Functional systems of students' organism depending on physical fitness to physical load

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Abstract

Purpose: to study reaction of cardio vascular system and erythrocyte homeostasis in students with different fitness for physical load.

Material: we tested students (n=150, from them n=105 – boys and n=45 – girls). дівчата). Measurements were fulfilled after maximal physical load on ergo meter (Kettler, German). The load was 2,7 W/kg.

Results: indicators of vegetative blood circulation's regulation depend on fitness level to maximal physical load. In 1st group students it manifested as sharp asymmetric indicators' reverse between sympathetic and para sympathetic regulation of blood circulation. Besides, there appear reversibly and irreversibly changed forms of erythrocytes in periphery blood. In 2nd group students maximal physical load causes higher indicators of sympathetic circuit. In 3rd group students, under maximal physical load we did not find asymmetry between sympathetic and para sympathetic blood circulation's regulation.

Conclusions: between changes of vegetative blood circulation's regulation and students' fitness to maximal physical load there are multidirectional vectors of organism's functional state. They manifest as natural changes of forms of periphery blood erythrocytes.

Keywords: functional state, vegetative regulation, blood circulation, erythrocytes, students.

Introduction

For sustaining of homeostasis continuous metabolism and energy exchange with environment are required [7, 8]. It ensures self-regulation of physiological functions and sustains life activity at optimal and relatively constant level. In this respect human organism is half closed thermodynamic system, which consists of different organs and tissues [30]. According to requirements of internal medium and organism action's stability in respect to external conditions two systems are used: vegetative nervous system (VNS) and endocrine system. The first realizes general regulation: with sympathetic and para sympathetic sectors. The second influences on all organism's cells with influence of hormones and biologically active substances. Integral system is [32] is Eritrean system, in which the effecting final link is erythrocyte (Ep).

The mentioned above VNS sectors have their own sensor components, which perceive physical and chemical indicators of internal medium. Ep is directly information form of alive, which plays the role of feedback between two regulation systems. Ep is a formation component of organism's functional system (OFS) in [30, 34].

M. Holcik [33], F. B. Jensen [34], H. Mairbäurl [44] devoted their works to Ep different morphological functional properties. It permits to predict OFS state under influence of the following: external and internal factors, not standard, stress or de-adaptation development of processes [36, 37].

In other works influence of walking training on iron metabolism [41]; influence of resistance to insulin reduction on ferritin concentration after trainings [40]; change of ultra-marathon runners' blood morphology

and chosen biochemical parameters [35]; changes of pro-inflammation markers and lysine concentration in response to trainings [31, 39] are noted.

Extreme factors are connected with trainings loads and psycho-emotional stress. Extreme factors are such external factors of influence on human OFS [25, 27].

In such conditions there appears OFS tension, resulted in not saving expenditure of functional reserves and their quick exhaustion. The temporary dynamic of such changes is studied rather completely in different studies [26, 42].

However, such data are not systemized. The have not contain complex approach to studying of mechanisms of adaptive reaction's (OFS) formation [8, 49]. Even to less extent organism's reactions to extreme conditions and psycho-physical factors' influence on students' Ep are studied [38, 50]. Insufficient attention to this problem [43, 45, 46] can manifest in the future as reduction of mental and physical workability, weakening of educational processes' effectiveness. Besides, it can cause disorder of health and disharmony of students' health, who are differently prepared for physical loads (PL_{max}).

As N.V. Ivanova [9] and B.P. Lisovskiy [13] note, in unfavorable conditions there are: reduction of sensitivity to extreme action on students' organism PL_{max} ; reduction of OFS reserves to homeostasis restoration, caused by this factor.

In this respect cardio vascular system (CVS) and erythrocyte link of homeostasis are the weakest [1, 11]. Vegetative and neuro motor regulation of nervous muscular system (NMS) has a number of general systemic structural functional properties, which naturally reflect in state of Ep [44, 46]. There is certain interest to influence of sympathetic and para sympathetic sectors of CNS on athletes' CVS. With it no attention is paid to homeostatic function of Ep and CVS reaction with PL_{max} on students.

The purpose of the work: to study reaction of cardio vascular system and erythrocyte homeostasis in students with different fitness for physical load.

