Rehabilitation principles for motor dysfunctions according to the Kozyavkin Method

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The proposed book is devoted to theoretical principles of motor dysfunction rehabilitation according to Prof. Kozyavkin’s Method and reflects 17 years of experience by the staff at the Institute of Medical Rehabilitation and the International Clinic of Rehabilitation.

Readers will be informed about fundamentals related to the organization of human movement systems and rehabilitation principles for disorders of function caused by brain lesions and, in particular, cerebral palsy. They will come to understand how this idea evolved into a fundamentally new tendency in medical treatments and will learn about the effectiveness and application of the given system of rehabilitation.

The book will be useful to child neurologists, pediatricians, specialists in medical and physical rehabilitation and students attending related academic institutions.


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Introduction

Motor dysfunctions are one of the main causes of child disabilities and rank the problem of cerebral palsies together with the most important tasks which social pediatrics, child neurology and medical rehabilitation face.

For many years, the history of the development of medical treatments for CP was based on attempts to eliminate the most obvious disorders of movement and posture. Countless rehabilitation methods were developed, including methods of physical therapy, drug, and surgical treatments. However, it has become more and more evident that fundamentally new approaches are needed for rehabilitating patients with cerebral palsy. These seem to be real and tangible if based on combinations of practical experience and scientific research.

Prof. Kozyavkin’s Method is an example of such harmonious interaction between science and practice in the field of medical rehabilitation - The System of Intensive Neurophysiological Rehabilitation.

Scientific research of the mid-80ies threw a new light on cerebral palsy by revealing the role of vertebral components in the etiopathogenesis of this illness. The interdependence of the spinal column and brain functions were taken into account and an integral system of rehabilitation was created based on Prof. Kozyavkin’s methodology of biomechanical spinal correction.

By combining spinal corrections with an entire system of medical acts, a new functional state takes shape in the child’s organism. It is accompanied by normalization in muscle tone, an increase in microcirculation and an activation of tissue trophism; it ensures quicker motor and mental developments in the child and, thus, contributes to raising his quality of life.

The normalization of spinal functions constitutes a condition for rehabilitating body symmetry and neural and muscular interaction. By removing functional obstacles, the flow of proprioceptive information is activated, which, in turn, stimulates compensatory and plastic possibilities in the brain and the entire organism.

The methodological principles of the given system were attained by contemporary integrative anthropology and medicine which consider the organism as an integral system with close connections to the external environment. Its success is based on both manifest disorders and the normalization of body structures and functions as a whole.

Creating a program for biodynamic movement correction became a significant step in developing and improving Prof. Kozyavkin’s Method. For the first time in the history of medical rehabilitation, the problem of restoring body activities was determined by basing analyses on functional muscular coordination. Universal principles of spiral connections of body muscles led to further development of the
system of rehabilitating body symmetry, posture and movements. This involves using both functional possibilities of a patient’s body muscles as well as external efforts which complement muscle pull. “Spiral”, our self-developed suit for correcting movements has been highly effective in our work as it enables redressing spastic tissues, sustaining body symmetry, strengthening pulls by body and abdominal flexor muscles and bringing the positions of the body and extremities back to normal.

The proposed book is devoted to theoretical principles of motor dysfunction rehabilitation according to Prof. Kozyavkin Method and reflects 17 years of experience by the staff at the Institute of Medical Rehabilitation and the International Clinic of Rehabilitation.

Readers will be informed about fundamentals related to the organization of human movement systems and rehabilitation principles for disorders of functions caused by organic lesions of the nervous system. They will come to understand how this idea evolved into a fundamentally new tendency in medical treatments and will learn more about the main results of the given system of rehabilitation.
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Cerebral palsy viewed as a medical and social problem
1.1. General information about Cerebral Palsy

The History of Cerebral Palsy

The actual term “cerebral palsy” (CP) has existed for more than a century. It is likely that the illness has existed without being actually named since the dawn of human history. Nevertheless, in spite of its long history, there has been no unity of opinion in regard to this problem to this very day.

The general term CP is sometimes called Little’s illness, in honor of William John Little, a British surgeon and orthopedist. In the mid-XIXth century, he first established connections between childbirth complications and infant disorders related to mental and physical developments [Little W.J., 1843]1. These ideas were set forth in an article, “On the influence of abnormal parturition, difficult labors, premature birth and asphyxia neonatorum on the mental and physical conditions of the child, especially in relation to deformities” [Little W.J., 1862]2. This article was addressed to the British Royal College of Midwives and has been often quoted in publications dedicated to cerebral palsy.

Little’s work attracted the attention of his contemporaries. As a result, several critical comments appeared immediately after the article was published [Kavcic A.,2005]3. Little answered the critics and did not try to prove his precedence in affirming and describing neurological consequences of pathological childbirth. As he was not able to find support for his theses in English medical records, he decided to quote William Shakespeare [Shakespeare W., 2003]4. In Little’s opinion, Shakespeare portrays a moving picture of Richard III, where readers can guess at deformities attributed to premature birth or, possibly, childbirth complications:

“I, that am curtailed, of this fair proportion, Cheated by features by dissembling Nature,
Deformed, unfinished, sent before my time
Into this breathing world, scarce half made-up,
And that so lamely and unfashionable
That dogs bark at me as I halt by them...

Similar movement disorders continued to be referred to as “Little’s illness” until 1889, when William Osler, a Canadian physician suggested using the term “cerebral palsy”. [Osler W., 1889]⁵. In his monograph, “Cerebral Palsies in Children”, Osler noted the connection between difficult labor and brain lesions in children.

Sigmund Freud, the famous Viennese neuropathist, prominent psychiatrist and psychologist first referred to cerebral palsy as a separate nosological form which combines diverse motor dysfunctions of cerebral origin [Freud S., 1897]⁶. In all other XIXth century publications dedicated to motor dysfunctions in children, the term “cerebral palsy” was used only in relation to other terms (for example, cerebral birth palsy”). And yet, daily clinical work and practice of the second half of the XIXth century required more concrete terminology. In his monograph, Freud writes that the term “cerebral palsy” combines “pathological conditions which have been long since known and where rigidity muscle or spontaneous muscle twitching predominate over paralysis”.

Freudian classification and interpretation of cerebral palsy were much wider than succeeding formulations by other authors. He even suggested applying this term to
cases of complete absence of paralysis, for example, epilepsy or mental retardation. Such interpretations of CP were closer to concepts of early “brain damage”, which was formulated much later [Amiel-Tison C, 1994].

It is likely that Freud could not find another way of arranging this sphere of child neurology and so, suggested including all motor disorders in children into one single nosological group. At first, Freud explored cerebral hemiplegia. Subsequently, he included all motor lesions into one group which he named cerebral dyplegia, thus, naming and taking into account both sides of the body. He then proceeded to enumerate four kinds of lesions: 1) general cerebral rigidity; 2) paraplegic rigidity; 3) bilateral hemiplegia and 4) general chorea and bilateral athetosis [Freud S., 1983]. Later, Freud again included all these motor disorders into one nosological unit - cerebral palsy.

In the XXth century, the absence of a unified notion that might determine its nosology led to further complications in conducting scientific research. Specialists became more and more convinced that the creation of a general view regarding CP was greatly needed. Some researchers interpreted CP as a single clinical nosology, others saw it as a list of similar syndromes [Phelps W.M., 1947].

