0.01$
Those engaged in hand-to-hand combat (n = 28), strokes / minute	3.2±0.23 $p<0.01$	2.4±0.20 $p<0.01$ $p_2<0.01$

Note: p - reliability of differences between athletes and control, p_1 - reliability of differences in hand-to-hand fighters with boxers and those who go in for karate, p_2 - reliability of differences in test results when tilting the head to the right and to the left.

The research revealed the peculiarities of the reaction of the heart rate at rotational loads of different durations in the examined representatives of different types of martial arts. It was found (table 2) that in the case of an increase in the duration of vestibular stimulation by 2 times, it increased in the control by 46.9%, that is, not strictly proportional to the increase in rotations. The found dependence among the athletes was inverse: the lower the reaction to five revolutions, the more its increase was at 10 revolutions (for boxers by 33.9%, among those who go in for karate by 40.0%, among hand-to-hand fighters by 50.0%).

In boxers, in a test with five revolutions, the chronotropic reaction of the heart turned out to be on average 5.3±0.25 beats/minute, then at 10 revolutions it additionally increased by an average of 1.8 beats / minute, reaching 7.1±0.27 beats/minute. For karate fighters, these values were 4.5±0.22 beats / minute, 1.8 beats / minute, 6.3±0.31 beats / minute, respectively. For hand-to-hand fighters, these figures were 3.2±0.33 beats/minute, 1.6 beats / minute, 4.8±0.29 beats/minute, respectively. Consequently, the relative increase in the reaction of the heart in the first and second was greater than in the third. It can be thought that it is for hand-to-hand fighters that more economical mobilization of the functional reserves of the heart under the influence of a vestibular stimulus and a more economical reaction of the heart muscle

with an increase in the duration of the acting stimulus are characteristic [22,23].

Table 2. Dynamics of an increase in heart rate among athletes with different duration of vestibular load in the form of head tilt down

Observation groups	Dynamics of growth of heart rate during exercise	
	5 spins in 10 seconds	10 spins in 20 seconds
Control group (n = 18), beats / minute	6.6±0.54	9.7±0.70 $p_2<0.01$
Boxers (n = 26), beats / minute	5.3±0.25 $p<0.01$ $p_1<0.01$	7.1±0.27 $p<0.01$ $p_1<0.01$ $p_2<0.01$
Karate practitioners (n = 24), strokes / minute	4.5±0.22 $p<0.01$ $p_1<0.01$	6.3±0.31 $p<0.01$ $p_1<0.01$ $p_2<0.01$
Those engaged in hand-to-hand combat (n = 28), strokes / minute	3.2±0.33 $p<0.01$	4.8±0.29 $p<0.01$ $p_2<0.01$

Note: p - reliability of differences between athletes and control, p_1 - reliability of differences in hand-to-hand fighters with boxers and those who go in for karate, p_2 - reliability of differences in changes in heart rate at different duration of vestibular load.

The value of systolic blood pressure in boxers, karate and hand-to-hand fighters was comparable - 113.4±0.67 mm Hg, 112.4±0.52 mm Hg. and 112.0±0.73 mm Hg. Art., respectively. The average value of this indicator in the control group was slightly higher - 123.6±1.16 mm Hg. Art. ($p<0.05$), which is consistent with the data on the formation of some hypotension in regularly involved in sports [24,25].

Under rotational load, the main reaction of systolic blood pressure at any position of the head in space was an increase. Approximately 10% of the surveyed had a slight decrease (only 1-2 mm Hg). The magnitude of the increase in systolic blood pressure in all athletes and in the control group was comparable - 4.0±0.67 mm Hg; 3.9±0.59 mm Hg; 3.9±0.46 mm Hg and 3.8±1.02 mm Hg. Art., respectively. The found constancy of the response of systolic blood pressure to rotation was observed at any position of the head [26,27]. No intergroup differences were found for this indicator.

