MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
SUMY STATE UNIVERSITY
ACADEMIC AND RESEARCH MEDICAL INSTITUTE

Eastern Ukrainian Medical Journal

116, Kharkivska st., Sumy 40007, Ukraine
e-mail: eumj@med.sumdu.edu.ua
eumj.med.sumdu.edu.ua
ISSN: 2663-5909 (print)/2664-4231 (online)

How to cite / Як цитувати статтю: Ataman Yu**,** Yukhymenko L, Kolesnyk A, Brizhata I, Tonkopei Yu, Sytnyk O. Age dynamics of vegetative and neurodynamic functions among children at the age of 5-7 during mental loads. *East Ukr Med J*. 2024;12(3):505-514

DOI: https://doi.org/10.21272/eumj.2024;12(3):505-514

ABSTRACT

Yurii Ataman
https://orcid.org/0000-0002-6398-1016
Department of Physical Therapy, Occupational Therapy and Sports Medicine, Sumy State University, Sumy, Ukraine

Liliia Yukhymenko
https://orcid.org/0000-0002-4455-6233
Department of Anatomy, Physiology and Physical Rehabilitation. Bohdan Khmelnytsky National University of Cherkasy, Cherkasy, Ukraine

Anna Kolesnyk
https://orcid.org/0000-0001-8505-0813
Department of Physical Therapy, Occupational Therapy and Sports Medicine, Sumy State University, Sumy, Ukraine

Iryna Brizhata
https://orcid.org/0000-0002-9988-4285
Department of Physical Therapy, Occupational Therapy and Sports Medicine, Sumy State University, Sumy, Ukraine

Yuliia Tonkopei
https://orcid.org/0000-0002-9093-2180

AGE DYNAMICS OF VEGETATIVE AND NEURODYNAMIC FUNCTIONS AMONG CHILDREN AT THE AGE OF 5-7 DURING MENTAL LOADS

Purpose. To trace changing dynamics of vegetative and neurodynamic functions among children at the age of 5-7 during mental loads. The study usually starts for the senior pre-school and junior school age. Individual children's features and work of organ systems ensure adaptive reactions (including those during intensive mental loads). Therefore, we should pay attention to age dynamics of statistical and spectral peculiarities of heart rhythm for pre- and post-load states of kids.

Material and methods. 112 children at the age of 5-7 participated in the research. They come from senior pre-school and junior school institutions in Sumy, a Ukrainian city. The research determines functional activities and nervous power of children via the Diahnost-1M methodology.

The Fazahraf methodology estimates values of the cardiovascular system and influence of the vegetative nervous system on the heart rhythm. The technique collected and analyzed electrical potentials of spectral peculiarities of regulatory functions and significant statistical values of the heart rhythm.

Because of the stage-by-stage research approach and data heterogeneity, we conducted a multi-level mathematical assessment. Most data were not subject to normal distribution since there was a sharp asymmetry of low-stage discretization.

Results. Children may have different features during and after mental loads. They can be defined via most spectral and statistical values of the varying heart rhythm.

The heart rhythm reactions among children at the age of 5 are shifted to sympathicotonia. During mental loads, the dominance of sympathetic influence and instable control of regulatory systems was typical for the

Department of Public Health, Medical and Biological Foundations of Physical Culture, A. S. Makarenko Sumy State Pedagogical University, Sumy, Ukraine

Olha Sytnyk
https://orcid.org/0000-0002-2020-2684
Department of Physical Therapy, Occupational Therapy and Sports Medicine, Sumy State University, Sumy, Ukraine

6-year-old sample. Besides, we established a relation between nervous power and cardiovascular activities (r=0.42; p<0.05). In contrast to other age samples, the 7-year-old group showed a balanced cooperation of the sympathetic and parasympathetic nervous systems. Simultaneously, there was an obvious resistance to external stimuli during mental loads (r=-0.36; p<0.05).

Conclusions. Children at the age of 7 are more adapted to solve mental tasks with a certain speed. Therefore, we should pay a great attention to age functioning of physiological systems. In this way, we may apply the person-centered approach within the study process to raise adaptive abilities of the children's nervous system.

Keywords: children, heart rhythm variability, mental load, regulation, nervous lability, nervous power.

Corresponding author: *Anna Kolesnyk, Assistant of the Department of Physical Therapy, Occupational Therapy and Sports Medicine of Sumy State University, Ukraine*
E-mail: kas100188@gmail.com

РЕЗЮМЕ

Юрій Атаман
https://orcid.org/0000-0002-6398-1016
Кафедра фізичної терапії, ерготерапії та спортивної медицини, Сумський державний університет, м. Суми, Україна

Лілія Юхименко
https://orcid.org/0000-0002-4455-6233
Кафедра анатомії, фізіології та фізичної реабілітації, Черкаський національний університет імені Богдана Хмельницького, м. Черкаси, Україна.

