

Effect of the physical rehabilitation program using kinesiotaping technique on the cerebral hemodynamics of 3-4-year-old children with cerebral palsy in the form of spastic hemiparesis

VITALII KASHUBA¹, BORIS DOLINSKYI², BOZHENA BUKHOVETS³, VALERIYA BORSHCHENKO⁴, GALINA DISHEL⁵

¹National University of Ukraine on physical education and sport, Kyiv, UKRAINE

^{2,3,4,5}Pedagogical University named by K. D. Yshinskyi, UKRAINE

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Abstract.

Background. The article presents the structure and content of the program of physical rehabilitation of 4-year-old children with cerebral palsy (CP) in the form of spastic hemiparesis using the method of kinesiotaping. **Material and methods.** The theoretical analysis of special and scientific-methodological literature; pedagogical methods: observation, survey, experiment (ascertaining and formative), instrumental (transcranial Doppler of cerebral vessels), mathematical data processing. The ascertaining experiment involved 71 4-year-old children with cerebral palsy in the form of spastic hemiparesis. **Results.** Considering the analysis of cerebral hemodynamics by indicators of linear blood flow velocity in the respective vessels of the subjects, it should be noted that before rehabilitation, the difference between the studied indicators of cerebral hemodynamics of the control and the experimental groups was not observed ($p>0.05$). After rehabilitation, the proportion of children with no blood flow disorders among children of the control group increased as follows: in the common carotid artery – by 28.60%, in the internal carotid artery – by 20.0%, in the vertebral artery V3 – by 25.70%, in the anterior cerebral artery – by 28.6%, in the middle cerebral artery – by 25.70%, in the posterior cerebral artery – by 25.7%, in the vertebral artery V4 – by 22.90%. At the same time, the increase in the proportion of children without blood flow disorders in the experimental group was: in the common carotid artery – by 25.0%, in the internal carotid artery – by 33.3%, in the vertebral artery V3 – by 25.0%, in the anterior cerebral artery – by 36.1%, in the middle cerebral artery – by 22.2%, in the posterior cerebral artery – by 22.2%, in the vertebral artery V4 – by 50.0%. **Conclusion.** In the formative experiment, the research has tested the developed program of physical rehabilitation of 4-year-old children with cerebral palsy in the form of spastic hemiparesis, using the technique of kinesiotaping in a specialized rehabilitation center. The practical effectiveness of the proposed program has been proved by quantitative changes (at the level of $p<0.05$) of the studied indicators of cerebral hemodynamics. The results of the study confirm the effectiveness of the proposed program of physical rehabilitation, aimed at improving the indicators of cerebral hemodynamics.

Key words: physical rehabilitation, cerebral palsy, kinesiotaping, spastic hemiparesis, blood flow.

Introduction.

The problem of the developing incidence of cerebral palsy (CP), which is the main cause of children's disability (Andrieieva et al., 2019; Grygus et al., 2019), remains an urgent issue in pediatric neurology (Kashuba, et al., 2017; Savliuk et al., 2020), as the incidence of the disease does not tend to decrease, both worldwide and in Ukraine. (Bukhovets, 2016; Dido et al., 2021). Depending on the form, children with CP may suffer from: limited mobility and inability of the child to perform even one of the motor skills (turning to the side or abdomen, etc.) (Kovesdy et al., 2017), profound mental retardation, delayed mental development, paralysis or paresis (Krusevich et al., 2013), spasticity or hypotonia (Bukhovets, 2017).

There are suggestions that among the pathogenetic aspects of motor deficit in cerebral palsy is the instability of the cellular genome (Kashuba et al., 2016, 2020), which plays an important role in the formation of movements (Lennon et al, 2000). Reduced motor activity of children with cerebral palsy leads to impaired blood flow in the cervical spine according to transcranial Doppler (Galan et al., 2017) characterized by a decrease in diameter, systolic (Lazareva, 2014), mean, diastolic, and volumetric velocities and increased pulsation of the resistance index of the vertebral arteries (Andrieieva et al., 2017). Cerebral palsy is characterized by persistent disorders of cerebral hemodynamics in terms of linear blood flow velocity and venous outflow through the direct sinus (Tuchkov, 2016). However, according to the results of many scientific studies (Kashuba, et al., 2012) the use of kinesiotaping in the physical rehabilitation of children with CP contributes not only to the correction of motor disorders (Bukhovets et al., 2016), but also to the improvement of cerebral hemodynamics (Kashuba et al., 2017).

