Journal of Physical Education and Sport ® (JPES), Vol.20 (6), Art 493, pp. 3660 - 3670, 2020
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Link between brain circulation and nervous mobility of athletes and non-athletes during the orthostatic test

LILIIA YUKHYMENKO[1], MYKOLA MAKARCHUK[2], YEVGENIY IMAS[3], YAKIV SHCHERBASHYN[4], LESIA KOROBEYNIKOVA[5], GEORGIY KOROBEYNIKOV[6], MYROSLAV DUTCHAK[7]
[1]Cherkasy National University named after Bohdan Khmelnytsky, UKRAINE
[2]National University named after Taras Shevchenko, UKRAINE
[3,4,5,6,7,] National University of Physical Education and Sport, Kiev, UKRAINE

Published online: December 30, 2020
(Accepted for publication: December 15, 2020)
DOI:10.7752/jpes.2020.06493

Abstract.
Purpose: to study the cerebral blood circulation in people during a tilt-table test depending on the level of nervous processes mobility and physical fitness. *Material:* to studied compensatory reactions of systemic hemodynamics and blood circulation of the brain to orthostasis in athletes (n=31) and non-athletes (n=31) aged 18-21 years who had different levels of FMNP in rheoplethysmography. First, we examined the level of functional mobility of nervous processes in athletes and non-athletes by the original method, then we divided them into groups with high and low levels of FMNP. The next step was to check hemodynamic parameters in groups with different levels of FMNP and physical performance and recorded them in lying and head-up-tilt positions of the body obtained by passive movement on the turntable at 90^0. There was a 15-minute pause between lying and head-up-tilt rheograms. Brain rheograms were recorded in the basin of the internal carotid arteries (front-mastoid region) and the vertebro-basilar basin (mastoid-occipital region) of both brain hemispheres. Head-up-tilt test for each subject was used at least 3 times. *Results:* The obtained results showed that both athletes and non-athletes with a high level of functional mobility of nervous processes were characterized by a low tone of resistive vessels in the internal carotid arteries basin of both hemispheres compared to those with a low level of FMNP. It was compensated by the predominance of the narrowing effect of the elastic type vessels and vascular resistance in the vertebro-basilar basin of the brain, which balanced the processes of cerebral blood flow. Participants with a low level of nervous processes mobility in response to orthostatic load showed opposite changes in cerebral hemodynamics, which was manifested by excessive spastic effect of vascular resistance in the internal carotid arteries and simultaneous vasodilation of resistive vessels in the vertebro-basilar basin of both hemispheres. *Conclusion:* Athletes with different FMNP showed differences in the economy of the cardiovascular system in favor of people with high level. Therefore, the development of individual training programs and prediction of their effectiveness should be based not only on the information about differences in their physical fitness, but also on the level of their FMNP.
Keywords: athletes, brain circulation, mobility, orthostatic

Introduction

Carrying out training sessions or rehabilitation exercises without taking into account individual variants of mobility of nervous processes can lead to both pre-pathological and pathological heart disorders and cerebral hemodynamics (CRH) (Donnelly et al., 2016; Korobeynikov et al., 2016). At the same time, a comprehensive systematic assessment of the functional features of the cardiovascular and nervous systems, the state of physical qualities allows addressing issues of monitoring the adaptive capacity and level of physical fitness of an athlete, contributes to the correction of the training process. The activity of the cardiovascular system, the CRH optimality depend on ones morpho-functional development, its regulatory structures, the influence of environmental conditions (Baevsky et al., 2011; Yukhymenko et al., 2018). The CRH indicators of blood circulation obtained during exercise with a change in body position in space are very important. Such indicators of hemodynamics reflect complex interactions of myogenic, neural, metabolic, humoral factors which underlie autoregulation processes of homeostasis maintenance (Jeong et al., 2012; Aponchuk et al., 2017).

In this work, we proceeded from the fact that the central nervous system (CNS) carries out the management and coordination of all human organs and systems. On the other hand, we took into account the fact that the cardiovascular system is crucial for optimal brain function (Staals et al., 2016; Odynets et al., 2019). It is known that the individual specificity of hemodynamics is determined by the innate properties of the nervous system, which confirms the high coefficient of heredity (Holzinger) (Makarenko et al., 2011; Korobeynikov et al., 2018). The leading characteristics of the nervous processes mobility affecting the functional state of the brain vessels are the speed of nervous excitation, the speed of excitation propagation by the nerve fibers of blood

Corresponding Author: GEORGIY KOROBEYNIKOV, E-mail: k.george.65.w@gmail

vessels, the speed of its termination. It is known that neurogenic mechanisms of cerebral hemodynamics autoregulation have a corrective effect on the blood, participating in the redistribution of blood flow and changing the tone of cerebral vessels. Several literature sources proved that angiotonic changes were indirectly related to the lability of nervous processes and depended on the level of metabolism in neural networks, the activity of humoral and metabolic mechanisms (Boedtkjer et al., 2018; Yukhymenko et al., 2019). Therefore, in our opinion, it is interesting to find out the participation of nervous processes in the cerebral hemodynamics autoregulatory mechanisms of athletes and untrained people. The solution of this problem is of practical importance for physical therapy and sports, it can be useful for organizing the work of automatic systems operators, drivers and the military (Korobeĭnikov et al., 2000; Olena et al., 2017). Knowledge of the individual reactivity of the cerebral circulation can significantly supplement the criteria of human resistance to stress stimuli arising during life. We should note that the role of nervous processes mobility in the nature of cerebral circulation under such conditions has not been studied yet. Such studies are promising for sports because they deepen knowledge about the diversity of human adaptive mechanisms (Baggish et al., 2010; Romanenko et al., 2018). Information about the state of cerebral hemodynamics is important not only for athletes but also for coaches. Knowledge of cerebral hemodynamics will allow to develop individual modes of training physical activity, to exercise self-control and monitor the dynamics of physical development, to conduct a timely assessment and a clear prediction of changes in the functional state of a person.

It should be noted that scientists, using typological approaches, determine different options for blood circulation depending on the constitutional characteristics of a person, his/her blood group and reactivity of the organism. Researchers noted numerous cases of multifaceted reactions to the same stimulus in people with different individual characteristics and types of higher nervous activity. The study of hemodynamic parameters of healthy people with different nervous processes mobility under orthostatic load allows identifying genetically determined features of the regulatory mechanisms of blood circulation and its adaptive abilities (Makarenko et al., 2011; Tushchenko et al., 2019).

