ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**2**): 37-45
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.2-1

Mechanisms of the adaptive reactions development in the students' body

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Abstract
Introduction. **The article substantiates the importance of the mechanisms of adaptive reactions, which includes various functionally related subsystems.** Aim of Study. **The aim of the article is analysis of psychophysiological indicators, central hemodynamics and heart rate variability of students' organisms at the first year of study.** Material and Methods. **Contingent: students of University. The average age 17.5 ± 0.6 years. Methods for studying the properties of attention (tables Anfimov, Schulte), short-term arbitrary visual memory; 5-minute heart rate variability (HRV) records.** Results. **It is established that differences in mental functions are due to the specifics of educational process. High level of MVB, HR, SDNN and LF/HF ($p \leq 0.05$), in group I indicates increased hemodynamics and sympathicotonia. In the group II indicators point to optimal level of central hemodynamics and activation of the sympathetic link. Group III smallest LF/HF ($p \leq 0.05$) and normal hemodynamic characteristic. Group IV: lowest VLF and VLF%, the highest LF% and VEI – it's may be the result of reduced ergotropic resources under stress.** Conclusions. **It is proposed to evaluate the mechanisms of adaptive reactions development: optimal, compensatory, decompensatory, overstrain.**

KEYWORDS: students, heart rate variability, central hemodynamics, psychophysiological indicators, functional systems, organism.

Received: 10 October 2022
Accepted: 3 June 2023

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Introduction

Development of highly sensitive registration methods and their processing means for obtaining diagnostic data can be used not only in clinical medical practice, but also for the purpose of diagnosis, prevention and correction of psychophysiological conditions of persons with different intensions [10, 19, 26].
Cardiac registration is very common in clinical practice and facilitates evaluation of cardiac rhythm indicators, investigation of structural defects of conduction, violation of the function of automaticity, etc. [3, 4, 20, 25].
The functional system theory, proposed by K. Anokhin and developed in the works of his followers [23, 27], shows that the human organism is a complex system of functionally connected physiological subsystems. Their concerted work depends on homeostasis. The interaction of the subsystems to maintain homeostasis is manifested in the electrical activity of the organism – electric biopotentials that serve as a source of information [4]. The internal structure of the system, its relationships

and the level of functioning will depend on the external environment, in which the system is located [8]. Therefore, when analyzing subsystems and their connections, it is necessary to consider the structure of functions, which are formed under the influence of both internal and external factors.

The response to any stimuli is manifested in a change of the nervous system state, which is a component of the functional system of the organism as a whole. The analysis of mental functions, which are based on nervous processes, facilitates an assessment of how quickly the body reacts to the presented stimulus and how effectively it uses the received information to form a “reaction-response”. Attention is not a self-sustaining mental process, but it is a necessary condition for the acquisition of knowledge and practical skills. Attention has a number of specific characteristics: volume, performance, persistence, switching, and distribution. According to scientists, studying the properties of attention makes it possible to assess an individual’s ability to organize, regulate and control their own activities [8, 14, 18]. Memory involves processes of organizing and preserving past experiences. This allows memory to be used in the subsequent life situations, which are related to the acquisition of activity and learning experience [7, 15]. As the researchers claim, the registration of short-term memory indicators characterizes the state of higher nervous activity and working capacity of a person [18, 24].

Organism is a self-regulating system, represented by the extensive interaction of central and peripheral formations. These formations are components of an active complex with certain physiological properties and may include anatomical formations, combinations of humoral substances, while all components are united by selective interdependence and harmoniously support one another to obtain any adaptive effect in the organism [27]. Integral systemic reactions to the action of the environment are always specific; non-specific is only the adaptation that determines the manner of these reactions of the organism to the action of a stimulus [9].

The study of integrative indicators of the organism’s functional state makes it possible to effectively evaluate the organization of different types of human activity [11, 15, 18]. The physiological side of any functional state finds reflection in changes of vegetative reactions. Deviations resulting from vegetative shifts are most clearly reflected in changes in the activity of the cardiovascular system [19, 23]. Regulation of blood circulation is a multi-circuit hierarchically organized system, in which the dominant role is determined by the urgent needs of organism. Changes in regulatory systems are preceded by hemodynamics, metabolic, and energy shifts. Determination of the state of the organism’s regulatory systems and their deviation from normal functioning is an important prognostic criterion in assessing the course of adaptive reactions to environmental conditions [4].

