

## THE PROBLEM OF INTERHEMISPHERIC ASYMMETRY IN DETERMINING INDIVIDUAL LATERAL PREFERENCES IN CHILDREN WITH INTELLECTUAL DISABILITIES

### PROBLEM ASYMETRII MIĘDZYPÓŁKULOWEJ W OKREŚLANIU INDYWIDUALNYCH PREFERENCJI LATERALNYCH U DZIECI Z NIEPEŁNOSPRAWNOŚCIĄ INTELEKTUALNĄ

Tereza Azatyan<sup>1(E,F,G)</sup>

<sup>1</sup> Department of the Theory and Methodology of Physical Education and Adaptive Physical Culture, Armenian State Institute of Physical Culture and Sport, Yerevan, Armenia

Authors' contribution  
Wkład autorów:  
A. Study design/planning  
zaplanowanie badań  
B. Data collection/entry  
zebranie danych  
C. Data analysis/statistics  
dane – analiza i statystyki  
D. Data interpretation  
interpretacja danych  
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#### Summary

The purpose of the study was a theoretical review of the problem of interhemispheric asymmetry and lateral preferences in children with intellectual disabilities. Data analysis from numerous studies in neuropsychology have allowed a new view of the possibility of developing compensatory mechanisms for various disorders of higher mental functions with specific features of the lateral organization profile types of motor and sensory functions that play a basic role in the mental development of children with disabilities. The analysis of the presented scientific approaches and factual studies allow to state the presence of hidden contradictions in the issues of determining correlations of interhemispheric asymmetry in impaired development. The review of the literature presented in this paper proves the presence of qualitative peculiarities of the organization of movements in brain of schoolchildren with intellectual disabilities. At the same time, the theoretical analysis revealed a lack of consensus on the influence of lateral preferences in the difficulties encountered, which determines the relevance and necessity of further search for opportunities to use neuropsychological data and the individual lateral preferences in the development of movement skills.

**Keywords:** interhemispheric asymmetry, interhemispheric interaction, lateral preferences, intellectual disability, movement, brain

#### Streszczenie

Celem artykułu był teoretyczny przegląd problemu badania asymetrii międzypółkulowej i preferencji lateralnych u dzieci z niepełnosprawnością intelektualną. Analiza danych z licznych badań z zakresu neuropsychologii pozwoliła uzyskać nowy wgląd w możliwości rozwoju mechanizmów kompensacyjnych w przypadku różnych zaburzeń wyższych funkcji psychicznych o specyficznych cechach profilu lateralnej organizacji typów funkcji motorycznych i sensorycznych, które odgrywają podstawową rolę w rozwoju umysłowym dzieci z niepełnosprawnościami. Analiza przedstawionych podejść naukowych i badań opartych na faktach pozwala stwierdzić obecność ukrytych sprzeczności w kwestiach określania korelacji asymetrii międzypółkulowej w zaburzonym rozwoju. Przegląd literatury przedstawiony w niniejszym artykule dowodzi obecności jakościowej specyfiki organizacji ruchów w mózgu u dzieci z niepełnosprawnością intelektualną w wieku szkolnym. Jednocześnie analiza teoretyczna ujawniła brak konsensusu co do wpływu preferencji lateralnych na napotymane trudności, co determinuje istotność i konieczność dalszych poszukiwań możliwości wykorzystania danych neuropsychologicznych i indywidualnych preferencji lateralnych w rozwoju umiejętności ruchowych.

**Słowa kluczowe:** asymetria międzypółkulowa, interakcja międzypółkulowa, preferencje lateralne, niepełnosprawność intelektualna, ruch, mózg

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**Address for correspondence / Adres korespondencyjny:** Tereza Azatyan, Department of the Theory and Methodology of Physical Education and Adaptive Physical Culture, Armenian State Institute of Physical Culture and Sport, 11 Alek Manukyan street, 0070 Yerevan, Armenia, e-mail: tereza.azatyan@sportedu.am, phone: +374 10 55 3310, ORCID: <https://orcid.org/0000-0002-3218-257X>

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## Introduction

The disclosure of neuropsychological mechanisms of the brain's commissural system functioning and its contribution to the realization of any mental function is an important task of modern neuropsychology. According to the modern concepts developed in the brain sciences, the regularities of interhemispheric interaction (and interhemispheric asymmetry as its special case) are among the most important fundamental bases of brain functioning as a paired organ. It is the presence of functional connections between hemispheres that ensures the advantages of the brain as a paired organ [1-4]. Impairment of the quality of interhemispheric integration during complex information processing can affect some aspects of intellectual development and complex cognitive activity. At the same time, preserved interhemispheric connections often provide the reorganization of functions necessary in case of unilateral brain damage. The problem of the functional interhemispheric asymmetry of the brain, like many similar fundamental phenomena that do not fit into familiar schemes, has undergone a number of stages in its development.

