Article

The Influence of the Balance of the Autonomic Nervous System on the Electroencephalographic Activity of the Brain in Healthy Schoolchildren

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Abstract: Objective of the study: Analysis of electroencephalographic data of the brain in healthy schoolchildren depending on the type of autonomic regulation of the body.
Materials and methods: The study involved 12 boys aged 10 to 12 years. Bioelectrical activity of the brain in schoolchildren with different types of autonomic regulation (TAR) was studied using the electroencephalography (EEG) method.
Results: Determination of the types of autonomic regulation and the corresponding EEG indicators made it possible to identify the features of physical adaptation and functional activity during ontogenesis in children under conditions of increased academic loads.

Keywords: electroencephalography, brain, types of autonomic regulation, schoolchildren.

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1. Introduction

The modern school education system requires a scientifically based approach to the educational process, which should be based on the physiological indicators of the body of schoolchildren in ontogenesis [1, 2]. Children in the process of morphological and functional development are influenced by stress factors of increasing school workload [3,4]. In this regard, the choice of the most optimizing effect of physical education on the adaptation and functional state of children, depending on the types of autonomic regulation, should be based on promising diagnostic methods. the functional state of students who are in real conditions of exposure to constantly increasing learning loads, including information and computer technologies [5, 6]. The purpose of the study. Given the different rates of formation of the bioelectric activity of the brain and the mechanisms of autonomic regulation of cardiac activity in students of the age of second childhood (10-12 years), it seems relevant to study the EEG characteristics of schoolchildren at a certain stage of ontogenesis [2, 8].

2. Material and methods

The study involved 12 boys aged 10-12 years old. The research work was carried out based on MBU "School No. 32" in Tolyatti. The measurements were carried out from September 2024 to November 2024.EEG studies were performed using Neuron-Spektr-4/VPM, a hardware and software complex that combines 21 channels for recording EEG or long-latency evoked brain potentials, 4 polygraphic channels for recording short-latency evoked brain potentials. The heart rate variability (HRV) parameters were evaluated using the Varikard 2.51 software hardware complex to determine the types of autonomic regulation (TAR).

3. Results

For a more detailed study of the mechanisms that form the regulatory basis of the types of autonomic regulation (TAR), the indicators obtained by recording the EEG of the cerebral cortex were studied. The type of EEG recordings of the brain activity of children with different TBR I – II, III, IV presented in Table 1 had the following distinctive features.

Table 1: Assessment of the functional state of regulatory body systems in schoolchildren according to heart rate variability (HRV) [8]

Heart rate regulation type	HRV parameter features according to the dominant regulation type	Interpretation of the HRV data obtained
Moderate predominance of central regulation type I (MPCR)	SI›100 cond. units. VLF›240 ms^2 SI›100 U VLF›240 ms^2	Moderate predominance of sympathetic heart rate regulation
Significant predominance of central regulation type II (SPCR)	SI›100 cond. units. VLF (ms^2) ‹240 SI›100 U VLF (ms2) ‹240	Significant predominance of sympathetic heart rate regulation
Moderate predominance of autonomous regulation type III (MPAR)	SI›70‹150 cond. units. VLF›240 ms^2 SI›70‹150 U VLF›240 ms^2	Moderate predominance of parasympathetic activity
Significant predominance of autonomous regulation type IV (SPAR)	SI‹25 cond. units. VLF›500 ms^2 TP›8000–10 000 SI‹25 U VLF›500 ms^2 TP›8000–10 000	Significant predominance of the parasympathetic department

Note: SI – stress index for regulatory systems, VLF – index (high – hyperadaptive, low – energy deficient state), TP – total power of the HRV spectrum.

