

The relationship between the indicators of anxiety in adolescents with the features of autonomic regulation of the heart rate

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Abstract.

The study is devoted to the study of the relationship between the characteristics of the manifestation of anxiety in adolescents studying in a boarding-type educational institution, with indicators of heart rate variability, reflecting the functional state of the cardiovascular system and the body as a whole.

The study involved adolescents aged 14-16 years old, studying in a boarding school (112 people). The study of the level and characteristics of the manifestation of school anxiety was carried out according to the method of A.M. Prikhodzhan. Evaluation of heart rate variability indicators was carried out using a cardiorythmographic program with subsequent analysis of the studied parameters according to R.M. Baevsky, according to which the types of autonomic regulation were identified in the examined adolescents: vagotonic, sympathicotonic, eutonic. The data obtained in the course of the study were processed using the «Statistica 10.0» program. For all studied indicators, the mean and error of the mean, the reliability of differences were calculated. To identify the relationship between the indicators of anxiety and the features of autonomic regulation of cardiac activity, a correlation analysis was carried out.

It was shown that adolescents with increased anxiety demonstrate an increase in indicators reflecting sympathetic influences on the heart rate, both at rest and in orthostasis. For adolescent girls, a large number of negative correlations between heart rate variability indicators, reflecting the sympathetic effect on heart rate, are characteristic, compared with boys who have an opposite relationship. In adolescent boys, a decrease in the level of general anxiety is accompanied by an increase in the activity of the parasympathetic division of the ANS, and in girls, an increase in sympathetic influences on the heart rate.

Keywords: adolescents, boarding school, school anxiety, indicators of heart rate variability, type of autonomic regulation, sympathetic and parasympathetic influences.

Introduction

Currently, the education system, along with unfavorable environmental conditions, is not aimed at preserving and strengthening the health of the subjects of the educational process, but at its deterioration. This is evidenced by the massive violation of the physical and neuropsychic development of children, which manifests itself in neurotic conditions, defects in puberty, deterioration in the level of physical fitness. Among the factors that negatively affect the peculiarities of the formation of adaptive reactions to the learning process, in educational institutions of various levels, it is necessary to highlight the irrational intensification of the educational process, physical inactivity, the unfavorable socio-economic situation of children and adolescents, insufficient qualifications of teachers in the formation, preservation and strengthening of the child's health, massive parental illiteracy in matters of child health (Assis, 2020). The maximum level of mental and physical stress, which is combined with high emotional stress, often leads to overstrain of physiological systems and a deterioration in the functional state of the body, accompanied by an increase in the level of anxiety (Bezrukikh, 2010).

School anxiety is a deep concept that includes various indicators of persistent school emotional distress.

The problem of adolescent anxiety is one of the most pressing problems in modern psychology, since anxiety, acquiring a stable form, often becomes the cause of the appearance of neuroses and inappropriate behavior (vanDalen, 2020). This condition leads to a decrease in self-esteem and a decrease in educational productivity, apathy, conflicts with teachers and parents. The inability to assert itself leads to rebellion against parents, teachers and society as a whole, which is expressed in the fact that the child begins to get involved in informal companies, in the manifestation of aggression towards people around, in the acquisition of bad habits and unwanted friends (Brown, 2019; Connor, 2019; Stelzig, 2019).

In addition to behavioral disorders, an increase in the level of anxiety adversely affects the functioning of organs and systems of the body, leading to psychosomatic disorders (Lebedeva, 2019; Creswell, 2020).

Considering this fact, the purpose of this study was to study the relationship between the characteristics of anxiety manifestations in adolescents studying in a residential educational institution, with indicators of heart rate variability,

reflecting the functional state of the cardiovascular system and the body as a whole.

Materials and methods

The study involved 112 students of the 8th, 9th and 10th grades, enrolled in a multidisciplinary boarding school in the city of Kemerovo, in the amount of 112 people.

The assessment of indicators of anxiety was carried out according to the method of A.M. Prikhozhan. The main feature of scales of this type is that in them anxiety is determined by a person's assessment of anxiety in certain situations of everyday life. The tests present situations for which, in adolescent children, internal anxiety occurs. They assess the level of anxiety for the situation by points from 0 to 4 (Prikhozhan, 2007).