The initial view of functional interhemispheric asymmetry as a stable, constant property related only to cortical activity has significantly changed as experimental and clinical data have accumulated. Investigations not only in morphology and physiology, but also in neuropsychology, biology, linguistics, genetics, sociology, biochemistry, neurology, endocrinology and other disciplines revealed new differences in the activity of the left and right cerebral hemispheres. Issues of not only right or left hemisphere dominance, but also interhemispheric interaction began to be developed. The number of experimental works on studying the functional specificity of cerebral hemispheres continues to grow. On the basis of the results obtained, various models of interhemispheric interaction in specific mental processes, formation of lateral preferences, etc. are proposed.

The clinical and empirical data interpreted with the help of private models often contradict each other in assumptions about the basic factors of the functional hemispheric organization [2]. All the models that have been proposed still leave open such important questions as the functional unilateralism or bilateralism of hemispheres, the leading role of hemispheres in the realization of certain mental functions, and the specificity of hemispheres in processing information of a certain type (modality). At the present stage special attention is paid to ways of processing information of each hemisphere.

At the present time, due to the changes toward integration that we observe not only in the field of school education, but also in the system of supplementary education, the problems of searching for new technologies of influence on the child's psyche take on special significance. These new technologies should meet at least two requirements simultaneously: saving energy and time resources, and maximum success from the position of solving a set of tasks per unit of time. The number of children around the world with mental and intellectual developmental disabilities is growing, and they need help from medics, psychologists, special educators, and social workers. A full analysis of the causes of adverse trends in both somatic and psychological health and their social consequences will only be possible through a comprehensive analysis of social, environmental, medical, and possibly political trends in society.

The solution of this problem is complicated by a number of objective circumstances: according to psychophysiological and neurophysiological research data, the overwhelming majority of modern 8-11 years old children have not developed school important functions by the beginning of their schooling. The discovered functional immaturity of the cortex and regulatory structures of the brain are the cause of persistent learning difficulties that are rigid in relation to correction in more than half of the cases. Therefore, the close attention of pedagogical practitioners is turned to the achievements of those sciences that answer the questions: where does the problem come from and what are the mechanisms of its compensation [5].

Large cerebral arteries play an important role in changes in cerebral vascular resistance. Constriction and dilation of large arteries change the regional vascular resistance in the brain and, thus, regulate the pressure

in the brain's microvessels, which provide a protective mechanism preventing perfusion pressure fluctuations in the thin-walled intracranial vessels. The operation algorithm of these arterial systems, the researchers relate to the structural and functional organization of the cerebral vascular system, which allow to formulate the concept of internal (autonomous) mechanisms of cerebral circulation regulation under various disturbing influences, which can be, for example, changes of the system arterial pressure, and neuronal activity of the cerebral sections [6].

Currently, the literature lacks a clear understanding of the interhemispheric features of cerebral blood flow in elementary and middle school children with intellectual disabilities, which indicates the relevance of further study of this issue.

The main direction in solving this problem is the establishment of its structural neuromorphological basis [7]. At the same time, the majority of studies are devoted mainly to the analysis of functional interhemispheric asymmetry [8,9] and only a few consider its morphological [10] and biochemical bases [9,10].

### **Aim of the work**

The aim of this work was to investigate the interhemispheric asymmetry in determining individual lateral preferences in intellectually impaired children.

### **Review results**

The asymmetry of the morphological parameters of the cortical branches of paired vessels in the right and left hemispheres was studied, among others, in the works of Barabash [11], Dunst et al. [2], Helland et al. [12], Mikadze [10], Sichko [9]. There are works concerning the asymmetry of the morphological parameters of extracranial parts of the main arteries: common carotid arteries [13], vertebral arteries [14]. At the same time, there are few studies in which the indices of paired vessels were compared with regard to gender [15] in the dynamics of their changes at different age periods [16].