One of the initiatives directed towards generalization and further development of contemporary views on cerebral palsy was worked out in the Little Club in 1957 by Ronald McKeith and Paul Polani. After two years of research, they published “The memorandum on terminology and classification of cerebral palsy”. According to the members of the Little Club, cerebral palsy is defined as a non-progressive brain lesion which manifests itself through movement disorders and body postures during the early years. Clinical presentations which arise as a result of a neurodevelopmental disorder are non-progressive, but variable [MacKeith R.C., 1959].

Other scholars of different scientific schools set forth their own views. Thus, Prof. K. A. Semenova, a leading Russian specialist in problems related to cerebral palsy and manager of the biggest treatment center for CP patients in Moscow suggested the following definition: “CP embraces a group of different clinical syndromes which appear as a result of brain underdevelopment or brain damage during different stages of ontogenesis and are characterized by the patient’s inability to maintain normal posture and perform arbitrary movements” [Semenova K.A., 1972].
A concordant definition was suggested by the academician, Levon Badalyan. In his opinion, the term cerebral palsy embraces a group of syndromes which appeared as a result of brain underdevelopment or brain damage in prenatal, intranatal and early postnatal periods. Brain lesions manifest themselves by muscle tone disorders and movement coordination dysfunctions, and the inability to maintain normal posture and perform arbitrary movements. Movement disorders are often accompanied by sensitive disturbances, mental and speech delays and spasms [Badalyan L.O., 1980].

In spite of the polymorphic clinical picture, most existing classifications of CP take into consideration only muscle tone conditions and the localization of movement disorders. Very often, a diagnosis includes patients with absolutely different motor possibilities and does not take into account the dynamics of the patient’s motor status in regard to long-lasting rehabilitation treatments. Rehabilitation classifications of CP were suggested and effectively put into practice by the rehabilitation school in Truskavets [Kozyavkin V.I., 1999]. Besides the generally accepted parameters, this classification also includes characteristics related to the patient’s locomotor and posture possibilities.

The immediate aim of rehabilitation treatment of CP patients is to raise the quality of life, which had been prearranged to a large extent by the limited conditions of movement functions. Many years of experience in practical work and scientific research were conducted under Prof. Kozyavkin’s supervision and led to elaborating a new idea of cerebral palsy and, in particular, the significance of verterbogenic components and etiopathogenesis in this illness [Kozyavkin V.I., 1996]. A new multi-modular system of rehabilitation was built up on this principle, which emphasizes biomechanical corrections of the spinal column. Applying integral influences on different levels of the nervous system creates a new functional condition in the child’s organism. This is accompanied by a normalization in muscle tone, an amelioration in microcirculation and metabolism, an activation of plastic possibilities of the nervous system and contributes to the child’s motor and mental developments. A more detailed description of rehabilitation systems is set forth in the second chapter.

A major milestone regarding a consensus on cerebral palsy was reached at the International Seminar on definition and classification of cerebral palsy in Maryland (USA) in July, 2004. The participants confirmed the importance of acknowledging this nosological form and emphasized that CP is not an etiological diagnosis, but a clinical and descriptive term. The results of seminar work groups were published in the article, “Proposed definition and classification of cerebral palsy” [Bax M., 2005]. The authors suggested the following definition: Cerebral palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behavior, and/or by a seizure disorder.
Cerebral palsy viewed as a medical and social problem

CP Epidemiology

Cerebral palsy often leads to serious neurological disabilities, which, in turn, disturb the patient’s social adaptation and his quality of life. According to statistics of the World Health Organization, 10% of the world population is made up of people with limited health possibilities, and more than 100 million of the fore-mentioned are children under 16 years.

According to statistics, more than 150,000 such children and teenagers have been counted in Ukraine. Mental disturbances, illnesses of the nervous system and sense organs (vision, hearing impairments, etc.) are the leading forms of disease. Up to 60 - 70% of the causes of child disabilities are due to perinatal pathologies.

In general, the number of child disabilities has increased considerably in the past few years. In 1992, the general index for child disabilities showed 95.7 per 1,000, whereas in 2004, it reached 170.4 per 1,000, that is, the index increased by 78% [Martyniuk V. Y., 2006].

Index fluctuations regarding the rate of CP in Ukraine from 1996 to 2004 are shown in the graph below (illustration 1.1.1).

Similar indices have been registered in other countries. According to statistics of the United Cerebral Palsy Association, close to 764,000 children and adults in the USA show symptoms of cerebral palsy [www.ucp.org, 2006]. Today, this diagnosis is established yearly for eight thousand newborns and children. Moreover, 1200 - 1500 preschoolers are diagnosed annually with this illness.

In Great Britain, 2.1 cases of cerebral palsy per 1000 newborns have been registered [Pharoah P., 1998]. In Denmark, in the course of the past 40 years (from 1965 to 2004), CP illnesses exceeded 2 cases per 1000 newborns [Odding E., 2006].

Illustration 1.1.1. Index of cerebral palsy illnesses

![Illustration 1.1.1. Index of cerebral palsy illnesses](image-url)
Authors have remarked on the increase in premature infants with low and extremely low birth weight. The clinical picture of the illness shows a decrease in the number of patients suffering from dyplegia and an increase in the number of patients with hemiplegic forms of CP. Cerebral palsy is more often encountered in countries with a low standard of social and economic developments. Spastic forms of CP are the most widely-spread, among which the lowest numbers can be attributed to patients with dyplegia. 25 - 80% of the children have other associated syndromes, depending on the degree of motor deficiencies. A large number of these children suffer from cognitive disorders, the extent of which depends on the various forms of CP and the presence of epilepsy. Epilepsy is observed in 20 - 40% of CP cases, mainly in children suffering from hemi and tetraplegias.

Computer tomography shows structural brain disorders in 70% of the children suffering from spastic forms of CP. According to neurosonography results, organic brain lesions are more distinctly associated with hemiplegia, whereas normal neurosonographic results are more frequently observed in patients with dyplegia. The most significant risk factors are perceived in infants with low birth weight, multiple pregnancies and intrauterine infections. These cases should be strictly controlled by the doctor.

Causes of CP and risk factors

As long ago as 1862, William Little, a British surgeon and orthopedist advanced a hypothesis that cerebral palsy is predominantly caused by premature births, newborn asphyxia and childbirth traumas.

Understanding cerebral palsy onsets has increased significantly in the last 30 years. Epidemiological studies have shown that the quality of obstetrical and neonatal assistance has risen in the past twenty years, but this has not contributed to decreasing the incidence of cerebral palsy [Nelson K. B., 1986]20.

These observations were continued in N. Badawi’s research. She confirmed that asphyxia during childbirth causes encephalopathy in newborn infants only in individual cases [Badawi N., 1998]21. These results have refuted ideas about childbirth complications being the main cause for encephalopathy in newborn infants (illustration 1.1.2).

In 2003, common work groups at the American Academy of Pediatrics and the Academy of Obstetrics and Gynecology studied neonatal encephalopathy and cerebral palsy and selected several indispensable criteria affirming that the most severe hypoxic and ischemic brain injuries during childbirth cause neonatal encephalopathy, which can lead to future development of cerebral palsy [Hankins G. D. V., 2003]22. These criteria are as follows:

1) the presence of metabolic acidosis in fetal blood circulating in umbilical arteries during childbirth;
2) early beginnings of neonatal encephalopathy in children with a gestation period of 34 weeks and more;
3) the development of cerebral palsy as spastic tetraplegia or dyskinetic lesions;
4) the exclusion of other possible causes (trauma, blood coagulation disorders, genetic dysfunctions and others).