Despite the number of studies of cerebral hemodynamics conducted in different positions of the body, their results indicated the ambiguity of compensatory reactions that developed in these conditions (Korobeĭnikov 1993; Korobeĭnikov 1994; Kapilevich et al., 2019; Korobeynikov et al., 2019). The role of typological characteristics as the leading components of the general state of the CNS in the adaptive responses of cerebral blood circulation in response to gravitational loading is still unclear. Currently, there is virtually no analysis of changes in the CNS during postural load in humans, depending on the level of nervous processes mobility.

The purpose of the research was to study the cerebral blood circulation in people during a tilt-table test depending on the level of nervous processes mobility and physical fitness.

The working hypothesis was that higher brain structures stimulate the nature and direction of the compensatory-adaptive response of the CRH. At the same time, the phenomenon of autoregulation is manifested in the blood supply to cerebral vessels, it is related to the speed-time properties of FMNP and depends on the level of physical fitness of a person.

Materials and methods

In accordance with the purpose of the study, we first identified the level of functional mobility of nervous processes and physical fitness, and then studied the features of cerebral circulation in different experimental positions. We examined 188 students of Bohdan Khmelnytsky Cherkasy National University, aged 18-21 (90 athletes and 155 non-athletes). We selected 62 people (31 athletes and 31 non-athletes) who had a high and low level of nervous processes mobility, and formed 4 groups of participants. Non-athletes: group I (n= 17) and group II (n = 14) had respectively high and low levels of nervous processes mobility. Athletes: group III had high (n =16) and group IV had low (n = 15) levels of nervous processes mobility. At the time of examination, athletes were in the process of deepening their sports specialization with a standard of physical activity, with 10-12 hours per week on average. All individuals agreed to participate in the study. The research was conducted in accordance with the provisions of the Helsinki Declaration (1975, 1996-2013). This was confirmed by the Law on Bioethical Expertise № 2 of 03.12.2020 of Bohdan Khmelnytsky Cherkasy National University (order № 291 on the establishment of the bioethics commission dated 22.12.2015). Establishment of The individual features of the higher parts of the central nervous system (CNS) were determined in accordance with the nervous processes mobility on the computer device ("Diagnost-1M", Ukraine) with the help of the original method (Makarenko et al., 2016). The measure of the nervous processes mobility was the time (seconds) of the test task to differentiate 120 signals of sound modality. Pure sound signals with tones of 300, 600 and 1000 Hz were used. Two of them (300 and 1000 Hz) were positive, during their presentation the subjects should press the appropriate keys with their left or right hand. During the brake signal (600 Hz) presentation they should not press any of them. The faster the subject performed tasks related to the differentiation of auditory signals, the higher was his/her ability of nervous processes. The test was conducted in the "feedback" mode, which allowed the subject to adjust the supply of auditory signals at the individual optimal rate (the rate of stimulus varied within ± 20 ms, depending on error reactions: in case of error it decreased, and after the correct answers it increased).

The Rufier Index (IR) was used to examine both healthy non-athletes and professional athletes and to assess physical fitness of all participants (Korobeĭnikov et al., 1995; Yarmak et al., 2019). We used the following technique: after 5-minute rest in a sitting position, the heart rate was calculated for 15 seconds (P1), and then the participant performed 30 squats for 30 seconds. The heart rate was calculated immediately after squats: P2 for the first 15 seconds and P3 the last 15 seconds of the first minute of the recovery period. The obtained results were calculated by the formula:

$$IP = 4\ (P1+P2+P3) - 200 / 10$$

The assessment was performed according to the scale (for adults): up to 0.5 – high; 0.5-5 – good; 6-10 – average; 11-15 – satisfactory; > 15 – low physical fitness. All examined athletes had high (90.1%) and good (9.9%) levels of physical fitness, while non-athletes had good (2.1%), average (23.4%) and satisfactory (74.5%) levels of fitness.

After that, we performed rheoencephalography. ReoCom XAI Medica rheoencephalograph (Kharkiv, Ukraine) was used to study the compensatory reactions of systemic hemodynamics and cerebral circulation. Registration of hemodynamic parameters was performed in lying and head-up tilt body positions. The tilt-table test was obtained by passive body movement on a turntable at 90^0. There was a 15-minute pause between recumbent rheogram recordings and the tilt-table test. The examined person was in a lying position for at least 5 minutes to achieve relative stabilization of the functional parameters of the CRH (signal recording took place at the sixth minute), and in orthostasis it was at least 6 minutes (signal recording took place at the second minute).

Rheography (REG) was recorded in the basin of the internal carotid arteries (front-mastoid region) and in the vertebral-basilar basin (mastoid-occipital region) of both hemispheres of the brain. We determined heart rate (HR), total peripheral vascular resistance (TPVR), mean blood pressure (APm), amplitude of systolic wave (ASW), amplitude of diastolic wave (ADW), dichroic index (DI), large vascular tone (Tl), tone of the middle and small vessels of the brain (Tms).

Statistical processing of the obtained results was carried out by methods of mathematical statistics, using Excel and Statistic software packages for Windows 8.0. The significance of changes and differences between the compared values was assessed by the nonparametric Wilcoxon-Mann-Whitney test. The relationship between the indicators was checked by calculating the Spearman correlation coefficient (rs). Differences between groups and their correlation were considered significant at $P \leq 0.05$.

Results

Indicators of participants rheograms in different body positions were within the norm and formed a sample that did not fall under the law of normal distribution. There was a significant increase in heart rate in response to changes of body position (Table 1).

Table 1 Indicators of systemic hemodynamics of the examined people in different conditions
(median, upper and lower quartiles)

Indicators	lying position		head-u- tilt position (tilt-table test)	
	non-athletes	athletes	non-athletes	athletes
TPVR, dyn cm^5/m^2	1640 (1692.3;1612.1)	1582 (1628.2;1566.4)	1862.4 (1901.7;1826.2)	1822.4 (1883.5;1798.7)
HR, bpm	58.2 (78.2;52.4)	55.2 (78.2;50.3)	82.3 (100.4;80.1)*	71.3 (92.2;68.4)*
AP_m, mmHg	83.7 (89.1;80.5)	78.7 (88.7;62.4)	85.2 (88.9;82.4)	80.2 (84.1;79.5)

Notes: * – relative to lying position; TPVR – total peripheral vascular resistance, HR – heart rate, APm – middle arterial pressure

It should be noted that athletes had lower values of systemic hemodynamics in both studied body positions (but not significantly) compared with non-athletes. This indicates a tendency to more economical functioning of the cardiovascular system (CVS).

No significant differences were found in the CRH of athletes and non-athletes in lying position (Table 2). There was a tendency of decreasing in athletes CRH indicators compared with non-athletes in both hemispheres of the studied brain basins. During the tilt-table test, we observed a simultaneous decrease in ASW, Tms and an increase in ADW and Tl in lying position ($p < 0.05$). Thus, athletes had a more economical level of functioning of systemic hemodynamics and CRH compared with non-athletes in both positions, and their compensatory reactions were smoother. These results indicate that a higher level of physical performance helps to optimize the CVS compensatory-adaptive responses to the tilt-table test.