During processing, the answer to each of the questions is evaluated by the number of points corresponding to the number rounded off when answering it. The total score is calculated for the scale as a whole and separately for each subscale. The resulting score is the primary grade, which is then converted to a scale. A standard ten is used as a scale assessment. For this, the subject's data are compared with the normative indicators of a group of students of the corresponding age and gender. The result obtained on the whole scale is interpreted as an indicator of the general level of anxiety, on separate subscales - for individual types of anxiety (Prikhozhan, 2007).

Assessment of indicators of heart rate variability (HRV) using a cardiorythmographic program based on a mathematical analysis of the heart rate (Baevsky, 2002).

For the analysis, 420 cardiointervals (R-R), 210 at rest (lying), 210 while standing with the registration of the transition period were recorded.

Thanks to the method, it is possible to identify the degree of activity of various links in the sinus node control system: the nuclei of the vagus nerve, cortical-subcortical relationships, humoral-hormonal mechanisms of regulation.

The subsequent analysis of the recorded cardiomass was to calculate simple statistical indicators of the variability of the array. These indicators were calculated both for the state of rest and for orthostasis: heart rate (heart rate, beats/min); mode (Mo, sec) - the most common values of R-R cardiointervals; mode amplitude (Amo, %) - expressed as a percentage, the number of interval values corresponding to the mode; variation range (ΔX , sec) - the difference between the value of the largest and the smallest cardiointervals; standard deviation (SDNN, ms) -

characterizes vagus regulation; root-mean-square difference between the duration of adjacent R-R intervals (RMSSD, ms) - a measure of HRV with a short cycle duration; stress index of regulatory systems (IR, conventional units) (Baevsky, 2001; Shlyk, 2009).

Based on the results of the analysis of indicators of heart rate variability, a conclusion is formed about the functional state of the body and the type of autonomic regulation. The following types are distinguished: sympathicotonia - the predominance of the sympathetic division of the ANS, vagotonia - the severity of parasympathetic influences on the heart rate, eutonia - the balance of the influence of the ANS divisions.

The data obtained in the course of the study were processed using the «Statistica 10.0» program. A database was created in the format of the «Statistica 10.0» program, which includes 112 surveyed persons. For all studied indicators, the mean value (M) and the error of the mean (m) were calculated. The significance of the difference

in characteristics (p) in the compared groups was assessed by Student's t test (t)

In order to identify the relationship between the parameters of heart rate variability and indicators of anxiety in adolescents, a correlation analysis was carried out.

Results

An analysis of the anxiety indicators of adolescents studying at the boarding school revealed significant differences in the studied indicators among boys and girls. Thus, it has been shown that in all anxiety indicators, adolescent girls are more anxious than boys (Fig. 1).

Anxiety associated with self-esteem is characterized by higher rates of variation. This is due to the urgency of self-determination, the formation of self-awareness, characteristic of this age group. If in the field of interpersonal relations some adolescents have serious difficulties, and their level of interpersonal anxiety may be high.

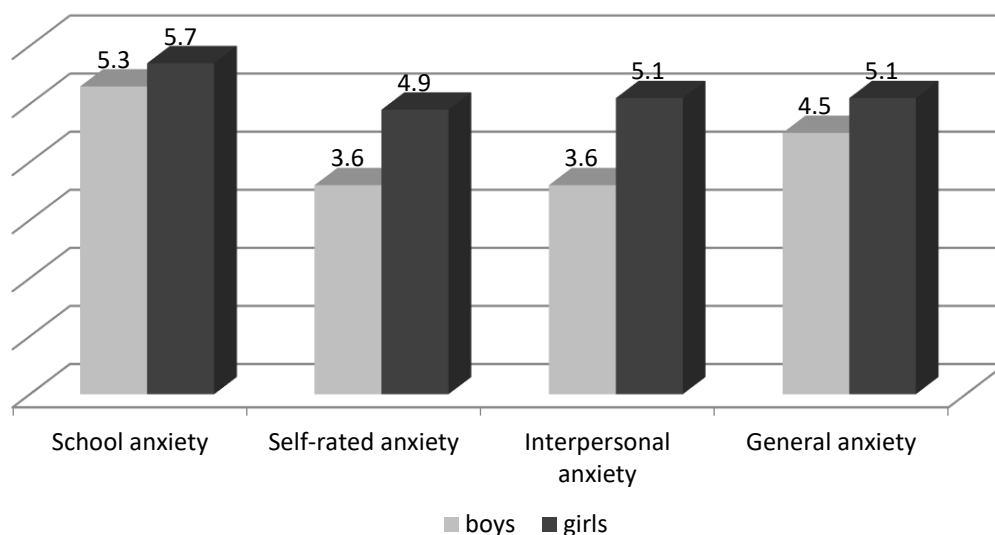


Fig. 1. Anxiety indicators of adolescents of different sexes enrolled in boarding school (in points)

