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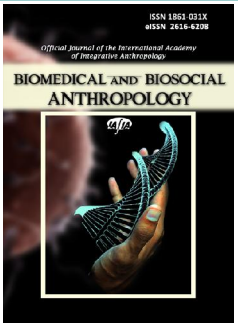

Prenosological screening of autonomic regulatory systems tension in secondary school students

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Adolescence is characterized by increased reactivity to stress factors, among the sources of which the educational environment plays a significant role. The content of education and educational process organization, as well as interpersonal relationships, is the predominant stress factors of the educational environment. In the context of education reform, new pedagogical projects are being introduced, in particular, on the basis of meritocratic education, providing for the intensification of the educational process. It may affect the state of the autonomic regulatory systems of students. The purpose of the research is to study the activity level of autonomic regulatory systems among students of secondary school, who are studying in meritocratic and traditional gymnasium education systems. The study involved 60 students: 42 studied in meritocratic system (19 in SG-1, 23 in SG-2), and 18 in traditional system (SG-3). Heart rate variability (HRV) was used as a physiological marker of stress. ECG was recorded during 5 minutes in a darkened room in a rest state with closed eyes in a sitting position at the 5th, 6th and 7th grades. Intergroup comparisons of HRV parameters were carried out according to the Mann-Whitney, Kruskell-Wallis, Dunnett criteria, and the φ-criterion of the angular Fisher transformation. Differences were considered significant at $p \leq 0.05$. In the 6th grade, there was a tendency ($0.05 < p \leq 0.07$) to lower values of Mean, SDNN, TR, ΔX, RMSSD, pNN50 among students in meritocratic system compared to the traditional one. However, this trend reached the level of statistical significance in the students of SG-1 compared to the control (SG-3). In meritocratic education different student groups differed in the level of school stress in 6th and 7th grades. Students in SG-1, compared to SG-2, characterized by lower values % HF, HFn, pNN50 against the background of higher values of % LF, LFn, LF/HF, IC, CC1, CC0. Thus, a higher level of school-based stress in conditions of meritocratic education is determined not so much by the intensification of the educational process as by social factors of the educational environment and/or individual typological traits of students.

Keywords: *autonomic and central nervous regulation, heart rate variability (HRV), school-based stress, meritocratic education, adolescents.*

Introduction

The period of study in primary school includes the processes of self-identification of the individual against the background of interconnected but heterochronous changes in the biological, cognitive, emotional and social functioning of the organism [14]. That is why adolescence is considered a period of increased susceptibility to stress [12, 33]. Sources of stress in adolescence can be various factors, including the educational environment [11, 12, 18]. Stressful situations are common in the educational environment and affect students on a daily basis [25, 32]. In particular, in a study by Sripongwiwata S. et al. [32] identified the following factors of school stress: the content of educational material, methods of teaching and learning, personal experiences related to learning, interpersonal relationships with teachers and classmates, group social factors. The leading factors of school stress are the content of education and the organization of the educational process, namely: a large amount of educational material;

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difficult to understand the content of education; too tight training schedule; lack of time for repetition and consolidation of educational material; too frequent control of knowledge; final evaluation; unfair evaluation system; competitive educational environment. As pupils move to higher levels in the education system, they face higher academic requirements and expectations. The need to meet these expectations and academic requirements can also be a source of stress in adolescence. Thus, it was shown that among 11-year-old pupils the level of school stress was stable, while school stress increased in 13- and 15-year-old pupils [18]. According to research by Krivolapchuk I. A. [16], the highest psychophysiological "value" of intensive intellectual activity is inherent in pupils at the beginning of school and during puberty.

Previous research has shown that school stress can interfere with pupils' academic performance [13], probably due to the negative impact on memory processes [29, 36]. In addition, stress can prevent the integration of new information into the existing knowledge structure, which can complicate a deep multidisciplinary understanding of the learning material. In addition, stress, changing the balance between memory systems, can interfere with the creative solution of complex and/or new problems, which, in turn, can lead to underestimation of pupils' abilities and underestimation of their self-esteem [37].

A study of school stress in more than 18 countries in North America, the United Kingdom, Eastern Europe, the Nordic countries, and Germany found a trend toward marked increases in adolescent school stress between 1994 and 2010 [15].