In children with I–II TBD (sympathicotonia), a pointed hypersynchronous alpha rhythm was recorded over both hemispheres, which was dominant. The maximum amplitude of the alpha rhythm in the left hemisphere was 136 Mv (average –43 mv), 145 MV above the right hemisphere (average – 41 MV). The interhemispheric asymmetry of the alpha rhythm was 18.4%. The alpha rhythm index over the left hemisphere (on the spectrum) is 41.2%, over the right hemisphere (on the spectrum) – 40.7%. Alpha rhythm prevails in the occipital leads. EEG indicators in students of TAR I–II reflect the typological features of the neural activity of brain structures, namely: a high index of 41.2–40.7% (left/ right, cerebral hemispheres) and the amplitude of activity of a pronounced dominant alpha rhythm, which is formed by the ascending activating effects of the reticular formation and/or thalamic structures on the cerebral cortex. Diagnosed by the method HRV high stress index values express increased activity of the sympathetic division of the autonomic nervous system (VNS). In these children with type I–II TB, the controlled system is destabilized, and dysregulatory manifestations occur in the activity of the central nervous system (CNS). At the same time, the processes of self-regulation are suppressed, adaptive capabilities are reduced to maintain a normal level of functioning. the cardiovascular system, the management of the central nervous system is achieved with significant functional stress on the regulatory systems of the body. Therefore, gymnastic exercises and exercises for developing flexibility, exercises for relaxing muscles, with metered physical activity were offered for these children. Fig. 1, Table 2.

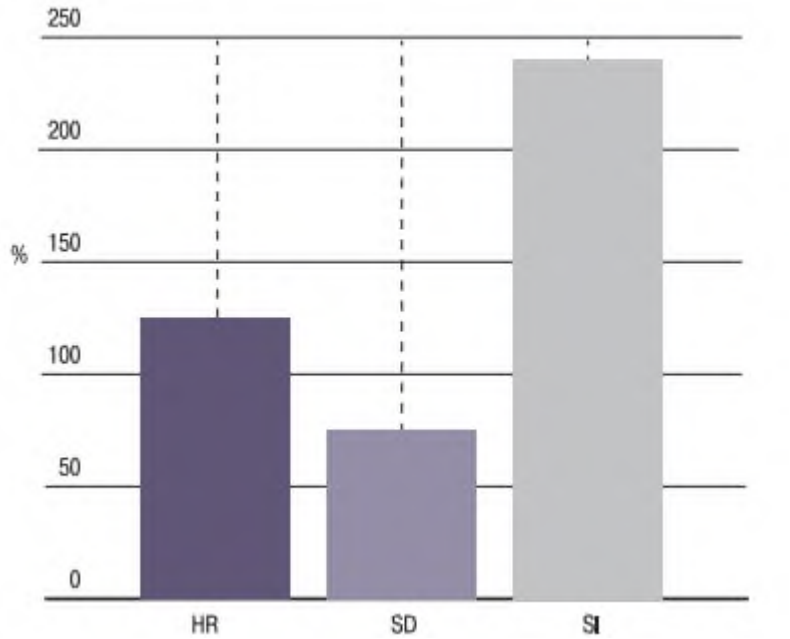

Figure 1. HRV parameters in schoolchildren with TAR I-II (HR – heart rate, SD – standard deviation for cardio-interval, SI – stress index for regulatory systems).

Table 2. HRV and EEG indicators in schoolchildren with different types of vegetative regulation

Vegetative regulation type	SI – stress index, U	Maximum amplitude of the left/right cerebral hemisphere alpha rhythm, μV	Index of the left/right cerebral hemisphere alpha rhythm, %
I–II	297	136; 145	41,2; 40,7
III	140	83; 71	34,3; 24,7
IV	39	32; 35	12,9; 10,6

In the examined children of the III TAR (normotonia), a pointed alpha rhythm was recorded over both hemispheres. The maximum amplitude of the alpha rhythm over the left hemisphere was 83 mv (the average was 24 MV), over the right hemisphere –71 mv (average – 20 MV). Interhemispheric asymmetry of alpharrhythmia is 18.4%. The alpha rhythm index over the left hemisphere (on the spectrum) is 34.3%, over the right hemisphere (on the spectrum) – 24.7%. The alpha rhythm prevailed in the parietal-occipital and posterior temporal leads.

