Psychophysiological Correlates of Teenagers Adaptation in an Innovative Educational Institution of a Boarding School

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Abstract: The article presents the results of a study of the relationship of psychophysiological characteristics with indicators of the autonomic regulation of the body of adolescents studying in an innovative educational institution of a boarding type. The article shows that, compared with boys, adolescent girls had a lower level of visual-motor response, functional mobility of nervous processes, and brain performance. Correlations between heart rate variability indicators reflecting sympathetic influences on the heart rhythm and the level of functional mobility of nervous processes have been established. And negative connections were established with the performance of the brain, indicating the predominance of the parasympathetic activity of the autonomic nervous system in adolescents with a high level of functional mobility of nervous processes and the performance of the brain. Adolescents with a low level of neurodynamic characteristics differed from their peers in the deterioration of cognitive indicators and the functional state of the body, poor adaptation.

1. Introduction

At the present stage, more and more new technologies, forms, training modes are being added to the education system. In addition, new types of educational institutions are being created. The problem is that innovations are often introduced without appropriate scientific psychological and physiological approaches. This contributes to the development of fatigue and overwork in students, caused by the influence of training loads that do not correspond to the functional capabilities of the student's body and, as a result, to a deterioration in their health.

The current scientific problem is becoming especially significant for non-standard educational institutions, the goals, and objectives of which are mainly associated with the implementation of more complex curricula. Described in modern studies, the increasing impact on the psyche and body of students of school factors indicates the relevance of studying the problems of adaptation of students to innovative learning conditions. In this regard, adolescence is of particular interest. Precisely during this period of ontogenesis, serious neuroendocrine rearrangements (as well as a reassessment of values, changes in interests, adaptation to adulthood) occur.

Adolescence is the most controversial and challenging period in the life of both the child and their parents. Most often, adolescent difficulties are associated with puberty. During this period, the body begins to produce a large number of hormones, controlled by the thyroid gland and the pituitary gland [1]. These hormonal changes lead to rapid physical development and growth; in connection with this, the child's psychophysical state also changes; he/she becomes more impressionable, irritable, conflicting, vulnerable, and his/her mood quickly changes. Regardless of age, each person has own properties of the nervous system. The individual characteristics of the nervous system determine the speed, strength, and poise of the reactions we show. They can be reflected in the type of thinking, in speech, in a strategy of behavior. The properties of the nervous system are biological, innate, not acquired qualities. However, typological properties can be corrected by 25% [2]. The application of knowledge about the typological properties of the nervous system can help in choosing an effective model of behavior that allows you to maintain the optimal functional state of the body and its adaptive capabilities. In this regard, the study of the functioning of the autonomic functions of the body, due to the influence of processes of higher nervous activity, is of interest.

In this connection, the study aimed to study the relationship of typological and cognitive characteristics with heart rate variability of adolescents studying in a boarding school.

2. Materials and Methods

The study was conducted on the basis of the Governor's multi-disciplinary boarding school (GMLI) in Kemerovo. The object of the study was students of older adolescents (14-16 years old) in the amount of 116 people of both sexes.

To study neurodynamic and cognitive functions, the automated psychophysiological program “PFK” was used. It allows one to determine the following indicators: the speed of a simple visual-motor reaction (PZMR, ms); the speed of a complex visual-motor reaction (SZMR, ms); functional mobility of nervous processes (UVP NP, s); brain performance (RGM, number of signals); the nervous system balance in response to a moving object (RDO, ms) [3]. Using the "ORTO" automated cardiac rhythmographic program, the time (PULS is the heart rate, beats per min.; M is the average value of cardio intervals, sec; Mo - fashion, sec; AMo - fashion amplitude, %; X is the variation range, sec; SDNN is the standard deviation, ms; RMSSD is the rms difference between the duration of adjacent R-R intervals, ms; SI is a stress index, conventional units) and spectral (HF is a high-frequency component, beats / min^2; LF is the low-frequency component, beats / min^2) characteristics of heart rate variability (HRV) were evaluated [4].