Despite the proven positive experience in the use of kinesiotaping in the physical rehabilitation of children with cerebral palsy (Bukhovets, 2018), the problem of its use in many respects still remains unresolved (Baiteriakova, 2019). The purpose of the research is to theoretically substantiate and develop a physical rehabilitation program for preschool 4-year-old children with cerebral palsy in the form of spastic hemiparesis (Lazareva et al., 2017), using the technique of kinesiotaping in a specialized rehabilitation center aimed at improving cerebral hemodynamics (Tuchkov, 2016).

The generalized analysis of the special scientific literature shows that the problem of physical rehabilitation of children with cerebral palsy is still actively studied. Scientists claim that the leading link in the set of rehabilitation measures is physical rehabilitation, which is based on the use of physical culture (Lazareva et al., 2017). Despite the great interest of domestic and foreign scientists and the results of discussions so far, the problem of physical rehabilitation of children with cerebral palsy is a topical issue (Lazareva et al., 2017).

Materials and Methods.

Participants. The study involved 71 4-year-old children with cerebral palsy in the form of spastic hemiparesis.

Procedure / Test protocol / Skill test trial / Measure / Instruments. To achieve the purpose, a research plan was developed, which allowed obtaining sufficiently complete and reliable information. This plan consisted of data analysis of special and scientific-methodological literature, pedagogical research (ascertaining and formative experiments), instrumental (transcranial Doppler of cerebral vessels), mathematical data processing.

To perform the theoretical analysis of special scientific and methodological literature, the research used the reference sources of domestic and foreign authors, which revealed the application of kinesiotaping to children with cerebral palsy.

The research used the pedagogical experiment, which was based on the process of identifying the advantages of the proposed program of physical rehabilitation of children with cerebral palsy over the standard program. Methodologically, the work was carried out in certain directions. To assess cerebral hemodynamics and for clinical diagnosis of cerebrovascular pathology, the research used a neurophysiological method of functional diagnosis – transcranial Doppler (TCD), which is the most informative non-invasive instrumental method, which allows to conduct research repeatedly and in dynamics. In the TCD system, there are the following areas of diagnosis of cerebral vessels: direct scan (duplex 68 scan) and indirect scanning (mathematical and graphical registration of blood flow velocity in vessels without visualization of vessel structure, cm/s) (Kashuba et al., 2017). The standard set of examination began with the study of blood flow in the extra-cranial carotid basin on both sides – in the common carotid arteries (CCA) and in the extra-cranial vertebrasilar basin – in the vertebral arteries (VA), then examined blood flow in the intracranial part of these basins, namely, in the carotid – siphons of the internal carotid arteries (ICA), in the middle/anterior cerebral arteries (MCA; ACA), in the vertebrasilar basin – the posterior cerebral artery (PCA). In parallel with the study of the arterial blood flow, the research examined the venous flow, namely the intracranial department, represented by the index of the direct sinus. Blood flow in the arteries was assessed by qualitative (Doppler shape, ratio of elements, frequency distribution in the spectrum, blood flow direction, sound characteristics of the signal) and quantitative (linear blood flow, hemispheric asymmetry (A) of the blood flow in the same vessels of different hemispheres), relative characteristics and indicators of vascular reactivity (Bukhovets 2017). The set tasks of the scientific research were solved with the help of ascertaining and formative experiments. The ascertaining experiment was employed to determine the peculiarities of the state of the studied contingent and to obtain the source material to determine the strategy of the physical rehabilitation program for children with cerebral palsy and to conduct a further formative experiment. The formative experiment was conducted to determine the effectiveness of the proposed program of physical rehabilitation for 4-year-old children with cerebral palsy in the form of spastic hemiparesis using the technique of kinesiotaping.

Data collection and analysis / Statistical analysis. The research used the selective method to assess the average performance of children with cerebral palsy. The hypothesis about the normality of the distribution of empirical data was tested using the Shapiro-Wilk test (Kashuba et al., 2012). The mean values of the two pairwise unrelated samples were compared using Student's t-test. The calculation of the t-test was carried out in accordance with the results of testing the hypothesis of equality of general variances of the sample data using Fisher's F-test.

Results

The goal of the developed program was to improve the cerebral hemodynamics of 4-year-old children with cerebral palsy in the form of spastic hemiparesis. The proposed program of physical rehabilitation differs from the standard existing programs by a complex approach to solving the problem of physical rehabilitation of children with cerebral palsy using the technique of kinesiotaping.