A. MacLennan’s research also confirmed that 75% - 80% of cases showing CP development were caused by prenatal factors, whereas only 10% were connected with birth traumas and asphyxia [MacLennan A., 1999].

Prenatal factors are the most frequent causes for CP onset and thus, can contribute to developmental disorders of the brain at any period of intrauterine growth. They may depend on genetic changes, inadequate blood circulation or toxic or infectious injuries to the brain structure.

The nervous system goes through a series of periods during its developmental process, namely: primary neurulation, prosencephalic development, neuron proliferation, neuron migration, organization and myelination [Volpe J.J., 2001] (diagram 1.1.3).

The human brain is most sensitive in certain critical periods when its complex organization and developmental features are duly taken into consideration. One single factor during different periods of brain development can lead to various changes. Thus, cerebral ischemia prior to the 20th week of gestation can lead to disorders of neuron migration; during the 26th and 34th week gestation period, it may cause periventricular leukomalacia and between 34th and 40th week period - focal or multifocal brain damage.

Brain damage provoked by an inadequate blood supply depends on many factors: disorders of anlage and development of the brain’s vascular system, efficiency
decrease of cerebral blood flow and its regulator mechanisms and reaction levels of brain tissues to low oxygenation.

*Premature births and low weight at childbirth* are the two most important risk factors of CP, especially in developed countries with a sufficiently high level of medical assistance. Cerebral palsy develops in 10 – 18% of newborn infants with a birth weight of 500 – 999 gr. [Michael E.M., 2004].25

A premature child with immature brain structures and cerebral blood supply has lower potentials to bear physical and other stresses. Embryonic types of blood circulation in the brain predominate in these children, which determine the inadequacy of blood supply in periventricular substances. This, in turn, can lead to hemorrhage in the brain marrow and periventricular leukomalacia. It can further be revealed as a clinical picture of spastic dyplegia.

Brain tissues of lateral ventricles are the most sensitive between 26 and 34 months of gestation. Descending corticospinal fibers responsible for the motor control of lower extremities make their way through this zone and so, damage can generate spastic dyplegia. Both upper and lower extremities suffer even more when more severe lesions occur, thus damaging movement centers and tracts (centrum semiovale, corona radiata).

Periventricular leukomalacia is usually symmetrical. It is supposed that it is caused by ischemic lesions of white brain substance in premature infants. Capillaries of

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### Diagram 1.1.3. Fundamental stages of the development of the nervous system

<table>
<thead>
<tr>
<th>Period name</th>
<th>Time</th>
<th>Key events</th>
</tr>
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<tbody>
<tr>
<td>Primary neurulation</td>
<td>3-4 week gestation period</td>
<td>Formation of the nerve tube, brain and spinal cord to the upper lumbar level</td>
</tr>
<tr>
<td>Secondary neurulation (prosencephalic development)</td>
<td>5-6 week gestation period</td>
<td>Formation of the face, principal brain layers, lower lumbar, sacral and coccygeal segments of the spinal column and cauda equina</td>
</tr>
<tr>
<td>Neuron proliferation</td>
<td>2-4 month period of pregnancy</td>
<td>Formation of neuroblastoma and glia in ventricular and subventricular zones</td>
</tr>
<tr>
<td>Neuron migration</td>
<td>3-5 month period of pregnancy</td>
<td>Anlage of principal layers of the cerebrum and cerebellum, gyri formation</td>
</tr>
<tr>
<td>Organization</td>
<td>6 month period of pregnancy - first years of life</td>
<td>Maturity and differentiation of neurons and glia, development of dendron branching, formation of synapses, selective dying off of neurons</td>
</tr>
<tr>
<td>Myelinization</td>
<td>From 6th month of pregnancy to 20 years</td>
<td>Gradual myelinization of all sections of the central and peripheral nervous systems</td>
</tr>
</tbody>
</table>
the germinal matrix in periventricular areas are especially sensitive to hypoxic and ischemic lesions as they are located on the fringes of blood supply zones between the striatal and thalamic arteries. Clinical pictures of asymmetrical lesions show clearer lesions of one part of the body and resemble spastic hemiplegia even though a more correct term in such a case would be “asymmetric and spastic dyplegia”.

The blood supply to the brain in children born full term is sufficient and comes close to the adult’s. Hypoperfusion can be mainly observed in “water parting” areas of principal cerebral arteries. Formations of spastic hemiparesis may be identified by vascular lesions located in the blood supply area of the central brain artery.

Damage to basal ganglions lead to extrapyramidal manifestations in the form of hyperkinetic or distonic types of CP.

V. I. Kozyavkin’s research deserves great attention; it is directed towards studying special structural and functional features of the brain and spinal column in children suffering from cerebral palsy [Kozyavkin V. I., 1996]. The author explored spinal pathologies when determining the etiopathogenesis of cerebral palsy and so, drew attention to the vertebrogenic factor. Analyses were used from magnetic resonance imaging records for 120 children suffering from various forms of CP. 72% of the patients displayed consequences due to childbirth traumas of the spinal cord (cysts, dilatation of the central canal, local adhesions) and the spinal column (dislocation, vertebrae fractures, appearance of degenerative and dystrophic lesions), more often manifested in the cervical section of the spinal column. These research studies showed that cerebral palsies are direct, if not mediated lesions of cerebral and spinal structures.

In 10 - 20% of the cases, CP takes shape at the expense of postnatal brain lesions. They may be brought on by meningitis, viral encephalitis, hyperbilirubinemia, cerebral cranium traumas and others [Taylor F., 2006].

In most cases, it is very difficult to establish an accurate cause of CP as lesions are very often connected with other factors. Thus, the concept of “risk factors” is commonly employed when complexities involved in naming causes of CP are taken into account. The risk factor does not refer to the causes of the illness, but to variables which increase risks in regard to the origin of the illness. Main risk factors which increase probabilities of development of cerebral palsy are presented in diagram 1.1.4. The occurrence of risk factors does not necessarily mean that cerebral palsy is taking shape in a child, but their absence does not exclude the onset of the illness.

Detecting causes of brain lesions and risk factors of CP development can without doubt facilitate early diagnosis and prophylactic measures for this illness. One of the methods for early diagnosis, early treatment and prophylactics of developing CP is the new component program according to the Kozyavkin’s Method – “Early rehabilitation”, which is described in greater detail in the second chapter.
### Diagram 1.1.4. Risk factors involved in CP development

<table>
<thead>
<tr>
<th>Prenatal</th>
<th>Perinatal</th>
<th>Postnatal (0-2 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prematurity (gestation age is less than 36 weeks)</td>
<td>Premature rupture of fetal membranes and breaking of waters</td>
<td>Infections of the brain (encephalitis, meningitis)</td>
</tr>
<tr>
<td>Low (less than 2500 gm.) or very low weight (less than 1500 gm.) at birth</td>
<td>Prolonged and protracted labor, application of obstetric assistance</td>
<td>Postnatal hypoxia</td>
</tr>
<tr>
<td>Mother’s condition or illness: epilepsy, hyperthyrea, TORCH-infections, trauma, harmful habits</td>
<td>Anomalies of fetus presentation</td>
<td>Seizures syndrome</td>
</tr>
<tr>
<td>Infectious and toxic influences on fetus</td>
<td>Vaginal hemorrhage during labor</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>Pregnancy complications: gestosis, bleeding in third trimester, insufficiency of uterine neck, placenta insufficiency, multiple pregnancy</td>
<td>Bradycardia, hypoxia of fetus</td>
<td>Neonatal bilirubinemia</td>
</tr>
<tr>
<td>Newborn asphyxia</td>
<td></td>
<td>Brain trauma</td>
</tr>
<tr>
<td>Birth traumas of the brain and spinal cord, traumas of the spinal column</td>
<td></td>
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</tbody>
</table>
1.2. Clinical forms of CP

Clinical manifestations of CP may vary from negligible symptoms to apparent disorders. The severity of illness is connected with the character, level and localization of damage to the brain. Early manifestations are often visible immediately following the child’s birth, whereas explicit signs of CP become evident in infancy.