Under conditions of doubling the time of the rotational load, the increase in systolic blood pressure in athletes was on average 1.7±0.39 mm Hg. Art. (about 40.0%) more than with a ten second load. At the same time, there was no correlation between these values. The increase in systolic blood pressure in the case of doubling the duration of the rotational load in the control group was significantly greater - 4.6±0.92 mm Hg. Art. (121.0%; $p<0.01$) than among the representatives of all sports taken into the study.

The level of diastolic pressure before vestibular loading did not differ significantly among all examined athletes and averaged 69.6±1.10 mm Hg (in control 80.3±0.45 mm Hg). The average value of the diastolic blood pressure response value during rotational load in the examined athletes slightly and comparable increased in all on average by 1.6±0.42 mm Hg. Art.

The found dynamics of diastolic blood pressure determined the changes in pulse pressure during vestibular stimulation [28]. In the control group, changes in this indicator for each subject were multidirectional and at the group level were unreliable - 1.1±1.26 mm Hg. Art. ($p>0.05$), while boxers, karate fighters and hand-to-hand fighters showed a significant increase in pulse pressure by an average of 2.5±0.43 mm Hg. Art. ($p<0.01$). The revealed features indicated a high degree of adaptation of the cardiovascular system among representatives of martial arts to rotational loads and a high margin of safety of the functional capabilities of their circulatory system.

Regular feasible muscular activity in the form of sports training stimulates the level of implementation of metabolic processes, increases and maintains at an increased level the processes that implement protein synthesis and energy production in the body. This has a positive effect on the mental and physical potential of a person [29].

In conditions of increasing physical activity in the human body, the phenomenon of fatigue inevitably arises - a special physiological state that temporarily occurs against the background of active prolonged muscular activity and leads to a decrease in its effectiveness. The development of the phenomenon of fatigue against the background of exercise is a strong stimulant that uses the reserves available in the organs and cells of the body, and causes the implementation of recovery processes. It can be acute, occurring in a short time, and it can be chronic, persisting for weeks or months. Fatigue in athletes can be general, exciting the implementation of many functions of their entire body, and local, affecting a separate small muscle group, organ or one organ system. There are two phases of fatigue. The first phase is compensated fatigue, in which there is no pronounced weakening of sports performance due to the activation of the reserve capabilities of the body. The second phase is uncompensated fatigue associated with the exhaustion of the body's reserve capacities and a pronounced decrease in working capacity [30].

After the completion of physical activity, including against the background of fatigue, recovery develops, associated with a gradual transition of physiological and biochemical parameters to the level of the initial state. The period during which the general functional status is restored after sports activities is called the recovery period. In the period of recovery, assimilation processes are very pronounced. At this time, the increase in energy reserves is mainly going with an excess over the initial level (the phenomenon of over-recovery). This is of great biological importance for

increasing, including in martial arts, the level of training of a person and his organ systems, which contributes to an increase in overall performance. In sports, there are phases of early and late recovery. The early phase ends a few minutes after light activity, after hard work a few hours later. The late phase of physical recovery can last for several days [31].

After physical exertion, including in martial arts, the functions of individual body systems are restored at different times. The earliest after exercise returns to the level of outcome, the function of external respiration, later the heart rate and blood pressure level stabilize, and even later, after a day or more, sensorimotor reactions are optimized, and the basal metabolism can be restored within three days [32](Figure 1).

Figure 1. The beginning of the recovery process against the background of physical fatigue (https://krasunia.ru/wp-content/uploads/7/2/2/722cfed115aa2932506f5e3fa22cbde9.jpeg)

Long-term sports activity leads to the development of adaptation to it as a result of the inclusion of hidden reserves of cells and organs. Physiological changes in the parameters of the organism that occur against the background of physical exertion are based on complex rearrangements in all systems of a living organism. The important mechanisms of adaptation in conditions of physical activity of a sports nature include an increase in the reserves of glycogen and triglycerides in the composition of muscle fibers, an increase in the activity of respiratory enzymes, an increase in the number of mitochondria in all cells of the body, inhibition of anaerobic metabolism due to an increase in aerobic metabolism. A person who has adapted to sports loads has much larger reserves and is able to use them quickly [33].