Material and methods

Participants: The research was fulfilled in Vasyl Stefanyk Precarpathian National University and National Academy of Home Affairs (Ivano Frankovsk). We tested students (n=150, from them n=105 – boys and n=45 – girls).

Students were divided into 3 groups. In 1st groups students practiced physical culture from time to time (n=48). In 2nd group students practiced physical culture regularly (n=68). In 3rd group students practiced regularly different kinds of sports (n=34).

Organization of the research: The measurements were fulfilled within standard physical culture lesson. The measurements were fulfilled after maximal physical load on ergo meter (Kettler, German). The load was 2,7 W/kg.

With the help of program «CardioLab+» we fulfilled 5 minutes recording of R-R-cardio intervals. All data were processed with special program [29].

For studying of erythrocytes' conformation and biochemical properties we took capillary blood by protocol of glucose concentration in blood determination [46]. Sampling of material was fulfilled directly before PL_{max} and 1-3 minutes after recreation period.

Hemoglobin concentration was studied by standard method. Erythrocytes' quantity was studied by unified calculation method in Goryayev chamber. Gematocrit was studied by micro-method with the help of application of standardized geparinized capillary [24]. Morphological study of erythrocytes was fulfilled on scanning electronic microscope «JEOL-25M-T220A» (Japan) as per commonly accepted methodic [28].

Statistical analysis: for statistical comparison of OFS indicators with PL_{max} we used earlier calculated data [16].

Statistical processing of results we fulfilled with the help of program GrafPad Prism 4.0 (GrafPad Software Inc., CIIIA). We used non parametric methods of the

research (Wilcoxon, Manna-Whitney tests). Selective parameters have the following values: $\langle x \rangle$ – mean arithmetic; D^* – statistical dispersion; $\delta_{\langle x \rangle}$ – mean square deviation; $\delta^*_{\langle x \rangle}$ – mean square deviation from mean arithmetic; $[\langle x \rangle \pm dx]$ – interval of confidence. The found changes were considered to be significant, when the received level was less that the level of confidence ($P < 0,05$).

Results

It was found that generalized indicators of sympathetic nervous system's activity (ISNS) in respect to PL_{max} in 1st group students had mean arithmetic 4,5. After PL_{max} this indicators was 15,1. Indicators of para sympathetic nervous system's activity (PSNS) in respect to PL_{max} was 19,0. After PL_{max} this indicators was 4,7 (see table 3).

Vegetative system complex in 1st group boys had characteristic changes: indicators ISNS increase 3,9 times and indicator of para sympathetic nervous system reduces nearly 4,8 times. The same changes were observed in girls of 1st group: ISNS increases 3,2 time s and indicator of para sympathetic nervous system reduces 2,3 times.

After PL_{max} in 1st group students we observed especially great changes by Bayevskiy's index [1]: in 5,8 times and in girls - 5,6 times. However, absolute indicators of girls (223,4) were much less the of boys (417,3).

The calculations' combined results of 1st group are given in tables 1 and 2.

Girl students of 2nd group differ by ISNS and PSNS indicators. ISNS mean arithmetic values before and after PL_{max} were 4,0 and 6,7. PSNS indicators were: before PL_{max} - 16,2 and after PL_{max} - 10,5 (see table 3). ISNS indicators of 2nd group boys were: before PL_{max} - 4,5; after PL_{max} - 11,2 ($p < 0,05$). PSNS indicators were: before PL_{max} - 16,8; after PL_{max} - 6,8 (see table 4). Comparing with 2nd group girls, the boys' ISNS indicators are higher and PSNS indicators are lower (before and after PL_{max}). In boys we also observed reverse of ISNS and PSNS indicators in Table 1. Cardio-respiratory indicators of 1st group girls' functional system after physical load.

Table 1. Cardio-respiratory indicators of 1st group girls' functional system after physical load

Indicators		$\langle x \rangle$	$D^*_{\langle x \rangle}$	$\delta_{\langle x \rangle}$	$\delta^*_{\langle x \rangle}$	$\langle x \rangle \pm dx$
ISNS	Before load	3,27	4,33	2,08	0,56	2,07;4,46
	After load	9,52	125,03	11,18	2,38	4,59;14,57
PSNS	Before load	17,13	22,78	4,77	1,28	14,39;19,87
	After load	8,26	14,71	3,83	0,81	6,57;9,95
HBR	Before load	83,8	165,23	12,85	3,43	76,41;91,19
	After load	99,69	693,86	26,34	5,61	88,07;111,3
ITB	Before load	40	306,67	17,51	4,68	29,94;50,06
	After load	223,34	67893,98	260,56	55,55	118,4;348,3
SPO ₂	Before load	98,6	0,37	0,61	0,16	98,25;98,95
	After load	98,04	0,65	0,80	0,17	97,7;98,4