1.2.1. Pathology of motor systems in CP

Various clinical forms of cerebral palsy may appear as a result of developmental disorders or damage to brain centers and conduction pathways at the early stage of ontogenetic development. The fundamental motor systems which ensure control of human posture and movements are as follows:

1. **The terminal motor pathway** (the lower motoneuron composed of cranial and spinal nerves) - brings about stimulation of muscle contractions and movements.

2. **The pathway for direct activation of movements** (the upper motoneuron, corticobulbar and corticospinal tracts) - executes movements, which are controlled consciously. The path is connected with conscious movement skills.

3. **The pathway for indirect activation of movements** (the upper motoneuron, the extrapyramidal system: corticorubral and corticoreticular pathways, rubrospinal, reticulospinal, vestibulospinal pathways and analogous pathways to cranial nerves) - ensures subconscious and automatic muscle activity which is directed towards posture, maintaining muscle tone and realization of movements, which are concomitant to conscious movements.

4. **Control circuits** on different levels of the nervous system directed towards the integration and coordination of sensory information, stimulation of direct and indirect pathways of movement activation for controlling movement activity. Included in control circles - the subcortical and cerebellar.

   The **Subcortical control circuit** includes basal ganglia and the extrapyramidal system. It produces programs for postural control, ensures supportive and servicing components of motor activity.

   The **Cerebellar control circuit** includes the cerebellum, the pons cerebella, reticular formation, red nuclei, inferior olive, thalamus and cortex. The circuit ensures the integration and coordination of movement executions of smooth and skeletal musculatures.

   The **pyramidal system** includes corticospinal and corticonuclear pathways. They begin at the pyramidal cells of the motor zone of the telencephalon (anterior central gyrus) where the upper motoneuron is situated. Movement pathways make their way from this point to the lower neuron, which, in turn transmits cortex signals
Clinical forms of CP

to skeletal muscles. The corticospinal pathway proceeds to motor neurons of
the anterior horns, whereas the corticonuclear pathway makes its way to motor
nuclei of brainstem cranial nerves. The corticospinal pathway controls body and
limb movements, whereas the corticonuclear pathway - face and neck muscles
(illustration 1.2.1).

Lesions of the central motor neuron contribute to the development of central
(spastic) palsies. This is manifested by muscle hypertension, like spasticity,
hyperreflexia with extended thones of tendon reflexes, clonus, pathological and withdrawal reflexes as well as pathological movement synkinesie.

Lesions of the lower motor neuron in the pyramidal system contribute to peripheral (flaccid) palsies located on the affected side. They are observed on the faces when the nuclei of brainstem cranial nerves are affected; in the body and limbs when the nuclei of anterior horns of the spinal cord are affected. Peripheral palsies are not included in the CP group.

The extrapyramidal system is more ancient in phylogenesis. Its parts are located in different layers of the cortex, subcortex and brainstem. The system is formed by basal nuclei (paleostriatum and neostriatum) and the cerebellum. The Paleostriatum includes the pale globe and the substantia nigra of cerebral peduncle; the neostriatum - the tegmentum and caudate nucleus (illustration 1.2.2). Pathways for indirect activation of movements begin at the structures of extrapyramidal systems. They also go to the lower motor neuron which is thus doubly controlled by both the pyramidal and extrapyramidal systems.

The influence of the paleostriatal system on motor activity is especially evident in infants. Children under 6 months show characteristically high muscle tone, which slowly decreases in neck, arm and leg muscles. Neostriatal systems in motor
ontogenesis are most active in children aged 2 to 7 years. These children are often emotional, restless; they talk a lot and they gesticulate energetically.

Yielding to movement priorities of the pyramidal system, the more ancient extrapyramidal system leaves behind the following important functions: sequence regulation, strength and duration of muscle contractions, automatic activation of an entire complex of muscle groups, which are indispensable for executing a conscious and conceived movement. This system is responsible for automated acts, coordinated work of the skeletal musculature, timely start and termination of movements and their accurate execution. The basal ganglia are a central link in the extrapyramidal system. They allow for realizing positions of body links for executing movements, controlling synergies related to complex movement acts (walking, running and so on) and ensuring movement flow. Basal ganglia cause inhibitions of movement links in conditioned and unconditioned reflexes. As they do not have direct connections to alpha motor neurons of the spinal cord, they mediate their influence through the reticulospinal pathway to gamma motor neurons of the spinal cord. The latter regulate the flow of proprioceptive and afferent impulses which enter the spinal cord from muscle spindles. These impulses influence the excitability of alpha motor neurons and thus, determine the operating condition of skeletal muscles.

Two diametrically opposite syndromes may arise when the functions of basal ganglia are not executed. A hypertonic and hypokinetic syndrome (like Parkinson’s disease) develops when the pallidum segment is affected. A hypotonic and hyperkinetic syndrome (athetosis and other forms of hyperkinesis) develops when the striatal segment is affected.

Lesions of the **palliostriatal system** are manifested by general body stiffness, muscle supertension in both flexor and extensor muscles, which tests confirm as a symptom of “cogwheel” rigidity. Patients display movement slowness, weak movement expressions in reactivity, sluggish mimicry, mask-like faces, absence of arm and leg coordination when walking. This condition in clinical pictures of diseases of the nervous system is called hypokinesis.

Children affected by lesions of the **striatal system** show excess movements - hyperkinesis in different locations. They can be observed in the body (axial, torsional hyperkinesis), in limbs (chorea disease, athetosis, ballism, myoclonia and tremor), in facial and neck muscles (tics, spasmodic torticollis) and in vocal chords (vocal hyperkinesis). Hyperkinesis usually appears when children try to maintain a certain position or perform a delicate act. Hyperkinesis is absent when children are completely relaxed or asleep. These lesions are manifested by a decrease in muscle tone from hypo- to atonia. Dystonia often progresses and is apparent in joint overextension, especially when attempts are made to move around. Typical cases of dystonic muscles show foot flexures, arm extensions, back overextension, neck extension and rotation, all of which are manifestations of the hypotonic and hyperkinetic syndromes.
The cerebellum takes part in organizing movement activities, constructing ballistic movements as well as regulating the organism’s autonomic functions. Cerebellum nuclei carry out movement corrections and ensure their accuracy, all of which are needed in connection with the constant activity of inertial strength appearing when movements are called for.