Table 2 Rheography indicators in the basin of internal carotid artery and in vertebral-basilar basin of the examined people in the conditions of tilt-table test (median, upper and lower quartiles)

Indicators	lying position		head-up-tilt position (tilt-table test)	
	left	right	left	right
front-mastoid region non-athletes				
ASW, Ω	0.066 [0.086;0.057]	0.067 [0.083;0.054]	0.038 [0.061;0.030]*	0.036 [0.065;0.029]*
ADW, Ω	0.019 [0.042;0.015]	0.021 [0.049;0.017]	0.027 [0.045;0.021]*	0.028 [0.041;0.023]*
DI,%	55.0 [66.9;52.2]	56.0 [68.4;51.1]	58.2 [69.1;54.0]	57.0 [69.6;52.1]
T_l, c.u.	0.65 [1.22;0.55]	0.61 [1.18;0.57]	0.83 [1.23;0.87]*	0.86 [1.16;0.79]*
T_{ms}, c.u.	0.55 [0.74;0.50]	0.57 [0.78;0.52]	0.34 [0.52;0.29]**	0.30 [0.55;0.28]**
front-mastoid region athletes				
ASW, Ω	0.058 [0.081;0.052]	0.060 [0.079;0.051]	0.032 [0.056;0.028]*	0.034 [0.055;0.029)]*
ADW, Ω	0.016 [0.033;0.011]	0.020 [0.027;0.015]	0.025 [0.034;0.019]*	0.024 [0.037;0.020]*
DI,%	52.1 [62.4;48.1]	53.0 [59.2;50.2]	56.2 [63.7;48.7]	55.0 [62.3;50.2]
Tl, c.u.	0.60 [1.16;0.53]	0.58 [1.12;0.51]	0.80 [1.17;0.67]*	0.79 [1.11;0.70]*
Tms, c.u.	0.52 [0.68;0.46]	0.51 [0.66;0.48]	0.32 [0.49;0.27]**	0.29 [0.45;0.18]**
mastoid-occipital region non-athletes				
ASW, Ω	0.063 [0.086;0.060]	0.065 [0.083;0.061]	0.032 [0.057;0.029]*	0.034 [0.055;0.030]
ADW, Ω	0.015 [0.023;0.010]	0.017 [0.028;0.012]	0.022 [0.041;0.018]*	0.024 [0.041;0.021]*
DI,%	51.8 [66.1;48.7]	51.7 [65.3;48.2]	54.2 [67.7;50.0]	53.8 [68.6;51.2]
Tl, c.u.	0.58 [1.22;0.52]	0.56 [1.18;0.52]	0.79 [1.27;0.73] *	0.76 [0.96;0.72]*
Tms, c.u.	0.50 [0.72;0.47]	0.51 [0.74;0.48]	0.31 [0.49;0.28]**	0.26 [0.45;0.22]**
mastoid-occipital region athletes				
ASW, Ω	0.058 [0.079;0.048]	0.059 [0.080;0.051]	0.027 [0.048;0.022]*	0.028 [0.050;0.021]
ADW, Ω	0.012 [0.019;0.008]	0.014 [0.022;0.010]	0.020 [0.038;0.015]*	0.019 [0.040;0.014]*
DI,%	49.9 [62.1;40.3]	50.1 [72.2;44.1]	51.1 [70.4;46.7]	49.9 [71.2;43.8]
Tl, c.u.	0.54 [1.06;0.48]	0.52 [1.11;0.49]	0.76 [1.17;0.68]*	0.74 [0.93;0.70]*
Tms, c.u.	0.47 [0.69;0.41]	0.45 [0.70;0.39]	0.28 [0.45;0.21]**	0.23 [0.41;0.18]**

Notes: * – the reliability $p < 0.05$, ** – $p < 0.01$ in lying position; ASW – amplitude of the systolic wave, ADW – amplitude of the diastolic wave, DI – Dicrotic index, Tl – tone of large vessels, Tms – tone of the medium and small vessels of the brain.

Comparison of blood circulation indicators of people with different levels of TMNP recorded in lying position showed that most of the systemic hemodynamics parameters in the internal carotid arteries basin did not differ significantly (p> 0.05), although they had some peculiarities (Table 3).

There was no relationship between FRNP and TPVR (p> 0.05) in lying position. In these conditions, the interhemispheric asymmetry did not exceed 10-11% in all subjects that corresponded to generally accepted clinical norms.

Table 3 Indicators of systemic hemodynamics of examined people with different levels of FMNP in the conditions of tilt-table test (median, upper and lower quartiles)

Indicators	Groups	lying position		head-up-tilt position (tilt-table test)	
		left	right	left	right
TPVR, dyn cm^{-5} c	I	2100.2 [2234.7;2095.0]	2088.1 [2154.2;2062.1)	2250.6 [2293.1;2215.6]	2282.4 [2307.4;2267.5]
	II	1220.3 [1277.3;1179,7]	1231.0 [1282.2;1202.7]	1414.1 [1469.1;1387.3]$^{\#\#}$	1417.3 [1472.3;1388.2]$^{\#\#}$
	III	2078.3 [2114.3;2021.4]	2063.5 [2114.5;2025.6]	2280.7 [2316.7;2246.9]	2294.2 [2347.8;2251.3]
	IV	1214.4 [2258.3;1182.5]	1219.5 [1264.8;1193.5]	1430.6 [1479.3;1402.7]	1435.4 [1485.6;1414.7]
HR, bpm	I	59.5[76.4;52.1]		80.1[101.5;77.8]**	
	II	56.8[73.5;51.1]		83.3[88.8;72.4]*	
	III	51.4[68.3;50.1]		70.2[82.2;68.8]*	
	IV	56.3[74.2;52.1]		72.3[85.3;69.8]*	
APm, mmHg	I	88.8[99.6;82.0]		88.9(101.5;82.4]	
	III	80.2(106.1;78.7]		86.3[103.3;82.5]	
	III	81.3[105.3;79.3]		81.9[105.,2;80.1]	
	IV	76.2[94.3;72.8]		78.6[100.2;76.8]	

Note: * – the reliability of the differences p <0.05, ** – p <0.01 in lying position; # – p <0.05, ## – p <0.01 between high and low levels; TPVR – total peripheral vascular resistance, HR – heart rate, APm – middle arterial pressure. Regardless of the level of physical fitness, people with high FMNP tended to have higher performance and heart rate. In the CRH, both non-athletes and athletes with a high level of FMNP showed a slightly higher but not significant (p> 0.05, Table 4) tone of resistive vessels compared to people with a low level of TMNP. Table 4 Rheography indicators in basin of internal carotid artery of the examined people with different levels of FMNP in conditions of tilt-table test (front-mastoid region, median, upper and lower quartiles)