Анна Колесник
https://orcid.org/0000-0001-8505-0813
Кафедра фізичної терапії, ерготерапії та спортивної медицини, Сумський державний університет, м. Суми, Україна

Ірина Бріжата
https://orcid.org/0000-0002-9988-4285
Кафедра фізичної терапії, ерготерапії та спортивної медицини, Сумський державний університет, м. Суми, Україна

Юлія Тонкопей
https://orcid.org/0000-0002-9093-2180
Сумський державний педагогічний університет імені А. С. Макаренка, Кафедра громадського здоров'я та

ВІКОВА ДИНАМІКА ВЕГЕТАТИВНИХ ТА НЕЙРОДИНАМІЧНИХ ФУНКЦІЙ ДІТЕЙ 5-7 РОКІВ У ПРОЦЕСІ РОЗУМОВОГО НАВАНТАЖЕННЯ

Мета: прослідкувати динаміку змін регуляторних вегетативних механізмів та нейродинамічних функцій дітей 5 – 7 років під час розумової діяльності. Адже на старший дошкільний та молодший шкільним вік припадає початок навчання. Індивідуальні особливості дитини, функціонування провідних систем організму забезпечують адаптивні реакції та специфічну відповідь, у тому числі на інтенсивне розумове навантаження. Тому, окрему увагу слід приділити аналізу вікової динаміки статистичних і спектральних характеристик серцевого ритму у фоновому режимі та після виконання розумового навантаження.

Матеріал і методи. У дослідженні взяли участь 112 дітей (дітей від 5 до 7 років старшої дошкільної ланки освіти та першого рівня початкової школи закладів міста Суми (Україна). У план дослідження включено визначення функціональної рухливості та сили нервових процесів дітей інструментальною методикою «Діагност-1М».

За допомогою інструментальної методики «Фазаграф» вивчали показники серцево-судинної системи та регуляторний вплив вегетативної нервової системи на серцевий ритм. Метод включав збір та аналіз електричних потенціалів спектральних характеристик регуляторних функцій і вагомих статистичних показників серцевого ритму.

Зважаючи на етапність дослідження та неоднорідність змінних даних математична обробка була багаторівневою, бо переважна більшість даних через різку асиметрію малого ступеня дискретизації не підлягала умовам закону нормального розподілу.

Результати. У дітей вірогідні особливості під час розумового навантаження та після його завершення, встановлені за більшістю спектральних та статистичних показників варіабельності серцевого ритму.

Реакції серцевого ритму дітей п'яти років зміщені у бік симпатикотонії. Перевага симпатичного впливу та нестабільність

медико-біологічних основ фізичної культури, м. Суми, Україна

Ольга Ситник
https://orcid.org/0000-0002-2020-2684
Кафедра фізичної терапії, ерготерапії та спортивної медицини, Сумський державний університет, м. Суми, Україна

контролю регуляторних систем на тлі розумової активності, була характерною для вибірки шестирічних. Також встановлено зв'язок між силою нервових процесів та рівнем активності функціонування їх серцево-судинної системи ($r=0{,}42$, $p<0{,}05$). У семирічних дітей констатували узгоджену участь симпатичної та парасимпатичної ланки вегетативної нервової системи та виражену стійкість до зовнішніх подразників під час розумового навантаження ($r=-0{,}36$, $p<0{,}05$) на відміну від дітей п'яти та шести років.

Висновки. Діти семи років більше пристосовані до вирішення поставлених розумових завдань у певному швидкісному ритмі. Тому, врахування вікових закономірностей функціонування фізіологічних систем має бути вагомим чинником упровадження особистісно-орієнтовного підходу у навчальний процес з метою підвищення адаптаційних можливостей нервової системи дітей.

Ключові слова: діти, варіабельність серцевого ритму; розумове навантаження; регуляція; функціональна рухливість нервових процесів, сила нервових процесів.

Автор, відповідальний за листування: *Анна Колесник, кафедра фізичної терапії, ерготерапії та спортивної медицини, Сумський державний університет, м. Суми, Україна*
e-mail: *kas100188@gmail.com*

INTRODUCTION / ВСТУП

An important period of children's development is the senior pre-school and junior school age when an intensive study starts. The elementary education is an initial study level. Here, we see a comprehensive children's development: new abilities, skills, knowledge, individual values emerge for effective use in different activities [1, 2].

It is these periods that focus on children's independence, intellectual and psychomotor performance on biological, physical and psychological levels. However, the individual approach application requires study of accompanying stages of vegetative cognition regulation [1, 3, 4].

Another disputable question is the heterochronic brain ripening within children's cognition improvement. Thus, there were physiological explanations of similarity among 6-year-old kids (as to morphological and functional aspects of nervous ripening, usually typical for 5-year-old persons). Nevertheless, most works dealt with 7-year-old development, in particular physiological adaptation to the study process [4, 5, 6, 7].

Worldwide, modern researchers regard the age of 4-7 as the first childhood. Especially, the age of 6-7 attracts a deep interest when intensive psychophysiological development of children takes place [1, 4].