In the surveyed adolescents, school anxiety has a higher value of the indicator, the lowest value of the indicator is magical anxiety (Table 1).

Table 1. Indicators of anxiety of adolescents studying in boarding school (point)

Indicators of anxiety	Anxiety level
School - 4.3 points	Average
Self-rated - 3.7 points	Low
Interpersonal - 3.6 points	Low

Magic - 2.2 points	Low
General - 3.9 points	Low

The results of the assessment of certain types of anxiety are shown that according to:

- *anxiety associated with self-esteem*: 46.9% of adolescents have a low level, 32.6% - an average level and 20.4% - a high level of anxiety;

- *interpersonal anxiety*: 48.9% of adolescents have a low level, 28.5% of adolescents have an average level and 22.6% have a high level of anxiety;

- *school anxiety*: 36.7% of adolescents have a low level, 26.6% of adolescents have an average level and 36.7% have a high level of anxiety.

- *general anxiety*: 38.8% of adolescents have a low level, 34.7% of adolescents have an average level and 26.5% have a high level of anxiety.

Based on the results of assessing the level of general anxiety, the students were divided into three groups: group 1 - a low level of anxiety (from 1 to 3 points), group 2 - an average level of anxiety (from 4 to 7 points), group 3 - a high level of anxiety (from 8 to 10 points).

The results of a comparative assessment of the indicators of heart rate variability (HRV) in the selected groups showed that in adolescent children with an average level of anxiety there is an increase in the activity of the parasympathetic division of the autonomic nervous system (ANS) in comparison with representatives with a high level of anxiety, which are characterized by activation of sympatho - adrenal activity (Table 1).

Table 2. Indicators of heart rate variability in adolescents with different levels of general anxiety

HRV indicators	1st group (n=44)	2nd group (n=38)	3rd group (n=18)	P<0.05
AMo at rest, %	43.1±3.98	35.3±3.09	44.15±4.54	1-2,2-3
AMo in ortho, %	54.4±3.71	53.06±4.29	52.76±5.41	
ΔX at rest, sec	0.198±0.029	0.203 ± 0.029	0.214±0.029	1-3
ΔX in ortho, sec	0.332±0.029	0.307± 0.041	0.225±0.025	
Mo at rest, sec	0.623±3.71	0.644±0.025	0.605±0.028	
Mo in ortho, sec	0.806±0.029	0.818±0.032	0.765±0.022	
SI at rest, conventional units	144.2±31.39	114.4±29.5	189.07±72.9	2-3
SI in ortho, conventional units	353.07±67.4	301.6±58.37	339.1±95.7	

There is a large value of the variation range (ΔX), reflecting the tone of the vagus nerve in the regulation of the heart rhythm and a lower value of the stress index (SI), which is an indicator of the total activity of the central circuit of the regulation of the cardiovascular system, which indicates an increase in the influence of the parasympathetic division of the autonomic nervous system. on the heart rate in adolescents with a low level of anxiety (Table 1).

The carried out correlation analysis of the studied indicators made it possible to reveal the dependence of the peculiarities of the manifestation of anxiety and the indicators of HRV, determined by gender (Table 3).