Against the background of systematic sports training, the volume of the heart is able to increase 2-3 times, the maximum oxygen consumption increases 10 times, pulmonary ventilation - 20-30 times, the resistance to the development of a state of hypoxia significantly increases. A person with high morphological and functional parameters of organ systems is able to perform a long-term large amount of sports work. The morphofunctional features of organs and their systems in the body, arising under conditions of regular sports loads, including martial arts, are called physiological characteristics of fitness. Under these conditions, the processes of higher nervous activity, the work of the neuromuscular, respiratory, cardiovascular, excretory systems are improved, the metabolism is intensified and the work of the entire endocrine system is improved [34] (Figure 2).

Figure 2. High physical fitness (https://im0-tub-ru.yandex.net/i?id=818f03fc04a507c03e9395f25478928c-l&ref=rim&n=13&w=640&h=640)

Improvement of the functional mechanisms of neurohumoral regulation in sports is strongly associated with an increase in the ability of the adrenal cortex to generate the required amount of corticosteroids, an increase in the synthetic properties of the endocrine pancreas, a physiologically justified weakening of insulin synthesis and a decrease in its level in the blood outside of exercise, a weakening of the insulin response to glucose entering the blood during consumption of carbohydrate food and muscle load, inhibition of synthesis in the liver of triglycerides and low density lipoproteins [35].

A well-trained athlete uses less energy at rest than a physically untrained person. At rest in the morning, on an empty stomach, on days not preceded by serious physical activity, the total energy expenditure of a trained person is 15% less than that of an untrained person. This is due to a decrease in the level of oxygen consumption and the optimization of the gas exchange process in the lungs. So, at rest in trained people the ventilation activity of the lungs is lower than in those who do not regularly exercise. This is determined by the low frequency and greater depth of respiratory acts. These indicators are strongly associated with

the level of fitness and the severity of maximum oxygen consumption. The more trained a person is, the more oxygen his body can consume during maximum sports work. The highest rates (5.5-6.5 l/min) were found among international-class athletes who are in the best shape during the examination. Slightly lower values of this indicator (about 4.5-5.5 l/min) are observed in less trained masters of sports and individual first-class athletes. In people with a second or third sports category, the value of maximum oxygen consumption is even lower, amounting to approximately 3.5 - 4.5 l/min. A value of this parameter less than 3 l/min indicates a low level of fitness. As a result of the increase in the strength capabilities of the respiratory muscles, the volume of the vital capacity of the lungs increases, the value of the oxygen utilization coefficient increases, the ability of the respiratory center to maintain excitement for a long time increases [36].

The slightly reduced level of the minute blood volume in the trained person at rest compared to the level in the untrained is associated with the optimal heart rate. A decrease in heart rate is a reliable sign of physiological fitness. In athletes involved in martial arts, the heart rate also decreases, which is not observed in physically untrained people, even young people [37,38] (Figura 3).

Figure 3. Regular physical activity normalizes heart activity (http://www.vladimirantonov.ru/wp-content/uploads/2015/04/VO2MaxTest.jpg)

Muscle activity in martial arts helps to increase the lumen of blood vessels and reduce their tone [39]. Against the background of regular sports training, the level of blood pressure among martial arts fighters is physiologically permissible decreases. As a result of an increase in the density of the location of blood vessels and their high elasticity in regularly exercising, blood pressure outside the load is slightly lower than normal [40]. The maximum heart rate in those who regularly exercise under physical stress can reach a high frequency, and the systolic pressure can be at a low level for a long time. In an untrained person, the heart cannot reach a high frequency of contractions, and an increase in systolic and diastolic pressure in him can lead to pre-pathological and pathological conditions even in conditions of short-term intensive work [41]. In the case of regular training in martial arts, additional capillaries are formed in the myocardium, the capacity of the coronary vessels increases, the content of myoglobin increases, and the density of adrenergic nerve fibers increases [42]. For this reason, martial artists increase the maximum rate of contraction and relaxation of the heart with an increase in the stroke and cardiac output and the frequency of its contractions [43].