The profession of a teacher is associated with constant stress. Teachers must work with pupils and parents. They need to constantly improve their skills and qualifications and be aware of all innovations. This is a strong load on the organism, which is manifested in changes of the nervous system state and vegetative functions [12, 23]. Establishing the mechanisms of stress reaction formation in students of pedagogical institutions is important for predicting the development of adaptive changes in the organism in the conditions of professional activity.

Aim of Study

The aim of the article is to analyze psychophysiological indicators, central hemodynamics and heart rate variability of students’ organisms at the first year of study.

Materials and Methods

The research was conducted at the Ternopil Volodymyr Hnatiuk National Pedagogical University, Kremenets Taras Shevchenko Regional Academy of Humanities and Pedagogy, Drohobych Ivan Franko State Pedagogical University. Students of pedagogical universities acquire competencies that allow them to plan their future activities by profession. Therefore, future teachers feel a lot of stress in the conditions of educational activities at the university. First year students experience strong psycho-emotional stress because their educational activities have changed significantly: ways of processing information, acquiring professional skills and abilities. This is the reason for choosing this contingent to study the mechanisms of adaptive reaction development. The cohort of students consisted of first year students of different specialties, who showed differences in the content, training workload and motor mode: group I – Foreign Philology (n = 97), group II – Physical Education (n = 98), group III – Mathematics (n = 88), and group IV – Biology (n = 90). The present study was conducted on healthy volunteers. There were no pronounced chronic somatic diseases and physical disabilities in the sample studied (based on medical cards of the examined students). The average age of examined subjects was 17.5 ± 0.6 years old. The examination was carried out in stationary conditions from 8.00 to 13.00 o’clock with the same requirements [22].

Heart rate variability (HRV) is a marker that reflects autonomic regulation of cardiac cycle intervals. The use of HRV is a common method of diagnosing the functional state of the body, as it is sensitive to physiological and psychological changes [17]. Traditional data collection procedures for establishing short-term HRV in clinical or laboratory settings involve recording a 5-minute RR-interval. Research shows that recording short--term recordings (5 min) of heart rhythm is valid for data analysis data [2]. Because of the relative ease of recording, 5-minute measurements are widely used and are the most common source of published HRV [1-4, 6-8, 10, 11, 13, 14, 16, 20-24, 26].

The indexes of HRV were obtained from 5-minute cardiac interval records using a diagnostic computer system "Omega-M" to assess the functional state of the human organism (LLC "Dynamics" Research Laboratory, St. Petersburg, Russian Federation). The HRV indexes were obtained and analyzed: RRNN – average duration RR-intervals, (ms); SDNN – standard deviation of values of normal RR-intervals, (ms); RMSSD – square root of the mean of the squared difference of RR-intervals, (ms); CV – coefficient of variation, (%); NN50 – number of pairs of consecutive RR-intervals that differ by more than 50 ms; pNN50 – percentage of NN50 from the amount of all analyzed RR-intervals, (%); HRV-index – triangular index, (un.); HF, HF% – absolute and relative indexes of high-frequency oscillations (0.15-0.40 Hz), (ms^2); LF, LF% – absolute and relative values of the low-frequency component of the spectrum (0.04-0.15 Hz), (ms^2); VLF, VLF% – absolute and relative values of the very low--frequency component of the spectrum (0.003-0.04 Hz), (ms^2); LF/HF – indicator of vegetative balance between the activity of sympathetic and parasympathetic departments of the autonomic nervous system, (un.); TP – total spectrum power, (ms^2); Mo (mode) – value of RR-interval, which is most common in this dynamic range, (ms); AMo (amplitude of mode) – correlation of the amount of RR-intervals with the value Mo to the general amount of RR-intervals, (%); VS (variation span) – difference between maximum and minimum values of RR-intervals, (ms) [20, 22].

Based on the indicators of the dynamic series the indicators of cardiac activity are calculated by the diagnostic complex: VEI – vegetative equilibrium index, (un.); VRR – vegetative rate of rhythm, (un.); IARP – indicator of adequacy of regulatory processes, (un.); WI – workload index, (un.) [3, 4, 20].

Regulatory influences of central hemodynamics were evaluated according to indicators (which were obtained with a tonometer of the "Omega-M" diagnostic complex) of heart rate (HR), systolic pressure (SP), diastolic pressure (DP) and on their basis the following indexes were calculated: pulse pressure (PP), systolic blood volume (SBV), minute volume of blood (MVB), double result, or the Robinson index (DR) and adaptation potential (AP) [4, 19]. According to these data we can make conclusions concerning potential abilities of the human hemocirculatory apparatus and to assess the level of metabolic and energy processes in the organism [12, 18, 27].