The cerebellum is composed of two hemispheres and the vermis. The neuron bodies form the cerebellum cortex and nuclei layers in the white substance matter of the hemispheres and vermis - cogwheel, suberose, globular and fastigial nuclei. Various zones of the cerebellum are responsible for controlling movement accuracy. The most ancient section of the cerebellum is the flocculonodular lobe which controls body balance and maintains muscle tone. Median sections of the cerebellum near the vermis coordinate body movements and thoracic and pelvic girdles. Intermediate sections coordinate fine motor arm activities, whereas lateral sections of the cerebellar hemisphere take part in planning movements (illustration 1.2.3).

Illustration 1.2.3. Cerebellum: a) sagittal section of the brainstem, b) somatotopical representation of body parts in the cerebellum
The cerebellum has an important function, namely, ensuring mutual coordination of postural and conscious movements as well as correcting their accuracy and conformity. Such movement coordination is realized by the cerebellum according to the comparison principle, that is, comparative signals equipped with an activity program which flow from the motor cortex and proprioceptors (illustration 1.2.4).

When active and conscious movements are performed, impulses from the cerebral motor cortex descend to the spinal cord and transmit instructions to muscles through lower motor neurons. At the same time, information about movement intentions from this same cortex zone is transmitted to the cerebellum. At this time, action potentials from proprioceptive neurons, which innervate joints and limb tendons, ascend to the cerebellum and transmit information about actual positions of limbs and the entire body. The cerebellum juxtaposes impulses from the cerebral motor cortex and proprioceptors of the extremities (signal comparison) and so can compare planned movements with executed movements. When a discrepancy is detected, the cerebellum sends signals to the motor cortex and the spinal cord to have it removed. Free-flowing and coordinated movements are results of this work in the cerebellum.

The clinical picture of cerebellum lesions is manifested by the *ataxic hypotonic syndrome*. Low muscle tone (hypotonia or atonia) is observed and displays an ataxic gait, difficulties in equilibrium and movement coordination, asynergy with static
and locomotor function disorders. Ataxia manifests itself by disorders related to equilibrium, movement coordination and sequence of arbitrary movement acts.

Any parts of the body may be included in ataxia depending on the location of the brain lesion. Paravertebral musculature suffers when the cerebellar vermis is affected; ataxia progresses in the body; speech disorders are observed; speech becomes indistinct and staccato-like. Ataxia related to eyeball movements is manifested by nystagmus. Dysmetria - difficulties performing finger-nose and heel-knee tests as well as many others. When the patient attempts to correct dysmetria, he is seized by ataxic intention tremors with trembling of the limbs when terminating movements and adiadochokinesia with difficulties in alternating supinator and pronator arm movements.

Cerebellar ataxia is observed in patients attempting to keep their balance when walking. They must place their legs wide apart so that the support area ensures better body stability. Thus, the patient is “thrown about” by lesions in the cerebellar hemisphere. When a child is affected to a light degree by ataxia, he cannot follow a straight line by walking heel and toe or jump on one leg. When rotating, he is “pulled” sideways and cannot follow movement trajectories.

The cerebellar vermis, brainstem and spinal cord are all directly associated with the development of such important movements as walking, running and swimming. The cerebellar cortex together with pontine tracts plays an important role in ensuring manipulative movements and motor speech functions. The cerebellum and premotor cortex also preserve reflexive memory which is connected with developing such skills as bicycle riding and piano playing.

1.2.2. Forms of CP

As a rule, the actual classification of CP is based on muscle tone condition and lesion location. According to this principle, all forms of CP may be divided into two groups - pyramidal and extrapyramidal (illustration 1.2.5).

Pyramidal forms of CP are mainly connected with lesions of the corticospinal pathway; they are characterized by spastic disorders of muscle tone. Spastic tetraparesis (tetraplegia), spastic diparesis (diplegia) and spastic hemiparesis (hemiplegia) can be distinguished depending on dominating lesion areas.

Extrapyramidal forms are divided into athetoid (dystonic, hyperkinetic) and ataxic (cerebellar, hypotonic) forms.

There are also mixed forms of CP with different combinations of pyramidal and extrapyramidal systems.
Clinical forms of CP

Illustration 1.2.5. Clinical forms of CP

Pyramidal (spastic) forms
- Tetraparesis
- Diparesis
- Hemiparesis
- Mixed

Extrapyramidal forms
- Athetoid
- Ataxic

Spastic diparesis

Dominating lesions of the lower limbs lead to the development of spastic diparesis (diplegia). This form of CP is called Little’s disease. It is quite common and numbers between 10 to 33% of all patients.

Lesions occur gradually as the child’s movements are developed. Spastic palsies can occur in legs and arms during the first months. In future, arm movements may be renewed and the clinical picture may show predominating leg paralysis.

Versions of triplegia with leg and single arm lesions are referred to as transitional forms of CP. Such children have a higher muscle tone, continually maintain tonic labyrinthine and neck reflexes and show delays in motor development. During medical testing, increased tendon reflexes, foot clonus and pathological reflexes can be observed. Contractures of hip muscles and foot deformities develop quickly; leg movements are abruptly restricted [Sussman M.D., 1992]. Sensitivity and pelvic organ functions may be preserved.

Speech and mental disorders are sometimes moderate, but they often appear against the background of microcephaly, hydrocephaly and epileptic symptoms, which tends to complicate prognosis [Zucker M. B., 1986].

Spastic diparesis shows predominant movement disorders of the lower limbs, but should be differentiated from spinal paraplegia which may be a consequence of childbirth trauma or a deficiency in the development of the nervous system. In such cases, sphincter functions suffer and autonomic disorders are observed. In contrast to cerebral diparesis, there are no spasms and no retardation in mental development [Badalyan L.O., 1980].
Spastic tetraparesis

Depending on brain lesion localization, spastic tetraparesis (tetraplegia) may cause paralysis to extend to all four extremities. This is the most severe form of CP; its frequency rate fluctuates between 9 to 43% among all forms of CP.

Hypertension may occur in both the upper and lower extremities and muscles, or it may only predominate in the arm muscles. Contractures and bone deformations are formed very early. Mimetic and mastication muscles suffer, oral synkinesis appears and pseudobulbar disorders progress. Spastic dysarthria affects speech articulation and there are severe delays in motor and mental developments. There is a possible development of double hemiplegia with asymmetric lesions of the right and left sides of the body.

Spastic hemiparesis

Spastic hemiparesis (hemiplegia) is observed in 25 – 40% of the children suffering from CP. This form is characterized by one-sided lesions of the extremities and especially their distal sections. Right-sided hemiplegia is twice as common as left-sided. Simultaneously, lesions of homolateral nuclei VII and XII pair of cranial nerves can be observed to various degrees.

As the patient grows older, the muscle tone in affected extremities increases; they fall behind in growth and development compared to the healthy side. There is a possibility of an insignificant decrease in unilateral sensitivity, but this is very difficult to define in children. Contrary to adults, children gradually develop hemiatrophy, which occurs only in early brain lesions. Simple muscle atrophy without qualitative electroexcitability disorders is observed. Focal or general seizures are observed in 30 - 49% of the patients. This reduces the probability of normal mental development.

Athetoid form of CP

Extrapyramidal cerebral palsy has many names - hyperkinetic form of CP, athetoid or dystonic paralysis. The frequency rate among patients suffering from CP is between 9 to 22%. This form of palsy manifests itself as hypotonia during the child’s first two months; dystonic attacks appear at 3 - 4 months; these attacks are due to sudden muscle hypertension and are conditioned by an increased activity in reduced tonic reflexes.