Table 3. Correlation dependence of heart rate variability indicators with indicators of anxiety in boys

HRV indicators	School	Self-evaluating	Interpersonal	General
SDNN in ortho	-0.53	-0.20	-0.26	-0.35
ΔX in ortho	-0.46	-0.06	-0.14	-0.21

Note: $r \leq 0.35$ significant dependence

Table 4. Correlation dependence of heart rate variability indicators with indicators of anxiety in girls

HRV indicators	School	Self-evaluating	Interpersonal	General
SDNN in ortho	0.26	0.46	0.31	0.33
AMo in ortho	-0.30	-0.42	-0.33	-0.33
SI in ortho	-0.21	-0.41	-0.27	-0.29
ΔX in ortho	0.23	0.41	0.29	0.31
RMSSD in ortho	0.28	0.42	0.30	0.34

Note: $r \leq 0.35$ significant dependence

Correlation analysis data shown in Tables 3 and 4 indicate a greater number of connections between anxiety indicators and HRV parameters in girls. At the same time, they also show negative relationships of all types of anxiety with indicators of heart rate variability, reflecting sympathetic effects on heart rate. In other words, girls with a predominance of vagal influences are highly anxious. Whereas, for boys, the opposite

tendency is characteristic: negative correlations between the parameters characterizing the predominance of the parasympathetic part of the ANS and indicators of anxiety.

The correlation analysis data was confirmed by the percentage distribution of adolescents by the type of autonomic regulation, taking into account gender.

Table 5. Percentage distribution of adolescent boys by type of autonomic regulation, taking into account the level of general anxiety

General anxiety level	Vagotonics	Eutonics	Sympathotonics
Low level	62.5%	12.5%	25%
Average level	66.6%	33.4%	0%
High level	0%	80%	20%

Thus, among boys with a high level of anxiety, there are more eutonics, while a high percentage of vagotonics is characteristic of low and medium levels of anxiety (Table 5).

The percentage distribution of adolescent

girls by type of ANS, taking into account the level of general anxiety, indicates a high percentage of students with sympathicotonia and a low level of anxiety (Table 6).

Table 6. Percentage distribution of adolescent girls by type of autonomic regulation, taking into account the level of general anxiety

General anxiety level	Vagotonics	Eutonics	Sympathotonics
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Low level	18.2%	27.3%	54.5%
Average level	50%	20%	30%
High level	37.5%	37.5%	25%

In other words, for adolescent girls, a high level of anxiety is preferable for adapting to the learning environment in a boarding-type educational institution, in contrast to boys, in whom a decrease in the level of general anxiety is accompanied by an increase in the activity of the parasympathetic division of the ANS.

Discussion

Studying at school presupposes the acquisition of new knowledge, and cognition is always accompanied by anxiety. With the elimination of this anxiety, the difficulties of cognition disappear, which are a necessary condition for the successful assimilation of knowledge.

However, the intensity of the school experience should not exceed the threshold of individual anxiety of each child, after which he begins to exert not a mobilizing, but a disorganizing influence (Fairchild, 2019).

The results of the study showed that, in general, the manifestations of school anxiety are more pronounced in girls. This may be due to greater responsibility and dependence on the opinions of others in girls at a given age.

The manifestation of anxiety, due to gender, is manifested in the fact that girls and boys react to danger in different substances: in girls - acetylcholine, in boys - adrenaline. This is reflected in the fact that girls react anxiously to any danger, for boys a situation of danger without a threat to their lives causes excitement and cheerfulness. Having greater stress resistance, girls are more anxious than boys. Such anxiety is often experienced by schoolgirls who are excellent students and have a responsible attitude to learning. Due to the fact that they are anxious about their studies, they often have nervous breakdowns, especially with the complication of activities (Fairchild, 2019).

On the one hand, children with severe anxiety are most often more executive and responsible in learning: they prepare their lessons on time, fulfill all the requirements of teachers, and do not violate the rules of behavior at school. On the other hand, the manifestation of high school anxiety can lead to a decrease in the functional reserves of the body and maladjustment.

The conditions of education in boarding-type educational institutions differ significantly from the conditions of a general education school. While studying at a boarding school, teenagers live in a hostel, in rooms for several people. In addition, students are constantly exposed to stressful factors, such as: being outside the family, a new team of teachers and classmates, the inability to be alone, etc. All this negatively affects the psycho-emotional status of a teenager. The success of training in such conditions presupposes not only a high level of development of intellectual abilities, but also good stress resistance and sufficient functional reserve capacities of the body (Varich, 2018).

Emotional processes and features of heart rate regulation have a common neurophysiological basis: prefrontal, ventromedial cortex, amygdala. Changes in the emotional state are accompanied by an increase or decrease in heart rate variability (Kolpakov, 2019; Cabral, 2020).