Statistical processing of the obtained data was carried out using the software package “Statistica 8”. For each parameter studied, the mean value (M), the representativeness error of the mean (m) were calculated. The reliability of the differences of attributes (P) in the compared groups was evaluated according to the Mann-Whitney U-test. Correlation coefficients, according to the Spearman significance criterion, were calculated [5].

3. Research Results

As a result of the study of neurodynamic characteristics, reflecting the properties of the nervous system and indicators of memory and attention in students of 8th, 9th and 10th grades, a regular decrease in the time of visual-motor response and an increase in the mobility of nervous processes and brain performance in the examined adolescents were revealed (Table 1).

TABLE 1. PSYCHOPHYSIOLOGICAL CHARACTERISTICS OF TEENAGERS BY CLASS

Indicators	8th grade (n=34)	9th grade (n=38)	10th grade (n=44)	P<0.05
PZMR, ms	316.7±9.3	326.9±13.1	315.5±9.0	
SZMR, ms	484.5±12.1	480.8±10.96	468.6±9.6	1-3
UVP NP, s	72.5±4.03	68.4±3.1	64.7±3.7	1-3
RGM, number of signals	545.3±11.7	562.0±15.4	585.1±11.8	1-3
RGM, number of errors	154.8±3.9	162.5±7.2	156.1±5.9	
Memory for numbers, score	6.5±0.4	5.4±0.3	6.2±0.3	
Memory for words, score	6.8±0.4	6.5±0.3	7.3±0.2	
RAM, score	7.5±0.4	7.4±0.6	7.7±0.4	
Volume of attention, score	7.4±0.5	6.6±0.6	6.7±0.4	

With a pronounced tendency to improve the neurodynamic characteristics of adolescents with age, the indicators of memory and attention did not have a clear age dynamic (Table 1).

However, as a result of the correlation analysis, a close relationship of neurodynamic indicators with the cognitive characteristics of the subjects was found. In students of 8th grade, the attention volume indicator had negative connections with PZMR (r = -0.43), UVP NP (r = -0.56), and a positive relationship with RGM (r = 0.54). In turn, RGM is positively associated with indicators of short-term memory (r = 0.43). For adolescents studying in the 9th grade, negative correlation relationships between PZMR and memory for numbers (r = -0.54), with random access memory (r = -0.57) are characteristic. And these adolescents had a positive relationship with memory for words (r = 0.63). Also, positive connections were noted between RGM and attention volume (r = 0.61). In students of the 10th grade, a negative correlation between the SZMR and RAM (r = -0.41), between the PZMR and the amount of attention (r = - 0.49) were revealed.

Analysis of the neurodynamic characteristics of adolescents from different sexes showed that the values of SZMR and UVP NP of adolescent girls are higher than in boys, which indicates a higher functional activity of the links of the reflex arc of the latter. In boys, the RGM score is higher, which shows the best ability of the central nervous system nerve cells to withstand prolonged concentrated excitation without going into a state of protective inhibition (Table 2).

TABLE 2. NEURODYNAMIC INDICATORS OF TEENAGERS TAKING INTO ACCOUNT THEIR GENDER

Indicators	Boys	Girls	P<0.05
SZMR, ms	460.8±11.3	491.4±8.5	0.04
UVP NP, s	62.8±2.1	65.2±0.8	0.02
RGM, the number of signals	595.4±15.0	543.9±9.1	0.003
RGM, the number of errors	167.263±6.2	152.969±3.8	0.04

Analysis of the distribution of students by the level of indicators of UVP NP and RGM taking into account gender showed a higher percentage of students with low levels of UVP NP and RGM among teenage girls (32% and 24%, respectively). In terms of PZMR, there were no significant differences between adolescents of different sexes.

Since the intensity and direction of the reaction of any body system in the process of adaptation depends on the initial level of its functional state, and the reaction of the autonomic system to any endogenous effect differs in people of not only different sexes but also with different typological features [6], an analysis to identify the relationship of neurodynamic characteristics with indicators of autonomic regulation of adolescents was carried out.