On the one hand, the compulsory pre-school education stimulates a comprehensive development at the age of 6-7. On the other hand, the curriculum may inhibit the psychophysiological development among 6-year-old children. The insufficient age research of nervous and study adaptation features can lead to physiological disorders and maladaptive processes [2, 6].

The autonomic nervous system is considered to perform reflex regulation of internal organs. Additionally, it affects emotions and general state of children. Adaptation is possible due to neurohumoral control, vegetative functions and children's maturity [8, 9].

The cardiovascular system plays a relevant role in developing normal body adaptation [9]. Many experts assessed hemodynamic and vegetative adaptation to human stress [10, 11]. Previously, it was confirmed that psychological, emotional and physical overloads at junior school cause vegetative disorder of compensatory and adaptive mechanisms. Such a progress inevitably decreases the children's body performance.

Moreover, scientists are interested in all biological processes for children's adaptation to intensive environment conditions. Meanwhile, there is a lack of knowledge about regulation assessment and its physiological functions: general activity, heart neurohumoral control, relation between sympathetic and parasympathetic sections of the vegetative nervous system [6, 12].

Even a physiologically acceptable level of study load has a direct influence on body work. It activates corresponding adaptive reactions. Excessive mental loads may cause tiredness. That results in the rising vagotonic impact of the vegetative nervous system with regulation tiredness and cortex inhibition [6, 13, 14].

For a long time, physiologists have focused on heart rhythm variability and frequency ranges within study adaptation [15]. They also discussed how relations emerge between heart rhythm variability and teenagers' psychophysiological state [16]. However, there are insufficient research data on autonomic nervous regulation among studying children at the age of 5-7. Consequently, we are going to assess the heart rhythm control and accompanying nervous processes in terms of physiology and medicine.

Purpose. To trace changing dynamics of vegetative and neurodynamic functions among children at the age of 5-7 during mental loads.

Material and methods. The research comprised 112 persons (55 boys – 49.11%; 57 girls – 50.80%). The age is 5-7 years, senior pre-school and junior school institutions in the Ukrainian city of Sumy. We followed the Declaration of Helsinki, discussed all research issues with children's parents. The hygiene conditions corresponded to valid standards.

Within our research, we defined lability and nervous power via the Diahnost-1M neurodynamic methodology by M. Mararenko (2019). As a basis, we selected the "imposed mode" with a gradual increasing load [15, 16].

The stimuli were geometric figures. Children were preliminarily instructed how to work at the speed of 30 and 40 stimuli per minute.

Participants had to concentrate the highest attention during the test. We arranged all speed load variables and error percentage.

The quantitative lability value was maximal speed of stimuli when each participant made 5-5.5% of mistakes in a certain series. The nervous power value corresponded to general number of error percentage from the sum of received stimuli. The less errors are, the higher nervous power is (brain performance).

As an informative technique, phasegraphy analyzed the autonomic regulatory influence on children's heart rhythm. Here, we tested the Fazahraf device to record and assess electrocardiosignals derived from heart electrical potentials. They were also used to process ECG changes [16].

Simultaneously, we considered spectral regulatory peculiarities of the autonomic nervous system (LF, HF, LF/HF) and significant heart rhythm indexes (SDNN, RMSSD, HR, AMo, Mo, IN). They are indicated in Table 1.

Table 1

Interpretation of basic indexes of heart rhythm variability

Abbreviations	**Index name**	**Physiological functions**
HR	Heart rate	Medium level of functional status
SDNN	Standard deviation of NN intervals	Cumulative effect of vegetative regulation
RMSSD	Root mean square of successive differences	Activity of parasympathetic chain in vegetative regulation
SI	Stress index	Stress level or regulatory systems
AMo	Mode amplitude	Activity of sympathetic chain in vegetative regulation
Mo	Mode	Probable level of cardiovascular functioning
HF	High frequency	Relative activity of the parasympathetic nervous system
LF	Low frequency	Relative activity of the vasomotor center
LF/HF	Ratio of low frequency to high frequency	Relative activity of the sympathetic nervous system

The ECG was recorded several times: sitting rest for 1 minute, before examination, recovery.

The mathematical statistical processing of data, due to their heterogeneity, was multi-level and took place in several stages: first, according to the Dixon criterion, in order to determine the error distribution for small amounts of data of a series of observations n ≤ 25 and to check the maximum or minimum value in a series of observations, artifacts were determined according to the formula (1):

$$D = \frac{|x_0 - x_1|}{|x_0 - x_m|}, \quad (1)$$

where X_1 is the average closest to X_0 in the ordered series, and X_m is the last average (largest or smallest) value.

The next step of mathematical processing was the application of the Shapiro-Wilk test to check whether the sample and data fit the normal distribution.