Indicators	Groups	lying position		head-up-tilt position (tilt-table test)	
		left	right	left	right
ASW, Ω	I	0.068 [0.077;0.062]	0.070 [0.089;0.066]	0.033 [0.052;0.027]**	0.030 [0.045;0.026]**
	II	0.062 [0.079;0.058]	0.064 [0.075;0.059]	0.040 [0.058;0.034]$^{*\#}$	0.041 [0.057;0.038]$^{*\#}$
	III	0.057 [0.072;0.060]	0.067 [0.075;0.061]	0.028 [0.046;0.022]**	0.029 [0.042;0.021]**
	IV	0.059 [0.073;0.051]	0.060 [0.078;0.054]	0.039 [0.065;0.029]$^{*\#}$	0.038 [0.062;0.032]$^{*\#}$
ADW, Ω	I	0.023 [0.042;0.017]	0.024 [0.041;0.021]	0.035 [0.049;0.031]*	0.038 [0.052;0.032]*
	II	0.016 [0.029;0.012]	0.018 [0.031;0.014]	0.021 [0.036;0.018]$^{*\#}$	0.025 [0.042;0.021]$^{*\#}$
	III	0.019 [0.037;0.013]	0.021 [0.039;0.017]	0.037 [0.052;0.030]*	0.039 [0.050;0.031]*
	IV	0.013 [0.023;0.009]	0.014 [0.025;0.010]	0.022 [0.041;0.016]$^{*\#}$	0.024 [0.040;0.015]$^{*\#}$
DI, %	I	56.8 [77.3;50.8]	57.1 [73.7;52.1]	48.1 [63.6;44.3]	47.9 [61.5;42.3]*
	II	54.3 [71.4;49.4]	52.2 [68.2;49.2]	68.1 [74.8;62.5]$^{*\#\#}$	67.3 [75.5;61.9]$^{*\#\#}$
	III	50.2 [72.4;46.1]	51.4 [70.3;49.4]	42.4 [61.2;39.9]	43.2 [63.2;40.1]*
	IV	49.7 [70.2;40.3]	50.6 [69.1;44.3]	62.5 [80.3;59.5]$^{*\#\#}$	63.3 [85.3;60.0]$^{*\#\#}$
Tl, c.u.	I	0.64 [0.85;0.61]	0.63 [0.81;0.58]	0.90 [0.99;0.84]*	0.88 [0.94;0.82]*
	II	0.67 [0.88;0.61]	0.66 [0.83;0.60]	0.79 [0.98;0.71]$^{*\#}$	0.77 [0.94;0.70]$^{*\#}$
	III	0.58 [0.77;0.52]	0.56 [0.78;0.50]	0.83 [0.99;0.78]*	0.82 [0.98;0.79]*
	IV	0.65 [0.83;0.60]	0.63 [0.84;0.58]	0.77 [0.95;0.70]$^{*\#}$	0.75 [0.94;0.69]$^{*\#}$
Tms, c.u.	I	0.53 [0.68;0.44]	0.54 [0.73;0.49]	0.35 [0.57;0.30]*	0.32 [0.48;0.27]*
	II	0.48 [0.68;0.41]	0.50 [0.69;0.47]	0.83 [0.99;0.77]$^{**\#\#}$	0.82 [0.96;0.79]$^{**\#\#}$
	III	0.50 [0.72;0.47]	0.48 [0.72;0.44]	0.32 [0.53;0.28]*	0.30 [0.49;0.25]*
	IV	0.44 [0.63;0.37]	0.42 [0.65;0.36]	0.72 [0.96;0.63]$^{**\#\#}$	0.70 [0.97;0.62]$^{**\#\#}$

Note: * – the reliability of the differences $p < 0.05$, ** – $p < 0.01$ relative to lying position; # – $p < 0.05$, ## – $p < 0.01$ between high and low levels; ASW – amplitude of the systolic wave, ADW – amplitude of the diastolic wave, DI – Dicrotic index, Tl - tone of large vessels, Tms - tone of the medium and small vessels of the brain.

Regardless of the level of nervous processes mobility and physical activity in this position of the body, participants with a high level of nervous processes mobility showed a correlation of Tms and HR (rs = 0.32), Tms and APm (rs = 0.33). Both athletes and non-athletes with a low level of nervous processes mobility showed a correlation between ADW and TPVR (rs = 0.32-0.35). This indicates the consistency of the regulatory processes of blood flow from the internal carotid arteries basin. The subjects with a high level of nervous processes mobility showed a close relationship between ADW and HR (rs = 0.31-0.34) in non-athletes, which may indicate a high probability of complications of venous blood return from the brain to systemic blood flow.

The analysis of systemic indicators and CRH indicators in the head-up tilt position indicated clear individual and typological differences both in direction and in the severity of the corresponding changes found in the studied compensatory reactions depending on the level of nervous processes mobility. Speaking about systemic hemodynamics, there was a tendency to TPVR increase and a significant increase in HR ($p < 0.01$). TPVR indicators in the examined people with a high level of nervous processes mobility (both athletes and non-athletes) were significantly higher than in people with low level, which indicated their less favorable blood circulatory conditions ($p < 0.05$).

All participants showed a unidirectional response to an increase in Tl and a decrease in ASW. The most confident increase in Tl occurred in people with a high level of nervous processes mobility (both athletes and non-athletes) compared to people with a low level. We compared the Tl indicators dynamics taking into account the level of physical performance of the examined people. The comparison showed that non-athletes increased this indicator on the left by 34.3% and on the right by 39.6%, respectively. The mentioned above indicator was higher in athletes: 43.1% on the left and 46.4% on the right ($p < 0.05$). Tl indicator of the examined people with a low level of nervous processes mobility was significantly lower, and ASW was higher than similar indicators in people with a high level of nervous processes mobility ($p < 0.05$).

Non-athletes and athletes with a low level of nervous processes mobility were characterized by an increase in DI by 25.41-25.62% on the left and 28.9-29.3% on the right ($p < 0.05$). At the same time, people with a high level of nervous processes mobility increased DI by 15.8-16.2% on the left and by 16.9-17.1% on the right ($p < 0.05$). This increase in DI in the examined people with a low level of nervous processes mobility was accompanied by a significant narrowing of resistive vessels (by 72.9-73.4% on the left and 63.8-64.2% on the right, $p < 0.051$). Despite the limited blood flow to the internal carotid artery basin, they increased ADW by 23.8-24.1% on the left and 25.8-26.2% on the right, $p < 0.05$, which indirectly indicated the deterioration of the functional state of cerebral blood circulation.