The increase in strength and endurance of muscles that occurs during regular sports activities leads to an increase in the functional capabilities of extracardiac factors of blood circulation. There is an increase in the work of skeletal muscles, strengthening of the valves of the veins, the suction effect of the chest, large vessels and heart cavities is activated [44].

IV. CONCLUSION

Regular sports activity trains the body and allows a person to do a very significant job. This leads to an increase in the functional activation of all body systems, an increase in their reserve characteristics due to an increase in the level of fitness. Each organ, each organ system, as a result of targeted muscle training, increases the level of biological capabilities, resulting in significant human performance. Currently, physiology needs to clarify information about the effect of irritation of vestibular receptors during motor activity on the functional state of the cardiovascular system. In this regard, it is very important to continue the study of the dynamics of the parameters of cardiac activity with various feasible regular variants of sports activity in the course of targeted training, including in single combats.

Martial arts help enhance adaptation to vestibular loads and optimize reactions heart in response to vestibular irritation. The specificity of movements, which takes place in different types of martial arts, affects the reaction of the heart in tests with a change in the position of the head in space. These changes are directly related to the heart rate and are the most physiological in hand-to-hand fighters compared to boxers and karate fighters. Changes in blood pressure values, apparently, are not associated with the peculiarities of movements in representatives of different types of martial arts.

ACKNOWLEDGMENT

The authors would like to thank their colleague for their contribution and support to the research. They are also thankful to all the reviewers who gave their valuable inputs to the manuscript and helped in completing the paper.

REFERENCES

[1] V.Y. Karpov, S.Y. Zavalishina, E.D. Bakulina, A.V. Dorontsev, A.V. Gusev, T.Y. Fedorova and V.A.

Okolelova, "The Physiological Response of the Body to Low Temperatures", Journal of Biochemical Technology, Vol.12, No.1, 2021, pp.27–31. https://doi.org/10.51847/m1aah69aPr

[2] S.Y. Zavalishina, E.D. Bakulina, M.V. Eremin, E.S. Kumantsova, A.V. Dorontsev and E.S. Petina, "Functional Changes in the Human Body in the Model of Acute Respiratory Infection", Journal of Biochemical Technology, Vol.12, No.1, 2021, pp. 22–26. https://doi.org/10.51847/F8mofsugnZ

[3] S.Y. Zavalishina, V.Y. Karpov, A.Y. Zagorodnikova, A.A. Ryazantsev, R.R. Alikhojin and N.N. Voronova, "Functional Mechanisms for Maintaining Posture in Humans during Ontogenesis", Journal of Biochemical Technology, Vol.12, No.1, 2021, pp.36–39. https://doi.org/10.51847/5LNdtyTcdH

[4] V.Yu.Karpov, S.Yu. Zavalishina, A.V. Gusev, V.I. Sharagin and E.S. Petina, "Physical Rehabilitation of Girls with Neurocirculatory Dystonia", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.2045–2050.

[5] V.Yu. Karpov, S.Yu. Zavalishina, A.V. Dorontsev, K.K. Skorosov and D.A. Ivanov, "Physiological Basis of Physical Rehabilitation of Athletes after Ankle Injuries", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.2051–2055.

[6] S.Yu. Zavalishina, V.Yu. Karpov, A.V. Dorontsev, E.N. Kaldarikov and R.V. Koziakov, "Functional Features of the Body in the Presence of Scoliosis", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.2008–2012.

[7] V.Yu. Karpov, S.Yu. Zavalishina, A.V. Romanova and T.M. Voevodina, " Physiological Mechanisms of Rehabilitation in Vegetative Vascular Dystonia", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.1261–1265.

