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DEVELOPMENT OF OBJECT-MANIPULATIVE ACTIVITY OF HANDS UNDER INFLUENCE OF INFORMATION AND COMMUNICATION TECHNOLOGIES IN PATIENTS WITH INFANTILE CEREBRAL PALSY

E.F. Legkaya[1], E.V. Kostenko[2,3], L.S. Khodasevich[4,5]
[1]Sochi Institute (branch) of the FSBEI of HE "People's Friendship University of Russia", Sochi, Russia
[2]SAHCI "Moscow Scientific and Practical Center for Medical Rehabilitation, Rehabilitation and Sports Medicine of the Moscow City Health Department", Moscow, Russia
[3]N.I. Pirogov Russian National Research Medical University, Moscow, Russia
[4]FSBEI of HE "Kuban State Medical University" of the Ministry of Health of Russia, Krasnodar, Russia
[5]Research Center of Balneology and Rehabilitation – branch of the FSBI "North-Caucasian Federal Scientific and Clinical Center of the Federal Medical and Biological Agency" in Sochi, Russia

Key words: infantile cerebral palsy, physical rehabilitation, information and communication technologies, object-manipulative hand activity.

Annotation. The most important component in the rehabilitation of patients with infantile cerebral palsy is the development of object-manipulative activity, the content of which is object manipulation of the child's hands. The purpose of this work was to study the development of object-manipulative activity of hands under the influence of information and communication technologies in patients with this disease. Based on the informed consent from parents, 50 patients with cerebral palsy aged 6-10 years took part in the study, half of whom underwent remote physical rehabilitation within 6 months using the "Perst" ("Finger") computer program. The developed technology had a positive effect on the tactile-kinesthetic processes of fingers and speech-movement disorders. The improvement in the mobility of fingers and the ability to perform purposeful coordinated motor acts were due to the improvement in the object-manipulative activity of hands in patients with infantile cerebral palsy.

Introduction. Infantile cerebral palsy (ICP) is characterized by its versatility of clinical signs. For many years, efforts of teachers, psychologists, neurologists, pediatricians, coordinators, massage therapists and other experts are aimed at treating these signs. Unfortunately, it is not possible to treat this disease fully, but it is possible to ease the state of some patients. Recovery of physical health of disabled children with this pathology is related to the formation of motor stereotypes, which is achieved with enhancing the neuromuscular apparatus, improving cooperation and coordination of precise movements [1].

Main direction of the therapeutic and pedagogical work with child patients is the development of object-manipulative activity (OMA), which includes a child's object manipulations [2]. OMA is often accompanied by mental, speech, hearing and kinesthesia disorders, which substantially affects perception of the environment in whole, socially important skills such as an ability to serve yourself independently, limits the amount of information, complicates intellectual activity [3-4].

During last years, modern information and communication technologies (ICT) are successfully used in the system of traditional school [5-7] and advanced professional education [8]. They became one of perspective directions of use both in education [9-12] and in rehabilitation [13-14] for disabled people, including people with cerebral palsy. Therefore, the purpose of this work was to study OMA of hands in patients with infantile cerebral palsy under ICT's influence.

Methods and organization. Based on the informed consent from parents, 50 patients with cerebral palsy (46 boys and 4 girls) aged 6-10 years (average age was 8,3±1,3) participated in the study. Bases for the study were the Sochi rehabilitation center "Victoria" (Sochi) and the Support and Experimental Center for Children and Adolescents with Disabilities (Arkhangelsk). Use of remote technologies allowed inviting children, who lived in other regions: in Krasnodar Krai, Rostov, Sverdlovsk and Moscow Oblast, the Northwestern Federal District, Tatarstan and Tyva.