Notes: ISNS – contribution of sympathetic sector of CNS in organism's regulatory processes; ISNS - contribution of para sympathetic sector of CNS in organism's regulatory processes; ITB – index of tension by Bayevskiy, reflecting regulatory systems' tension and prevailing of central mechanisms over autonomous; HBR – hear beats rate; SPO₂ – Oxy-hemoglobin concentration in blood %.

For 2nd group girls such reversing is not characteristic. They have ISNS increase 1,5times and PSNS reduction 1,6 times.

2nd group boys have Bayevskiy's index increased 3,6 times. In 2nd group girls its increment after PL_{max} is only 2.4 times.

In 3rd group the same dynamic is observed. But in 1st and 2nd group these indicators change to less extent.

Study of erythrocyte link showed that after PL_{max} in 1st group there is significant increase of hematocrit

and hemoglobin y ($P < 0,05$). In 3rd group (boys and girls) it happens against the background of erythrocyte quantity increase. It is facilitated by progressing of hemo-concentration. PL_{max} in 2nd group students causes reduction of periphery erythrocytes (PE) (in average by $15,3 \pm 1,25\%$, $P < 0,05$).

In 1st group, comparing with 2nd group, fig. 1 a, we found many reversibly and irreversibly changed forms of PE (see fig. 1 b). In 3rd group erythrocytes after PL_{max} remain nearly unchanged (see fig. 1 c).

Table 2. Cardio-respiratory indicators of 1st group boys' functional system before and after physical load

до і після фізичного навантаження

Indicators		<x>	D* _{<x>}	δ _{<x>}	δ* _{<x>}	<x>±dx
ISNS	Before load	4,53	14,77	3,84	0,906	2,63;6,43
	After load	15,13	80,52	8,97	1,67	11,72;18,55
PSNS	Before load	19	33,15	5,76	1,36	16,15;21,85
	After load	4,73	18,73	4,33	0,8	3,08;6,38
HBR	Before load	81,26	181,56	13,47	3,17	74,59;87,93
	After load	116,9	393,16	19,83	3,68	109,5;124,5
ITB	Before load	71,05	4546,26	67,43	15,89	37,68;104,6
	After load	417,3	116366,1	341,12	63,35	287,5;547,2
SPO ₂	Before load	98,05	1,84	1,36	0,32	97,38;98,72
	After load	97,93	0,66	0,81	0,15	97,62;98,24

Notes: see table 1.

Table 3. Cardio-respiratory indicators of 2nd group girls' functional system after physical load

Indicators		<x>	D* _{<x>}	δ _{<x>}	δ* _{<x>}	<x>±dx
ISNS	Before load	4	12,76	3,55	1,17	1,356,67
	After load	6,73	30,26	5,50	1,02	4,64;8,83
PSNS	Before load	16,17	38,33	6,12	1,98	11,7;20,63
	After load	10,46	30,38	5,51	1,02	8,36;12,6
HBR	Before load	87,55	103,69	10,07	3,33	79,99;95,12
	After load	99,3	359,41	18,95	3,52	92,08;106,5
ITB	Before load	73,89	4661,42	67,34	22,35	39,43;124,58
	After load	181,16	60986,1	246,9	45,85	87,16;275,2
SPO ₂	Before load	97,85	3,12	1,74	0,56	96,57;99,11
	After load	97,7	2,87	1,69	0,31	97,05;98,3

Notes: see table 1.

Table 4. Cardio-respiratory indicators of 2nd group boys' functional system after physical load

Indicators		<x>	D* _{<x>}	δ _{<x>}	δ* _{<x>}	<x>±dx
ISNS	Before load	4,5	14,54	3,55	1,05	2,17;6,81
	After load	11,21	77,12	8,78	1,37	8,47;13,15
PSNS	Before load	16,82	45,89	6,76	1,99	12,44;21,2
	After load	6,80	24,01	4,90	0,76	5,28;8,34
HBR	Before load	86,5	92,48	11,72	3,47	78,86;94,1
	After load	105,17	152,95	12,37	1,93	101,3;109,0
ITB	Before load	72,77	7233,2	72,43	21,66	25,17;120,3
	After load	260,47	48623,59	220,51	34,44	191,6;329,4
SPO ₂	Before load	98,29	0,54	0,69	0,2	97,85;98,74
	After load	97,5	1,29	1,14	0,178	97,14;97,86

Notes: see table 1.