TABLE 3. RELATIONSHIP OF NEURODYNAMIC CHARACTERISTICS WITH INDICATORS OF VARIABILITY OF THE HEART RHYTHM (R)

Indicators	PZMR, ms	UVP NP, s	RGM, number of signals
PULS at rest, beats per min.		0.31	-0.34
PULS in ortho, beats per min.		0.33	
M at rest, sec.		- 0.31	0.34
M in ortho, sec.		- 0.32	
Mo at rest, sec.		- 0.32	0.35
Mo in ortho, sec.		- 0.36	
AMo in ortho, %		0.36	-0.31
SDNN in ortho, ms		- 0.35	0.34
SI to ortho, arbitrary units		0.38	-0.32
LF, beats / min^2	0.29		
HF, beats / min^2	- 0.29		

Note: Only correlations with a statistically significant correlation coefficient (r) $p < 0.05$ are indicated.

The UVP NP indicator had significant positive relationships with the temporal characteristics of heart rate variability (AMo, SI, PULS), reflecting sympathetic effects on the heart rhythm, and, conversely, this indicator had negative connections with the indicators (SDNN, X, Mo) characterizing parasympathetic activity ANS. Positive correlations of the RGM indicator with the temporal characteristics of HRV, such as M, Mo, SDNN, and negative relations with the PULS, AMo, SI indicators were noted (Table 3). The PZMR index was distinguished by the presence of reliable relationships only with the wave characteristics of HF and LF; with temporary indicators of HRV, no connections were identified (Table 3). A negative association with a high-frequency characteristic (HF) and a positive one with a low-frequency characteristic (LF) indicate that an improvement in the functional state of the central nervous system (CNS) of adolescents is accompanied by an increase in parasympathetic effects on heart rate and a decrease in sympathetic.

During the assessment of the state of the regulatory systems of the body, including the results of diagnostics of the state of the autonomic nervous system at rest and during an orthostatic test, and the nature of the transition process, integral conclusions about the functional state and adaptive capabilities of the adolescent organism were obtained. Based on these findings, students were divided into the following three groups: Group 1 with optimal functional state of the body, satisfactory adaptation (21.7%); Group 2 with a

slight or moderate decrease in the adaptive capacity of the body (58.7%); Group 3 with a significant decrease in the functional capabilities of the body, poor adaptation (19.6%).

A comparative analysis of the psychophysiological characteristics of adolescents, taking into account the integral conclusion about the functional state of their body, revealed some features of the neuro-vegetative status of the subjects. So, the average value of the MCHP indicator was higher among students with poor adaptation (group 3). The optimal values of this indicator were recorded in high school students with satisfactory adjustment (group 1) and a moderate decrease in the adaptive capacity of the body (group 2) (Fig. 1).

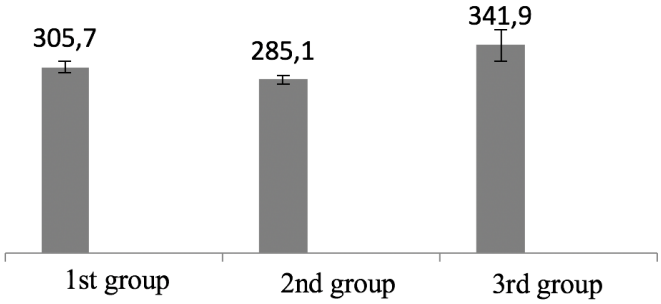

Fig. 1. The indicator of PZMR of adolescents, taking into account the integral conclusion about the functional state of the body and adaptive capabilities (in ms).

An increase in the response time to visual stimuli indicates a deterioration in the functional state of the central nervous system of adolescents with poor adaptation.

Also, students of this group had lower values of indicators of short-term visual memory and attention volume (Fig. 2).