All patients were disabled since childhood, with preserved intelligence. A pediatrician and neurologist defined compliance of their mental and physical health to the age standards and stated the clinical form of cerebral palsy. Spastic diplegia was registered in 45 cases (90%), hemiparesis – in 5 cases (10%). In accordance with the Gross Motor Function Classification System (GMFCS) [15], 4 levels of motor dysfunctions were defined. I level was registered in 38 children (76%), II – in 6 (12%), III – in 4 (8%), IV – in 2 (4%). Furthermore, sensorimotor disturbances were also revealed. They include: apraxia – in 27 cases (54%), trunkal ataxia – in 30 (60%), disturbance in the position sense or moving parts of the body – in 38 (76%), disturbance in chewing function – in 11 (22%), dysphagia – in 12 (42%), dysarthria – in 20 (%), delay in speech development – in 16 cases (32%). Sensory disorders were also registered: strabismus – in 20 children (40%), myopia – in 6 (12%), nystagmus – in 4 (8%), ptosis – in 4 (8), high-frequency hardness of hearing – in 4 (8%), disturbance of tactile sensitivity – in 29 (58%), stereognosis disturbance – in 20 (40%).

When evaluating physical development of patients, we carried out wrist dynamometry (WD), measured height, body mass, chest girth. OMA of hands was evaluated using following tests: “Fingers mobility”, “Hold-test”, “Moving cubes”, “Working fingers”. The space praxis was defined using the neuropsychological method of the optic-kinesthetic organization of physiological pose tests “Goat”, “Scissors” and “Ring”.

Depending on use of correcting effects, patients with cerebral palsy were divided into 2 groups (main and control), which were comparable by the frequency of sensorimotor and sensor disturbances. In order to correct mechanisms of sensor perception and organizing movement by developing OMA, children of the main group went through physical rehabilitation for development of fine motor skills and performed specialized exercises built into the “Perst” computer program [16]. Physical exercises installed into the “Perst” computer program made substantial effect on the patient’s organism by including emotional, mental and cognitive activity into the training process. Their mechanical performance contributed to the development of coordination and precision of moving wrists. Classes for this program with a duration of 15-20 minutes a day were conducted every day during 6 months. Children of the control group were also observed, they did not perform specialized exercises.

Diagnostic exercises of the “Perst” program were presented in form of a certain keyboard typing including 5 words. Composition of words and their sequence in each block were strictly defined (5 blocks of tasks, each block consists of 5 diagnostic exercises). During classes, the computer program suggested to perform diagnostic exercises using specific fingers (based on colors). Program data (control exercises) were subject to processing with calculation of mean error, taking into account the diagnostic block and mean time of its performance.

The statistical data processing was carried out using the standard package: MS Excel 2010, IBM SPSS Statistics 17. Following parameters were calculated: minimal and maximal, mean, non-parametric criteria of Mann-Whitney U-test, MacNemar’s test and Pearson’s χ^2-test. Results were deemed as statistically significant if $p<0,05$.

Results and discussion. When examining main and control groups at the beginning of the study, anthropometric indicators of children complied with physiological signs of growth and development typical for this age. 6 months after testing, an insignificant growth rate ($p>0,1$) was registered in both groups. The analysis of dynamic nature of height and body mass, as well as chest organs at the beginning and the end of study allowed assuming the expected process of growth and physical development in case of an absence of significant differences (Table 1).

Table 1

Dynamics of anthropometric indicators, sensor and sensorimotor disturbances in patients with cerebral palsy of the main and control group and the beginning and the end of the study