For pairwise comparisons, the Wilcoxon T-test was used, taking into account the difference of each pair of variables, forming an overall ranked series in ascending order. The smaller of the two sums was taken as the actual T-criterion of application. Whereas for odd numbers, the Mann-Whitney test (with continuity correction) is used. After all, the vast majority of data due to sharp asymmetry of a small degree of discretization was not subject to the conditions of the law of normal distribution.

Table 2

Change of statistical heart rhythm indexes among children at the age of 5-7 before and after mental loads (median – Me; upper quartile -Q_1; lower quartile – Q_4; c.u.)

Heart rhythm indexes	**Distribution parameters**	**5 years, *n*=37**		**6 years, *n*=37**		**7 years, *n*=38**	
		Before load	**After load**	**Before load**	**After load**	**Before load**	**After load**
HR	Me	92.04**	83.02	84.6	85.07	82.1	80.9
	Q_1	95.8	88.1	91.9	91.1	92.9	88.9
	Q_4	83.3	78.1	81.2	81.3	78.1	77.7
SDNN	Me	67.9	84.1	77.5**	82.1	66.8**	81.1
	Q_1	106.1	104.5	116.1	193.1	95.1	136.9
	Q_4	53.1	74.8	58.9	58.9	38.8	48.8
RMSSD	Me	68.2	104.9	83.1*	92.1	72.2*	89.1
	Q_1	148.9	121.2	137.9	264.1	131.1	141.3
	Q_4	54.2	79.2	63.1	63.8	42.2	48.2
SI	Me	74.6*	42.4	65.7*	47.7	58. 7	62.9
	Q_1	125.7	59.1	106.1	81.2	161.4	132.1
	Q_4	51.9	29.3	32.4	11.9	35.1	19.2
AMo	Me	35.8*	32.9	28.9	32.2	29.8	32.1
	Q_1	43.9	44.5	37.1	38.1	46.2	41.2
	Q_4	26.9	22.1	26.9	26.2	25.1	26.2
Mo	Me	650.2**	744.4	678.1	676.0	725.1	673.8
	Q_1	724.9	828.1	713.7	724.1	814.2	776.1
	Q_4	572.3	626.1	624.9	625.1	625.0	625.2

*Notes: Significant statistical differences *p<0.05, **p<0.01 (age comparison during and after mental loads)*

The statistical probability of differences was considered significant under the condition of p<0.05 or less. For ranked variables, the relationship was determined using the Spearman rank correlation coefficient (r_s) (2):

$$r_s = \frac{\sum_{i=1}^{n}\left(r(x)_i - \bar{r}(x)\right)\left(r(y)_i - \bar{r}(y)\right)}{\sqrt{\sum_{i=1}^{n}\left(r(x)_i - \bar{r}(x)\right)^2 \sum_{i=1}^{n}\left(r(y)_i - \bar{r}(y)\right)^2}},$$

(2)

where $\bar{r}(x)$, $\bar{r}(y)$ – are the average values of ranks in samples $r(x)_i$ and $r(y)_i$; n - is the number of even members of the sample [17].

The Excel package was used for the initial preparation of tables and intermediate calculations. The main part of the mathematical processing was performed using the standard statistical package STATISTICA 8.0.

Research results. We defined functional changes among children at the age of 5-7 during various mental loads. The instrumental, sensitive and informative techniques focused on the heart rhythm regulation indexes. That partially reflects neurohumoral interactions. It was also relevant to assess tones and reactivity of the autonomic nervous system for vegetative regulation.

The pre- and post-load data of heart rhythm regulation among kids at the age of 5-7 show corresponding reactions. Reliable significance was detected for variables with spectral and statistical indexes before and after mental loads. Prior to the task, we calculated the statistically probable differences of sympathetic activation as well as the AMo, SI, HR and other values. Consequently, we traced the SI and HR rise against HF.

However, the post-load state showed an obvious fall of the above-mentioned indexes. It means decrease of their sympathoadrenal impacts.

A considerable difference was found for the Mo rise against the completed task. That may imply a falling activity of the central control loop.

In case of the RMSSD and SDNN variables, we detected no reliable differences. Nevertheless, children tended to activate the parasympathetic nervous system after mental loads. The insignificant parasympathetic influence may have partially led to decrease in the HR, AMo and SI regulation during recovery.

In contrast to statistical variables, more sensitive spectral values reflect a sharp LF/HF rise after mental loads. That is launched via the activated sympathetic vascular center. Simultaneously, the LF and HF spectra tended to fall. This fact may indicate a probably weaker baroreflex and parasympathetic impacts on the cardiovascular functions (Table 3).

Table 3

Change of spectral regulatory functions among children at the age of 5-7 before and after mental loads (median – Me; upper quartile -Q_1; lower quartile – Q_4; c.u.)