The proposed program of physical rehabilitation in a specialized rehabilitation center was developed for 4-year-old children with cerebral palsy in the form of spastic hemiparesis. Its total duration was 14 days and it

included one fixed course of 10 days. The program was implemented in two motor modes (gentle training, training). Under this program, 36 children with cerebral palsy in the form of spastic hemiparesis were physically rehabilitated; they made an experimental group.

The first 5 days of the course of physical rehabilitation for children used gentle-training motor mode. Later, the training mode was used. The developed program of physical rehabilitation consisted of sensory integration, Bobath therapy and kinesiotopeing.

The practical implementation of the method of kinesiotopeing was realized according to the generalized symmetrical schemes of kinesiotopeing: muscles of the girdle of the upper extremities and torso. According to the chosen scheme of kinesiotopeing of the girdle of the upper extremities, the deltoid muscle was first taped, the place of attachment of which was deltoid hump: the sensitivity zone of the humerus, innervation C5, C6 (axillary nerve), and the function of flexion and extension of the limbs, abduction of the shoulder joint. Kinesiotopeing was performed by applying a Y-shape tape 5 cm wide and 20 cm long from the wide side of the deltoid muscle, taking the shoulder back and arm to the side. Then the child's arm was directed forward, bent at the elbow joint.

Next, kinesiotopeing of the large circular muscle was performed, the place of attachment of which was the medial sulcus of the biceps muscle from the humerus, inverted by the C6-C7 nerve (subscapular nerve). The large circular muscle provides movement in the upper extremities and performs internal rotation of the arms. Constant contraction of the muscle can change the shoulder blade reflex, which leads to the fact that the shoulder blade comes to a state of re- or ra-traction, when the hand moves up. Kinesiotopeing of the large circular muscle was made with an I-shape tape 2.5 cm wide and 15 cm long, to perform flexion and extension of the shoulder joint.

Kinesiotopeing procedure: the child's elbow was bent and the arm was unfolded at 45 degrees, in this position a tape was carefully applied to the place where the muscle was attached. The arm was unfolded 90 degrees so that it would be parallel to the floor, then at the point where the large circular muscle reaches maximum tension, the tape was completely attached.

Kinesiotopeing of the pectoralis major muscle, the place of attachment of which was the sulcus of the humerus with nerves C5-C8, T1 (medial and lateral pectoral nerves). The pectoralis major muscle provides movement to the upper extremities, performs internal rotation of the humerus, flexion and extension of the arms, raises the ribs and participates in the respiratory act. The procedure of kinesiotopeing of this muscle was that the child's shoulders were unfolded back and a Y-shape tape 5 cm wide and 15 cm long was applied starting from the intertrochanteric sulcus of the humerus and unfolding the shoulder wider, stretching the arm back slightly to attach the other ends of the tape to the clavicle and sternum costal heads.

When kinesiotopeing the triceps, the place of attachment was the process of the ulna. This muscle is connected to nerves C6-C8 (radial nerve); its function is to provide lengthening of the forearm and fixation of the head of the shoulder. Kinesiotopeing procedure: the child's arm was bent at an angle of 45 degrees, an X-shape tape 30-25 cm long and 5 cm wide was applied on the elbow, then the elbow was bent at an angle of 90 degrees, the ends of the tape were fixed on the shoulder, while the arm and the shoulders were bent.

When kinesiotopeing the brachioradialis muscle, the place of attachment was the lateral, anterior and one third of the posterior parts of the radial bone, with nerves C5-C7 (radial nerve). Its function is to ensure the forearm flexion works as a supinator and pronator of the forearm. The kinesiotopeing procedure consisted of providing an angle of 45 degrees between the child's forearm and elbow, an I-shape or Y-shape tape 5 cm wide and 15 cm long was applied. One edge of the kinesiotope fixed the lateral supracondylar process of the humerus, as the arm was extended. The kinesiotope was directed to the place of muscle attachment and was fixed when the arm was straightened at the elbow joint.

The scheme of kinesiotopeing of torso muscles began with kinesiotopeing of the anterior scalene muscle, the place of attachment was the hump of the anterior scalene muscle. This muscle is connected to nerves C5-C6 (posterior branches of the motor nerve). The muscle works as a lateral flexor muscle. Kinesiotopeing procedure: an I-shape tape 5 cm wide and 10 cm long was applied approximately 1/3 along the clavicle, and then the tape was slowly turned in the opposite direction and attached along the neck.