To evaluate the psychophysiological functions the following were determined: amount, productiveness, stability of attention (Anfimov tables), switching of attention (red-black Schulte tables), distribution of attention; short-term visual memory for words, syllables, figures and numbers [18]. The use of these methods to determine the properties of attention and short-term memorization allows to characterize psychophysiological functions that are important for the professional development of future teachers and influence the formation of the organism's adaptive reactions [15, 17].

When choosing research methods, attention was paid to the fact that the selected methods did not take a lot of time, did not tire the participants, were simple and objective, adequately reflected the state of the body's functional systems under the action of the dominant factor, which is the educational process. The objectivity and reliability of the chosen methods is confirmed by a large number of scientific publications [1-4, 6, 7, 10, 12-14, 18, 21-24, 27].

Statistical processing of the results was performed using the Statistica 6.0 software package [5]. The normality of the distribution of the sample was determined by the Shapiro–Wilk test. Samples should be described by median and interquartile ranges (25th and 75th percentiles). The significance of differences between groups was determined using the non-parametric Kruskal–Wallis test to compare three or more unrelated groups [5, 16]. There factor analysis was conducted in each group. The principal component method and variation rotation of data were used for factor analysis [5]. From the data of the whole sample, the optimal values were determined for each indicator – these were the indicators of central hemodynamics and heart rate variability, which were within the norms [17, 20, 22], and psycho-physiological, which characterized high abilities of attention and memory (the biggest number of signs, the least time of doing test, etc.) [18]. The indicators of factor I of each group were compared to the optimal and deviations from them were presented in %. On the basis of obtained deviations characteristics of mechanisms of the development of adaptive reactions were established.

Ethical approval for the original studies and further ethical approval for the secondary data analysis were obtained from the Education's Research Ethics Committees of the Ternopil Volodymyr Hnatiuk National Pedagogical University (protocol No. 2 dated 05.09.22).

Results

Students of group I (Table 1) were characterized with the highest scores in evaluations of the amount of memory for words, syllables, group III – the highest speed of switching attention, memory for numbers and figures, group IV – the amount, efficacy and separation of memory that met the requirements of vocational training. The lowest indexes of psychophysiological functions were recorded among the students of group II [18].

The central hemodynamic indexes (Table 2) are the basis for the statement about strengthening of regulatory influences on the cardiovascular system of examined students from group I – the highest meaning MVB [6.0 (5.4; 6.6) l/min, $p \leq 0.05$] was caused by the significant input of HR [the greatest among the examined groups – 83 (74; 89) beats/min, $p \leq 0.05$)]. In group II MVB was formed because of the highest value of SBV [75.6 (70.1; 83.0) ml/min, $p \leq 0.05$]. Arterial pressure of the examined students from all the groups was within age norms [13]. The high value of SP in group II [131 (124; 138) mmHg, $p \leq 0.05$] can be explained by age peculiarities of functioning of the organism. Indicators of a satisfactory functioning of the hemodynamic apparatus of students from groups III and IV was confirmed by the indicators of HR, SP, DP, SBV, MVB (Table 2), which were within the norms [13, 17].

The indicators of AP and DR show no significant differences ($p \geq 0,05$) and indicated a satisfactory level

Table 1. Comparison of indicators of psychophysiological functions of students

	Indicators	group I (n = 97)	group II (n = 98)	group III (n = 88)	group IV (n = 90)
attention	amount, signs	778 (860; 903)*	662 (508; 828)*	737 (617; 865)*	**841 (720; 945)***
	stability, %	0,94 (0,91; 0,97)	0,93 (0,88; 0,96)	0,94 (0,92; 0,97)	0,94 (0,92; 0,98)
	productivity, signs	735 (660; 883)*	584 (448; 731)*	693 (543; 796)*	**786 (684; 858)***
	division, signs	19 (17; 23)*	19 (17; 20)*	20 (19; 21)*	**21 (18; 24)***
	switching, s	231 (216; 252)*	297 (263; 341)*	**230 (220; 261)***	256 (237; 280)*
memory	for syllables	**5 (4; 6)***	2 (2; 3)*	4 (3; 5)*	4 (3; 5)*
	for words	**8 (7; 8)***	7 (6; 8)*	8 (5; 9)*	7 (6; 9)*
	for numbers	6 (4; 7)*	6 (4; 7)*	**7 (4; 8)***	6 (5; 8)*
	for figures	6 (4; 7)*	5 (5; 6)*	**8 (7; 9)***	7 (5; 8)*