Disturbance indicators	Main group (n=25)		Control group (n=25)	
	Initially	6 months after	Initially	6 months after
Anthropometry				
Body length (cm)	116,0±8,3	116,8±8,1	115,1±4,8	115,5±4,8
Body mass (cm)	23,5±4,3	24,4±4,3	22,3±3,8	22,5±3,6
Chest girth (cm)	59,8±2,0	60,3±2,0	60,2±2,3	60,7±2,3
Sensorimotor disturbances (absolute and relative number of patients)				
Apraxia	14 (56%)	4 (16%)**	14 (56%)	14 (56%)
Trunkal ataxia	15 (60%)	13 (52%)	15 (60%)	15 (60%)
Disturbance in the position sense	19 (76%)	14 (56%)	19 (76%)	20 (80%)
Disturbance in chewing	5 (20%)	5 (20%)	6 (24%)	6 (24%)
Dysphagia	10 (40%)	10 (40%)	11 (44%)	11 (44%)
Dysarthria	9 (36%)	2 (8%)**	11 (44%)	11 (44%)
Delay in speech development	8 (32%)	1 (4%)*	8 (32%)	8 (32%)
Sensor disturbances (absolute and relative number of patients)				
Strabismus	10 (40%)	10 (40%)	10 (40%)	10 (40%)
Myopia	3 (12%)	3 (12%)	3 (12%)	3 (12%)
Nystagmus	2 (8%)	2 (8%)	2 (8%)	2 (8%)
Ptosis	2 (8%)	2 (8%)	2 (8%)	2 (8%)
High-frequency hardness of hearing	2 (8%)	2 (8%)	2 (8%)	2 (8%)
Disturbance of tactile sensitivity	14 (56%)	11 (44%)	15 (60%)	15 (60%)
Stereognosis disturbance	10 (40%)	5 (20%)	10 (40%)	10 (40%)

Note: ** – p<0,01, * – p<0,05 significance levels; χ^2 – values of the Pearson's test in comparison with initial values.

Comparing results of the evaluation of sensorimotor disturbances in patients of the main group at the beginning of the study with the data obtained 6 months after revealed a number of important differences. Thus, apraxia, observed at the beginning in 13 children (52%), at the end was registered in 4 children only (16%). Dysarthria and delay in speech development, which we revealed initially in 9 (36%) and 8 children (32%), were revealed in 2 (8%) and 1 (4 %) respectively 6 months after. After conducting classes of developing fine motor skills in patients with cerebral palsy using exercises of the "Perst" program, comparison of the main and control groups showed significant differences (p<0,05) in the ability to perform purposeful motor acts (praxis), dysarthria and delay in speech development. Among other sensorimotor disturbances, there were no significant differences (Table 1).

We did not note any effect of ICT on sensor systems of patients with cerebral palsy. However, when following a suggested routine of performing special exercises of the program, we noticed positive tendency of influencing such sensor disturbances as the disturbance of tactile sensitivity and stereognosis disturbance. Initially, 14 (56%) children were registered with the disturbance of tactile sensitivity and 11 (44%) – with the stereognosis disturbance. 6 months after, these disturbances were registered in 11 (44%) and 5 (20%) children respectivelly (p>0,05). The number of children with kinesthetic disturbances in the control group did not change after 6 months (Table 1).

Test of optic and kinetic organization demonstrated that among 25 patients of the main group, only 6% of children could repeat the “Goat” pose with the right hand and 2 % – with the left hand; “Scissors” finger pose was performed with the right hand by 9 % of children, and with the left hand by 0 %; 18 % of children performed the “Ring” finger pose with the right hand and 6 % – with the left hand. We noticed significant positive dynamics (p<0,05) of “Goat”, “Scissors” and “Ring” tests for both hands in children of the main group. The control group did not show any significant differences in all pose tests. After the study, comparing the main and control groups revealed significant differences in all pose tests for both hands (Table 2).

Table 2

Dynamics of indicators of physiological pose tests for fingers

Tests		Main group (n=25)		Control group (n=25)	
		Initially	6 months after	Initially	6 months after
“Goat” test	right hand	6 (24%)	18 (72%)**	8 (32%)	8(32%)
	left hand	2 (8%)	11 (44%)**	3 (12%)	3(12%)
“Scissors” test	right hand	9 (36%)	24 (96%)**	3 (12%)	3(12%)
	left hand	0 (0%)	11 (44%)**	2 (8%)	2 (8%)
“Ring” test	right hand	18 (72%)	24 (96%)*	14 (56%)	14(56%)
	left hand	6 (24%)	17 (68%)**	5 (20%)	5(20%)

Note: * – p<0,05, ** – p<0,01 levels of significance of differences according to the McNemar’s test in comparison with initial values.