We observed a significant decrease in vascular tone of resistance vessels in the examined people with a high level of nervous processes mobility (33.7-34.2% on the left and 40.5-41.1% on the right, $p < 0, 05$) both in athletes and non-athletes. Moreover, there was an increase in the resistive vessels tone in people with a low level of nervous processes mobility, especially in non-athletes. Comparison of the resistive vessels tone in the examined people with different levels of nervous processes mobility showed that Tms was lower in people with a high level than in people with a low level ($p < 0.01$) in the conditions of orthostasis.

The tilt-table test helped to establish a relationship between the nervous processes mobility and TPVR ($p < 0.05$). The people characterized by a low level of the studied typological feature, showed a feedback tendency between Tms and HR (rs = - 0.22). Correlation analysis between the systemic and CRH indicators in people with a high level of nervous processes mobility manifested the relationship between HR and Tl (rs = 0.31).

Having analyzed CRH indicators in the vertebral artery basin and major brain arteries and artery tone of different calibers in participants with different levels of nervous processes mobility and different physical fitness in lying position, as in the internal carotid arteries we did not reveal differences among them (Table 5). Comparison of CRH indicators in different groups of the examined people showed the same differences in the basilar internal carotid arteries, which was also unreliable ($p > 0.05$). The values of interhemispheric asymmetry did not exceed 9-10%. Tms in people with a high level of nervous processes mobility correlated with HR (rs = 0.33) and APm (rs = 0.32). People with a low level of nervous processes mobility had the relation between ADW and TPVR (rs = 0.34) both in the internal carotid basin and in the basin of the vertebral arteries.

Table 5 Rheoencephalogram indicators in the vertebral-basilar basin of the examined people with different levels of FMNP in the conditions of tilt-table test (mastoid-occipital region, median, upper and lower quartiles)

Indicators	Groups	lying position		head-up-tilt position (tilt-table test)	
		left	right	left	right
ASW, Ω	I	0.066 [0.073;0.060]	0.065 [0.080;0.062]	0.031 [0.048;0.028]**	0.032 [0.047;0.028]**
	II	0.059 [0.075;0.052]	0.060 [0.085;0.054]	0.032 [0.051;0.029]*	0.030 [0.046;0.028]*
	III	0.060 [0.069;0.052]	0.062 [0.071;0.056]	0.028 [0.036;0.022]**	0.029 [0.037;0.024]**
	IV	0.055 [0.070;0.050]	0.056 [0.075;0.052]	0.030 [0.049;0.025]*	0.029 [0.048;0.023]*
ADW, Ω	I	0.021 [0.032;0.018]	0.022 [0.037;0.019]	0.032 [0.047;0.029]*	0.034 [0.050;0.030]*
	II	0.014 [0.025;0.010]	0.016 [0.024;0.010]	0.018 [0.030;0.012]$^{\#}$	0.022 [0.037;0.017]$^{\#}$
	III	0.019 [0.030;0.014]	0.020 [0.033;0.016]	0.030 [0.044;0.025]*	0.032 [0.046;0.028]*
	IV	0.010 [0.022;0.006]	0.014 [0.021;0.009]	0.016 [0.027;0.011]$^{\#}$	0.020 [0.029;0.016]$^{\#}$
DI, %	I	52.5 [81.2;48.8]	54.8 [78.3;50.4]	66.0 [77.9;60.5]*	67.2 [81.8;62.4]*
	II	50.1 [71.4;49.4]	48.9 [68.2;49.2]	36.3 [74.8;32.5]$^{**\#\#}$	32.3 [75.5;29.9]$^{**\#\#}$
	III	49.4 [79.5;45.4]	50.3 [79.7;47.3]	62.3 [84.3;57.4]*	63.5 [80.5;59.3]*
	IV	46.4 [57.8;40.2]	46.9 [66.1;41.4]	32.7 [65.4;28.5]$^{**\#\#}$	32.3 [66.3;30.1]$^{**\#\#}$
Tl, c.u.	I	0.61 [0.78;0.57]	0.59 [0.80;0.52]	0.87 [1.09;0.83]*	0.84 [1.04;0.80]*
	II	0.63 [0.78;0.59]	0.61 [0.78;0.57]	0.74 [0.94;0.72]$^{*\#}$	0.75 [0.90;0.69]$^{*\#}$
	III	0.56 [0.72;0.50]	0.58 [0.78;0.51]	0.84 [1.01;0.80]*	0.85 [1.06;0.78]*
	IV	0.60 [0.74;0.53]	0.59 [0.75;0.50]	0.70 [0.88;0.64]$^{*\#}$	0.71 [0.91;0.63]$^{*\#}$
Tms, c.u.	I	0.50 [0.72;0.47]	0.51 [0.69:0.45]	0.73 [0.80;0.70]*	0.78 [0.91;0.73]*
	II	0.45 [0.61;0.42]	0.48 [0.66;0.43]	0.32 [0.49;0.30]$^{**\#\#}$	0.36 [0.54;0.31]$^{**\#\#}$
	III	0.46 [0.70;0.41]	0.50 [0.73;0.46)	0.70 [0.85;0.67]*	0.72 [0.99;0.65]*
	IV	0.40 [0.71;0.34]	0.42 [0.76;0.36]	0.28 [0.49;0.22]$^{**\#\#}$	0.30 [0.54;0.24]$^{**\#\#}$

Note: * – the reliability of the differences $p < 0.05$, ** – $p < 0.01$ relative to lying position; # – $p < 0.05$, ## – $p < 0.01$ between high and low levels; ASW – amplitude of the systolic wave, ADW – amplitude of the diastolic wave, DI – Dicrotic index, Tl – tone of large vessels, Tms – tone of the medium and small vessels of the brain.

At the same time, we found differences in the CRH indicators of the examined people with different levels of nervous processes mobility and physical fitness in head-up tilt position during the tilt-table test in the vertebral arteries and cerebral artery basins. They differed from data obtained in the internal carotid arteries basin in these conditions. We recorded a decrease in DI by 27.5-28.2% on the left and 31.6-32.3% on the right ($p < 0.05$) both in athletes and non-athletes with a low level of nervous processes mobility. But this indicator increased (by 24.3-25.7% on the left and by 20.1-22.6% on the right), ($p < 0.05$) in those people who had a high level of nervous processes mobility. Such changes in DI in people with a low level of nervous processes mobility, regardless of their level of physical fitness, were accompanied by significant dilatation of resistive vessels (28.3-28.9% on the left and 23.6-24.7% on the right, $p < 0.05$ -0.01). In addition, the narrowing of resistive vessels was 45.6% on the left and 52.9% on the right ($p < 0.05$-0.01) in people with a high level of the studied typological features.