Note: Indicators that had the biggest differences between the groups are given in bold.
* differences between groups at $p \leq 0.05$ (Kruskal–Wallis criterion)

Table 2. Comparison of indicators of central hemodynamic system of students

Indicators	group I (n = 97)	group II (n = 98)	group III (n = 88)	group IV (n = 90)
SP, mmHg	123 (118; 131)*	131 (124; 138)*	124 (118; 136)*	123 (119; 133)*
DP, mmHg	74 (63; 78)	71 (64; 79)	75 (72; 87)	78 (69; 81)
HR, beats/min	**83 (74; 89)***	77 (65; 82)*	79 (72; 89)*	80 (76; 97)*
SBV, ml/min	73.3 (65.7; 78.5)*	**75.6 (70.1; 83.0)***	67.1 (62.1; 71.8)*	68.2 (63.5; 71.9)*
MVB, l/min	**6.0 (5.4; 6.6)***	5.7 (5.2; 6.0)*	5.3 (5.0; 5.8)*	5.7 (5.1; 6.1)*

Note: SP – systolic pressure, DP – diastolic pressure, HR – heart rate, SBV – systolic blood volume, MVB – minute volume of blood. Indicators that had the biggest differences between the groups are given in bold.
* differences between groups at $p \leq 0.05$ (Kruskal–Wallis criterion)

of adaptation [25] with reduced functional abilities of the systolic heart work [17]. Adaptive reactions in the organism were formed at low levels of energy--exchange processes, which may be the result of the inclusion of central hemodynamics in the compensatory mechanisms.

Students from group I were characterized by the indicators of HRV (Table 3), that is evidence of the activity of the sympathetic regulation link. The highest results for SDNN among the examined students should have shown at the predominance of the vagus influence on the rhythm of the heart [7, 22]. However, the obtained results are consistent with those reported by other scientists: an increase of SDNN in the conditions of acute stress was associated with a decrease of the respiratory rate [24]. The spectral indicator of vegetative balance LF/HF was 2.43 (1.18; 3.64) un., which indicates the predominance of the sympathetic link of regulation [22]. The indicator of VLF% went beyond the norm [20] and amounted to 50 (40; 60) %. As is noted in research papers, low HRV values are associated with stress responses and increased sympathicotonia [7]. WI showed no high values [20]. Such discrepancies between the data of regulatory reactions can be explained by the formation of decompensatory mechanisms under the influence of training intension and age-related changes in the organism.

The examined students from group II were characterized by indicators of HRV, which were within the norm [20, 22]. The spectral indicator of vegetative balance (LF/HF) indicated the predominance of activity of the sympathetic

Table 3. Comparison of indicators of HRV of students

Indicators	group I (n = 97)	group II (n = 98)	group III (n = 88)	group IV (n = 90)
Mo, ms	720 (680; 800)	720 (610; 860)	760 (680; 840)	680 (640; 760)
AMo, %	25.68 (22.97; 27.21)*	**25.32 (22.28; 40.18)***	30.34 (22.37; 35.99)*	30.07 (26.78; 34.34)*
RRNN, ms	723 (662; 791)	711 (629; 796)	754 (672; 828)	743 (619; 780)
SDNN, ms	**63.3 (55.0; 70.1)***	60.1 (36.5; 68.7)*	49.7 (42.1; 74.5)*	56.0 (46.1; 62.9)*
CV, %	8.8 (8.0; 9.9)*	6.6 (5.8; 8.7)*	7.5 (5.3; 9.2)*	7.9 (6.0; 9.3)**
HRV-index, un.	15 (12; 15)*	**17 (14; 19)***	13 (10; 16)*	13 (11; 15)*
HF, ms	628 (192; 1016)	586 (213; 1040)	797 (273; 1297)	562 (256; 901)
LF, ms^2	891 (675; 1590)	630 (457; 1966)	720 (379; 1094)	1020 (592; 1402)
VLF, ms^2	1771 (1355; 2267)*	902 (500; 1432)*	756 (594; 1232)*	854 (612; 1616)*
LF/HF, un.	**2.43 (1.18; 3.64)***	2.21 (1.14; 3.20)*	**0.88 (0.63; 2.39)***	2.05 (0.66; 3.16)*
TP, ms^2	3596 (2724; 4480)	2600 (1236; 4611)	2098 (1865; 4925)	2803 (2042; 3157)
HF%	18 (8; 25)	21 (13; 30)	31 (12; 43)	19 (11; 43)
LF%	29 (23; 39)*	31 (24; 40)*	27 (24; 35)*	**39 (29; 52)***
VLF%	**50 (40; 60)***	45 (43; 56)*	41 (29; 53)*	**33 (24; 47)***
VEI, un.	80.2 (72.8; 105.6)*	95.6 (71.5; 218.4)*	117.9 (73.6; 164.0)*	**122.7 (91.4; 157.0)***
VRR, un.	0.43 (0.38; 0.45)*	0.30 (0.28; 0.37)*	0.36 (0.27; 0.40)*	0.37 (0.29; 0.43)*
WI, un.	62.6 (50.6; 86.9)	59.5 (39.6; 156.0)	86.7 (45.1; 108.7)	**91.8 (73.7; 114.3)**