In schoolchildren of the III TAR, at normal values of the voltage of regulatory systems, EEG indicators indicate a moderate dominance of the alpha rhythm, which is the main rhythm of the brain of a healthy person. The alpha rhythm index was determined at the level of 34.3–24.7% (left-right hemisphere), the average value of which was 28%, which is comparable to the theta rhythm index of 18.9%. These data indicate the most optimal interaction between the sympathetic and parasympathetic divisions of the ANS and the central regulatory structures of the brain in the process of regulating heart rhythm. This is a condition of the body It can be taken as a physiological norm of the functional state of regulatory systems reflecting the high adaptive capabilities of the body. In this case, it is the controlled cortical sections of the central nervous system and a balanced system of self-regulation of the central nervous system and ANS that allows you to achieve the optimum cardiac functions during physical exertion of schoolchildren with III TAR without overstrain of the control system of its functional state Fig. 2, Table 2.

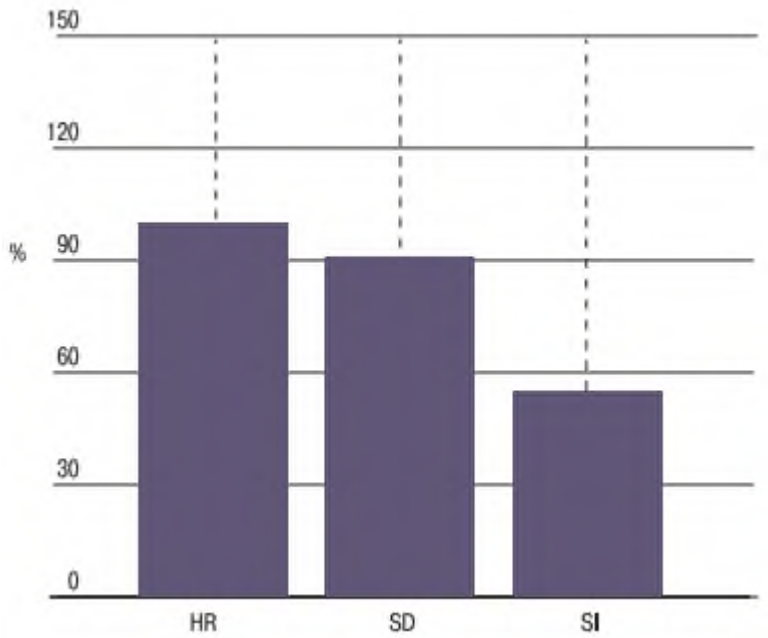

Figure 2. HRV parameters in schoolchildren with TAR III.

In the examined children of type IV TAR (parasympathicotonia), irregular alpharrhythm in combination with theta rhythm was recorded over both hemispheres. The maximum amplitude of the alpha rhythm over the left hemisphere was 32 MV (average – 24 MV), over the right hemisphere – 35 MV (average – 17 MV). The alpha rhythm index over the left hemisphere (on the spectrum) is 10.6%, over the right hemisphere (on the spectrum) – 12.9%. Alpharrhythm prevailed in the posterior temporal and occipital leads. An increase in the slow-wave activity index was recorded over both hemispheres. HRV rates in children with IV The TAR was at the lower limit of the norm or was lowered. In children with type IV TBD, there was a pronounced predominance of autonomous regulation compared with types I, II, and III , the lowest heart rate, the highest duration of cardiac intervals (R–R), the spread of cardiac intervals (MxDMn), and low values of the Si stress index were found (Fig. 3).