The highest DI indicator was found in participants with a high level of nervous processes mobility compared to those who had a low level ($p < 0.05$ - 0.01). The DI and Tms dynamics in the vertebrobasilar basin probably demonstrated the typological features of compensatory changes in the examined people with low and high levels nervous processes mobility to ensure oxygen homeostasis in the head-up tilt position. In these conditions, the highest value of the resistive vessels tone was recorded in people with a high level, especially in non-athletes, and the least value was observed in people with a low level of nervous processes mobility ($p < 0.05$).

During the tilt-table test all examined people showed an increase in Tl and a decrease in ASW ($p < 0,05$-0,01) in the vertebrobasilar basin and in the internal carotid arteries basin in the head-up tilt position. Comparison of ASW in participants with different ANPs and physical fitness did not reveal differences in these conditions ($p > 0.05$). The most significant increase in Tl was observed in people with a high level of nervous processes mobility of (41.3-42.6% on the left and 40.5-42.3% on the right, respectively). This indicator was 16, 7-17.5% on the left and 20.2-21.3% on the right, respectively ($p < 0.05$), in people with a low level.

Regardless of the level of physical fitness, the comparison of Tl indicators showed the predominance of the tone of elastic type arteries in people with a high level of nervous processes mobility compared with people with a low level ($p < 0.05$). We noted complications of cerebral blood outflow both in people with high and low nervous processes mobility that was proved by ADW increase. At the same time, ADW indicator was significantly higher only in those who had a high level of nervous processes mobility (especially in athletes) and became higher compared to people with a low level ($p < 0.05$).

The connection between DI, Tms and nervous processes mobility ($r_s = 0.34$-0.32) was revealed both in athletes and non-athletes. This indicates the dependence of venous outflow from the temporal and occipital regions of the brain on the level of the studied typological features. The low level of nervous processes mobility in the tilt-table test, on the contrary, caused an increase in the venous lumen in these basins.

Discussion

Our study supplemented a lack of knowledge about cerebral mechanisms of blood circulation regulation during tilt-table testing in people with different levels of physical fitness and nervous processes mobility.

Having studied cerebral blood circulation, we concluded that the concept of hemodynamic norm (as a guideline for optimal existence) in physiology was traditionally based on the averaging of the functional indicators complex obtained in specific conditions of human activity. Such a complex is an appropriate interval where quantitative changes in physiological processes do not turn into qualitative ones.

Since all the examined people were almost healthy, we analyzed the rheograms (recording in lying position) and calculated the averages to obtain the "norm" of the relevant rheographic parameters for men 18-21 years of age.

Scientists agree that relatively healthy people have heterogeneous indicators of cerebral circulation and cerebral vascular tone, which complicates the interpretation of actual experimental information (Malikov et al., 2019).

Other authors emphasize the similarity of the parameters in lying position, especially in non-athletes (Averyanova et al., 2016). We obtained data which were close to such results both in athletes and non-athletes, because we did not find significant differences between groups I, II and III, IV.

However, we noted lower rates of systemic hemodynamics (in both body positions, but not significant) in athletes compared with non-athletes, which indicated a tendency to more economical functioning of the CVS. Regarding the absence of differences between hemodynamic parameters in the examined groups with different levels of nervous processes mobility, we can assume that individual-typological properties were not manifested in conditions of relative rest, because there was no need to build individual response strategies in optimal conditions. The results of other studies indicated no differences between the indicators of cardiovascular activity of people with different nervous processes mobility during rest (Furlan et al., 2000; Makarenko et al., 2011).

We used the orthostatic gravity test to identify, firstly, individual and typological features of compensatory reactions of cerebral blood circulation and secondly, to analyze the value of physical fitness, which was different in athletes and non-athletes. The results showed that there was a tendency to decrease the vascular resistance tone during the tilt-table test in athletes compared to non-athletes. This probably indicated more favorable conditions for brain tissue perfusion (Bodo et al., 2005).

Thus, the athletes had a more economical level of systemic and CRH functioning compared to non-athletes both in lying and head-up tilt positions. The compensatory responses were smoother. These results proved that a higher level of physical performance helped to optimize the CVS compensatory-adaptive responses to tilt-table test.

Regardless of the level of nervous processes mobility and physical fitness, people with a high level of nervous processes mobility expressed a relationship between Tms and HR ($r_s = 0.32$) and Tms and APm ($r_s = 0.33$) in this position of the body. This evidently indicated the work of a constrictive mechanism of distribution vessel autoregulation to maintain optimal regional hemodynamics (Jeong et al., 2012; Kapilevich et al., 2019). Both athletes and non-athletes with a low level of nervous processes mobility manifested a correlation between ADW and TPVR ($r_s = 0.32$-0.35). This indicates the consistency of the regulatory processes of blood flow from the internal carotid arteries basin. The people with a high level of ANP displayed a close relation between ADW and HR (rs = 0.31-0.34) in non-athletes, which may indicate a high probability of complications of venous return of blood from the brain to the systemic circulation.

It is known that a wide range of variability in the regulation of cerebral blood flow is a consequence of the interaction between systemic and local physiological mechanisms. At the same time, the typological features of cerebral blood flow today remain unclear. It is proved by researchers that a change in the tone of small arterial vessels and arterioles was among the leading links in the autoregulation of cerebral circulation. Elastic vessels have moderate resistance to blood flow. Therefore, the terminal arteries and arterioles (precapillary) vessels, which have a relatively small lumen and thick walls with developed smooth muscles, have the greatest resistance to blood flow (Yarmak et al., 2019).

In addition, it is well-known that constriction or dilatation of resistive vessels of the brain may be the result of other regional (changes in the capacity of the venous region of the regional vascular bed) and systemic causes (changes in systemic blood pressure). According to modern views, regional vascular tone is created by the combined action of factors of myogenic, humoral and neurogenic regulation of tissue blood circulation [28].

Changes in systemic hemodynamics and CRH in head-up tilt position manifested themselves, both in direction and in the degree of corresponding changes, in compensatory reactions depending on the level of nervous processes mobility.

TPVR values were significantly higher in people with a high level of nervous processes mobility (both athletes and non-athletes) than in people with a low level, indicating their less favorable blood circulatory conditions ($p < 0.05$).

Both non-athletes and athletes showed a significant decrease in vascular tone of resistance vessels in people with a high level of nervous processes mobility and an increase in the resistive vessels tone in people with a low level of nervous processes mobility, especially in non-athletes. This situation can be considered unfavorable for venous regional outflow into the systemic blood circulation on the background of increased heart rate. Comparison of the resistive vessels tone in people with different levels of nervous processes mobility during orthostasis showed that Tms in people with a high level was lower than in people with a low level of FMNP ($p < 0.01$).