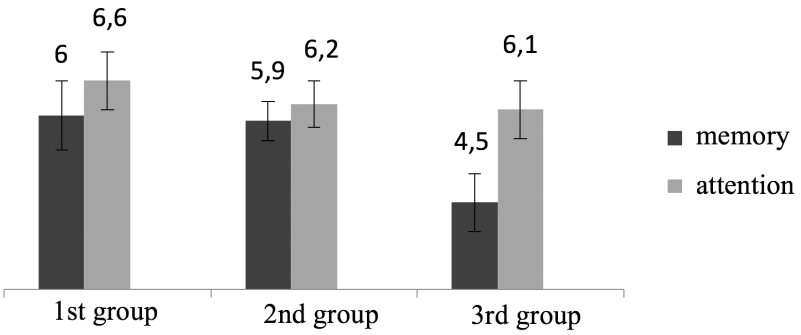

Fig. 2. Short-term memory for numbers (SM) and attention volume (AV) of adolescents, taking into account the integral conclusion about the functional state of the body and adaptive capabilities (score).

4. Discussion

In general, adolescents improve their time and accuracy of sensory reactions, improve the neurodynamic properties of the nervous system by the age of 16. An increase in the strength and mobility of nervous processes occurs, but excitation processes continue to prevail over inhibition.

The indicators of a complex visual-motor reaction and the level of functional mobility of nervous processes in girls, which have higher values compared to boys, indicate their slower visual-motor response to the presented stimuli. High RGM values in boys, if compared with girls, show a greater strength of their nervous system.

The revealed positive correlations of heart rate variability indicators, reflecting sympathetic influences on the heart rhythm, with the level of functional mobility of nervous processes, and negative correlations with the working capacity of the brain, indicate the following. The parasympathetic activity of the ANS in teenagers with a high level of functional mobility of nervous processes and brain performance prevails. A

decrease in the level of simple visual-motor reaction, accompanied by an increase in the values of low-wave and a reduction in the high-wave characteristics of the spectrum, indicates an increase in sympathetic effects on heart rate with a deterioration in the functional state of the central nervous system.

5. Conclusion

The dependence of the psychophysiological characteristics of adolescents studying in a boarding school on the functional state of their body, assessed by HRV, is confirmed by the following: the poor adaptation of students with a low level of neurodynamic characteristics, short-term memory and attention volume, the predominance of inhibition processes over excitation.

The data obtained indicate the need for psychophysiological monitoring at a critical stage of individual development. The choice of a learning strategy, taking into account the properties of the nervous system of students, can increase the efficiency of mastering the school curriculum and optimize the adaptation process.

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References

[1] Tarasova, O. L., Kazin, E. M., Fedorov, A. I., Igisheva, L. N., & Chetverik, O. N. (2017). Comprehensive assessment of neurodynamic and autonomic indicators in adolescents: Age, gender and typological features. *Human Physiology*, *43*(1), 45-54.

[2] Litvinova, N. A., Kazin, E. M., & Ivanov, V. I. (2006). The role of psychophysiological indicators in the success of adapting high school students to specialized education. *Vestnik of Tomsk State University*, *21*, 56-57.

[3] Ivanov, V. I., Litvinova, N. A., & Berezina, M. G. (2004). An automated complex for assessing individual typological properties and the functional state of the human body “PF Status.” *Valeology*, *4*, 70-73.

[4] Baevsky, R. M., & Ivanov, G. G. (2001). Heart rate variability: Theoretical aspects and clinical applications. *Ultrasound and Functional Diagnostics*, *3*, 106-127.

[5] Kashdan, E., Duncan, D., Parnell, A., & Schattler, H. (2016). Mathematical methods in systems biology. *Mathematical Biosciences and Engineering*, *13*(6), i-ii. http://dx.doi.org/10.3934/mbe.201606i

[6] Varich, L. A., Fedorov, A. I., Nemolochnaya, N. V., & Blinova, N. G. (2018). The relationship of psychophysiological indicators and cortisol levels of adolescents studying in a boarding school. *Vestnik of the Novosibirsk State Pedagogical University*, *8*(5), 230-244.