When kinesiotopeing the posterior scalene muscle, the place of attachment was the outer surface of the upper border of the second rib. The muscle is connected to nerves C2-C8 (posterior and anterior branches of the motor nerve); its function is to bend the cervical spine. For kinesiotopeing, an I-shape tape 2.5 cm wide and 10 cm long was applied in the recess between the clavicle and the free edge of the trapezius muscle, after turning the neck in the opposite direction, the tape was fixed along the neck.

It was also necessary to kinesiotope the widest muscle of the back, the place of attachment of which is the posterior lip of the intertrochanteric sulcus of the humerus, which is connected to nerves C6-C8 (thoracolumbar, mid-scapular nerves), as its function is to direct the humerus and scapula down. Kinesiotopeing procedure: an I-shape tape 5 cm wide and 40 cm long was applied from the spinous processes 3, 4 of the lumbar vertebrae of the corresponding side up to the abdominal muscle, the child raised shoulders, took the hand up and in the opposite direction from the tape, after which kinesiotope was fixed on a small hump of the humerus.

The muscle that straightens the spine, the place of attachment of which is the angle of the ribs and the processes of the transverse sulcus of the upper vertebrae, connected to the spinal nerve, and the function of

which is stretching the spine, was also kinesiotaped. Kinesiotaping procedure: the patient was in a standing position, a Y-shape tape 5 cm wide and 27.5 cm long was applied when the child leaned forward from the sacrum along the abdominal muscle, the other end of the tape was applied similarly. The dosing of the load was due to the increase in time and taping area.

The representatives of the control group, namely 35 children with cerebral palsy in the form of spastic hemiparesis, were engaged in a standard program, a distinctive feature of which was the absence of kinesiotaping technique.

The research has revealed that before the rehabilitation of the control group children, the median values of the linear velocity along the studied arteries on both sides were zero, i.e. the linear velocity was symmetrically sufficient. However, there was a violation of hemodynamics and increased linear blood flow velocity in some basins on the right: CCA – (0; 0; 20.0%), ICA – (0; 0; 7.0%), and on the left: VA_V3 – (0; 0; 13.0%), as well as manifestations of asymmetry of blood flow in all arteries, except VA_V4, where the average value was equal (0; 0; 0%) (Table 1).

Before rehabilitation, the indicators of cerebral hemodynamics of children in the experimental group were almost identical to those of children in the control group. Their results are presented in the table (Table 2).

Table 1. Analysis of cerebral hemodynamics of children with cerebral palsy in the control group before rehabilitation (n= 35)

Indicators	Average indicators, %								
	right			left			asymmetry		
	Me	25%	75%	Me	25%	75%	Me	25%	75%
Common carotid artery	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	24.0
Internal carotid artery	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	19.0
Vertebral artery, extra	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	16.0
Anterior cerebral artery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0
Middle cerebral artery	0.0	-5.0	0.0	0.0	-9.0	0.0	0.0	0.0	16.0
Posterior cerebral artery	0.0	-5.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0
Vertebral artery, intra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. Analysis of cerebral hemodynamics of children with cerebral palsy in the experimental group before rehabilitation (n= 36)

Indicators	Average indicators, %								
	right			left			asymmetry		
	Me	25%	75%	Me	25%	75%	Me	25%	75%
Common carotid artery	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	37.0
Internal carotid artery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0
Vertebral artery, extra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5
Anterior cerebral artery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5
Middle cerebral artery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.0
Posterior cerebral artery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5
Vertebral artery, intra	0.0	-13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

It should be noted that before rehabilitation, the difference between the studied indicators of cerebral hemodynamics was not observed ($p>0.05$).

The research has performed the distribution of rehabilitation participants by the frequency of cases of blood flow disorders. The research has found that in some cases more violations were recorded in the experimental group (VA_V4), and in other cases, on the contrary, more cases of violations were observed among the control group children. However, with the exception of MCA and PCA, the shares of children with symmetrically sufficient linear velocity among the participants of the control and experimental groups were not statistically significantly different ($p>0.05$) (Fig. 1).

After rehabilitation, the proportion of children without blood flow disorders among children of the control group increased as follows: CCA – by 28.60 %, ICA – by 20.0 %, VA_V3 – by 25.70 %, ACA – by 28.6 %, NCA – by 25.70 %, PCA – by 25.7 %, VA_V4 – by 22.90 %. At the same time, the increase in the proportion of children without blood flow disorders in the experimental group made: CCA – by 25.0 %, ICA – by 33.3 %, VA_V3 – by 25.0 %, ACA – by 36.1 %, MCA – by 22.2 %, PCA – 22.2 %, VA_V4 – by 50.0 %.