These data are a good basis for monitoring the level of school stress among Ukrainian pupils, as our education system is currently undergoing significant reforms and educational institutions are gaining considerable autonomy in determining the content of education and the choice of forms of educational process. In particular, in 2008 the all-Ukrainian pedagogical project "Intellect of Ukraine" was launched on the basis of meritocratic education with the use of educational models of acceleration, deepening, enrichment and problematization [8]. As you can see, the methodological basis of the project involves the intensification of the educational process, which is a leading factor in school stress.

Adolescents' adaptation to school stress and academic load places increased demands on regulatory systems, which are already stressful due to the puberty of pupils. Such an imbalance between the load on the system and its capabilities often causes the development of autonomic dysfunction and mental disorders in adolescence [6, 9, 24].

In the study of stress among pupils' youth traditionally use the assessment of the autonomic nervous system or hypothalamic-pituitary-adrenal system [26]. In the current study, we chose to assess the state of the autonomic nervous system in terms of heart rate variability (HRV), as HRV is considered a standard, reliable and non-invasive tool to provide a comprehensive, quantitative and qualitative assessment of the autonomic nervous system [31]. In addition, HRV parameters are recognized as a reliable and sensitive marker of both physical and psychological stress [2, 7, 35], in particular school stress [21, 30], or stress resistance [4].

HRV at different stages of ontogenesis is considered as a reliable biomarker of downward regulation of emotional, cognitive and behavioral processes [10]. The optimal level of HRV is related to health and the ability to self-regulate, as well as the ability to adapt and resistance. Higher HRV at rest is a sign of better management of emotions and stress, higher executive productivity and better social functioning [17, 27, 35].

High HRV indicates a healthy and adaptive autonomic support system, while low HRV may be an early indicator of abnormal functioning of the autonomic nervous system [5, 23]. High sympathetic modulation (LF, LF/HF), decreased vagus activity (HF) are typical markers of stress [28] and subjective perception of stress as stronger [26].

The aim of our study was to examine the level of tension of autonomic regulatory systems as an objective marker of school stress, among primary school pupils studying in meritocratic and traditional high school education systems.

Materials and methods

The study involved 60 students, of whom 42 studied according to the meritocratic system in two educational groups (SG-1 (n=19) and SG-2 (n=23)), and 18 - according to the traditional system (control group, SG-3). HRV measurements in this group of students were performed three times during the entire observation period: in the 5th, 6th and 7th grades.

5-minute electrocardiogram recording (II standard lead) was performed in a darkened room in a state of quiet wakefulness with closed eyes in a sitting position using the hardware-software complex "BrainTest" (SPE "DX-system", Kharkiv, Ukraine). Mathematical analysis of cardio signals was performed using the module "*Cardio Tension Test*" of the application package "*NeuroResearcher® Innovation Suite, V. 17.5*" (LLC "Institute of Medical Informatics and Telemedicine", Kharkiv, Ukraine).

The following groups of HRV indicators were analyzed [1, 19]: *statistical* - mean cardiocycle duration (Mean), mode (Mo), standard deviation (SDNN), variation scatter (ΔX), mode amplitude (AMo), coefficient of variation (CVr), percentage pairs of cardio intervals with a duration difference of more than 50 ms (pNN50); *spectral* - total power of the spectrum (TP), absolute power of low-frequency (VLF), low-frequency (LF) and high-frequency (HF) components of the spectrum, the relative power of these components (respectively VLF %, LF %, HF %), normalized power of these components (LFn, HFn), sympathetic-vagal balance index (LF/HF), centralization index (IC=(LF+VLF)/HF); *autocorrelation* - the value of the correlation coefficient after the first shift (CC1), the number of shifts of the autocorrelation function to reach

the value of the correlation coefficient equal to 0 (CC0).

Based on a set of quantitative indicators of HRV, the integrated indicator of regulatory systems activity (IARS) was calculated [1].

