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Rehabilitation of children with movement disorders resulting from cerebral palsy

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Lyudmila V. Sharova [1 ADEFG], Nikolay M. Belokrylov [1 BDEFG], Jana V. Nenakhova [2 BCEFG]

[1] Perm State Humanitarian-Pedagogical University, Perm, Russia
[2] Perm State Medical Academy named after acad. E. A. Wagner, Perm, Russia

Key words: *cerebral palsy, rehabilitation, physiotherapy, pediatric orthopedics, joint deformity, contracture, orthopedic devices*

Abstract

Background: *The origin and prevalence of cerebral palsy can hardly be considered fully understood. The relationship between orthopedic and neuropsychiatric disorders in children with cerebral palsy in the available literature is also insufficiently presented.*

Material/Methods: *Authors conducted a clinical and epidemiological analysis and examined the nature of motor disorders in 267 children with cerebral palsy aged from 3 to 16 years old. The monitoring period of patients ranged from 3 to 7 years. They underwent clinical neurological examination, radiography of the spine and joints, ultrasound examination of the joints and periarticular structures, electroencephalography and electroneuromyography in dynamics, with the help of a variational cardiointervalography characterized by an autonomic dysfunction (Veyn AM, 2000), studied the biomechanical parameters of walking, using scorecards, questioning and evaluate the effectiveness of the treatment using the special system to cerebral palsy (Pinchuk D Yu, Dudin MG, 2002).*

Results: *In 80% of cases, brain damage occurred during fetal development. The authors distinguished primary and secondary disorders of movements. 71 persons (26.6%) had neurogenic and myogenic contractures, and in 196 people (73.4%) contractions were exacerbated by bone deformities. In the rehabilitation system 163 people (61 %) had a need for a surgical operation.*

Conclusions: *The efficiency ratio of the functional status after rehabilitation in different age groups has improved by 10-22% more than before the treatment. It was shown objectively that improvement in the motor capacity in patients with cerebral palsy due rehabilitation has a positive effect on the function of the cerebral cortex.*

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Corresponding author:
Professor, Dr. Biol., Lyudmila V. Sharova
Perm State Humanitarian-Pedagogical University
614990 Perm, Sibirskaya 24, Russia
Phone: 342-219-07-06, 8-342-238-63-26
E-mail: sharovalv@bk.ru

Introduction

The adoption of the National Russian program "Health" is closely associated with a reduction in childhood disability, among which cerebral palsy (CP) constitutes 24%. The economic costs of caring for these children account for more than 1.5 million rubles a year. Questions of the origin and spread of the disease can hardly be considered fully explored [1]. Many works of Russian and foreign authors focused on neuropsychiatric disorders, systemic change, forecasting the results of neurological correction in these children [2, 3, 4]. At the same time, the relationship between orthopedic and neuropsychiatric disorders in the available literature is insufficiently represented. The pathology of the musculoskeletal system is detected in all patients with cerebral palsy. Movement disorders with cerebral palsy have different prospects for recovery and are very diverse in presentation and severity. As a rule, they are based on a modified activity tonus-forming structures of the brainstem and subcortical structures; therefore, leading lesions still remain neurological defects that are difficult to correct. At the same time, we see new approaches to conservative and surgical orthopedic rehabilitation of patients [4, 5, 3, 6]. The particular interest for us is the influence of restoring the ability of such children to walk independently on the autonomic and central nervous system [7, 8, 9]. The complexity of such interaction and the desire on this basis to optimize the results of rehabilitation of patients with severe cerebral palsy raises interest in the issue and its topicality. The revealed tendency of "reverse" or otherwise "rising motor-neurological" influences was the subject of our study.

The purpose of the work is to clarify the origin and nature of motor impairment in children with cerebral palsy and to improve the efficiency of orthopedic rehabilitation.

The following specific tasks have been proposed:

1. To conduct clinical and epidemiological analysis of motor disorders in children with cerebral palsy;
2. To explore options and to assess the possibility of orthopedic correction of movement disorders in children with cerebral palsy;
3. To identify the relationship between locomotor and neurological manifestations of cerebral palsy in terms of optimizing rehabilitation.