[8] V.Yu. Karpov, S.Yu. Zavalishina, A.V. Romanova, M.N. Komarov and V.I. Sharagin, "Congenital Heart Defects in Children and the Main Approaches to Rehabilitation After their Surgical Treatment", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.1303–1307.

[9] S.Yu. Zavalishina and E.S. Kachenkova, "Physiological changes in cardiovascular system with vestibular irritation among representatives of team sports", Teoriya i praktika fizicheskoy kultury, No.8, 2021, pp.24–26.

[10] S.Yu. Zavalishina, O.N. Makurina, G.S. Mal and E.S. Tkacheva, "Influence of Systematic Football Training on Adolescent Functional Characteristics", Biomedical & Pharmacology Journal, Vol.14, No.2, 2021, pp.533–540. https://dx.doi.org/10.13005/bpj/2155

[11] V.Yu. Karpov, S.Yu. Zavalishina, A.V. Dorontsev, N.N. Voronova, A.M. Shulgin, V.I. Sharagin and R.V. Koz'yakov, "Influence of Regular Feasible Physical Activity on the Platelet's Functional Activity of the Second Mature Age People", Systematic Reviews in Pharmacy, Vol.11, No.8, 2020, pp.439–445.

[12] S.Yu. Zavalishina, V.Yu. Karpov, M.V. Eremin, N.G. Pryanikova, S. Tatarova and R.V. Kozjakov, "The functional state of the body of older men experiencing regular recreational stress", International Journal of Pharmaceutical Research, Vol.13, No.1, 2020, pp.292–298.

[13] A.S. Nazarenko and A.S. Chinkin, "The influence of vestibular irritation on the statokinetic stability of athletes of various specializations", Science and Sports: Current Trends, vol.7, No.2, 2015, pp. 78–85.

[14] A.S. Nazarenko and A.S. Chinkin, "Cardiovascular reactions to vestibular irritation in various sports", Scientific notes of the University. P.F. Lesgaft, No.2(96), 2013, pp.106–111.

[15] A.S. Rovny, O.A. Rovnaya and V.A. Galimsky, " The role of sensory systems in the control of complex-coordinated movements of athletes", Slobozhansky scientific and sports bulletin, No.3(41), 2014, pp.78–85.

[16] D.V. Syshko, "Characteristics of electrical processes of the heart in boxers under conditions of vestibular stimulation", Pedagogy, psychology and medico-biological problems of physical education and sports, No.11, 2009, pp.114–117.

[17] E.S. Kachenkova, I.V. Kulkova, S.Yu. Zavalishina and E.S. Tkacheva, " Health-improving training of 50-60 year-old males in prevention of cardiovascular diseases", Teoriya i Praktika Fizicheskoy Kultury, No.9, 2020, pp. 62-64.

[18] K.D. Savina and G.D. Syshko, "Autonomic regulation and functional state of the sinus node in highly qualified athletes under conditions of vestibular stimulation", Scientific notes of the V.I. Vernadsky. Series: Biology, Chemistry, Vol. 27 (66), No.1, 2014, pp.161–169.

[19] A.S. Nazarenko, A.S. Chinkin, " Cardiovascular, motor and sensory reactions of athletes of different specializations to vestibular irritation", Human Physiology, Vol.37, No.6, 2011, pp.98–105.

[20] A.S. Chinkin and R.I. Khusnullina, " Vestibular reactions of young athletes engaged in ski jumping", Human physiology, Vol.34, No.2, 2008, pp.118–123.

[21] M.V. Parfenov, I.V. Grigorieva, A.A. Sikorsky and D.S. Grigoriev, "Features of functional fitness of basketball players with different levels of vestibular stability", Bulletin of the Tula State University. Physical education. Sport, No.3, 2017, pp.130–139.

[22] S.V. Korsakov, I.A. Solodov, A.N. Shatagin, A.V. Melikov and E.G. Andreeva, "Training to develop balance while learning to move on roller skis", Scientific notes of the University. P.F. Lesgaft, No.8 (138), 2016, pp.79–96.