According to the “Working fingers” test, mobility of the right and left hands’ fingers improved in the main group. The greatest improvement of the right hand mobility was noted in the middle finger, mobility of which improved in 5 (20%) children, than before working with the “Perst” computer program. 4 (16%) children improved movement of the ring finger, 3 (12%) – movement of the thumb, 2 (8%)

– movement of the index finger and 1 (3%) – movement of the little finger. Mobility of the left hand fingers was increased in the middle finger of 7 (28%) children with cerebral palsy, in the ring finger – 3 (12%), in the index finger – 2 (8%), in the little finger – 1 (4 %). When evaluating hands mobility of the control group patients at the beginning and end of the study, there were no significant differences in total mobility of fingers on both hands (Table 3).

Table 3

Dynamics of fingers' mobility in the main and control groups of patients with cerebral palsy at the beginning and the end of the study (%)

Fingers	Main group(n=25)		Control group (n=25)	
	Right hand	Left hand	Right hand	Left hand
Little finger	32/36*	40/48*	28/28	28/28
Ring finger	20/36*	32/44*	24/24	16/16
Middle finger	52/72*	48/76*	4/4	36/40
Index finger	80/88*	76/88*	84/84	72/72
Thumb	80/92*	84/88*	8/8	76/76

Note: * – $p<0,05$, ** – $p<0,01$ level of significance of differences according to the McNemar test in comparison with initial values; the numerator is the beginning of the study, the denominator is the end.

The analysis of wrist dynamometry results of patients of the main group at the end of the study presented an increase in strength of the right wrist's muscles from 6,5±4,0 to 8,1±3,7 kg ($p<0,01$) after performing exercises for 6 months. Strength of the left wrist's muscles also increased from 4,1±3,5 to 6,4±3,1 kg ($p<0,01$) respectively. When testing children of the control group in dynamics, we noticed a positive change of tested indicators, which can be possibly related to growth and development of children. However, differences were statistically insignificant. Thus, when performing initial wrist dynamometry, the right hand muscle strength was 6,9±3,9 kg, left hand – 5,6±3,8 kg. When measuring muscle strength 6 months after, there were no significant differences, it was equal 7,0±3,9 and 5,6±3,8 kg respectively (Table 4).

The time of simple visual-motor reaction on the software and hardware complex "Neurosoft-psychotest" reduced by 172,59 ms. Therefore, before training mean average of the response time was 883,3±73,2 ms, after training – 710,7±67,6 ms ($p<0,01$), which indicated an increase of attention and concentration (Table 4).

The "Fingers mobility" test performance improved from 1,7±0,9 to 2,2±0,8 points, the "Moving cubes" test – from 9,7±5,6 to 17,2±10,2 points ($p<0,01$). The "Hold test" performance of the left hand was 2,8±1,3 points, the right hand – 2,6±1,2 points. After training the performance improved to 4,2±0,6 points ($p<0,01$) and 4,2±0,9 points ($p<0,01$) respectively. Test evaluation of fine motor skills, simple visual-motor reaction and finger mobility of the control group at the beginning and the end of the study did not present significant differences between analyzed signs. Comparison of the main and control groups 6 months after showed significant differences in wrist dynamometry indicators (wrist muscle strength) of the right and left hand, simple visual-motor reaction, “Hold test” for both hands and the “Cubes” test in case of p<0,01 and fingers mobility in case of p<0,05 (Table 4).

Table 4

Test evaluation of fine motor skills in children with cerebral palsy of the main and control groups at the beginning and the end of the study

Tests		Main group (n=25)		Control group (n=25)	
		Initially	6 months after	Initially	6 months after
WD	right hand (kg)	6,5±4,97	8,1±3,6**	6,9±3,9	7,0±3,9
	left hand (kg)	4,1±3,5	6,4±3,1**	5,6±3,8	5,6±3,8
Simple visual-motor reaction (ms)		883,3±73,2	710,7±67,6**	886,5±38,9	886,4±36,4
Fingers mobility (points)		1,7±0,9	2,2±0,8*	1,5±1,1	1,50±1,1
“Moving cubes” (points)		9,7±5,6	17,2±10,2**	10,6±11,2	10,8±11,2
“Hold test”	right hand (points)	2,8±1,3	4,2±0,6**	2,2±1,6	2,5±1,6
	left hand (points)	2,6±1,2	4,2±0,9**	2,5±1,2	2,6±1,2

Note: ** – p<0,01, * – p<0,05 level of significance according to the Mann-Whitney U test in comparison with the main group 6 months after; WD – wrist dynamometry.