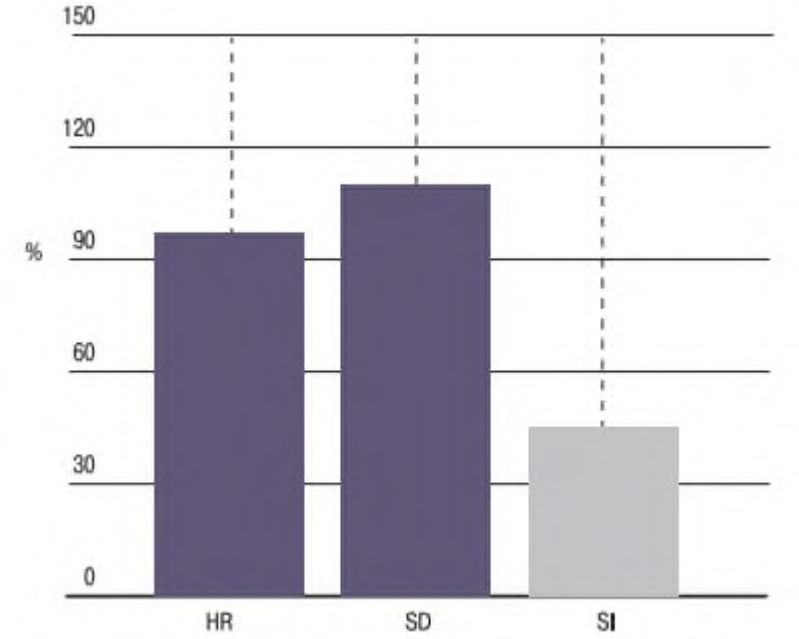

Figure 3. HRV parameters in schoolchildren with TAR IV.

These children often have arrhythmias of various etiologies, fatigue, which can be interpreted as an imperfection of regulatory mechanisms. In this regard, outdoor games and relay races with a metered load were proposed for them. (Fig. 3, Table 2). Thus, the study showed that there are characteristic rhythmological differences in the EEG pattern in children with different types of

autonomic regulation, which allows us to judge the features of brain electrogenesis in schoolchildren. That is, the neuroregulatory activity of the central regulatory circuit controls genetically determined combinations of functional parameters of the ANS departments.

3. Discussion

As noted in the work of D.B. Demin, L.V. Poskotinov, E.V. Krivonogova [2], especially in sympathotonics, higher background activity of subcortical diencephalic brain structures was noted. The "maturation" of the EEG wave structure is accompanied by an increased frequency of hypersynchronous, high-amplitude EEG variants, which is consistent with the data we have obtained. The formation of hypersynchronous EEG patterns in schoolchildren with an increase in sympathetic activity indicates the presence of dysfunctions of the diencephalic structures of the brain and damage to thalamocortical connections, which may underlie a violation of the central mechanisms of regulation of vascular tone. It is known that a controlled increase in the activity of the parasympathetic department of autonomic regulation can lead to an improvement in the state of cerebral blood flow and bioelectric processes of the brain [10]. In children, mainly from groups with a balanced vegetative tone, after performing corrective physical exercises, rhythms are regulated and bioelectric activity shifts towards higher amplitudes in the alpha range, which may indicate a decrease in the level of emotional stress during task performance and synchronization of cortical-subcortical interactions [11].

EEG indicators in students with parasympathetic activity are characterized by a predominance of slow-wave activity reflecting the deep structures of the brain, being an indicator of the mesolimbic effect on the cerebral cortex associated with the emotional state [12].

The results obtained indicate the need for a differentiated approach in physical education classes for children with different types of autonomic regulation, confirmed by the individual characteristics of EEG indicators. HRV also reflects the tension of the functional systems responsible for regulating the body during stress [13-17]. The HRV frequency spectrum fully reflects changes in the sympathetic and parasympathetic divisions of the ANS [18, 19], which must be taken into account when analyzing the health of schoolchildren after physical exertion. The proposed equal workload for children with different TVD can lead to dysregulatory manifestations and a decrease in the adaptive capabilities of students [9]. Building a trajectory of physical education classes based on the typology of the child's body and confirmed by EEG indicators will help strengthen the body of schoolchildren and preserve their health.

4. Conclusions

The EEG study determined the parameters of brain electrogenesis in schoolchildren with various types of cardiovascular system functions.

It has been established that the rhythmological differences in the EEG in children with different TAR correspond to the characteristic features of TAR and can be considered as selective neuro-regulatory influences of the central regulatory circuit on the ANS departments, depending on the genetically determined regulatory typology.

Application of artificial intelligence: The review is written without the use of artificial intelligence technologies.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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