Heart rhythm indexes	Distribution parameters	5 years, *n*=37		6 years, *n*=37		7 years, *n*=38	
		Before load	**After load**	**Before load**	**After load**	**Before load**	**After load**
HF	Me	63.9	62.1	61.1*	52.1	61.9	50.1**
	Q_1	78.8	67.9	74.2	63.7	71.1	59.8
	Q_4	48.9	53.9	47.6	45.7	48.1	37.8
LF	Me	178.9	131.1	127.3*	77.8	148.7	73.2**
	Q_1	323.8	222.1	299.1	147.2	253.1	113.2
	Q_4	68.9	104.9	55.1	43.9	53.1	32.2
LF/HF	Me	0.41*	0.46	0.48*	0.68	0.42	0.69**
	Q_1	0.74	0.58	0.78	1.09	0.89	1.18
	Q_4	0.23	0.32	0.28	0.38	0.26	0.53

*Notes: Significant statistical differences *$p<0.05$, **$p<0.01$ (age comparison during and after mental loads)*

All these features may raise HR and other elements of sympathetic activation.

A detailed description of age peculiarities among children at the age of 5 before and after mental loads is represented in Figure 1. Here, we observe that heart rhythm reactions demonstrate a spectral and statistical shift to sympathicotonia. $p<0.05$ and $p<0.01$ are typical for the median heart rhythm variability before and after mental loads.

For children at the age of 6, we also see a considerable sympathetic activity. It may stand for self-regulation via the RMSSD rise ($p<0.05$) after mental loads. The SDNN change ($p<0.01$) can indicate the functional reserve optimization among kids at the age of 6. Besides, mental loads caused a probable SI fall ($p<0.05$) as a moderate prevalence of the central mechanism over the vegetative one (Figure 2).

The post-load AMo increase represents the sympathetic activation and the RR interval growth. Simultaneously, the pre-load RMSSD decrease may be an indirect sign of sympathicotonia within the heart rhythm variability.

Among children at the age of 7, we can notice probable changes of the RMSSD and SDNN values ($p<0.05$ and $p<0.01$, respectively) before and after mental loads. Consequently, there is a sympathetic shift. On the contrary, it was untypical to observe the post-load SI rise (Figure 3). That reflects a higher regulatory stress reaction to mental loads, in contrast to kids at the age of 5-6 with the increasing pre-load SI.

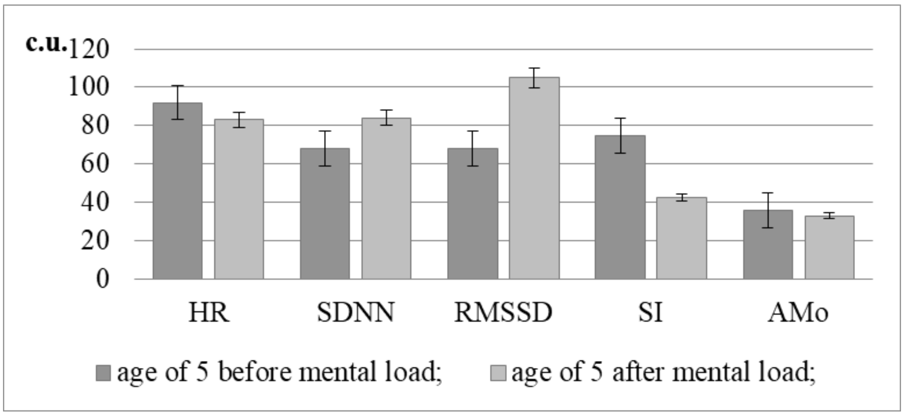

Figure 1 – Dynamics of statistical indexes of heart rhythm variability among children at the age of 5 before and after mental loads (c.u.)

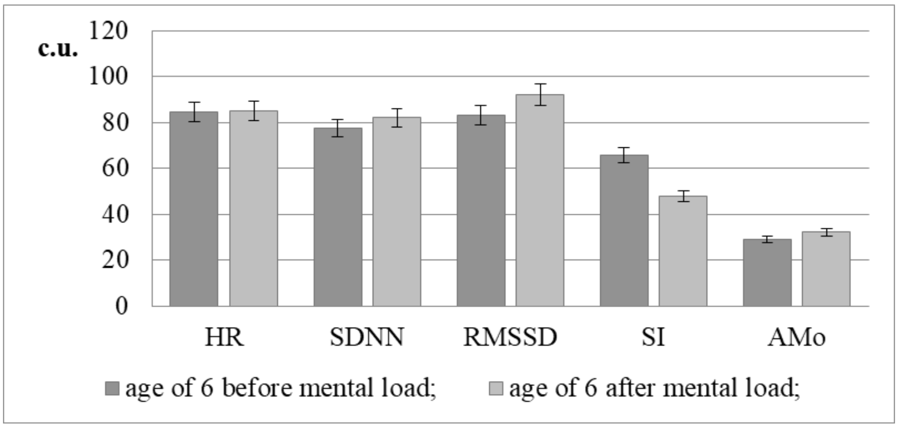

Figure 2 – Dynamics of statistical indexes of heart rhythm variability among children at the age of 6 before and after mental loads (c.u.)