In older children, extrapyramidal forms of CP are manifested as forced movements (choreoathetosis, tics, torsions) and muscle dystonia. Muscle rigidity sets in as soon
as energetic movements are attempted, hyperkinesis intensifies in the body and extremities. Mental development does not suffer very much, but apparent speech and movement disorders hamper the patient’s learning and his social adaptation.

Besides severe hyperkinesis such as double athetosis or choreoathetosis, and with the presence of nuclear icterus on the basis of immunological incompatibility of blood groups or the Rhesus factor, patients develop growing hearing difficulties or even complete deafness together with delays in speech development.

Ataxic form of CP

The ataxic cerebellar form of CP is represented by balance and movement coordination disorders. Even if the patient is able to walk, his gait is uncertain and unstable. Patients suffering from this lesion have problems executing rapid movements and movements which require fine control, such as writing. Tendon reflexes are usually overactive. Slow and gradual improvements of motor and mental functions are observed during the course of treatment. This form of CP occurs in 5 to 10% of CP cases.

Besides cerebellar lesions, areas of the frontal “pole” cortex may also suffer. Here, there are centers which manage the cerebellum through cerebellar frontal pons pathways. In such cases, patients develop Forster’s atonic-astatic form of CP, whereby static functions suffer sharply and deeply. Patients cannot maintain their heads; they are not able to sit, stand or walk while keeping their balance. Apart from apparent cerebellar pathology, there is predominant and severe mental retardation, lack of motivation and apparent delays in speech development.

In 9 – 25% of CP patients, mixed forms of the illness are observed. These are combinations of different forms of cerebral palsy. Combination of spastic forms with athetoid or atactic forms is widespread.

1.2.3. Fundamentals for diagnosis and rehabilitation classification of CP

CP diagnosis is based on the following key factors: the availability of reliable signs of early organic brain lesions and the evidence of a nonprogressive course of the illness; manifestation of pathological operations at a determined stage of brain development, delays in further maturity of the brain and formation of its functions; the availability of clinical symptoms in regard to centrally controlled lesions of movement functions; symptoms of motor deficiency.

Children with developing cerebral palsy noticeably lag behind other children of the same age in regard to motor development. Delayed motor development (DMD) and the inability to align the body are the first and fundamental syndromes of CP.
Manifestations of normal motor development may be conveniently evaluated (especially by parents) in the "motor ladder" shown below. Each step corresponds to one single stage of motor development. Each stage lasts 2 months (plus or minus 1 - 2 weeks according to individual variations).

Evidence for diagnosing delayed motor development can be justified when motor development drops below average parameters. Delayed motor development corresponding to one to two motor stages is considered as light, three to four stages as average severity. The consequences of II degree DMD depends on a timely diagnosis and rehabilitation measures. A child stands a good chance of restoring further normal rates of motor development if there is early rehabilitation treatment.

Delayed motor development corresponding to the fifth and sixth stages can be considered as lesions of severe degree. In such cases, a child’s body alignment and locomotion are seriously affected, which confirms a CP diagnosis.

Delayed motor development is connected with lesions of the nervous system and should be differentiated from other forms of DMD, which are conditioned by other causes, for example, severe somatic state or infectious illnesses. In these cases, delayed motor development has unspecific characteristics. As the child gets better,
his somatic and immune conditions are restored and the child gradually catches up with children of the same age.

Classifications of CP are based on topical diagnostics of lesions of the nervous system. However, the clinical picture of CP can change into another form during the first two years of a child’s life and in regard to motor function development [Badalyan L.O., 1988]30.

The following observations are important for normal motor development and body alignment during the child’s first year:

a) independent movements of all body parts with regard to one another;

b) the rotation of the upper part of the body with regard to the lower part;

c) the ability to maintain the body and all body parts in the terrestrial gravitational field (lying, sitting and subsequently, standing positions);

d) the capacity to relocate the body in regard to gravity force;

e) the gradual reduction of support areas as the body aligns itself for sitting, standing and walking.

These principles concerning the biomechanics of movements together with combinations of genetic factors determine potential possibilities of a child’s motor development [Cook R., 1996]31.

The formation of pathological motor patterns in CP is connected with the cerebral brainstem structures being released from controls by the endbrain cortex and cerebellum. Released from hierarchical subordination to higher motor centers, brainstem structures and cervical sections of the spinal cord begin to activate tonic reflexes (LTE, tonic neck reflexes, the grasp reflex, head-body righting reflex, pelvis-body righting reflex and others). In CP, these reflexes are not reduced by a determined date; on the contrary, they become more intensive. Their pathological activities prevent the development of spontaneous motor activity, expressions of congenital movement reflexes, such as support reflexes, the infant’s step movements and body rotations from supine to prone positions and back.

CP does not allow for the development of the cervical chain righting reflex, which is controlled by the midbrain, and subsequently, by the striate body and parietal segments of the brain cortex. Normally, this reflex allows the child up to 8 -10 months to increase the tone of dorsal muscle flexors, lower limbs and so, prepare the child for standing up.

The development of the cervical asymmetrical chain righting reflex enables the 6 - 8 month child to sit and maintain balance when in sitting and standing positions. At first, this reflex is controlled by the midbrain, labyrinth, cerebellum, subcortical nuclei, later, by cortical centers of frontal, parietal and temporal lobes in the brain. Lesions of sensory motor zones in pre- and postcentral gyri delay the formation of kinesthetic sensations, which, in turn, affects the development of movement patterns and formation of motoric automatisms and praxis [Semenova K.A.,1990]32.
In the clinical picture of a patient with CP, delays in reducing tonic reflexes determine different versions of muscle tone disorders. Continuous persistence of tonic reflexes and muscle hypertension creates flows of pathological proprioceptive impulsations. The child’s brain receives impulses from kinematic links with pathological patterns. As a result, there is no possibility of formation of normal movement stereotypes. Pathological patterns remain in the upper and lower limb joints; in time, this determines formations of myogenic and arthrogenic contractures, the development of persistent deformations of the limbs and the spinal column. Pathological movement habits are formed, which are then used by the child for further motor development. In connection with muscle tone pathologies in patients with CP, other body functions are also affected, namely, breathing, articulation, mastication, swallowing, functions of the internal organs and many other vital and important functions.

Depending on the localization of brain lesions, a CP clinical picture may show such forms of motor deficiency as paralysis, hyperkinesis, ataxia and dysmetria.

Apart from primary symptoms of motor function lesions, compensatory movement patterns develop, which patients employ to overcome muscle spasticity. Early motor ontogenetic disorders lead to formations of one of the following versions of pathological movement development - spastic, atonic or dystonic types.

Rehabilitation classification of CP

During primary diagnostics of CP, neurologists traditionally assess the degree of intensity of the following three fundamental neurological manifestations:

1) the degree of movement disorders: paresis, plegias;
2) the localization of motor deficiencies: mono-, hemi-, para-, tri-, or tetraplegia;
3) muscle tone condition: spasticity, rigidity, hypotonia, atonia, dystonia.

This practice in regard to current classifications does not reflect the course of movement disorders in CP when used in rehabilitation treatments.

And so, when a diagnosis “CP, spastic tetraparesis” is established for a 1-year old patient, it is hardly ever changed during the rest of his life. Nevertheless, all patients with such diagnoses will not be similar to each other. A patient suffering from CP finds himself in one medical institution and then another; he goes through repeated rehabilitation therapies; he receives a diagnosis when he is admitted to and discharged from hospital. His clinical history will show to what extent improvements were made in the patient’s rehabilitation treatments; however, this will by no means be reflected in his diagnosis.