The research has proved that in the experimental group after rehabilitation, statistically significantly lower proportions of children with blood flow disorders at linear velocities in ICA, MCA and PCA were recorded.

Before rehabilitation, statistically significant differences between the shares of children who do not have asymmetry, depending on the group, were not detected ($p>0.05$) (Fig. 2).

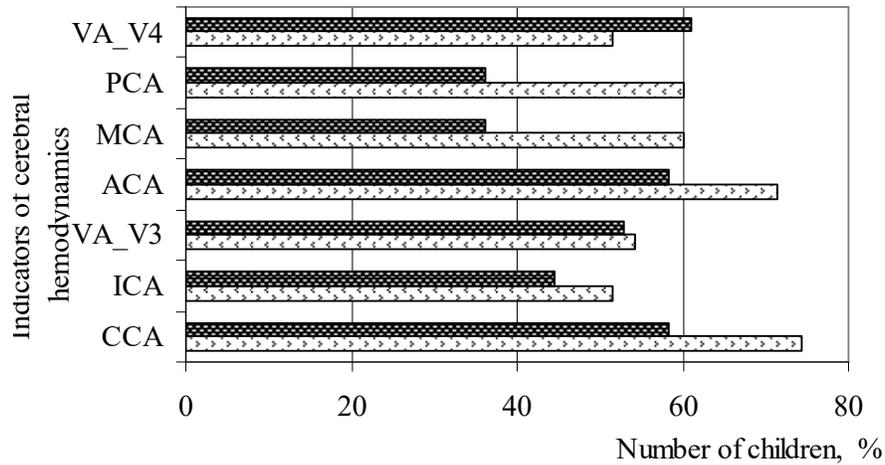


Fig. 1. Distribution of children with cerebral palsy according to the frequency of blood flow disorders before rehabilitation (n = 71), where
 □ – control group; ■ – experimental group

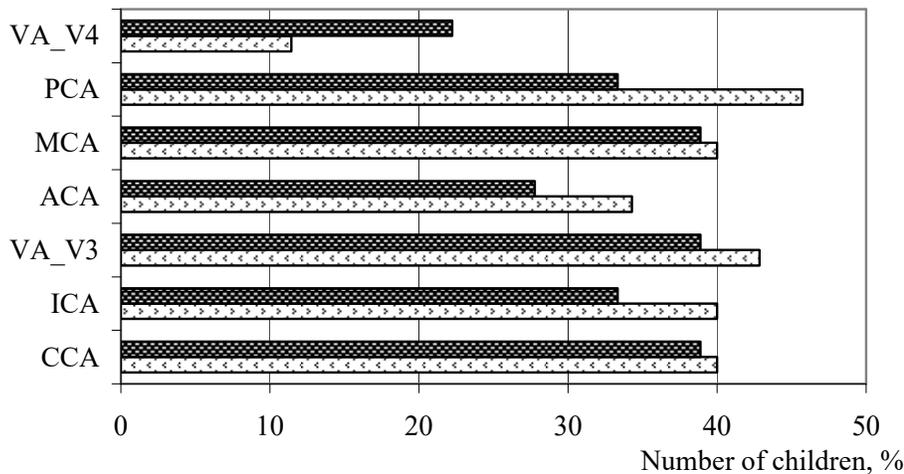


Fig. 2. Distribution of children with cerebral palsy according to the presence of asymmetry of blood flow before rehabilitation (n = 71), where
 □ – control group; ■ – experimental group.

After rehabilitation, the proportion of control group children with no asymmetry increased: CCA – by 22.86 %, ICA – by 17.14 %, VA_V3 – by 22.86 %, ACA – by 14.29 %, MCA – by 14.29 %, PCA – by 11.43 %, VA_V4 – by 5.71 %. At the same time, among the children in the experimental group, the increase was CCA – by 38.89 %, ICA – by 30.56 %, VA_V3 – by 30.56 %, ACA – by 13.89 %, MCA – by 33.33 %, PCA – by 27.78 %, VA_V4 – by 19.44 % (Fig. 3).

However, in contrast to the children of the control group, after rehabilitation the proportion of children in the experimental group with no asymmetry was statistically significantly higher ($p<0,05$) concerning CCA, ICA, MCA and PCA.