The median and interquartile scatter were chosen as a measure of the central trend and distribution, because the analysis by the Shapiro-Wilk criterion for most of the studied parameters refuted the hypothesis of compliance with the law of normal distribution. To test the hypothesis of equality of measures of the central trend in pairwise comparisons, the Mann-Whitney test was used, and for multiple comparisons, the nonparametric ANOVA by the Kruskal-Wallis test followed by a posteriori comparison by the Dunnett test. Nominal features were described as a percentage, and their pairwise comparison was carried out by the φ-criterion of Fisher's angular transformation. Differences at $p \leq 0.05$ were considered significant.

The study was conducted in accordance with the bioethical norms of the Declaration of Helsinki (as amended in 2013) after obtaining the written consent of parents and oral consent of students and approved by the Bioethics Commission of the Institute of Child and Adolescent Health of the National Academy of Medical Sciences of Ukraine.

Results

It was found that during the period of study in 5th and 7th grades the state of vegetative regulatory systems of pupils studying according to the traditional and meritocratic system of education is similar, which is indicated by the absence of statistically significant differences in all studied parameters of HRV. The typical structure of the HRV spectrum in the state of relative rest in both groups is represented by HF>LF>VLF, which indicates the prevalence of the autonomous control circuit over the central one.

At the same time, during the period of study in the 6th grade we observed a tendency ($0.05 < p \leq 0.07$) to a shorter duration of the cardiocycle by 6.7 % (p=0.07), lower heart rate variability by 14.6 % according to SDNN (p=0.06).) and 35.0 % according to the TP indicator (p=0.06) for pupils studying according to the meritocratic system of education. In these pupils, the tendency to decrease the total HRV was observed against the background of the tendency to weaken parasympathetic activity (lower values of ΔX (by 9.3 %, p=0.053), RMSSD (by 30.7 %, p=0.07), pNN50 (by 41.9 %, p=0.07)).

Based on the individual analysis of the activity of regulatory systems of pupils studying in different education systems, according to IARS, it was found that only a third of primary school pupils have optimal activity of autonomic regulatory systems (Fig. 1).

Note that statistically significant differences in the distribution of pupils by activity levels of regulatory systems depending on the education system we did not find. At the same time, in the three-year interval of observation of primary school pupils, the share of students with overstrain of regulatory systems was 1.5-2 times (p>0.05) higher than the meritocratic system of education compared to the traditional one. This category of pupils is characterized by a lack of adaptive-compensatory mechanisms that are unable to provide an adequate response of the organism to the influence of environmental factors. This is due to the fact that excessive activation of regulatory systems does not lead to an increase in functional reserves, as they have already reached the upper limit.

However, it should be noted that if in the 5th grade the share of pupils with depletion of regulatory systems was almost the same (4.8 % for meritocratic training and 5.6 % for traditional training, p>0.05), then later this category of pupils disappeared during meritocratic training, while in traditional education it almost doubled in the 6th grade and