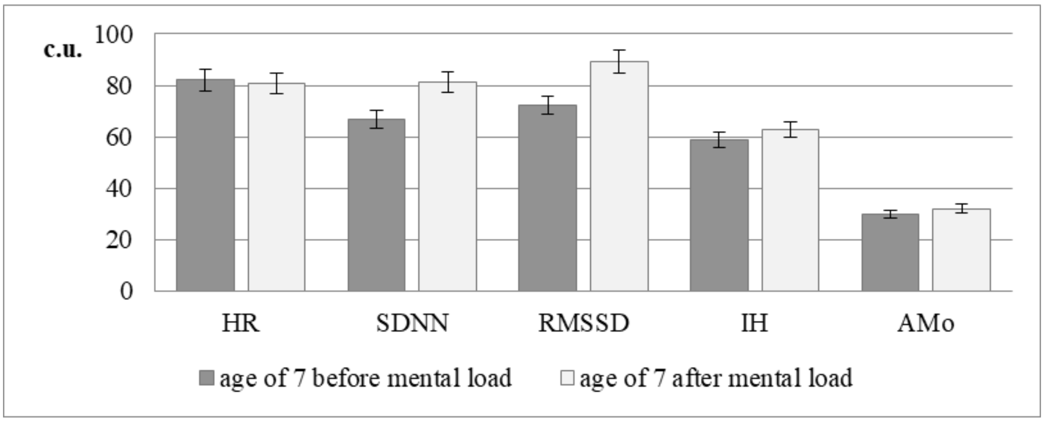

Figure 3 – Dynamics of statistical indexes of heart rhythm variability among children at the age of 7 before and after mental loads (c.u.)

Figure 3 confirms the 7-year-old tendency to the post-load SI rise. It may imply a stronger sympathetic impact after the mental work. Another sign of the cardiovascular activity is the statistically significant LF/HF differences before and after mental loads.

As an example, we compare the 6-year-old data. There was the sympathetic regulation prevalence after mental loads, which is accompanied by the LF/HF increase. Moreover, we observe an obvious LF and HF fall after mental loads (Figure 4).

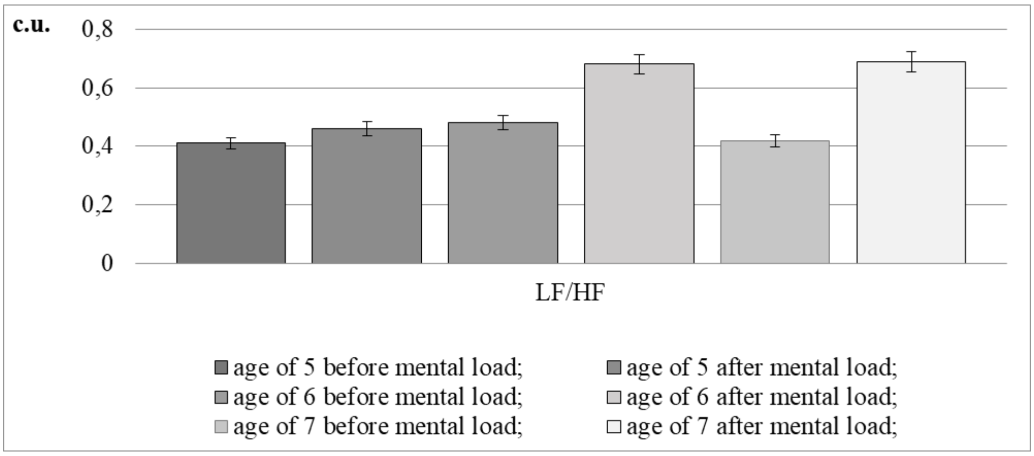

Figure 4 – Dynamics of the spectral LF/HF values before and after mental loads (c.u.)

To confirm the above-mentioned facts, we established vegetative regulatory relations among children at the age of 5-7 during mental loads. Via the correlation analysis, we proved influence of the HR, Mo and AMo variables on lability and nervous power for groups at the age of 5-7 (Table 4).

Table 4

Influence of neurodynamic and statistical indexes of heart rhythm for children at the age of 5-7 (n=112)

Age, sample	Index / index	Correlation coefficient	p
Before mental load			
6 years *n*=37	Nervous power / HR	0.42	<0.05
	Nervous power / Mo	-0.47	<0.01
7 years *n*=38	Nervous power / HR	-0.34	<0.05
	Nervous power / Mo	0.34	<0.05
During mental load			
5 years *n*=37	Lability / AMo	0.38	<0.05
	Nervous power / AMo	0.53	<0.01
6 years *n*=37	Lability / HR	-0.36	<0.05
7 years *n*=38	Nervous power / HR	-0.36	<0.05
	Nervous power / Mo	0.33	<0.05

Notes: Correlation spectrum of reliable coefficients

For kids at the age of 5, we have established a direct relation between the lability, nervous power and AMo values during recovery. Therefore, the sympathetic growth ($p<0.05$) led to effective work of children with the higher lability. However, simultaneous error increase stood for a low brain performance. Another feature is their considerable impact on the sympathetic cardiovascular regulation and heart force ($p<0.01$).