Materials and methods

We studied the character of motor disorders in 267 children with cerebral palsy aged 3 to 16 years old. The period of monitoring the patients ranged from 3 to 7 years. There were 158 boys (59.2 %) and 109 girls (40.8 %). Patients were distributed by forms of cerebral palsy as follows: double hemiplegia – 99 people (37.1%), hemi paresis form – 114 people (42.7 %), spastic diplegia – 48 people (18%), atonic-astatic form – 6 people (2.2%). The standard volume of the examination included different kinds of beam diagnostics: radiography segments of extremities, spine and hip joints, and joints ultrasound investigation (ultrasonography). We studied the bioelectric activity of the brain using an electroencephalograph and software of the “Neurosoft” company. We characterized vegetative dysfunction with the help of a variational cardiointervalography. The electroneuromyographic (EMG) study was conducted.

Analysis of autonomic regulation by method of variational cardiointervalography (CIG) and testing the neuromotor apparatus by electroneuromyography (ENMG) made it possible to detail the engine-vegetative syndrome of mismatch in children with cerebral palsy in different age groups depending on the severity of cerebral palsy. The role of these changes was evaluated in the formation of secondary motor disorders. Changes in the electroencephalogram were noted in the 3-point scoring system by Sheynkman, 2000 [10]. A clearly positive trend is evaluated by 3 points, moderate changes are given 2 points, and 1 point suggests minor changes noted in one direction. Using the computer program Statistica 6.0 linkage with certain parameters using the correlation coefficient R^2 was detected.

To evaluate the effectiveness of orthopedic correction of movement disorders we used the questionnaire survey of patients in long-term observation. Options of the orthopedic correction of movement disorders in patients with cerebral palsy have been detailed in view of the dynamics of clinical and electrophysiological changes, the neuropsychiatric status, disorders of the vegetative

nervous system and biomechanical characteristics. To assess the reliability of the results of treatment, the t-test was used, with results believed to be reliable at $p < 0.05$.

Correction pathology of the musculoskeletal system consisted of three main phases:

1. The preliminary stage: the preparation of all systems of the body to increase the amount of physical activity, the new motor mode, the fight against physical inactivity. The stimulation of vegetative support activities.

2. The preparatory stage: normalization of the muscular-tonic relationship. Reducing spasticity medication and orthopedic aids. The possible elimination of muscle contractions to ensure complete free movement in all segments of the musculoskeletal system. Restoring alignment of joints and periarticular structures of tissues. This stage is long, and its duration depended on the child's age, severity of disease, preservation of the psyche, the features of the previous treatment.

3. The main stage is associated with learning a normal walking stereotype and maintaining balance while moving. The use of medical equipment and adaptive physical education, the transition from simple movement to improving the function of movement, the development of fine motor skills and complex motor patterns.

The prospect of rehabilitation depends on the degree of preservation of the psyche, the ratio of the real calendar age and the maturity level of the nervous and muscular system, the severity of motor defects.

The objective of surgical treatment of cerebral palsy was the simplification of coordinated muscle activity, while maintaining their involvement in motor response by the intervention at the distal link of the engine, resulting in a decrease in the flow of proprioceptive impulses from a spastic muscle to the segmental motoneurons.

The group of up to 3 years was dominated by conservative orthopedic treatment. The originally set objectives were as follows: (1) to prevent deformation by their correction; (2) to take control of pathological movements; (3) to assist in the development and training of the necessary movements of the child with various forms of cerebral palsy.

Treatment was aimed at reducing muscle tone, eliminating pathological settings and contractures, and it consisted of a landmark use of plaster bandages. Later we used orthopedic products. Prosthetic and orthopedic devices made it possible to move the child and ensure the stable retention of limb segments in the right position. Patients used devices for walking, removable joint-immobilizers, splints, orthopedic shoes. We widely used modern materials for immobilization (bandage soft cast, scotchcast), and a modern version of pivot-hinged immobilizers. The main treatment was carried out in a clinic and rehabilitation center.

Options of orthopedic correction of pathology of the musculoskeletal system in different age groups of patients with cerebral palsy were analyzed. Group I consisted of children from 0 to 3 years, II – 4-7 years, III – 8-12 years, IV – 13-16 years. We used the results of systematic surveys, tables; recorded objective vegetative indices were compared with the obtained data. We used a table on which the outcome of the vegetative tone was assessed, and thus we formed an idea of the general vegetative status [11, 12]. We calculated the coefficient of efficiency of treatment (before and after orthopedic conservative and surgical treatment) by means of an estimate of 21 indicators, in which numerical expressions and condition are inversely proportional [5]. The results of comprehensive rehabilitation in the treatment of diseases of the musculoskeletal system in children with cerebral palsy measured by the coefficient of efficiency (CE) used the following point grading scale: CE from 2.0 – a significant improvement, CE from 1.2 to 1.99 – limprovement; CE from 1.06 to 1.19 – a slight improvement; CE from 0.95 to 1.05 – no improvement, CE less than 0.95 – impairment.