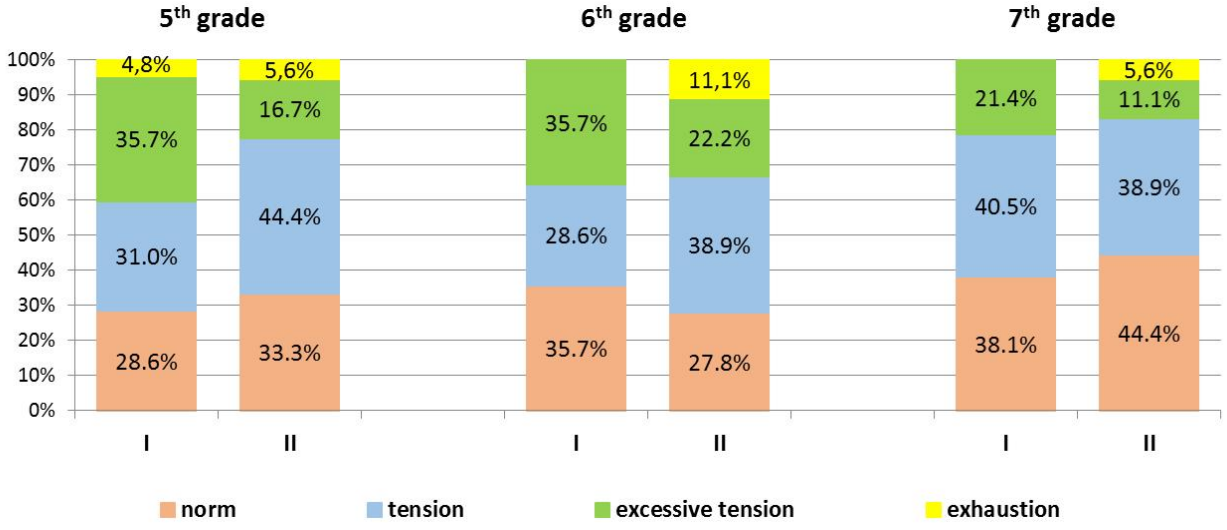

Fig. 1. Distribution of primary school pupils who study according to meritocratic (I) and traditional (II) education systems, according to the levels of activity of regulatory systems.

Table 1. Differences in HRV indicators of SG-1 and SG-3 pupils.

Groups / Indexes	Meritocratic training, SG-1 (n=19)			Traditional education, SG-3 (n=18)		
	Median	Lower quartile	Upper quartile	Median	Lower quartile	Upper quartile
Mean, mc	698.5 p=0.08	638.1	780.6	746.7	676.9	816.2
AMO, %	10.36 p=0.07	7.563	12.07	7.891	6.453	10.41
DX, mc	247.5*	225.0	414.0	353.5	316.0	445.0
CVr,%	6.891 p=0.08	5.591	9.332	8.014	7.231	10.08
SDNN, mc	47.55*	35.28	86.33	62.36	47.45	76.18
RMSSD, mc	34.18*	30.35	53.21	62.14	44.65	79.75
pNN50, %	15.84*	9.534	32.66	42.17	26.08	52.54
TP, mc^2	784.7*	444.8	2668	1635	798.0	2068
VLF, mc^2	124.8 p=0.07	65.37	222.9	144.3	89.13	194.9
HF, mc^2	358.2*	154.2	648.6	906.0	481.2	1327

Notes: * - probable ($p \leq 0.05$) differences between SG-1 and SG-3 pupils.

returned to the initial level in the 7th grade. This category of pupils is characterized by asthenia of regulatory mechanisms and the appearance of specific morpho-functional signs of maladaptation.

Since the level of school stress is determined not only by factors related to the content of educational material and organization of the educational process, but also by factors of interpersonal relationships and individual-typological properties of pupils, we conducted a comparative analysis of HRV parameters of pupils studying meritocratic system. different training teams (comparison of SG-1 and SG-2), followed by comparison with the control group (comparison of SG-1 and SG-3, SG and SG-3).

Comparing the two classes that studied the meritocratic system, we observed the following picture: in the 5th grade there were no significant differences in the activity of autonomic regulatory systems. In the 6th grade, pupils of SG-1, compared with SG-2, tended to higher values of % LF (45.5 %, p=0.054), LFn (44.0 %, p=0.07), LF/HF (by 79.9 %, p=0.07) and lower values of HFn (by 19.9 %, p=0.07). This indicates that students of SG-1 show a tendency to excessive autonomic support of the heart in conditions of relative rest, mainly due to the shift of autonomic balance towards sympathicotonia against the background of reduced specific activity of the vagus.

In the 7th grade, in pupils of SG-1, compared with SG-2, there was not only a significantly lower specific activity of the parasympathetic division of the ANS (HFn - by 31.5 % ($p \leq 0.05$), % HF - by 36.4 % ($p \leq 0.05$), pHN50 - by 52.9 %, (p=0.054)), but also the tendency to lower absolute activity (HF - by 44.7 %, p=0.07). Instead, the specific activity of the sympathetic nervous system was significantly higher (% LF - by 53.1 % ($p \leq 0.05$), LFn - by 47.0 % ($p \leq 0.05$)). As a result, in SG-1 pupils, the sympathetic-vagal balance was significantly shifted towards sympathicotonia (LF/HF was higher by 114.7 %, $p \leq 0.05$), compared with SG-2. In addition, SG-1 pupils were characterized by a higher level of centralization of heart rate control (IC higher by 73.9 %, $p \leq 0.05$), which was accompanied by the establishment of a close relationship between autonomous and central control circuits (CC1 higher by 20.6 %, CC0 higher by 200.0 %, $p \leq 0.05$) and the transition from the intra-systemic level of maintenance of autonomic homeostasis to the intersystem level with the involvement of higher vegetative centers of the hypothalamic-pituitary level (% VLF higher by 35.0 %, p=0.07).