The asymmetry of the vertebral artery is well enough studied. However, contradictory data on its nature can be found in the literature. Some authors point to the presence of a left-sided asymmetry of the vertebral artery diameter [17,18] while others point to a right-sided asymmetry [19-21]. Perhaps this is connected to the fact that the data were analyzed without taking into account the gender and age of the subjects. When researchers took the gender of the subjects into account, it was shown that males showed symmetry in vertebral artery diameters and females showed right-sided asymmetry [22]. In contrast, a left-sided diameter asymmetry in mature and middle-aged males and a vertebral artery diameter symmetry in females was revealed.

A bilateral asymmetry of morphological parameters was revealed for the anterior cerebral artery, with the right artery usually being longer than the left one [23]. Pavlova et al. [24] revealed on the contingent from the juvenile period to the senile period that the length, external diameter and area of the transverse lumen of the internal carotid artery, anterior cerebral artery, pre-communication part of the posterior cerebral artery, middle cerebral artery and posterior connective artery, differ in the right and left aspects in most observations. The author notes that only the external diameter of the anterior cerebral arteries and the posterior connective arteries in women, and the middle cerebral arteries in men, have directional asymmetry. Pavlova et al. [24] also note directional asymmetry in the area of the transverse lumen of cavernous and cerebral parts of the internal carotid, anterior cerebral arteries, pre-communication parts of the posterior cerebral arteries in men, and anterior cerebral arteries, pre-communication parts of the posterior cerebral arteries, middle cerebral arteries and posterior connective arteries in women. The external diameter and transverse lumen area of the arteries on the left were statistically significantly more predominant in women than in men [25].

The total area of the transverse lumen of the anterior cerebral artery, the pre-communicative part of the posterior cerebral artery, and the middle cerebral artery in men has a right-sided orientation. Barabash et al. [11] noted right-sided asymmetry of the common carotid artery lumen in a group of subjects from 11 to 71 years old.

Besides asymmetry of morphological parameters, there are some data in the literature concerning peculiarities of the hemodynamic indices of arteries depending on the arterial asymmetry [24,25]. In experiments on cats, Pavlova et al. [24] showed the predominance of the volume velocity of blood flow in the left common carotid artery compared with the right carotid artery. Dunst et al. [2] when studying the volume blood flow in rat carotid arteries, found that the volume blood flow in the left common carotid artery is higher than in the right common carotid artery; at the level of the villous circle more blood flows to the left hemisphere than to the right hemisphere.

#### *Blood flow asymmetry in the hemispheres of healthy children*

It is noticed that in healthy people, asymmetry of blood flow levels in the hemispheres is allowed up to 20% [12]. The asymmetry of blood flow of the left and right hemispheres can be caused by functional asymmetry of the brain [25,26] as well as morphologically by the left carotid artery branching directly from the aortic arch. Helland et al. [12] established that in old age the blood flow in the right hemisphere does not change, and in the left hemisphere it decreases. A number of authors [24-26] have not revealed an asymmetry of blood flow velocity parameters in internal carotid arteries. Other authors note the presence of an asymmetry of velocity indices of blood flow in the internal carotid arteries [26,27].

The absence of asymmetry of the mean linear velocity of blood flow, sex differences and shear stress asymmetry demonstrates that in the right and left arteries, regardless of sex, such hemodynamic parameters of blood flow (diameter, resistance, volume flow rate value) are maintained, which are necessary for the normal blood supply of both cerebral hemispheres. The results of the study [13] once again confirmed the position that cerebral hemodynamics has functioning mechanisms of its autoregulation that maintain the constancy of cerebral blood flow, which provides optimal parameters of shear stress regardless of gender and vessel localization.