Among children at the age of 6, mental load was usually accompanied with a statistically probable relation between nervous power, HR and Mo. Thus, the lower brain performance causes the higher cardiovascular activities in case of the HR rise ($p<0.05$) and the parasympathetic regulation fall. It was confirmed by the Mo reverse correlation ($p<0.01$), which concerns change of stress and attention. That must have been a reason why children with the lower nervous power made so many mistakes.

Besides, the recovery stage detected a reverse relation between the lability and HR values after mental loads. It may indicate a high lability value for kids at the age of 6. So, the load regulatory mechanisms were coordinated during the HR stabilization. The latter shows the vegetative regulation recovery. On the contrary, children with a lower lability demonstrated nervous tension on the recovery stage with higher vascular tones.

The 7-year-old sample represented relations between nervous power, HR and Mo before and after mental loads. In both cases, we established a reverse relation between the lower nervous power and the higher HR ($p<0.05$). A prevailing feature was relation between the high brain performance and the low HR. Indirectly, that may show the autonomic nervous activation with a subsequent impact on heart rhythm and brain performance. The latter is accompanied with the stress decrease as a direct relation between nervous power and Mo ($p<0.05$).

Consequently, these facts prove children' adaptation to external stimuli and high brain performance through a coordinated work of the sympathetic and parasympathetic nervous systems.

CONCLUSIONS / ВИСНОВКИ

We established a reliable difference by spectral and statistical values before and after mental loads among children at the age of 5-7.

The 5-year-old sample shows a heart rhythm reaction with a sympathicotonia shift before and after mental loads ($p<0.05$). The same is typical for the 6-year-old group. Here, we have a sympathetic prevalence with the RMSSD and SDNN rise ($p<0.05$ and $p<0.01$, respectively). Also, RR intervals tend to increase before mental loads.

The SI growth proves the regulatory instability among children at the age of 5-6 during different mental loads. On the contrary, kids at the age of 7 possess a better adaptation to mental loads.

Among children at the age of 5-6, the lability rather than performance brain structure matures faster.

Kids at the age of 5 reflect a direct relation between neurodynamic features with a sympathetic shift to raise lability processes ($r=0.38$; $p<0.05$).

Besides, children at the age of 6 demonstrate an obvious relation between nervous power and cardivascular activity ($r=0.42$; $p<0.05$). The nervous tension with higher vascular tones occurs on the recovery stage.

The 7-year-old group indicated a tendency to raise the regulatory stress as a reaction to mental loads. Here, we notice a reverse relation between HR and nervous power ($r=-0.36$; $p<0.05$). In contrast to persons at the age of 5-6, that shows a coordinated functioning of the sympathetic and parasympathetic systems. Another feature among children at the age of 7 is their obvious resistance to external stimuli and brain performance during mental loads.

Therefore, children at the age of 5-7 do not possess a strong nervous power in case of high lability. Simultaneously, there was a prevalence of various exciting and inhibiting stimuli. The mental work dominates over its quality. So, long and difficult work load for children at this age may cause vegetative disorders. Early start of school study (since the age of 5-6) can provoke disadaptive reactions.

AUTHOR CONTRIBUTIONS / ВКЛАД АВТОРІВ

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

FUNDING / ДЖЕРЕЛА ФІНАНСУВАННЯ

None.

CONFLICT OF INTEREST / КОНФЛІКТ ІНТЕРЕСІВ

The authors declare no conflict of interest.

REFERENCES/СПИСОК ЛІТЕРАТУРИ

1. Berdnyk O, Polka N, Rudnytska O, Dobrianska O, Shevchuk K. [School starting age as a risk factor for adolescent health]. *Child`s health*. 2022;(6.66):39–43. https://doi.org/10.22141/2224-0551.6.66.2015.74952
2. Demenko M, Harbuzova V, Obukhova O, Biesiedina A, Levchenko Z. Personal component of graphomotor skills of children aged 5–8 years. East Ukr Med J. 2023;11(4):442-452. https://doi.org/10.21272/eumj.2023;11(4):442-452
3. Verych S, Ren L. Correction of negative emotional states of children with special educational needs as a factor of motivation their educational and cognitive activities in condition of martial law. *Bulletin of the Chernihiv Collegium National University named after T.G.Shevchenko*.2023;23(179):14–18. https://doi.org/10.58407/visnik.232303
4. Kovalenko S, Kudiy L. *Heart rate variability. Methodical aspects.* Cherkasy: Cherkasy National University named after B. Khmelnytskyi, 2016. 298 p.
5. Perry S, Khovanova NA, Khovanov IA. Control of heart rate through guided high-rate breathing. *Sci. Rep.* 2019, 9(1):1545. https://doi.org/10.1038/s41598-018-38058-5
6. Lizohub V, Chernenko N, Palabiyik A, Bezkopulna S. [Method of definitions mental performance during

processing of information with different speed of presentation of stimuli]. *Visnyk Cherkaskoho universytetu: Cherkasy university bulletin: biological sciences series*, 2018 (1):70-79. https://doi.org/0.31651/20765835-2018-1-1-70-79