In our rehabilitation clinics in Lviv and Truskavets, a straightforward and practical rehabilitation classification of CP has been worked out and introduced in order to
clearly define the degree of the child’s motor development [Kozyavkin V. I., 1995]. In addition to the three diagnostic criteria, it is expected that obligatory diagnoses in regard to alignment and motor development stages will be established for each patient (illustration 1.2.7).

And so, we indicate in the patient’s diagnosis the alignment phase in order to describe opposition to gravity force: a) a lying position with no head control; b) a lying position with head control; c) sitting independently; d) rising with support devices; e) rising independently.

We define the following locomotor stages which describe his motor development: a) an absence of locomotion; b) locomotion by rolling over; c) crawling on the stomach and chest; d) non-alternating crawling (rabbit jump type); e) alternating crawling (reciprocal); f) walking on the knees; g) walking with support devices; h) pathological and independent walking.

The diagnosis necessarily includes concomitant disorders: a) the patient’s psychology; b) cognitive development; c) speech development; d) somatovegetative sphere.

In such a way, the assessment of motor development in each patient in regard to our classification is carried out by using syndromological, topical and functional diagnoses.

Complex approaches to diagnostics, treatment and active follow-up of all cases enables an interactive evaluation of the patient’s condition. This is particularly important for analyzing the effectiveness of rehabilitation.

<table>
<thead>
<tr>
<th>Muscle tone</th>
<th>Localization</th>
<th>Verticalization phase</th>
<th>Locomotor stage</th>
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<tbody>
<tr>
<td>Spastic</td>
<td>Tetraparesis with dominating lesions:</td>
<td>in a lying position with no head control</td>
<td>absence of locomotion</td>
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<tr>
<td></td>
<td>- on the right.</td>
<td>in a lying position with head control</td>
<td>locomotion by rolling over</td>
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<td>- on the left</td>
<td>sitting independently</td>
<td>crawling on the stomach</td>
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<td></td>
<td>- upper limbs</td>
<td>rising with support devices</td>
<td>non-alternating crawling</td>
</tr>
<tr>
<td></td>
<td>- lower limbs</td>
<td>rising independently</td>
<td>alternating crawling</td>
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<tr>
<td>Dystonic</td>
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<td>walking on the knees</td>
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<tr>
<td>Hypotonic</td>
<td>Diparesis</td>
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<td>walking with support devices</td>
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<td>Hemiparesis</td>
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<td>pathological and independent walking</td>
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<td>- right side</td>
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<td>Triparesis</td>
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1.3. Cerebral Palsy treatments

Cerebral palsy is a serious illness connected with perinatal lesions of the nervous system. If there is a timely diagnosis and progressive rehabilitation treatments, the severity of the illness may be considerably reduced. However, there is no unique standardized method for treating this illness. One method may be beneficial to one child, but will not necessarily be able to help another child. Parents and rehabilitation specialists should work together in order to define the child’s needs first, define apparent functional disorders and finally, work out an individual program for progressive rehabilitation.

Rehabilitation treatments for children with CP should be directed towards developing motor activity, speech, practical skills and expanding the patient’s social contacts. The child’s needs should be taken into account; these needs change as the child grows older. A two-year old child’s habits, which are indispensable for getting to know the surrounding world are considerably different from a schoolchild’s habits or from a teenagers needs, who longs for independence and freedom.

So-called “authors’ treatment methods” deserve special attention in this extensive sphere of rehabilitation. Today, the most widespread methods are: the Bobath method, Vojta method, dynamic proprioceptive correction, conductive education and intensive neurophysiological rehabilitation (illustration 1.3.1).

Principles for CP treatment according to the first four methods will be described in this chapter. Treatments using the intensive neurophysiological rehabilitation system will be set forth more in detail in the second chapter of the book.

One of the most important methods for treating CP is physical rehabilitation, which should be started during the child’s first months, after the diagnosis has been established. Physical rehabilitation is only one element of the child’s developmental program and should ensure a stimulating and interesting environment for the child in order to be successful.
Physical rehabilitation is an important component of the rehabilitation process. It should be supplemented by other effective methods and techniques. Children suffering from cerebral palsy, like other children, constantly require new experiences and interaction related to the surrounding environment in order to develop, grow and learn. Sensory stimulation programs may provide such experience for these children, who do not have many opportunities of communicating with the outside world because of their motor restrictions.

For many children with delayed motor development and communicative difficulties, speech therapy classes should be directed towards detecting and determining specific speech disorders and then, overcoming them by systematic execution of programs dealing with special corrective exercises.

Psychological help is a most important branch for increasing the patient’s abilities and can complement physical rehabilitation, just like lessons with a speech therapist. This help is also indispensable for the child’s family. Psychological consultations are important for patients of all ages, but especially for teenage patients. This is a most critical period for individual growth and maturity, during which physical rehabilitation and professional preparations can be jointly used for working out social programs and specialized educational programs.

Medical treatment is applied during the newborn’s critical period of brain lesions, mainly during the first six months. Medical treatment is essentially prescribed for CP patients with concomitant seizures or is sometimes used to reduce muscle spasticity and the intensity of involuntary movements.

Complex treatments of cerebral palsy may also include surgical interventions. Orthopedic interventions are fairly widespread; they are aimed at removing joint contractures and bone deformities.

Regardless of the patient’s age and adapted rehabilitation programs, treatments should not come to an end when the patient leaves the doctor’s office or is discharged from a rehabilitation center. Medical specialists should act as coaches who provide parents and patients with rehabilitation strategies and teach them indispensable skills for improving the patient’s lifestyle at home, at school and in the surrounding environment.

1.3.1. Physical rehabilitation of CP

Physical rehabilitation represents one of the most important methods of treating CP. During the first months of a child’s life, exercise programs are directed towards executing two main tasks: muscle atrophy must not be allowed to set in as a result of insufficient practice and use and also, the development of myogenic contractures must be prevented as muscle spasticity or rigidity fix the limbs in pathological positions.
Contractures are one of the most frequent and serious complications of cerebral palsy. A healthy child’s muscles and tendons stretch regularly when he walks, runs and performs daily movement activities. This ensures interdependent bone and muscle growth. In children with cerebral palsy, spasticity hampers muscle stretching. As a result, muscles do not develop adequately and rapidly enough, muscle length does not keep up with skeletal growth and subsequently, bone growth is also restricted.

Contracture formations in CP patients may lead to equilibrium disorders and loss of acquired movement skills. Physical rehabilitation programs should be directed towards prophylactic measures for these unwanted complications by means of a gradual stretching of spastic muscles.

Contributing to the child’s motor development is the most important task facing physical rehabilitation. Countless concepts are offered and a great number of rehabilitation plans have been developed all over the world to carry out this task.

As the CP patient gets older and reaches school age, treatment programs change from ensuring early motor development to placing more emphasis on the child’s adaptation to society. At this stage, physical rehabilitation efforts should be directed towards learning and shaping everyday skills, developing communicative faculties and preparing the child for collective social life. Physical rehabilitation should be directed towards developing the child’s independent locomotion, with the assistance of canes or wheelchairs, as well as developing fine motor activity of the hand for mastering such complex techniques as writing. The child should also be taught to perform tasks independently, such as eating, getting dressed and using bathroom and toilet facilities. By mastering these daily skills, children with CP will make life and work easier for people who look after them and will enhance their own self-confidence and self-esteem.