We established a relationship between the nervous processes mobility and TPVR ($p < 0.05$) during tilt-table test. There was a feedback tendency between Tms and HR (rs = - 0.22) in people characterized by a low level of the studied typological feature. This indicates a possibility of deterioration of venous outflow from the internal carotid artery with increasing heart rate during orthostasis in these people.

Correlation analysis of systemic and CRH indicators in people with a high level of nervous processes mobility indicated a relationship between HR and Tl (rs = 0.31), indicating the possibility of avoiding (a certain limit) excessive cerebral blood circulation. On the other hand, this connection does not exclude possible changes in the work of this compensatory mechanism, which in the case of insufficient tonic response of cerebral arteries may pose a risk of excessive cerebral circulation, especially in non-athletes.

The highest DI value was found in people with a high level of nervous processes mobility in comparison to people with a low level ($p < 0.05$ - 0.01) of nervous processes mobility. It is likely that the dynamics of DI and Tm in people with low and high nervous processes mobility in the vertebro-basilar basin demonstrated the typological features of compensatory changes to ensure oxygen homeostasis in head-up tilt position.

We recorded that people with high and low nervous processes mobility of had complications of cerebral blood flow in the vertebro-basilar basin, which was evidenced by ADW increase. At the same time, ADW value was significantly higher in people with a high level of ANP (especially in athletes) and became higher compared to people with a low level ($p < 0.05$).

There was a relationship between DI, Tm and the nervous processes ability (rs = 0.34-0.32) both in athletes and non-athletes, which indicated the dependence of venous outflow from the temporal and occipital regions of the brain on the level of the studied typological feature. The participation of the nervous processes mobility in the autoregulation of vessels vascular tone in the vertebro-basilar basin in people with a high level of nervous processes mobility was manifested by the spastic effect of vessels of both types. The low level of nervous processes mobility during the tilt-table test, on the contrary, caused an increase in venous lumen in these basins.

The established relations between the studied typological feature of higher nervous activity and some indicators of cerebral hemodynamics give us reason to believe that the nervous processes mobility is a leading link in the basic mechanisms of cerebral blood flow regulation. The level of nervous processes mobility development directly affects the contractile characteristics of vascular smooth muscle.

Low resistive vessels tone is responsible for maintaining the required diameter of blood vessels and maintaining the stability of blood pressure. However, this dynamics is compensated by prevailing constrictive effect in both elastic and resistance vessels of the vertebrobasilar basin of the brain, which helps to balance and optimize the characteristics of the general cerebral blood circulation. These changes were observed in people with a high level of nervous processes mobility. We also observed resistive vessels vasodilation and increase in the large-diameter arteries tone in the vertebro-basilar basin of people with a high level of nervous processes mobility, which prevented excessive cerebral blood circulation.

Thus, during tilt-table testing people with high and low levels of nervous processes mobility are characterized by labile adaptive types of CRH compensatory reactions, which have diametrically opposite functional variants.

The properties of nervous processes mobility that ensure the course of nervous processes, distribution or cessation of nervous excitation, maintenance of neuronal metabolism and synaptic transmission indirectly indicate their participation in compensatory reactions of cerebral vessels that develop in response to gravitational load. Taking into account the obtained results, we can assume that the nervous processes mobility may be involved in blood redistribution reactions responsible for optimizing cerebral blood circulation by regulating the tone of the pre- and postcapillary vessels of the brain.

Conclusion

1. We obtained differences in the cerebral vessels tone of people with different nervous processes mobility. We believe that it is necessary to determine the functional mobility of nervous processes to study individual variants of compensatory reactions of cerebral blood circulation during the gravitational tilt-table test.
2. People with a high level of functional mobility of nervous processes in the conditions of the tilt-table test have a high risk of regional venous outflow deterioration in the internal carotid arteries basin. On the contrary, people with a low level of functional mobility of nervous processes are characterized by excessive spastic action of resistant vessels in the internal carotid artery, which along with limited blood flow can be seen as a risk of stagnation in these areas of the brain.
3. Taking into account the level of physical fitness of people with different levels of functional mobility of nervous processes allowed us to identify a more economical level of the cardiovascular system functioning in athletes with a high level of the studied features of higher nervous activity. This was proved by optimizing the compensatory-adaptive responses to the tilt-table test of both systemic hemodynamics and cerebral blood circulation. Similar differences in cerebral hemodynamics were found in people with low nervous processes mobility, who had different physical performance. Such differences were relatively less pronounced in people with a high level of the studied property of higher nervous activity.
4. The obtained results indicated that the development of individual training (rehabilitation) programs should be based not only on differences in physical performance. The direction and nature of cerebrovascular adaptive-compensatory reactions that occur in response to an tilt-table test depending on the level of nervous processes mobility should be also taken into account.
5. The obtained data can be used in practice of medical and pedagogical control of athletes (as inspection of an athlete's functional condition, for systematic dispensary supervision, taking into account stages of training and competitive periods), practically healthy and physically active young men for the improving and preventive purpose (monitoring the cardiovascular system, selection and creation of individual fitness, bodybuilding, crossfit and other programs).
6. We recommend taking into account the individual characteristics of the resistive cerebral arteries tone in the functional diagnosis of cardiovascular pathology and hemodynamic cerebral disorders.

References

Aponchuk, L., & Shevchuk, T. (2017). The analysis of indices of cerebral blood circulation in women-smokers. *EUREKA: Life Sciences*, (1), 44-50. doi: 10.21303/2504-5695.2017.00287.

Averyanova, I. V., & Maksimov, A. L. (2016). Peculiarities of morphofunctional profiles and intersystem relations observed in young male north-born residents with different types of vegetative regulation. *Ekologiya cheloveka*, (9), 21-29.

Baevsky, R. M., Chernikova, A. G., Funtova, I. I., & Tank, J. (2011). Assessment of individual adaptation to microgravity during long term space flight based on stepwise discriminant analysis of heart rate variability parameters. *Acta Astronautic*a, 69(11-12), 1148-1152. doi: 10.1016/j.actaastro.2011.07.011.

Baggish, A. L., Fulco, C. S., Muza, S., Rock, P. B., Beidleman, B., Cymerman, A., & Weyman, A. E. (2010). The impact of moderate-altitude staging on pulmonary arterial hemodynamics after ascent to high altitude. *High Altitude Medicine & Biology*, 11(2), 139-145.doi: 10.1089/ham.2009.1073.

Bodo, M., Pearce, F. J., Baranyi, L., & Armonda, R. A. (2005). Changes in the intracranial rheoencephalogram at lower limit of cerebral blood flow autoregulation. *Physiological Measurement*, 26(2), 1-17

Boedtkjer, E. (2018). Acid–base regulation and sensing: Accelerators and brakes in metabolic regulation of cerebrovascular tone. *Journal of Cerebral Blood Flow & Metabolism*, 38(4), 588-602.doi: 10.1177/0271678X17733868.