It is interesting to note that despite the differences in some indicators of HRV between pupils of SG-1 and SG-2, there was no significant change in the structure of the distribution of the integrated indicator of the activity of regulatory systems. This is due to the fact that the values of IARS fell into the same functional class (mainly the voltage of regulatory systems), despite the change in the value of the indicator.

Comparing SG-2 and SG-3, we found significant differences only among 7th grade pupils in terms of CC0, which was lower by 76.0 % among pupils of SG-2 ($p \leq 0.05$). Also, SG-2 pupils had a tendency to lower values of the centralization index (by 46.1 %, p=0.07) against the background of a tendency to higher values of % HF (by 34.3 %, p=0.08). This indicates a lower level of relationship between the central and autonomic circuits of heart rate regulation due to the tendency to lower centralization of control and higher specific activity of the vagus in pupils of SG-2 compared to the traditional system of education.

At the same time, when comparing SG-1 and SG-3, significant differences were found only in the 6th year of study, which concerned many of the studied parameters of HRV (Table 1).

It was found that SG-1 pupils, compared with SG-3, were characterized by lower overall heart rate variability (SDNN - by 16.0 % ($p \leq 0.05$), TP - by 43.3 % ($p \leq 0.05$)) against the background of lower absolute activity of the parasympathetic nervous system. systems (ΔX - by 16.0 % ($p \leq 0.05$), RMSSD

- by 34.5% ($p \leq 0.05$), pNN50 - by 55.5 % ($p \leq 0.05$), HF - by 64.7 % ($p \leq 0.05$), CVr - by 6.5 % ($p=0.08$)). At the same time, there was a tendency to increase the sympathetic effects on the heart (AMO higher by 29.6 %, $p=0.07$), which is reflected in the tendency to a shorter duration of the cardiocycle (by 6.8 %, $p=0.08$). At the same time, there was a tendency to lower absolute activity of higher vegetative centers (VLF - by 33.4 %, $p=0.07$). This is probably a sign of an imbalance between the central and autonomous control circuits.

Discussion

As far as we know, this is the first study that studied the dynamics of the functional state of the autonomic regulatory systems of pupils during their studies in primary school with meritocratic education. The obtained results show that the 6th year of study is a turning point in the formation of mechanisms of vegetative regulation of pupils.

The presence of significant differences in HRV parameters among pupils studying under the meritocratic system, compared to the traditional system, depended on the teaching staff (comparison to SG-1 and SG-3, SG-2 and SG-3) and the year of study. At the same time, the two training groups that studied according to the meritocratic system also differed in the state of vegetative regulatory systems (comparison of SG-1 and SG-2). This suggests that the level of school stress in meritocratic education is determined not so much by the intensification of the educational process due to the use of educational models of acceleration, deepening, enrichment and problematization [8], as interpersonal relationships in educational teams and/or individual psychological characteristics of pupils.

This assumption is consistent with the literature that adolescents are more responsive to social and industrial stressors than children [12, 33]. During this period, relationships with peers become increasingly important, which means that social stressors that arise in the context of peers can have a particularly strong impact [20].

No significant differences in the HRV indicators of SG-2 and SG-3 pupils during grades 5-6 were observed, but in grade 7 there was a significant weakening of the relationship between the autonomous and central control circuits against the background of declining centralization of management and specific increase of vagal influences in the conditions of relative rest at meritocratic education. This is a sign of constant regulation at the intra-system level and a marker of physiologically lower cost of educational activities and higher adaptability among students of SG-2.

Pupils SG-1, differed from SG-2 (6-7 class) and from SG-3 (6 class) by lower overall heart rate variability. Low variability can be an early indicator of abnormal ANS functioning [5] and stress [23]. Lower HRV is seen as a sign of limited ability to regulate emotional state, executive productivity and social functioning [3, 17, 27, 35].