Note: Mo – mode, AMo – amplitude of mode, RRNN – average duration RR-intervals, SDNN – standard deviation of values of normal RR-intervals, CV – coefficient of variation, HRV-index – heart rate variability index, HF – absolute indexes of high-frequency oscillation, LF – absolute indexes of low-frequency component of the spectrum, VLF – absolute indexes of very low-frequency component of the spectrum, LF/HF – indicator of vegetative balance between the activity of sympathetic and parasympathetic departments of the autonomic nervous system, TP – total spectrum power, HF% – relative indexes of high-frequency oscillation, LF% – relative indexes of low-frequency component of the spectrum, VLF% – relative indexes of very low-frequency component of the spectrum, VEI – vegetative equilibrium index, VRR – vegetative rate of rhythm, WI – workload index

Indicators that had the biggest differences between the groups are given in bold.

* differences between groups at $p \leq 0.05$ (Kruskal–Wallis criterion)

link of regulation – 2.2 (1.25; 3.02) un. [22]. WI, at the same time, was 59.5 (39.6; 155.2) un. and pointed to the absence of intension of the organism's regulatory systems and predominance of the activity of the autonomous regulation contour [20]. Other indicators of HRV (the lowest – AMo [25.32 (22.28; 40.18), ms, $p \leq 0.05$], the highest HRV-index [17 (14; 19), un., $p \leq 0.05$] showed a high level of organism functioning under the influence of educational intension [14].

Indicators of HRV of students from group III were within the norm [20]. The value of the spectral indicator of LF/HF [0.88 (0.63; 2.39], un., $p \leq 0.05$] gives grounds for claiming the high activity of the autonomous regulation contour [22]. It can be assumed that the training intension corresponded to the high psychophysiological abilities of the persons in this group (Table 1) and had no stress influence at the organisms. That was displayed in a satisfactory functional state of central hemodynamics (Table 2) and heart rhythm formation.

In students from group IV values of most indicators of HRV met the standards [22]. The indicator of vegetative balance of LF/HF [2.05 (0.66; 3.16), un.] indicated the predominance of the activity of the sympathetic regulatory link. They were characterized by the lowest values of VLF% [33 (24; 47), %; $p \leq 0.05$] among the examined groups.

Factor analysis of the data was conducted for each examined group. Among the highlighted factors, the largest contributors to the overall dispersion were the first factors. That is why only the indicators, which were parts of the first factors of each group, were included in further analyses [8]. When comparing the data of each group with the optimal ones, a chart was presented (Figure 1).

As we can see in Figure 1, the largest deviations were found among the students of group I: spectral indicators LF/HF and VLF showed deviations of 80-100%; 20--40% – for VS, HRV, CV, HF%, VRR, WI; indicators of central hemodynamics, LF, LF%, HF, NN50, IARP – to 20%; the smallest deviations (to 10%) were found for AP, DR, Mo, RRNN, and RMSSD. A significant deviation of LF/HF (78%) was recorded [3, 11, 22].

In group II, factor I was formed by HRV indicators. The HRV index showed the highest deviations – 42%. VLF, WI and IARP were lower at 20-40%, NN50 and VEI – 10-20%, other indicators – to 10%, or were at the optimal level. Students of this group were characterized by high functional capacity of the organism, which was manifested in the negative deviations of indicators WI, IARP, VEI and significant positive deviations in indicators VS, HRV.