7. Ginty AT, Kraynak TE, Fisher JP, Gianaros PJ. Cardiovascular and autonomic reactivity to psychological stress: Neurophysiological substrates and links to cardiovascular disease. *Auton Neurosci*. 2017;207:2-9. http://dx.doi.org/10.1016/j.autneu.2017.03.003
8. Tonkopei Yu, Skyba O, Bondarenko V, Buhaienko T, Kurnyshev Yu, Liasota T. Determinants for predicting polyorganic functional changes of the musculoskeletal system in children with various degrees of joints hypermobility. *Acta Balneologica*. 2023; №1(173):31 – 35. https://doi.org/10.36740/ABAL202301105
9. Koch C, Wilhelm M, Salzmann S, Rief W, Euteneuer F. A meta-analysis of heart rate variability in major depression. *Psychol Med* 2019; 49(12): 1948-57. http://dx.doi.org/10.1017/S0033291719001351
10. Johnston BW, Barrett-Jolley R, Krige A, Welters ID. Heart rate variability: Measurement and emerging use in critical care medicine. *J Intensive Care Soc* 2020; 21(2): 148-57. http://dx.doi.org/10.1177/1751143719853744
11. Díaz-García J, González-Ponce I, Ponce-Bordón J, López-Gajardo M. Mental Load and Fatigue Assessment Instruments: A Systematic Review. *International Journal of Environ-mental Research and Public Health.* 2021, 19 (1)6 419. http://doi.org/10.3390/ijerph19010419
12. Massaro S, Pecchia L. Heart Rate Variability (HRV) analysis: A methodology for organizational neuroscience. *Organ Res Methods*. 2019; 22(1): 354-393. http://dx.doi.org/10.1177/1094428116681072
13. Reena T, Ravindra K, Sujata M, Tilak R. Analysis of Heart Rate Variability and Implication of Different Factors on Heart Rate Variability. *Curr Cardiol Rev J*. 2021 17 (5): e160721189770. http://doi.org/10.2174/1573403X16999201231203854
14. Kashyap AS, Kuragayala SD, Kasam KP. Echocar diographic correlation of cardiac function in patients of hypothyroidism. *East Ukr Med J.* 2023;11(3):314-325. https://doi.org/10.21272/eumj.2023;11(3):314-325
15. Mintser OP, Potyazhenko MM, Nevoit GV. *A brief record of heart rate variability in the clinical examination of patients: a study guide; series "Systemic Medicine"*. Kyiv-Poltava, Interservice, 2022. 151 p.
16. Lyzogub V, Khomenko S, Bezkopylnyi O. *Human neurodynamic properties and their research methods*: monograph. Cherkasy, 2019. 136 p.
17. Khomenko SM. *Statistical methods in natural sciences.* Cherkasy: CHNU named after B. Khmelnytskyi, 2020. 109 p.

Received 19.03.2024
Accepted 14.05.2024

Одержано 19.03.2024
Затверджено до друку 14.05.2024

INFORMATION ABOUT THE AUTHORS / ВІДОМОСТІ ПРО АВТОРІВ

Yurii Ataman – MD, Professor, Head of the Department of Physical Therapy, Occupational Therapy and Sports Medicine of Sumy State University, Ukraine.
E-mail: ata_kard@ukr.net

Liliia Yukhymenko – Doctor of Biological Sciences, Associate Professor of the Department of Anatomy, Physiology and Physical Rehabilitation of Bohdan Khmelnytsky National University of Cherkasy, Ukraine.
E-mail: liyukhimenko@ukr.net

Anna Kolesnyk – Assistant of the Department of Physical Therapy, Occupational Therapy and Sports Medicine of Sumy State University, Ukraine.
E-mail: kas100188@gmail.com
phone:+80664799054

Iryna Brizhata – Candidate of Pedagogic Sciences (Ph. D.), Associate Professor of the Department of Physical Therapy, Occupational Therapy and Sports Medicine of Sumy State University, Ukraine.
E-mail: brizhata@i.ua

Yuliia Tonkopei – Candidate of Science of Physical Education and Sport (Ph,D.), Associate Professor of the Department of Public Health, Medical and Biological Foundations of Physical Culture of A.S. Makarenko Sumy State Pedagogical University, Ukraine.
E-mail: ulcer130685@gmail.com

Olha Sytnyk – Candidate of Biological Sciences (Ph,D.), Associate Professor of the Department of Physical Therapy, Occupational Therapy and Sports Medicine of Sumy State University, Ukraine.
E-mail: o.sytnik@med.sumdu.edu.ua