Compared with SG-2, in pupils of SG-1 observed excessive autonomic support of cardiac activity due to increased specific activity of the sympathetic nervous system and higher autonomic centers. Compared with SG-3, in SG-1 pupils observed a decrease in the absolute activity of the parasympathetic nervous system with a shift in autonomic balance toward sympathicotonia due to activation of the hypothalamic-pituitary-adrenal system. This type of autonomic support of cardiac activity may indicate the depletion of intra-systemic mechanisms of homeostasis under the influence of school stress. Thus, in grades 6-7, SG-1 pupils were characterized by a higher level of school stress compared to SG-2 and SG-3 pupils.

According to the literature in children and adolescents, low vagus nerve tone at rest is associated with increased emotional reactivity, poor attention and inhibitory control of the prefrontal cortex, as well as a deficiency of many aspects of emotion regulation [21, 27, 34].

SG-1 pupils were characterized by higher LF/HF values against the background of lower HF values, compared with SG-2, which is a sign of subjective perception of a stressful situation (in our case, the learning process) as stronger [26]. In addition, the literature suggests that peer problems, anger, anxiety, and sadness were associated with lower RMSSD and HF values, and anxiety and anger were associated with higher LF/HF ratios [23]. Adolescents with low vagus nerve tone are particularly prone to internalization problems after exposure to stressors [20].

An increase in LF and LF/HF values with a concomitant decrease in HF power, along with a significant decrease in SDNN values observed in SG-1, indicates a weakening of vagus tone [2] and is a physiological marker of stress [28] and is classified as autonomic neurophysiological status, which requires the attention of a specialist for proper and adequate management of autonomic tone and counseling to prevent autonomic dysfunction [2].

Conclusions

1. The 6th year of study is a sensitive period in the formation of autonomic regulatory systems, which increases the body's sensitivity to the influence of environmental factors. One third of primary school pupils has optimal activity of autonomic regulatory systems.

2. Under the meritocratic system of education in 6th grade there is a higher level of stress of the autonomic regulatory systems, which is inversely proportional to the adaptive potential of pupils. The higher "cost" of adapting to meritocratic education in 6th grade compared to traditional education requires the introduction of more thorough pre-nosological screening of pupils' health during this period of study.

3. The level of school stress in meritocratic education is determined not so much by the intensification of the educational process, as interpersonal relationships in educational teams and/or individual psychological characteristics of pupils.

References

[1] Baevsky, R. M., Ivanov G. G., CHireikin, L. V., Gavrilushkin, A. P., Dovgalevskii, P. Ia., Kukushkin, Yu. A., … & Semenov, A. V. (2001). Анализ вариабельности сердечного ритма при использовании различных электрокардиографических систем (методические рекомендации) [Analysis of heart rate variability using different electrocardiographic systems (guidelines)]. *Вестник аритмологии - Bulletin arrhythmology,* 24, 65-87.

[2] Bagri, D. D. R., Gupta, D. A., Dube, D. A., & Gupta, D. R. K. (2016). Assessment Of Examination Stress And HRV in Adolescents: Assessment Of Examination Stress And HRV. *National Journal of Integrated Research in Medicine*, 7(4), 1-7.

[3] Beauchaine, T. P. (2015). Future directions in emotion dysregulation and youth psychopathology. *Journal of Clinical Child & Adolescent Psychology,* 1, 1-22. doi: 10.1080/15374416.2015.1038827

[4] Carnevali, L., Koenig, J., Sgoifo, A., & Ottaviani, C. (2018). Autonomic and brain morphological predictors of stress resilience. *Frontiers in neuroscience,* 12, 228. doi: 10.3389/fnins.2018.00228

[5] Condon, E. M. (2018). Chronic Stress in Children and Adolescents: A review of biomarkers for use in pediatric research. *Biological research for nursing,* 20(5), 473-496. doi: 10.1177/1099800418779214

[6] de la Torre-Luque, A., Fiol-Veny, A., Bornas, X., Balle, M., & Llabres, J. (2017). Impaired cardiac profile in adolescents with an increasing trajectory of anxiety when confronting an acute stressor. *European Child & Adolescent Psychiatry,* 26, 1501-1510. doi: 10.1007/s00787-017-1009-8

[7] Fagan, S. E., Zhang, W., & Gao, Y. (2017). Social adversity and antisocial behavior: mediating effects of autonomic nervous system activity. *Journal of Abnormal Child Psychology*, 45, 1553-1564. doi: 10.1007/s10802-017-0262-0