Large cerebral arteries play an important role in changing cerebral vascular resistance [18]. Constriction and dilation of large arteries change the regional cerebral vascular resistance and thereby regulate pressure in the brain microvessels, which is a protective mechanism preventing perfusion pressure fluctuations in thin-walled intracranial vessels. The anatomical basis for the mechanism of vasoconstrictor responses is a powerful muscular layer and rich innervation, which is characteristic of the cessational segments of the carotid and vertebral arteries. Constriction of the main arteries of the head occurs in response to increased arterial pressure, as well as in the cases of venous stasis and cerebral edema. The physiological sense of this reaction is to limit blood flow to the cerebral vascular system. Their dilation occurs when blood pressure drops. The regulation of blood flow to the brain is also provided by the function of the main arteries of the head located in the cavernous and atlanto-occipital sinuses. The role of the physiological bends of these arteries in limiting pulse and other variations of arterial pressure is important and it promotes the blood flow uniformity [26,27].

However, the algorithm of the operation of these arterial systems the researchers connect with the structural and functional organization of the cerebral vascular system, which has allowed to formulate the concept about the internal (autonomous) mechanisms of the cerebral circulation regulation under various disturbing influences, such as changes of the system's arterial pressure and the neuronal activity of the brain sections [27].

The given concept does not take into account the presence of a constant individual functional asymmetry of cerebral hemispheres that is a basic component of the psychophysiological state of a human body. Hence, the necessity arises to divide the structural and functional organization of the cerebral circulation system into two interdependent processes but having a certain functional independence: the first one is the basic one determining the functional asymmetry of the cerebral hemispheres blood supply and functioning of the main vessels feeding the brain; the second one is the presence of the "closing mechanism" of the main arteries, the mechanism of pial arteries, the mechanism of blood outflow regulation from the brain venous sinuses.

According to some authors [5-7], there is a physiological asymmetry of pulse blood flow in humans, which is manifested by the greater blood flow in the left hemisphere of the brain, which is caused by the functional asymmetry of the brain.

The studies of other authors, edited by Litosh [20], Sichko [9] show that the majority of healthy children in the age range from 8 to 11 years are characterized as individuals without blood supply asymmetry of the right and left internal carotid artery basins. In turn, Doppler studies in children 7-12 years old with intellectual disabilities revealed an insufficiency of blood flow mainly in the right cerebral hemisphere that agrees with modern neuroanatomical theories of the genesis of intellectual disability [17].

Currently, there are no clear ideas in the literature about the interhemispheric features of cerebral blood flow in primary and secondary school children with intellectual disabilities, which indicates the relevance of further study of this issue.

#### *The relevance of studying brain blood flow in young and middle school age children with intellectual disabilities*

Cerebral hemodynamic abnormalities have been found in children with disabilities: decreased blood flow in the prefrontal parts of the brain, reduced velocity indices in the carotid and vertebral arteries, obstruction of venous outflow and time of pulse wave distribution, increased peripheral resistance in the vertebral artery basin and elasticity of arterial vessels of large caliber, the signs of venous dyschemia [15-18].

Intellectual activity has a significant impact on cerebral blood circulation. An actively working brain needs to increase the intensity of blood flow, and this functional need is realized by active vascular reactions, providing blood supply of the brain tissue, adequate to its increased metabolic needs [18]. Therefore, it is extremely important to study cerebral circulation during mental work under conditions of natural human activity [19,20].

Thus, the studies conducted on the age-specific features of cerebral blood circulation indicate that children, compared with adults, are characterized by greater intensity and lability of blood supply of the brain. The tone of small caliber arteries decreases with age, the tonic tension of large caliber arteries increases, and the volume velocity of cerebral blood flow during ontogenesis changes in a wave-like manner.

Analysis of the literature made it possible to reliably state the fact that, at present, a large material based on the clinic of local lesions of the brain has been accumulated indicating the dependence of emotional and personality disorders on the localization of the lesion. These works show that disorders of higher mental functions are associated with functional abnormalities of the cortical and subcortical parts of the brain belonging to systems of different levels: stem and limbic structures, medio basal parts of the frontal and temporal cortices of both hemispheres. Besides, many works have stressed the important role of interhemispheric asymmetry in lesions of the brain structures of the right and left hemispheres in the appearance of certain personality peculiarities [21-23].

Thus, the complex nature of interhemispheric interaction and lateral perceptions formed under the influence of the functioning of each link, department, subcortical block, and cortex as a whole, will be unique for each individual and reflect his or her psychological features, including defects. Analysis of the literature shows that this process is also influenced by the time of exposure to the pathological factor, since the development of

each successive level of motor organization is impossible without reaching a certain level of maturity of the previous one. Affection of the lower parts of the central nervous system causes an impairment of elementary movements, whereas the higher parts cause an impairment of complex motor acts that require understanding [23]. This occurs in intellectual disorders and influences the strategy of selecting a compensatory pathway.