It has been shown that the level of general anxiety is interrelated with the peculiarities of autonomic regulation of the heart rhythm: highly anxious adolescents demonstrate a more pronounced activation of the sympathetic division of the autonomic nervous system, which indicates the generalization of anxiety and the possibility of its somatization. At the same time, an increase in the physiological activity of the sympathetic link in the regulation of the heart rhythm can be considered a physiological norm, which can be associated with an increased tension of the cardiohemodynamic system.

In boys, there is a pronounced dependence of HRV indicators on the level of school anxiety, while in girls, self-esteem and interpersonal types of anxiety come out on top, this once again confirms the great emotiogenic dependence of girls.

The manifestation of school anxiety is influenced by the following signs of the educational environment (Caldwell, 2019; Fairchild, 2019): 1) physical space - characterized by aesthetic features and determines the possibilities of the child's spatial movements; 2) human factors associated with the characteristics of the system "student - teacher - parents"; 3) school curriculum.

The onset of school anxiety is most often associated with socio-psychological factors, such as: unfavorable relations with teachers, regularly repeated assessment and examination situations, a change in the school team or rejection by the children's team (Creswell, 2020; Hugh-Jones, 2021).

One of the most important integral characteristics reflecting a person's response to changing environmental conditions is the balance of the activity of the sympathetic and parasympathetic divisions of the autonomic nervous system (ANS). ANS is a part of the body's nervous system, a complex of central and peripheral cellular structures that regulate the functional level of the body's internal life, which is necessary for an adequate response of all its systems (Baevsky, 2002).

In puberty, the activity of both sympathetic and parasympathetic components of autonomic regulation increases significantly, and autonomic dysfunction may occur. Its occurrence is facilitated by the incompleteness of the morphological and functional formation of the ANS and hormonal changes inherent in this age (Morozova, 2020). A temporary increase in the activity of the sympathetic link of autonomic regulation in adolescence ensures the adaptation of various body systems to external conditions. Thus, there is a kind of dualism in understanding the optimality of the predominance of one of the ANS departments (sympathetic or parasympathetic) at a certain point in time, under certain conditions in adolescence. The period when the lability of physiological systems to a greater extent show the instability of the organism as a whole to the adverse effects of pathogenic environmental factors (Zakharova, 2021; Chiu, 2021).

The response to psychoemotional stimuli differs in representatives of different types of autonomic regulation (Kircanski, 2019): in vagotonics, the emotional background is provided by the influence of the parasympathetic division of the autonomic nervous system, which is expressed in a decrease in anxiety indicators; sympathicotonia is combined with a high level of reactive and personal anxiety; in eutonics, the stability of the emotional background is carried out by the balanced influence of parasympathetic and sympathetic influences (Varich, 2020).

An increase in emotionality is more often observed in girls, and can manifest itself as vascular disorders, indicating an increase in subcortical influences and a weakening of the tone

of the cerebral cortex (Kolpakov, 2019; Zhu, 2019).

The weakening and decrease in the temporal and frequency indicators of HRV indicates changes in the structure of the system of neurohumoral regulation of the heart rate towards the dominance of cortical influences, that is, the tension of the regulatory systems associated with the actualization of a large number of resources (Billman, 2019; Ciccone, 2019).

Conclusion

The study made it possible to obtain very valuable prognostic data on the relationship between anxiety indicators and parameters of heart rate variability in adolescents studying in a boarding school. The established relationships between the level of anxiety and the indicators of heart rate variability in adolescents indicate the important role of psychoemotional well-being of students in the formation of adaptive reactions in the learning process.

It was shown that adolescents with increased anxiety demonstrate an increase in indicators reflecting sympathetic influences on the heart rate, both at rest and in orthostasis. For adolescent girls, a large number of negative correlations between heart rate variability indicators, reflecting the sympathetic effect on heart rate, are characteristic, compared with boys who have an opposite relationship.

In adolescent boys, a decrease in the level of general anxiety is accompanied by an increase in the activity of the parasympathetic division of the ANS, and in girls, an increase in sympathetic influences on the heart rate.

In other words, for adolescent girls, a high level of anxiety is preferable for adapting to the learning environment in a boarding-type educational institution, in contrast to boys, in whom a decrease in the level of general anxiety is accompanied by an increase in the activity of the parasympathetic division of the ANS.

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