Results

One of the predisposing risk factors for cerebral palsy being premature birth was present in 150 people (56.2%). Fetal hypoxia was recorded in 20 people (7.5%), intrauterine infection in 16 people (6%), fetal malnutrition in 10 people (3.8%). Intrapartum factors of birth trauma were found in 20 people (7.5%), birth asphyxia in 7 people (2.6%), neuroinfections in 3 people. 4 children of twins were found among patients with cerebral palsy. We detailed prenatal factors that characterize the

mother's health, and the factors that point to errors in the pregnancy process. For example, pregnant toxicosis was observed in 203 people (76%), the threat of termination of pregnancy - in 40 people (15%). In 24 mothers (9%) uterine bleeding impaired placental circulation, the abruption or the dislocation of placenta.

We distinguished primary and secondary movement disorders. The primary movement disorders have been associated with the neurological deficit, owing to the involvement of the motor cortex district or the dysfunction of the pyramidal tract. The most prominent are the muscular-tonic disorders diagnosed in all studied patients. Thus, hypertensive disorders were diagnosed in 169 people (63.3%), hypotonic (atonic-astatic) – in 6 people (2.25%), and mixed – in 92 people (34.45%).

Secondary orthopedic violations were attributed to the formation of bone deformities and contractures. With the growth and development of the child occurred worsening of contractures. Joint contractures were noted in all studied patients, of whom 71 (26.6%) were persons diagnosed with neurogenic and myogenic contractures. The contracture was of neuro-myo-osteogenic nature (mixed type) in 196 people (73.4%). Bone changes presented different options for changing the neck-shaft angle of femur and deformities of the foot. Coxa valga was observed in 248 people (92.9%), coxa vara – in 10 people (3.7%), a combination of the hip joint pathology with equinus deformity of the foot – for 218 people (81.6%), plano-valgus deformity of the foot in 110 people (43%). The combination of equinus and flat-valgus foot deformities was diagnosed in 156 people (58.4%).

Movement disorders combined with the syndrome of autonomic dysfunction in 200 people (75%), symptomatic epilepsy in 20 people (7.5%), and disorders of higher mental functions in 120 people (45%).

It turned out that in group I dependence of autonomic tone with age was the highest (correlation coefficient R^2 reached 0.958). As they get older, children's relationship with autonomic tone decreased, and the correlation coefficient R2 decreased in the 2nd and the 3rd age groups to 0.705 and 0.417, respectively. In adolescents newly diagnosed high dependence of age with autonomic dysfunction had a correlation coefficient $R^2 = 0.735$.

According to electroencephalography (EEG), the spastic form of cerebral palsy was accompanied by an immature cortex, prevalence of diffuse activation of the mesencephalic-stem structures and local thalamus-cortical insufficiency. Autonomic dysfunction syndrome was caused by a violation of compensatory mechanisms of regulation localized above-segments that presents itself in the nonspecific synchronizing and desynchronizing brain systems.

Statistics revealed changes in the muscle tone and autonomic disturbances in the representation of the group of patients (Table 1).

In the course of orthopedic correction of movement disorders neurodynamic segmental, suprasegmental and adaptation preconditions for the formation of functional systems of the motor analyzer are created. The treatment improves the integrative activity of the brain in a modified apparatus adaptation and regulation. So, there was a trend toward normalization of bio-potentials. In the middle of a course of rehabilitation an electroencephalogram (EEG) revealed evidence of suppression of pathological activity of subcortical brain structures. However, the most significant positive dynamics of EEG is set after the end of rehabilitation. EEG analysis of patients after rehabilitation treatment showed 100% of the positive trend. A slight positive trend was determined in only 20% of cases. Negative dynamics of EEG was not recorded in any case. A study in the dynamics of electroneuromyographic characteristic showed a reduction in the amplitude of the potentials in the flexors of calf.

Changes in the vegetative status based on the study parameters of cardiointervalography dynamics before and after surgical treatment are presented in Table 2.