Obviously, during rehabilitation, the linear velocity improved in both groups, but among children of the experimental group, there was a more noticeable tendency to decrease the asymmetry.

Regarding the direct sinus, the research has shown that if before rehabilitation the average value of the direct sinus of the control group was 1.83% higher than that of the children of the experimental group, then at the end of rehabilitation this difference was 21.44%. It should be noted that the decrease in the average value of

children in the control group was 36.0%, and among children of the experimental group - 53.38% (Table 3).

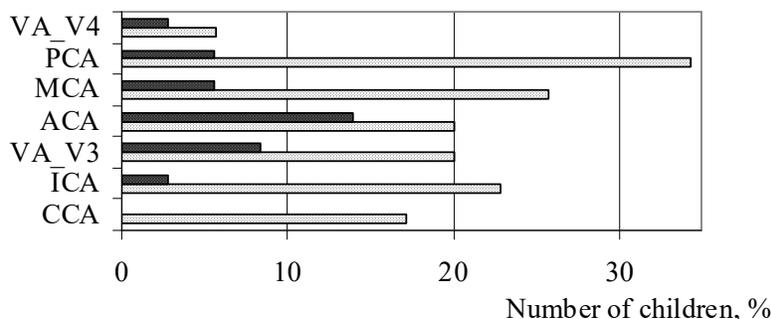


Fig. 3. Distribution of children with cerebral palsy according to the presence of asymmetry of blood flow after rehabilitation (n = 71), where

□ – control group; ▨ – experimental group.

Table 3. The average indicators of direct sinus among children with cerebral palsy before and after rehabilitation (n = 71)

Indicator	Average statistical values of indicators			
	before rehabilitation		after rehabilitation	
	Control group, n = 35	Experimental group, n = 36	Control group, n = 35	Experimental group, n = 36
\bar{x}	146.29	143.61	93.63	73.56
Me	149.00	133.00	93.00	75.00
25%	123.00	109.50	67.00	50.50
75%	177.00	178.50	114.00	92.00
s	34.61	40.57	32.14	26.53

The research has revealed that before rehabilitation there were no statistically significant differences concerning this indicator in the control and experimental groups ($p > 0.05$), but after rehabilitation the indicators of children in the experimental group were statistically significantly less ($p < 0.05$) than among children in the control group.

The obtained results show a more noticeable normalization of the direct sinus among children in the experimental group, which may indicate a positive effect of the proposed technique on the indicators of brain dynamics.

Discussion

The analysis of the special literature shows that the problem of physical rehabilitation of children with cerebral palsy is still actively studied. Scientists claim that physical rehabilitation, which is based on the use of various means of physical exercising, has the leading role in a set of rehabilitation measures (Andrieieva et al., 2019; Grygus et al., 2021). However, all means of physical exercising are aimed primarily at the development of motor function. It is known that among children with cerebral palsy, according to transcranial Doppler, there is a violation of cerebral hemodynamics. Scientists are discussing the effectiveness of the technique of kinesiotaping in the program of physical rehabilitation of children with cerebral palsy to improve the indicators of cerebral hemodynamics using the method of applying kinesiotape and its therapeutic properties (Bukhovets B. 2017).

Thus, the diversity of the clinical picture of forms of cerebral palsy and the discussion on the effectiveness of modern approaches in physical rehabilitation for children with cerebral palsy became the basis for creating modern programs using various methods of physical rehabilitation with a leading tool – exercise (Andrieieva et al., 2019; Grygus et al., 2021).

The results of the research have confirmed the effectiveness of the developed program of physical rehabilitation using the technique of kinesiotaping for 4-year-old children with cerebral palsy in the form of spastic hemiparesis in a specialized rehabilitation center.

Conclusions

The developed program of physical rehabilitation of 4-year-old children with cerebral palsy in the form of spastic diplegia in a specialized rehabilitation center has been successfully tested during the formative experiment: its effectiveness has been proved by quantitative changes (at $p < 0.05$) of the studied indicators.

Compliance with Ethical Standards

Conflict of Interest.

The authors declare that there is no conflict of interest that could be perceived as an obstacle to the publication of the article.

Competing Interests

The authors declare that they have no competing interests.

Ethical Approval.

All procedures performed in human studies complied with the ethical standards of the institutional and/or national research committee, as well as with the Helsinki Declaration of 1964 and its subsequent amendments or comparable ethical standards.

Informed Consent.

Informed consent was received from all individual participants included in the study. All subjects of the institutional survey agreed with the use of anonymous data for publication.

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