Table 5. Cardio-respiratory indicators of 3rd group boys' functional system before and after physical load

Indicators		<x>	D* <x>	δ <x>	δ* <x>	<x>±dx
ISNS	Before load	4,14	15,22	3,9	0,85	2,48;5,8
	After load	10,92	113,03	10,63	2,17	6,45;15,39
PSNS	Before load	16,09	59,29	7,7	1,68	12,8;19,38
	After load	9,92	36,47	6,04	1,23	7,38;12,46
HBR	Before load	77,47	180,86	13,44	2,93	71,72;83,22
	After load	99,16	200,77	14,17	2,89	93,2;105,11
ITB	Before load	53,80	2592,26	50,91	11,11	32,03;75,57
	After load	221,3	47233,0	217,3	44,36	129,9;312,7
SPO ₂	Before load	98,14	1,52	1,23	0,26	97,62;98,66
	After load	97,52	1,37	1,17	0,238	97,03;98,01

Notes: see table 1.

In students athletes we observed increase of EP aggregation ability (content of aggregates increased by 15,0%) and rising of their deformation coefficient (by 18,0%), caused by muscular work (see fig. 1).

Discussion

For finding of CNS and Er reactions we used structural functional study of EP and automatic data analysis. We used variation pulse metering and rhythm cardio monitoring. Analysis of results showed that VNS activity is determined by results of control of organism's vegetative system's regulation: by reaction of CNS and EP [16, 47]. Here the most feasible parameter of regulation process is rhythm of heart beat. Dynamic characteristics of heart beats rate permit to assess sympathetic and para sympathetic disorders in students' state [48].

Heart beat rate is easy to be registered. It reflects vegetative regulation processes [10, 16, 23]. With it HBR is indirect characteristic. It reflects regulation result at different OFS levels [15].

Different combinations of VNS links, ensuring vegetative homeostasis can correspond to one and the same HBR [6]. Tonus weakening of VNS para sympathetic sector can be followed by reduction of sympathetic sector's activity: with average HBR remaining constant [1, 20]. HBR change under stress appear earlier than hormonal and biochemical disorders. It is conditioned by the fact that nervous system's reaction goes in advance of humoral factors. It permits to timely find stress reaction's peculiarities including to EP under physical load [29]. Cardio interval metering is one of modern methods of myocardium and organism's in general diagnostic [48]. It can be used for the following: characteristic of heart condition; organism's adaptive potential in selecting for different kinds of sports; control of life provisioning processes in training and competition periods [23].

The conducted earlier studied showed [25, 50], that at the end of academic year students athletes have low functional state of organism. It requires more careful attention to their physical condition.

PL_{max} of different intensity plays important role in formation organism's general endurance [37]. It reflects general level of human workability. Endurance integrates great number of processes, which take place at different levels – from cell to the whole organism [18]. In most cases leading role in studying of endurance is played by finding factors, facilitating activation of energetic exchange and vegetative functions of its provisioning: cardio-respiratory and central nervous systems. With it study of cells' reactions under PL_{max} (EP, in particular) are remaining out of attention [37, 38].

EP is a convenient object for such kinds of researches. EP participate in sustaining of homeostasis at level of the whole organism [34, 44, 45]. These cells can participate in regulation of acid-alkaline and water electrolite balance, on micro-reological blood status. That is why with intensive PL_{max} it is interesting in students' OFS regulation [36, 49, 50].

We found that in 57,0% if 1st group students, under PL_{max} There appear negative morphological changes of EP. It is conditioned by metabolic disorders. The basis of such changes is exhaustion of organism's biosystem's functional potentials. It happens under negative influence of increased mental and physical loads of academic year [26, 27].

The received data witness that under PL_{max} High requirements are set to 1st group's students' organism (to energy supply systems and heart's external work. High external work of heart can be explained by prevailing of systolic blood pressure (BPs), which is accompanied by increase of myocardium demand in oxygen [18].