Table 1. Types of muscle tone and autonomic disorders in children with cerebral palsy

Groups	Types of muscle tone	Vagotonia		Sympathicotonia		Normal tone		Hypersympathi-cotonia		In all	
		p.	%	p.	%	p.	%	p.	%	p.	%
1st group	hypertension	12	4.5	3	1.1	–	–	1	0.4	16	6
	hypotension	2	0.8	–	–	–	–	–	–	2	0.8
	mixed	1	0.4	–	–	–	–	–	–	1	0.4
In all		15	5.7	3	1.1	–	–	1	0.4	19	7.2
2nd group	hypertension	10	3.7	25	9.4	2	0.8	32	12	69	25.8
	hypotension	5	2	–	–	–	–	–	–	5	2
	mixed	10	3.7	5	2	2	0.8	10	3.7	27	10
In all		25	9.4	30	11.2	4	1.6	42	15.7	101	37.8
3rd group	hypertension	17	6.4	22	8.2	3	1.1	12	4.5	54	20.2
	hypotension	–	–	–	–	–	–	–	–	–	–
	mixed	11	4.1	16	6	17	6.4	3	1.1	47	17.6
In all		28	10.5	38	14.2	20	7.5	15	5.6	101	37.8
4th group	hypertension	3	1.1	6	2.2	6	2.2	8	3.1	23	8.6
	hypotension	–	–	–	–	–	–	6	2.2	6	2.2
	mixed	6	2.2	–	–	9	3.4	2	0.7	17	6.4
In all		9	3.3	6	2.2	15	5.6	16	6	46	17.2

Table 2. Dynamics of indicators cardiointervalography (CIG) for orthopedic correction of motor disorders in patients with cerebral palsy

Indicators CIG	Period	1st group n = 19	2nd group n = 101	3rd group n = 101	4th group n = 46
Mode, s.	Before treatment	0.73±0.03*	0.48±0.02*	0.68±0.05*	0.73±0.03*
	After treatment	0.85±0.02	0.26±0.03*	0.48±0.02	0.75±0.06*
Variation range, s.	Before treatment	0.38±0.02*	0.25±0.04*	0.31±0.10*	0.45±0.02*
	After treatment	0.25±0.05	0.22±0.01*	0.21±0.10*	0.47±0.05
Mode amplitude, %	Before treatment	16±0.8*	29±2.4*	26±1.2*	22±4.2*
	After treatment	18±0.5*	26±1.2	25±2.2*	28±2.5
Tension index, conventional units	Before treatment	29.1±11.0*	120.8±10.0*	61.9±15.0*	33.8±10.0*
	After treatment	42.3±0.8	260.2±0.36*	163.4±5.0	40±15.0*
Index vegetative balance, %/s.	Before treatment	42.1±0.41*	116±1.22*	83.8±0.65*	48.8±2.11*
	After treatment	72±0.25	118.2±0.18*	119.04±0.10	59.6±1.57*
Adequacy of regulation processes %/s.	Before treatment	21.9±0.41*	60±1.21*	38±0.62*	30±2.11*
	After treatment	21.1±0.21*	100±1.1	52±0.08*	37±1.33*

The level of significance $p < 0.05$
** the accuracy of the ratio of physiological norm.*

Conservative treatment was performed in 104 people (39%); 163 people (61%) were operated on. The coefficient of efficiency of treatment in the comprehensive rehabilitation of children with cerebral palsy defined the effectiveness of orthopedic correction. Improving treatment outcomes corresponded with efficiency (CE) relative to the initial state (which in this case was evaluated as 100%) in the 1st age group by 22%; in the 2nd one by 12%, in the 3rd one by 10%, and in the 4th one by 18%.

Discussion

In our study, we distinguish between patients with cerebral palsy with primary and secondary movement disorders. It should be noted that an attempt to influence the primary level (but rather on the peripheral nervous system) leads to the formation of a new neurological deficit of another character, although it can decrease the spastic state on the whole [5]. In our study orthopedic

rehabilitation covered the area of secondary disorders. Treatment of movement disorders was integrated in all forms of cerebral palsy and started as soon as a diagnosis was set.

Our whole approach was no different from conventional concepts and anticipated succession stages of conservative and surgical treatment with multilevel correction of unsound strained limb segments and formed contractures [7, 9, 13, 14, 15]. Formation rehabilitation closely intertwined with questions of surgical tactics, the appropriateness of which was thoroughly discussed from the standpoint of predicting outcomes.

Conservative treatment was carried out from the first weeks of life, and continued throughout the period of growth. We used medications, massage, physical therapy, physical therapy treatments and orthopedic products.