Factor I of persons from group III included psychophysiological indicators (memory for syllables

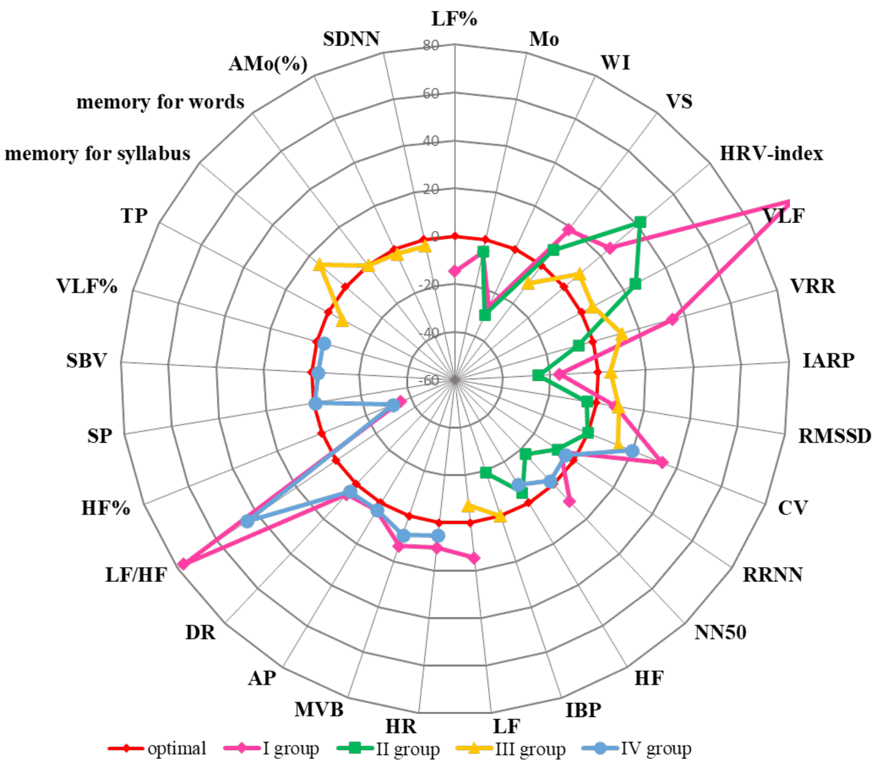

Figure 1. Deviation in % of indicators I factor of each group from the optimal

and words) and vegetative regulation. The values of these indicators were within ±14%. It can be stated that the regulatory activity of the heart rhythm occurred at an autonomous level without involving regulatory mechanisms of central hemodynamics.

Group IV. Spectral indexes of vegetative balance showed the largest deviations (LF/HF) – 45% and HF% – 32%, index CV – 20%, with the other indicators (Figure 1) showing deviations of 10%. Regulatory mechanisms of central hemodynamics were realized by strengthening the heart work. The deviation of the relative value of the respiratory component of the spectrum (HF%) against the background of negligible RRNN, NN50, HF and a significantly higher CV indicated decreasing in the activity of the autonomous regulation contour [24].

Discussion

Mechanisms of mental intension, which provide resultative human activity, in spite of their complexity and diversity, they eventually lead to the same result – changes in the functions of organs and systems of the organism [2, 3, 7, 14, 15, 18]. Stress appears as a result of an interaction between the individual and the environment, where the individual considers requirements of a situation as excess of functional resources [1].

Evaluating the psychophysiological support of the mental capacity of a person uses indicators of heart rate variability as a reliable marker of the functioning of the organism in general [15]. If psychophysiological functions and vegetative reactions of the individual are low and not able to rebuild in new functional creations, then they become a prerequisite for the development of maladaptation, greater severity of changes in the functioning of the cardiovascular system [4, 13, 14]. Markers of maladaptation include deviation of heart rhythm indicators, insufficient vegetative support, disturbance of the daily profile of blood pressure and heart rate, hypertensive response to professionally directed intension, disturbance of cerebral venous blood flow [21]. The development of autonomic reactions is a summary and a non-specific result that characterizes the influence of information processes. Stress perception activates physiological responses. Any changes that appear due to changes in the wave structure of the signal of the central nervous system will be reflected in the change in the rhythmic activity of the heart [27].