[23] E.V. Sinelnik and V.A. Lyapin, "Features of statokinetic resistance of athletes specializing in karate and kickboxing with different initial vegetative status", Pedagogical-psychological and medical-biological problems of physical culture and sports, Vol.11, No.4, 2016, pp.225–230.

[24] S.Y. Zavalishina and A.S. Makhov, "Physiologically verified training method for sambo wrestlers with hearing

impairments", Teoriya i Praktika Fizicheskoy Kultury, No.4, 2019, pp.72.

[25] E.S. Kachenkova, S.Y. Zavalishina, O.N. Makurina, I.V. Kulkova and E.S. Tkacheva, " Physiological Reaction of the Cardiovascular System of Men 50-59 Years to Feasible Regular Physical Activity", Biomedical & Pharmacology Journal, No.13(4), 2020, pp.1719-1727. DOI : https://dx.doi.org/10.13005/bpj/2046

[26] S.Y. Zavalishina, V.Y. Karpov, M.V. Eremin, E.D. Bakulina, A.S. Boldov and A.V. Dorontsev, "Optimization of Physiological Processes in Conditions Staged Activation of Motor Activity in Cardiac Patients", Biomedical & Pharmacology Journal. 2020; No.13(4), 2020,pp.1653–1658. DOI : https://dx.doi.org/10.13005/bpj/2040

[27] M.N. Komarov, S.Yu. Zavalishina, A.A. Karpushkin, A.V. Malyshev and E.S. Kumantsova, "Rehabilitation Potential of Physical Activity Complex with Elements of Sports and Health Tourism in Case of Dysfunction of the Cardiovascular System in Adolescence", Indian Journal of Public Health Research & Development, Vol.10, №10, 2019, pp.1814–1818.

[28] E.S. Kachenkova, S.Yu. Zavalishina, Yu.V. Zbrueva and O.I. Kosukhina, "The dynamics of the functional state of the body of men 50-59 years old against the backdrop of health training", International Journal of Pharmaceutical Research, №1, 2020, pp.1378–1385.

[29] S.Yu. Zavalishina and A.S. Makhov, "Functional characteristics of athletes with cerebral palsy, "Teoriya i Praktika Fizicheskoy Kultury, No.7, 2019, pp.39.

[30] V.Yu. Karpov, S.Yu. Zavalishina, A.A. Ryazantsev, I.V. Nazarova and A. M. Shulgin, "Physiologically Based Approaches to the Rehabilitation of Scoliosis, "Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.2040–2044.

[31] S.Y. Zavalishina, M.N. Komarov, A.V. Malyshev, R.V. Koziakov and Y.B. Kashenkov, "Physiologically justified rehabilitation of the children who underwent an operation for congenital heart disease, including tourism elements", Indian Journal of Public Health Research and Development, Vol.10, No.10, 2019, pp.1091–1095.

[32] O.N. Makurina, G.S. Mal, S.Yu. Zavalishina and I.N. Medvedev, "Functional Features of Platelets in Rats Fed a Standard Diet with Low Antioxidant Content During Ontogenesis ", Indian Journal of Public Health Research & Development, Vol.10, No.10, 2019, pp.999–1003.

[33] N.V. Vorobyeva, S.Yu. Zavalishina, G.S. Mal, M.A. Grishan, L.P. Lazurina and I.I. Fayzullina, "Physiological Features of Platelets in Aging Outbred Rats", Indian Journal of Public Health Research & Development, Vol.10, No.8, 2019, pp.1925–1929.

[34] G.S. Mal and S.Yu. Zavalishina, "Functional Platelet Activity During Ontogeny in Rats", Indian Journal of Public Health Research & Development, Vol.10, No.8, 2019, pp.1915–1919.

[35] S.Yu. Zavalishina and A.S. Makhov, "Physiologically justified result of use of static exercises for cerebral palsy diagnosed patients", Teoriya i Praktika Fizicheskoy Kultury, No.8, 2019, pp.41.