Approaches to surgical correction of movement disorders conditionally divided into several groups depending on the specific problem and the way to achieve it. Thus, increased muscle tone correction was carried out by decompressive miotenotomy, plastic elongation of muscles and tendons, or by the comparative elongation by means of shortening osteotomy. Correction of balance muscle strength was carried out by grafting (transposition) tendons of actively functioning muscles to eliminate motor deficits of individual muscle groups. Intervention on the bones, joints (osteotomy, arthrodesis, tenodesis, arthroplasty) was performed in order to eliminate improper position and increase the stability of the limb. In general, all the variety of complications of surgery occurred no more frequently than in the correction of the foot with the intervention of soft tissue [16].

With orthopedic correction of movement disorders, the following groups of patients were distinguished:

1. Carrying gypsum – 36 people (13.5 %).
2. Using only orthopedic products (orthopedic appliances and shoes) – 10 (3.7%).
3. A combination of gypsum with orthopedic products – 58 people (21.7 %).
4. A combination of surgical correction with the use of orthopedic products – 163 people (61%).

As other authors, we also adopted a differentiated approach to the choice of the treatment in children of different age groups, and the choice of surgical approach depended on the nature of the formed motor disorders [6, 14, 11, 6, 13, 8]. In general, it is quite possible to develop a reasonable system of correction of deformity in patients with cerebral palsy [17].

In children with cerebral palsy aged 0 to 3 years in the treatment we mainly used orthopedic correction of muscle tone, which was to immobilize limbs staged with casts, then followed by wearing orthopedic appliances and orthopedic shoes. In the age group of 4 to 7 years surgical treatment dominated aiming at normalization of muscles and ligaments, as in this period persistent limb deformities and contractures of the joints are formed that are unsuccessfully treated by casts. In groups of 8 to 12 years and from 13 to 16 years surgical treatment was aimed at eliminating distortions. Surgical interventions for the correction of movement disorders was performed with using the soft tissue surgery in 206 people (77.1%), and it needed bone procedures in 61 people (22.9%). Soft tissue interventions included myotomy, lengthening muscles and tendons in 156 people (58.4%), with the movement of the tendon changes in the functional purpose directed to convert flexors to extensors in 12 people (4.5%), transferring contracted muscles to the paralyzed antagonists in 22 people (8.2%), transplanting a muscle with its shortening to convert its function – in 16 people (6%). Interventions carried out on bones included corrective intertrochanteric osteotomy of the femur, sometimes in combination with pelvic osteotomy in 29 people (10.9%), combining shortening and corrective osteotomy of the femur (in cases of paralytic dislocation of the hip) with a corrective osteotomy of the pelvis in 14 people (5.2%). In cases of “trochanter failure” we held distal transposition of the greater trochanter in 5 people (1.9%); the correction of the foot with help of Ilizarov’s apparatus was performed in 5 people (1.9 %), and bone and plastic surgery performed on feet in 8 people (3%).

The dynamics of the neuropsychiatric status and electrophysiological parameters continued for 5-7 years of observations. After our treatment we noted a strong tendency to suppress the abnormal activity of the subcortical brain structures. There were also normalization mechanisms of vegetative support activities. Now it has become possible to predict the timing of development of

static-motor skills and improving mental functions in medical and social examination of patients with cerebral palsy.

Expansion of motor abilities of patients with cerebral palsy is a positive incentive to improve neuro-functional activity of the brain, which generally improved prognosis and was not contradicted by data of other authors [3]. In all age groups a growth rate adequacy of regulation was recorded and we registered the approach of the stress index to the age norm and the normalization of α-index (alpha-index) according to encephalography and reduced immature brain structures.

Thus, the assertion that the correction of movement disorders and the expansion of motor capacity in patients with cerebral palsy is a positive incentive for the improvement of the functional activity of the brain. It optimizes the results of rehabilitation in general.

Conclusions

1. Analysis of the causes leading to the formation of motor disorders in children with cerebral palsy has shown that in most cases there is a combination of several adverse factors both during pregnancy and during labor (childbirth). In 80% of cases brain damage that causes cerebral palsy occured during fetal development, and later this process compounded by intrapartum fetal abnormality .

2. The effectiveness of orthopedic correction of primary and secondary movement disorders proved positive dynamics of clinical, biomechanical, electrophysiological and neuropsychiatric changes.

3. Expansion of motor abilities in patients with cerebral palsy as a result of the operation is the ascending positive effect on the function of the cerebral cortex.

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