[8] Gavrysh, I. V., & Tkachov, A. S. (2017). Теоретико-методологічні основи реалізації компетентнісно орієнтованої освіти обдарованих учнів у межах науково-педагогічного проекту "інтелект України" [Theoretical and methodological bases for the implementation of a competently oriented education of gifted students within the framework of the scientific and pedagogical project "Intellect of Ukraine"]. *Педагогіка формування творчої особистості у вищій і загальноосвітній школах - Pedagogika formuvannya tvorchoyi osobystosti u vyshchiy i zagalnoosvitniy shkolakh,* 55, 133-141.

[9] Gleichmann, D. C., Solis, I., & Stephen, J. M. (2020). Troubled hearts: Association between heart rate variability and depressive symptoms in healthy children. *Applied psychophysiology and biofeedback,* 45(4), 283-292. doi: 10.1007/s10484-020-09488-7

[10] Holzman, J. B., & Bridgett, D. J. (2017). Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: a meta-analytic review. *Neurosci. Biobehav. Rev,* 74, 233-255. doi: 10.1016/j.neubiorev.2016.12.032

[11] Hussain, A., Kumar, A., & Husain, A. (2008). Academic stress and adjustment among high school students. *J. Indian Acad. Appl. Psychol.,* 34(9), 70-73.

[12] Johnstone, J. M., Roake, C., & Oken, B. (2016). School-based mindfulness intervention for stress reduction in adolescents: Design and methodology of an open-label, parallel group, randomized controlled trial. *Contemporary clinical trials communications*, 4, 99-104. doi: 10.1016/j.conctc.2016.07.001

[13] Kaplan, D., Liu, R. X., & Kaplan, H. B. (2005). School related stress in early adolescence and academic performance three years later: the conditional influence of self expectations. *Social Psychology of Education*, 8(1), 3-17.

[14] Kendall, P. C., & Peterman J. S. (2015). CBT for adolescents with anxiety: mature yet still developing. *Am. J. Psychiatry,* 172(6), 519-530. doi: 10.1176/appi.ajp.2015.14081061

[15] Klinger, D. A., Freeman, J. G., Bilz, L., Liiv, K., Ramelow, D., Sebok, S. S., … & Rasmussen, M. (2015). Cross-national trends in perceived school pressure by gender and age from 1994 to 2010. *European Journal of Public Health,* 25(2), 51-56. doi: 10.1093/eurpub/ckv027

[16] Krivolapchuk, I. A. (2008). The psychophysiological cost of intense information load in 5-to 14-year-old children and adolescents. *Hum Physiol,* 34, 413-420. doi: 10.1134/S036211970804004X

[17] Laborde, S., Mosley, E., & Mertgen, A. (2018). Vagal tank theory: The three Rs of cardiac vagal control functioning - resting, reactivity, and recovery. *Frontiers in neuroscience,* 12, 458. doi: 10.3389/fnins.2018.00458

[18] Löfstedt, P., Eriksson, C., Potrebny, T., Välimaa, R., Thorsteinsson, E. B., Due, P., … & Torsheim, T. (2019). Trends in perceived school stress among adolescents in five Nordic countries 2002-2014. *Nordisk välfärdsforskning,* 4(2), 101-112. doi: 10.18261/issn.2464-4161-2019-02-07

[19] Malik, M. (1996). Heart rate variability. standards of measurement, physiological interpretation, and clinical use. Task force of the European Society of cardiology and the North American Society of pacing and electrophysiology. *Eur. Heart J.,* 17, 354-381. doi: 10.1093/oxfordjournals.eurheartj.a014868

[20] McLaughlin, K. A., Rith-Najarian, L., Dirks, M. A., & Sheridan, M. A. (2015). Low vagal tone magnifies the association between psychosocial stress exposure and internalizing psychopathology in adolescents. *Journal of Clinical Child & Adolescent Psychology,* 44(2), 314-328. doi: 10.1080/15374416.2013.843464

[21] Mendoza-Castejón, D., & Clemente-Suárez, V. J. (2020). Psychophysiological stress markers and behavioural differences between rural and city primary school students. *International Journal of Environmental Research and Public Health,* 17(9), 3157. doi: 10.3390/ijerph17093157

[22] Mezzacappa, E, Kindlon, D, & Earls, F. (1998). Executive and motivational control of performance task behavior, and autonomic heart-rate regulation in children: Physiologic validation of two-factor solution inhibitory control. *Journal of Child Psychology and Psychiatry,* 39, 525-531.