It was found that under PL_{max} in boys changes of VNS indicators are more significant, comparing with girls. It can be explained by insufficient physical fitness of girls and specific reactions of female organism to academic loads [8, 9, 15].

The received by us data show that VNS indicators i 3rd group witness about students' better adaptation to changing conditions: the better is physical fitness, the higher are OFS compensatory mechanisms as well as

Fig. 1. Structural reconstruction of periphery erythrocytes in 1st group (a), 2nd group (b) and 3rd group (c) after single maximal physical load. Legend: 1 – normal forms of erythrocytes; 2 – reversibly changed forms of erythrocytes; 3- irreversibly changed forms of erythrocytes. Method: scanning electronic microscopy (scale 3500:1).

organism's adaptation to environment is quicker [1, 3].

Specific feature of students' athletes' hemo-dynamic reacting to PL_{max} is active work of mechanisms of blood circulation's periphery regulation. It is connected with strengthening of local blood flow [2, 4, 15]. The main mechanism of sustaining HBR low level is contracting abilities of left ventricle. With it general periphery resistance of vessels is low. Hearts of 1st group students work in not effective regime. That is why its compensatory potentials are limited. For these students high ISNS indicators are also characteristic. In homeostasis sustaining tonus of artery link dominates. As per our research general periphery resistance is high, while the power of left ventricle is minimal [1]. This type of blood

circulation is the least effective and has low adaptation potential [18].

As a number of authors note [6, 9, 10], human organism, depending on type of VNS on blood circulation, reacts to PL_{max} in complex way: changes in CNS work compulsory manifest also by changes of EP. When comparing ISNS values under PL_{max} we noticed a tendency to increase of changed EP forms. Independent on students' groups, under PL_{max} we observed changed EP indicators. However, comparing with relaxed state they increase only in 1st group (2,46 times) and 2nd group (1,79 times, $p < 0,05$).

By results of work of A. Ebner et al. [28], J. González-Alons [32], F. B. Jensen [36] it is known that the quantity

of circulating EP is one of factors for determination of blood rheological properties. Change of these indicators under PL_{max} can substantially influence on oxygen transportation blood function. Such change can result in disorders in microcirculation system. It changes students' OFS level.

Such phenomenon is conditioned by influence of factors, which accompany muscular activity. They include increased blood circulation, rising of temperature and acidosis [38, 44, 46].

Under such conditions disorder of EP wholeness appears, which can result in "anemia of load" [46]. Such changes influence negatively on somatic health, physical workability and educational progress of students.

All these require appropriate correction of training process and working out of adequate measures, directed on elimination of possible pathologies in students' organism, depending on their fitness to PL_{max} .

Conclusions

1. Depending on students' fitness to PL_{max} cardio-hemo-dynamic non uniformity of blood circulation manifests in the form of different indicators of blood circulation's vegetative regulation.

2. In the process of adaptation to maximal physical load in 1st group we observed sharp asymmetric reverse of indicators between sympathetic and para sympathetic regulation of blood circulation. With it, periphery link of blood circulation's regulation starts actively work. It manifests by emersion of reversibly and irreversibly changed forms of periphery erythrocytes.

3. Reacting of blood circulation system in 2nd group to maximal physical load manifests in gender distinctions of blood circulation vegetative regulation: boys demonstrated higher indicators of sympathetic circuit and lower – of para sympathetic one. It conditions symmetric reverse of these indicators before and after physical load. It depends on the presence of increased quantity of reversibly changed forms of periphery erythrocytes.

4. In 1st group, under maximal physical load we observed insignificant rising of sympathetic level and a little bit rising of para sympathetic one. It manifests as insignificant increase of quantity of deformed erythrocytes, without reduction of their sizes.

Conflict of interests

The authors state that there is no conflict of interest.

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Cite this article as: Popel' SL, Pyatnychuk GA, Pyatnichuk DV, Maystruv VV, Verboviy VP, Zemskaya NA, Kryzhanivskaya AF, Chovhan RYa. Functional systems of students' organism depending on physical fitness to physical load. *Physical education of students*, 2017;21(6):302–309. doi:10.15561/20755279.2017.0607

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Received: 20.06.2017

Accepted: 15.07.2017; Published: 08.12.2017