Donnelly, J., Budohoski, K. P., Smielewski, P., & Czosnyka, M. (2016). Regulation of the cerebral circulation: bedside assessment and clinical implications. *Critical Care*, 1(20), 1-17. doi:10.1186/s13054-016-1293-6.

Furlan, R., Porta, A., Costa, F., Tank, J., Baker, L., Schiavi, R., & Mosqueda-Garcia, R. (2000). Oscillatory patterns in sympathetic neural discharge and cardiovascular variables during orthostatic stimulus. *Circulation*, 101(8), 886-892.

Jeong, S. M., Shibata, S., Levine, B. D., & Zhang, R. (2012). Exercise plus volume loading prevents orthostatic intolerance but not reduction in cerebral blood flow velocity after bed rest. *American Journal of Physiology-Heart and Circulatory Physiology*, 302(2), 3333–3339. doi: 10.1152/ajpheart.00427.2011.

Kapilevich, L. V., Yezhova, G. S., Zakharova, A. N., Kabachkova, A. V., & Krivoshchekov, S. G. (2019). Brain bioelectrical activity and cerebral hemodynamics in athletes under combined cognitive and physical loading. *Human Physiology*, 45(2), 164-173.doi: 10.1134/S0362119719010080.

Korobeĭnikov, H. V., & Kharkovliuk, N. V. (2000). The characteristics of autonomic regulation in persons with different levels of mental work capacity. *Fiziolohichnyi Zhurnal*, 46(1), 82-88.

Korobeĭnikov, G. V. (1993). Assessment of reactivity of heart rhythm regulatory system in response to physical exertion. *Fiziologicheskii zhurnal*, 39(1), 10-14.

Korobeĭnikov, H. V. (1994). Study on transitional processes of the regulation of the heart rate in man exposed to strenuous muscular activity. *Fiziolohichnyi zhurnal*, 40(2), 38-42.

Korobeĭnikov, G. V. (1995). Physiologic mechanisms of functional reserve mobilization in man during strenuous muscle activity. *Fiziologiia cheloveka*, 21(3), 81-86.

Korobeynikov, G., Korobeynikova, L., Iermakov, S., & Nosko, M. (2016). Reaction of heart rate regulation to extreme sport activity in elite athletes. *Journal of Physical Education and Sport*, 16(3), 976-981. doi:10.7752/jpes.2016.03154.

Korobeynikov, G., Korobeynikova, L., Potop, V., Nikonorov, D., Semenenko, V., Dakal, N., & Mischuk, D. (2018). Heart rate variability system in elite athletes with different levels of stress resistance. *Journal of Physical Education and Sport*, 18(2), 550-554. doi: 10.7752/jpes.2018.02079.

Korobeynikov, G., Glazyrin, I., Potop, V., Archipenko, V., Glazyrina, V., Dudnyk, O., & Dakal, N. (2019). Adaptation to endurance load in youths. *Journal of Physical Education and Sport*, 19(3), 1035-1040. doi:10.7752/jpes.2019.s3149.

Makarenko, M. V., Lyzohub, V. S., Iukhymenko, L. I., & Khomenko, S. M. (2011). Heart rhythm in humans with different processing levels of acoustic information. Fiziolohichnyi zhurnal, 57(3), 33-39.

Makarenko, M. V., Lizogub, V. S., Yukhymenko, L. I., Khomenko, S. M., & Koval, Y. V. (2016). Technological support of estimating functional opportunities of higher parts of central nervous system in the individuals with auditory deprivation. *Amer J Engin Res*, 5(10), 67-71.

Malikov, M., Tyshchenko, V., Boichenko, K., Bogdanovska, N., Savchenko, V., Moskalenko, N. (2019). Modern and methodic approaches to express-assessment of functional preparation of highly qualified athletes. *Journal of Physical education and Sport*, 19(3), Art. 219, 1513-1518.

Odynets, T., & Briskin, Y. (2019). Effect of individualised physical rehabilitation programmes on the functional state of the cardiovascular system in women with post-mastectomy syndrome. *International Journal of Therapy And Rehabilitation*, 26(2), 1-10. doi: 10.12968/ijtr.2018.0003.

Olena, Y., Galan, Y., Nakonechnyi, I., Hakman, A., Filak, Y., & Oleksandra, B. (2017). Screening system of the physical condition of boys aged 15-17 years in the process of physical education. *Journal of Physical Education and Sport*, 17, 1017-1023.doi: 10.7752/jpes.2017.s3156.

Romanenko, V., Podrigalo, L., Iermakov, S., Rovnaya, O., Tolstoplet, E., Tropin, Y., & Goloha, V. (2018). Functional state of martial arts athletes during implementation process of controlled activity–comparative analysis. *Physical Activity Review*, 6, 87-93. doi: 10.16926/par.2018.06.12.

Staals, J., Booth, T., Morris, Z., Bastin, M. E., Gow, A. J., Corley, J., & Wardlaw, J. M. (2015). Total MRI load of cerebral small vessel disease and cognitive ability in older people. *Neurobiology of aging*, 36(10), 2806-2811. doi: 10.1016/j.neurobiolaging.2015.06.024.

Tushchenko, V., Lisenchuk, G., Odynets, T., Cherednichenko, I., Lytvynenko, O., Boretska, N., Semeryak, Z. (2019). The concept of building control for certain components of the system for training handball players. *Journal of Physical Education and Sport*, 19(4), 1380–1385. doi: 10.7752/jpes.2019.s4200.

Yarmak, O., Buhaienko, T., Zhukov, O., Cherniakova, Z., Vorona, V., Lidiia, B., & Blagii, O. (2019). Specificity of the relationship between the volume of physical activity and the physical condition of 18-19-year-old girls. *Journal of Physical Education and Sport*, 19(3), 1550-1555. doi:10.7752/jpes.2019.03224.

Yukhymenko, L., Makarchuk, M., Natalia, I., Korobeynikova, L., Korobeynikov, G., Borysova, O., & Gorashchenco, A. (2019). Links between system of information processing in brain and heart rate among athletes with different individual-typological characteristic. *Journal of Physical Education and Sport*, 19, 1041-1047. doi: 10.7752/jpes.2019.s3150.

Yukhymenko, L., Makarchuk, M., Korobeynikov, G., Korobeynikova, L., Imas, Y., & Kozina, Z. (2018). Hemodynamic aspects of compensatory reactions of human cardiovascular system in conditions of postural loads. *Physiotherapy Quarterly*, 26(3), 6-12. doi: 10.5114/pq.2018.78373.