[23] Michels, N., Sioen, I., Clays, E., De Buyzere, M., Ahrens, W., Huybrechts, I., … & De Henauw, S. (2013). Children's heart rate variability as stress indicator: association with reported stress and cortisol. *Biological psychology,* 94(2), 433-440. doi: 10.1016/j.biopsycho.2013.08.005

[24] Moksnes, U. K., Løhre, A., & Haugan, G. (2016). The Association Between School Stress, Life Satisfaction and Depressive Symptoms in Adolescents: Life Satisfaction as a Potential Mediator. *Soc Indic Re,* 125, 339-357. doi: 10.1007/s11205-014-0842-0

[25] Monteiro, N. M., Balogun, S. K., & Oratile, K. N. (2014). Managing stress: the influence of gender, age and emotion regulation on coping among university students in Botswana. *International*

Journal of Adolescence and Youth, 19(2), 153-173. doi: 10.1080/02673843.2014.908784

[26] Rotenberg, S., & McGrath, J. J. (2016). Inter-relation between autonomic and HPA axis activity in children and adolescents. *Biological psychology,* 117, 16-25. doi: 10.1016/j.biopsycho.2016.01.015

[27] Sætren, S. S., Sütterlin, S., & Makransky, G. (2019). A multilevel investigation of resiliency scales for children and adolescents: The relationships between self-perceived emotion regulation, vagally mediated heart rate variability, and personal factors associated with resilience. *Frontiers in psychology,* 10, 438. doi: 10.3389/fpsyg.2019.00438

[28] Sánchez-Hechavarria, M. E., Ghiya, S., & Saá-Munoz, N. A. (2019). Introduction of application of gini coefficient to heart rate variability spectrum for mental stress evaluation. *Arquivos brasileiros de cardiologia,* 113(4), 725-733. doi: 10.5935/abc.20190185

[29] Schwabe, L., & Wolf, O. T. (2010). Learning under stress impairs memory formation. *Neurobiology of learning and memory*, 93(2), 183-188. doi: 10.1016/j.nlm.2009.09.009

[30] Scrimin, S., Moscardino, U., & Mason, L. (2019). Effects of psychophysiological reactivity to a school-related stressor and temperament on early adolescents' academic performance. *The Journal of Early Adolescence*, 39(6), 904-931. doi: 10.1177/0272431618797008

[31] Sharma, V. K., Subramanian, S. K., & Rajendran, R. (2015). Heart rate variability in adolescents - normative data stratified by sex and physical activity. *Journal of clinical and diagnostic research: JCDR*, 9(10), CC08-CC13. doi: 10.7860/JCDR/2015/15373.6662

[32] Sripongwiwata, S., Bunterma, T., & Tangb, K. N. (2018). An investigation of learning stressors among secondary school students: A case study in northeast Thailand. *Kasetsart Journal of Social Sciences*, 39(2), 197-206 doi: 10.1016/j.kjss.2017.06.002

[33] Stroud, L. R, Foster, E., & Niaura, R. (2009). Stress response and the adolescent transition: Performance versus peer rejection stressors. *Development and Psychopathology*, 21, 47-68. doi: 10.1017/S0954579409000042

[34] Suess, P. E, Porges, S. W, & Blude, D. L. (1994). Cardiac vagal tone and sustained attention in school-age children. *Psychophysiology,* 31, 17-22. doi: 10.1111/j.1469-8986.1994.tb01020.x

[35] Thayer, J. F., Ahs, F., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews,* 36, 747-756. doi: 10.1016/j.neubiorev.2011.11.009

[36] Tyng, C. M., Amin, H. U., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in psychology,* 8, 1454. doi: 10.3389/fpsyg.2017.01454

[37] Vogel, S., & Schwabe, L. (2016). Learning and memory under stress: implications for the classroom. *npj Science Learn*, 1, 16011. doi: 10.1038/npjscilearn.2016.11