In group I the result of imbalance of regulatory influences on the heart rhythm upon activation of central hemodynamics is found as a decompensatory mechanism for the formation of adaptive reactions. Adaptation for training intensions was accompanied by high activity of cerebral ergotropic influences. Regulatory influences were manifested in increased blood flow due to HR, which affected the systolic heart function.

Insignificant deviations from the optimal values of cardio intervals and their statistical derivatives can testify to the influence of age peculiarities related to maturation of organism structures, which is manifested in the imperfect regulation of the heart rhythm [13]. The increased regulatory effects of central hemodynamics on the background of vagal activity corresponded to the compensatory mechanism of regulation by type A in group II.

Students of group III were characterized by indicators, which had no significant differences from the optimal ones, and indicated high parasympathetic activity of ANS. The presence of memory indicators in factor I confirms the data obtained by researchers that individuals with more memory capacity less often exhibit physiological signs of stress [6]. The optimal mechanism for the development of adaptive reactions was a specific characteristic for the studied group of students.

Adaptive reactions were formed with the activation of the sympathetic part, the enhancement of the activity of the hemocirculatory apparatus was regulated by cardiac output of the activity of the hemocirculatory apparatus and was regulated by cardiac output. The compensatory mechanism for the development of type B adaptive reactions was specific to students of group IV.

The described mechanisms of adaptive changes have been explained by models of visceral integration, which examines the physiological mechanisms of adaptation through the formation of the integration system of the brain that provides flexible management and coordination of the peripheral link of regulation [23], and double-circuit regulation of heart rate [3].

Conclusions

Differences of mental functions in students of different groups were established. Group I – the highest indicators of memory for words, syllables ($p \leq 0.05$), group III – high speed of switching attention, memory for numbers and figures, group IV – productivity, volume and distribution of attention, group II – the lowest indicators of psychophysiological functions. Such results may be due to the specifics of professional workloads, which differ in content and volume. High levels of MVB [6.0 (5.4; 6.6) l/min], HR [83 (74; 89) beats/min], SDNN [63.3 (55.0; 70.1), ms] and LF/HF [2.43 (1.18; 3.64), un.] in students from group I indicated an increase in the activity of the hemocirculatory system and the predominance of sympathicotonic effects on heart rhythm. In group II the highest SBV [75.6 (70.1; 83.0), ml/min] and lowest HR [77 (65; 82), beats/min, $p \leq 0.05$] with high LF/HF [2.2 (1.25; 3.02), un., $p \leq 0.05$] indicated the optimal level of regulation of central hemodynamics in the activation of the sympathetic link of regulation. Students from group III had the lowest values of LF/HF [0.88 (0.63; 2.39), un., $p \leq 0.05$] and hemodynamic parameters that corresponded to the norm. Students from group IV had the lowest VLF and VLF% [854 (612; 1616), ms^2 and 33 (24; 47), %; $p \leq 0.05$], the highest LF% (39 (29; 52), %, $p \leq 0.05$] and VEI [122.7 (91.4; 157.0), un., $p \leq 0.05$]. This may be the result of reduced ergotropic resources under stress and increased sympathicotonia.

According to the results of factor analysis, the important indicators were identified. Students from group I were characterized by a decompensatory mechanism of reactions to the workload, group II – a compensatory mechanism of regulation type A, group III – the optimal one, IV – a compensatory mechanism of regulation of type B.

However, there are some limitations. The expanding literature on HRV norms requires careful interpretation. Due to the lack of standardization of short-term measurement protocols, concurrent validity criteria, normative values for healthy non-athlete (in our case – students of pedagogical universities), optimal performance, and clinical populations, it is not recommended to use short-term interchangeably with 5-minute values. At the same time, recordings of heart rate variability in populations may be affected by duration, intensity, type of physical activity, food and drink consumption or testing environment. In our research, the potential environmental influences, such as testing participants in a similar environment at the same time of day, were not accounted for and controlled. These could contribute to inaccurate analyses and interpretations of received results.