A theoretical review of the problem in question has revealed a lack of unified approaches to diagnosing any interhemispheric asymmetry of sensory and motor spheres. This problem is especially acute for children with intellectual disability.

Clinical observations and the practical experience of some specialists show that students at special schools are characterized by a not-sufficient level of development of motor abilities. There are different points of view on the causes of motor deficiencies in oligophrenia. Thus, the experimental study conducted by Litosh in 1998 [20], allowed us to distinguish the presence of gender differences in the formation of motor skills such as speed and strength, flexibility, and endurance. Underdevelopment of motor skills is manifested in synkinesis, awkwardness of movements, unsteadiness of muscle tone, etc. in the absence of a primary lesion of the motor apparatus [25,26].

Despite the fact that the problem of motor development in intellectual disability has been studied, the author of this research have encountered virtually no works that reveal the role of interhemispheric interaction in these processes. Besides, the available factual data presented in the literature and obtained from various clinical and experimental materials are numerous and often contradictory. Thus, according to Luriya et al. [27], motor insufficiency is caused by the sterile paretic conditions of various muscles. Some authors attribute it to the underdevelopment of morphophysiological systems of the brain associated with motor function [27].

Violations of the coherence, accuracy, and tempo of movements observed in almost all intellectually disabled schoolchildren can be explained in terms of the following neurophysiological reasons from the central movement control apparatus:

- insufficient interhemispheric interaction on the background of an abnormally small size of the corpus callosum and various disorders in the pyramidal system that provides innervation of the muscles of the opposite side of the body can lead to misalignment when performing symmetrical actions and a violation of coordinated work in the "eye"-hand" system. In addition, disorders in the pyramidal pathway can lead to the disintegration of complex "serially organized" movements [14];
- slowness of motor reactions in intellectual disability may be caused by low rates of information processing in the right hemisphere. This is evidenced by the results of studies of the speed of visual information processing by the right hemisphere in oligophrenics conducted in 1978 by Genkina [28];
- impairment of movement accuracy in intellectual disability may be caused by inadequate innervation of the muscular apparatus.

In addition, Mikadze's research [10] demonstrated flattened lateral preferences, which may indicate incomplete processes of the functional development of each of the hemispheres and defects in physiological signs in the left hemisphere, especially in the frontal structures. This is also not conducive to the development of the voluntary control of movements. The dominance of the right hemisphere or flattened lateral sensorimotor preferences as compared to a sample of healthy children leads to the fact that intellectually disabled children gravitate to a synthetic way of perceiving information in its global image that does not highlight the specific functions of each link (part) [18].

Incompleteness (disorders) in levels B and C of movement organization (according to Bernstein [19]) due to early irradiating total lesion of the central nervous system and delayed formation of basic locomotor skills: coordination of movements, spatial organization of movements are impaired. As a consequence, equilibrium, accuracy in differentiating temporal intervals and muscle efforts are impaired, complex coordinated movements

become difficult to perform, and the ability to perform discordant movements is impaired even at the age when clear asymmetry and dominant selection in the hemispheres (left hemisphere) are normally observed. This is confirmed by studies that have pointed to the slowness and clumsiness of movements of schoolchildren with intellectual disability [4]. Movement disorders already at the B level are evidenced by the fact that even in adolescence schoolchildren have difficulty accepting and holding a given posture, differentiating their efforts, and switching to another type of physical exercise. Synergies, disorders of movement switching, unstable muscle tone (insufficient integration of A and B levels), and difficulties in developing complex motor formulas are recorded in many cases when they try to hold static postures. The latter feature may indicate the dominance of right hemispheric structures responsible for global perception and the analysis of information, which inhibits the ability to compose the whole into parts with their subsequent connection [21].

Left hemisphere underdevelopment, smoothed interhemispheric dominance observed in intellectual disability lead to difficulties in modeling hand position sequences and their memorization, slowness of movements, presence of perseverations, and extra movements [10].