[36] G.S. Mal, S.Yu. Zavalishina, O.N. Makurina, V.V. Zaitsev and T.I. Glagoleva, "Functional Features of Vascular Endothelium with Developing Arterial Hypertension", Prensa Med Argent, Vol.105, No.1, 2019, 1000331.

[37] E.S. Tkacheva and S.Yu. Zavalishina, "Functional Features of Platelet Secretion in Piglets During Early Ontogenesis", Biomedical & Pharmacology Journal, Vol.12, No.1, 2019, pp.485–489. http://dx.doi.org/10.13005/bpj/1665

[38] E.V. Morozova, S.V. Shmeleva, O.G. Rysakova, E.D. Bakulina and S.Yu. Zavalishina, "Psychological Rehabilitation of Disabled People Due to Diseases of the Musculoskeletal System and Connective Tissue", Prensa Med Argent, Vol.104, No.2, 2018, DOI: 10.4172/0032-745X.1000284

[39] A.S. Makhov and S.Yu. Zavalishina, "Physiological characteristics of children with Down syndrome against the background of regular football practices", Teoriya i Praktika Fizicheskoy Kultury, No.3, 2019, pp.54.

[40] S.Y. Zavalishina and A.S. Makhov, "Efforts to facilitate functional capabilities of motor sphere in children diagnosed with cerebral palsy", Teoriya i Praktika Fizicheskoy Kultury, No.1, 2019, pp.70.

[41] K.Patel, M.F. Blackard, D.A. Pandya, P. Srivastava, M. Gupta and A.S. Pandya, "Hyperuricemia and Cardiovascular Implications", WSEAS Transactions on Biology and Biomedicine, Vol. 17, 2020, pp.143–148.

[42] R. Ruvalcaba-Ontiveros, H. Esparza-Ponce, A. Carrasco-Hernandez, C.D. Gómez-Esparza, E. Orrantia-Borunda, J. G. Murillo-Ramirez, A. Duarte-Moller and J. M. Olivares-Ramirez, "Synthesis of Gold Nanoshells with Plasmon Resonance Tuned to the Infrared Region of the Electromagnetic Spectrum", WSEAS Transactions on Biology and Biomedicine, Vol.16, 2019, pp. 29–36.

[43] P.M. Parés-Casanova, A. Medina and H.K. Sofiane, "Skull Dorsal Asymmetries Between Three Different Rabbit Types Signals Stress in Paedomorpic Animals", WSEAS Transactions on Biology and Biomedicine, Vol.16, 2019, pp. 21-28.

[44] A. Canelo, I. Tejado, J.E. Traver, C. Nuevo and B.M. Vinagre, "A Human-inspired Simulator for the Study of Orientation and Balance Control", WSEAS Transactions on Biology and Biomedicine, Vol.16, 2019, pp.10-20.

Conflict of Interest

No conflict of interest is declared.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

This work was done in collaboration with all authors. Medvedev I.N. supervised the development of the general concept of the study and prepared the plan of the experiment, carried out the final analysis and interpretation of all the data obtained, completed the editing of the manuscript of the article, Karpov V.Yu. is the author of the research idea, led the

experiments, Makurina O.N. carried out a statistical analysis of the received digital materials, conducted a literary search, participated in the analysis of scientific data, Eremin N.V. participated in the study of people under supervision and analyzed the data obtained by her personally, Dorontsev A.V. participated in the study of people under observation and analyzed the data obtained personally by him, Sibgatulina F.R. participated in the study of people under observation and analyzed the data obtained personally by him, Ivanov D.A. participated in the study of people taken under observation, and analyzed the data obtained by her personally. All authors jointly discussed and agreed on the study design, its concept, the results obtained and their interpretation. All authors participated in the preparation of the final version of the manuscript, read it and approved it.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself
The study was conducted at the expense of the authors.