Disclosure and recognition

Indicators of psychophysiological functions, central hemodynamics and heart rate of students with different types of initial load were analyzed. The mechanisms of adaptive reaction development in an organism were defined and characterized.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Atsan N. Decision-making under stress and its implications for managerial decision-making: a review of literature. IJBSR. 2016;6(3):38-47.
2. Baek HJ, Cho CH, Cho J, Woo JM. Reliability of ultra--short-term analysis as a surrogate of standard 5-min analysis of heart rate variability. Telemed J. E. Health. 2015; 21:404-414.
3. Bakayev V, Bolotin A. Comparative analysis of the dynamics of heart rhythm variability indicators of long--distance runners in different training conditions. Sport Mont. 2019;17(2); 41-46.
4. Baker T, Nikolic G. O'Connor S. Practical Cardiology. Elsevier Australia; 2008.
5. Besklinska OP. The use of statistical computing technologies in humanitarian research. Foreign Languages. 2016;2;48-53. (in Ukrainian)
6. Burnett-Zeigler IE, Waldron EM, Hong S, Yang A, Wisner KL, Ciolino JD. Accessibility and feasibility of using technology to support mindfulness practice, reduce stress and promote long term mental health. Complement Ther Clin Pract. 2018;3:93-99.
7. Castaldo R, Melillo P, Bracale U, Caserta M, Triassi M, Pecchia L. Acute mental stress assessment via short term HRV analysis in healthy adults: A systematic review with meta-analysis. Biomed Signal Process Control. 2015; 18:370-377.
8. Hulka O. Strategies forming of adaptive reactions in the students' organisms with different character of educational load. Science and Education a New Dimension. Natural and Technical Sciences. 2019;193,VII(23):20-24. (in Ukrainian).
9. Li X, Zhou Y, Wong YD, Wang X, Yuen KF. What influences panic buying behaviour? A model based on dual-system theory and stimulus-organism-response framework. Int J Disaster Risk Reduct. 2021;64: 102484.
10. Lipatova O, Campolattaro MM, Dixon DC, Durak A. Sex differences and the role of acute stress in the open-field tower maze. Physiol Behav. 2018;189(15):16-25.
11. Liu X, Iwanaga K, Shimomura Y, Katsuura T. The reproducibility of cardiovascular response to a mental task. J Physiol Anthropol. 2010;29(1):35-41.
12. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. Pediatrics. 2016;138(3):e20161642.
13. McCraty R, Shaffer F. Heart rate variability: new perspectives on physiological mechanisms, assessment of self-regulatory capacity, and health risk. Glob Adv Health Med. 2015;4(1):46-61.
14. Mestanik M, Mestanikova A, Visnovcova Z, Calkovska A, Tonhajzerova I. Cardiovascular sympathetic arousal in response to different mental stressors. Physiol Res. 2015; 64(5):585-594.

15. Petrenko Yu O, Menshykh OE. Neurodynamic and psychiatric functions in young children with different levels of physical development: theory and practice. Cherkasy: ChNU; 2014. (in Ukrainian)
16. Riffenburgh RH, Gillen DL. Statistics in Medicine. 4th edition. Academic Press, Elsevier; 2020.
17. Romanenko VA. Diagnostics of motor abilities. Donetsk: DonNU; 2005. (in Ukrainian)
18. Rovnyi AS, Lyzohub VS. Psychosensory mechanics of athletes' movements control. Kharkiv: KhNADU; 2016. (in Ukrainian)
19. Shagivaleeva GR, Biserova GK. Socio-psychological adaptation of international students to learning and professional activities. Space and culture, India. 2019; 6(5):99-114.
20. Shutova T, Vysotskaya T, Pihaev R, Polshikova J. Dynamics of the morphofunctional state of students with the expansion of fitness means in physical education classes. J Human Sport Exerc. 2021;16(3);1006-1015.
21. Suslova N. Psychophysiological features of persons of 15-20 years with high blood pressure. Dissertation. Ternopil State Medical University named after I. Ya. Gorbachevsky; 2007. (in Ukrainian)
22. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation, and clinical use. Circulation. 1996;93:1043-1065.
23. Thayer J, Ahs F, Fredrikson M, Sollers J, Wager T. A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. Neurosci Biobehav Rev. 2012;36:747--756.
24. Trimmel M. Relationship of heart rate variability (HRV) parameters including pNNxx with the subjective experience of stress, depression, well-being, and every-day trait moods (TRIM-T): a pilot study. Ergon Open J. 2015;8(1):32-37.
25. Voloshyn Yu A, Kulish SN, Oliinyk VP. Ways to increase the information content of bioelectric signal analysis. Radyotekhnyka. 2019;196:98-105. (in Ukrainian)
26. Young HA, Benton D. Heart-rate variability: a biomarker to study the influence of nutrition on physiological and psychological health?. Behav Pharmacol. 2018;29(2):140--151.
27. Yumatov EA. To knowledge of the origin of the brain mental activity. World J Neurosci. 2014;4(2):170-182.