Sichko [9] notes that the hierarchy of motor deficits in intellectual disability is expressed by the significant underdevelopment of precise and subtle movements (level C and D according to Bernstein), the relative preservation of elementary movements (level B with an interested right hemisphere), the importance of the right hemisphere (level D), and the presence of a disorder of the right hemisphere. The reason for this is the underdevelopment of the premotor sections of the frontal lobes against the background of interhemispheric interaction disorders [27]. Proceeding from these features of insufficient functioning of the premotor areas in the case of total gross lesions of the cortical level of the central nervous system, we can observe pronounced difficulties in mastering cyclic movements.

Studying the qualities of the motor sphere of the children in special schools, it has been noted that when performing a motor task, those children mainly resort to the trial-and-error method, very often departing from the requirements of the instructions, i.e., they rely on the primary level of movement construction, rather than on the semantic level, which may testify that the right hemisphere or ambidextrous interest is greater [28].

The child's body is in a state of constant morphofunctional development. At different stages of the child's ontogenesis, the nature of adaptive reactions is determined by the degree of maturity of functional systems and the adaptive capabilities of the individual [29].

Due to the high prevalence of cerebral vascular diseases in children, the study of mechanisms providing blood supply to the brain of a child with developmental features is currently an urgent problem [12].

According to different authors, the number of children with intellectual disabilities in the general pediatric population ranges from 2% to 21%. The main role in the occurrence of encephalopathy belongs to various factors of the pre- and perinatal period and, probably, first of all, this syndrome is manifested in children who have undergone hypoxia, as well as in premature infants [8].

In 90% of cases perinatal injuries have hypoxic-ischemic and traumatic genesis [5]. Hypoxic-ischemic brain injuries in childhood are often the result of perinatal cerebral hypoxia, which leads to various metabolic disorders, neuronal damage, the formation of immaturity of central regulatory mechanisms, and a reduction of adaptation-compensatory capabilities of the central nervous system in various activities.

According to the literature, by the end of the period of the second childhood (approximately by the age of 11 years), the formation of indicators reflecting the degree of blood filling of large arteries, the total lumen of small vessels, and the tone of arterial and venous vessels is completed [14]. Therefore, age-related features of changes in the functional organization of hemodynamic processes were analyzed and compared in conditionally healthy children aged 8-11 and in children diagnosed with intellectual disability and mild intellectual disability under conditions of calm wakefulness. At the age of 8-9 in healthy children there was observed an increase in the

difference of the arterial tone of large, medium and small caliber arteries, the venous tone of large and small caliber, as well as the level of peripheral vascular resistance between the bifrontal area and vertebrobasilar basin of cerebral blood flow. At 10-11 years of age, a drop in vascular resistance in the frontal area is evident. The amplitude and gradient coefficient values of the rheoencephalogram do not correlate with the age of the examined children, indicating an earlier formation of this parameter [21,22].

The complexity of the organization of the cerebral circulation provides an intensive blood supply to the brain under loads different in quality and strength, and a variety of physiological conditions [27,28]. To date, the features of age-related changes in the regulation of blood supply to the brain both normally and in brain dysfunctions remain poorly understood [29,30].

## Conclusions

The review of the literature presented in this paper, which reveals the peculiarities of interhemispheric interaction and organization of movements, as well as the role of right and left hemispheres in motor development, proves the presence of qualitative peculiarities of the brain organization of movements in school children with intellectual disabilities. Clinical and empirical data interpreted by means of partial models often contradict each other in assumptions about the basic factors of the functional organization of the hemispheres. All proposed models still leave such important questions open as: the functional unilateralism or bilateralism of the hemispheres; the leading role of hemispheres in the realization of certain mental functions; the specificity of the hemispheres in processing information of a certain type (modality). At the present stage, special attention is paid to the ways of information processing by each hemisphere. At the same time, the theoretical analysis revealed a lack of consensus on the influence of lateral preferences in the difficulties encountered, which determines the relevance and necessity of further searching for opportunities to use neuropsychological data and the individual lateral preferences in the development of movement skills. According to the literature, by the end of the period of the second stage of childhood (approximately by the age of 11 years), the formation of indicators reflecting the degree of the blood filling of large arteries, the total lumen of small vessels, and the tone of arterial and venous vessels, is completed. Therefore, age-related features of changes in the functional organization of hemodynamic processes were analyzed and compared in conditionally healthy children aged 8-11 and in children diagnosed with intellectual disabilities.

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