Results of evaluating the speed of performing exercises and frequency of making mistakes when performing in testing blocks of the computer program showed significant improve of skills of repeating typed text, also due to improvement of fine motor skills, up to the fifth exercise of the first block (p<0,01). Time of performing this exercise was 3,37±0,96, as well as the formation of stabile skill up to the fourth exercise of the second block (p<0,01), the time of performing this exercise took 3,30±0,53. Since the fourth task of the first level of difficulty, children made significantly less mistakes when performing exercises (in case of high significance level of p≤0,01). A number of mistakes in following testing blocks decreases in all exercises in comparison with the first one, which indicates formation of the stabile skill of repeating typed text.

Parents of 22 children of the main group noted, that children started to show independence in performing such routine tasks as tiding up their room and holding utensils. Parents of 8 children, who participated in performing special exercises of the “Perst” program, informed that after 3 months of regular classes, their children learned to read by syllables and write, i.e. make words from cards with letters.

Thus, improvement in mobility of fingers and ability to perform purposeful coordinated motor acts were due to the development of manipulative activity of hands in patients with cerebral palsy. Manipulating objects is the main function of the hand, especially in case of correcting fine motor skills and manipulative activity function of hands [17]. In comparison with object activity, which includes genuine object actions, OMA consists of the following: state of sensor functions, speech and object-activity communication with others, beginner forms of social behavior and independence, perception of articulatory poses and movements [16]. Main indicators of the OMA development level, according to S.Yu. Meshchetyakova, are a number of action types; number of actions; animation (a number of actions made by a child per time unit); level of object manipulations development; degree of OMA involvement in communication with adults [8].

Conclusion.

1. The obtained results showed effectiveness of the “Perst” computer program for improving object-manipulative hand activity of patients with cerebral palsy. Suggested physical exercises in the following routine of 1 class per day (15-20 min) for 6 months were optimal for disabled children and contributed to the development of purposeful precise movements of fingers.

2. The “Perst” computer program influenced tactile-kinesthetic processes of fingers and speech-movement disorders due to increase of reverse kinesthetic afferentation. It was shown through the significant improvement of purposeful coordinated motor acts, which is indicated by obtained results of improving the OMA and decreasing in number of patients with dysarthria and delay in speech development among children of the main group.

3. Program implementation of the developed technology based on the “Perst” computer program can be recommended for the development of fine motor skills in patients with infantile cerebral palsy, delay in mental and speech development, as well as other limited health abilities.

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Information about the authors: Elena Fedorovna Legkaya – Lecturer of the Sochi Institute (branch) of the FSBEI of HE "People's Friendship University of Russia", Sochi, e-mail: lightfamily@mail.ru; **Elena Vladimirovna Kostenko** – Doctor of Medical Sciences, Head of the 7th branch, Leading Researcher of the Department of Medical Rehabilitation of Patients with the Nervous System Diseased of the Moscow Scientific and Practical Center for Medical Rehabilitation, Rehabilitation and Sports Medicine of the Moscow City Health Department, Professor of the Department of Neurology, Neurosurgery and Medical Generics of the Faculty of General Medicine of the FSBEI of HE "N.I. Pirogov Russian National Research Medical University" of the Ministry of Health of Russia, e-mail: ekostenko58@mail.ru; **Leonid Sergeevich Khodasevich** – Doctor of Medical Sciences, Head Deputy for Science of the Scientific and Research Center of the Balneology and Rehabilitation – the branch of the FSBI "North-Caucasian Federal Scientific and Clinical Center of the Federal Medical and Biological Agency" in Sochi, Professor of the Department of Medical Rehabilitation of the FSBEI of HE "Kuban State Medical University of the Ministry of Health of Russia", e-mail: nic_kir@mail.ru.