1.3.1.1. Neurodevelopmental treatment (the Bobath method)

Berta and Karel Bobath, a man-and-wife team, made a significant contribution to developing principles of physical rehabilitation. As long ago as the 1940s, they began to develop their own approach founded on Berta Bobath’s clinical observations.

Owing to their active work, publications, lessons and training courses, the Bobath concept of “neurodevelopmental therapy” spread throughout the whole world. After the Second World War, it made a significant contribution to developing principles for rehabilitating patients with CP.

The essence of their method can be explained by the hierarchical maturity theory in the nervous system, which was largely prevalent in those days. Consequently, the founders considered ontogenetic sequences in motor development as one of the main theoretical postulates for treatment.
According to the Bobath concept, motor problems in cerebral palsy appear as a result of brain structure lesions, which are responsible for antigravitational and postural mechanisms. These, in turn, decelerate and deform normal motor development. Therefore, neurodevelopmental treatments were aimed at rehabilitating systems which are most likely to be affected in CNS disorders. Special attention was paid to the sensomotor control of muscle work, muscle tone, movement memory and mechanisms for postural control. Practical tasks included reducing muscle spasticity, contractures and deformation prophylactics, suppressing pathological reflex activity and eliminating nonphysiological movement patterns. Various sensory stimuli were employed to stimulate the child’s motor development and form normal balancing reactions and physiological movement patterns. This system made the child a comparatively passive recipient of neurodevelopmental treatments.

With time and owing to their own experience and new achievements in neurophysiology, the Bobaths changed their approach somewhat and began to place more emphasis on other aspects of treatment. In their last publication in 1984, they described how key theoretical positions of their concept had been transformed [Bobath K., 1984]. At first, they defended their position, arguing for the necessity of placing the child in special “conditions which would suppress pathological reflexes”. Although these conditions did indeed lead to reduced spasticity, the founders later came to the conclusion that this lowered muscle tone was only temporary and was not maintained when the child attempted other movements.

With so many years of experience in rehabilitating patients with CP behind them, the Bobaths focused on the important influence of “key control points”. Thus, physiotherapy work was conducted during the child’s movement activities and was directed towards suppressing pathological movement patterns and stimulating development of more accurate movements.

In the end, the Bobaths came to the conclusion that it is not necessary to strictly control development of automatic straightening reactions as the child cannot spontaneously transfer these skills into conscious independent movements. It is more effective and reasonable to develop the child’s faculties for independently controlling his balance and managing his movements. They concluded that it was not important or necessary to stimulate the child by adhering strictly to standard ontogenetic sequences of motor development.
1.3.1.2. The reflex locomotion method (Vojta therapy)

Vojta’s therapy, also known as the reflex locomotion method was elaborated at the beginning of the 1950s by Vaclav Vojta, a Czech doctor.

The method was created empirically when Vojta was studying motor reactions to specific stimulation, which was applied when a child assumed a specific position. As long ago as 1964, Doctor Vojta stated that such stimulation causes “global dynamic muscle activity”, which can be observed during all forms of human locomotion [www. vojta.com, 2005]35.

These same “global patterns” constitute the theoretical basis for the reflex locomotion method. The term “global locomotion” means motor responses which appear during applications of the reflex locomotion method. Skeletal muscles are activated in a coordinated fashion, impulses arrive at all movement centers of the brain, all of which contributes to the formation of new reflex connections. This process includes not only body and limb muscles, facial and respiratory muscles, but also swallowing muscles, intestinal peristalsis and urinary bladder functions. “Global patterns” are also an essential part of other human movement activities, such as, grasping, turning over, crawling and walking. Doctor Vojta revealed that reflex reactions which occur in patients with movement disorders are similar to the reactions of healthy children. This meant that formations of important movement patterns can be stimulated during a child’s early years and thus, create “building blocks”, which are necessary for motor development.

Therefore, such motor reactions lay the basis for rehabilitating movements in patients with CP. They are provoked by applying measured pressure on specific body parts of a patient who is lying on his stomach or reclining on his side.

The reflex locomotion method aims at developing limb support functions, the child’s skills in controlling body positions and movement coordination. These skills are affected to a various extent in all patients with brain lesions, as well as patients with musculoskeletal system disorders of other etiology. In such cases, pathological movement patterns can be corrected with the assistance of the reflex locomotion method.
Applications of two coordinating complexes – crawling reflex and turning reflex are core components of the reflex locomotion method. Vojta studied both reflexes in patients with spastic paralyses, in healthy newborns and in infants.

Vojta’s therapy becomes effective when exercises are repeated often and for a longer period of time. Exercise procedures consist in maintaining the child in a specific reflex position and applying hand pressure to the selected zone. Influence zones are selected individually and depend on movement disorders and the intensity of appropriate reactions. When there is a responding reflex movement, this exercise should be repeated during the whole course of treatment.

Parents are essential partners in the treatment process. Assisted by specialists, they should study Vojta’s method and then, continue rehabilitation procedures at home.

Attention should be drawn to the fact that the reflex locomotion method is not aimed at practicing a specific movement, but at creating work patterns of muscle coordination, which can be used for building up further chains of movements.
1.3.1.3. The conductive education method (the Peto method)

Conductive education was elaborated after the Second World War by Andreas Peto, a Hungarian doctor and teacher. At first, this method was applied only at the Institute for Conductive Education in Budapest, which is named after the founder. With time, the method gained popularity and began to be used in many other countries.

According to Professor Peto, motor disorders are not only due to damage in brain movement centers, but are also the result of integration process disorders, which lead to inadequate interaction of different brain sections. Integrating abilities of the nervous system should be mobilized with the assistance of an active teaching process [www.peto.hu, 2006].

In Hungary, traditional programs of conductive education are directed by conductive specialists (conductors) who have a four year university education in specialized training programs. They plan and carry out their program individually, both as teachers and medical specialists. Group work is conducted according to pre-arranged programs including blocks, which are composed of exercise complexes and educational occupations. Activities are presented as games in specialized groups numbering between 10 and 25 children who are all affected with the same type of cerebral palsy. Conductors manage the group while ensuring motivational surroundings and providing emotional support.

Programs involve several years of prolonged work with the child. Exercise complexes are chosen according to pathological characteristics and the child’s movement and mental possibilities. Various objects and sport equipment are used in these complexes, for example, ball exercises, steps, gymnastic benches and poles; these are supplemented by walking exercises and practice on wall bars. Specialized equipment is used during the exercises, namely, ladders, tables and boxes made of rounded lacquered wooden planks.

All exercises are based on physiological movements. “Rhythmical intention” is widely used during these activities; these include rhythmical movements, dancing, singing and reciting poems. Rhythmical treatment also refers to rhythmic oral instructions, which are delivered during the performance of these exercises.
Rhythmical backgrounds heighten motivation and draw attention to required movements, thus contributing to the child’s learning process.

Motivation is a key factor of the child’s participation in this rehabilitation process. As a rule, children with cerebral palsy not only act and move more passively, but also express their wishes more passively, too. The conductive education method requires the child to play an active role in overcoming his motor deficiencies. If the aims are set out clearly, the child will become interested and so, will express appropriate motivation for further activities. Programs are designed to activate the child’s continuous participation in different sorts of activities, which teach children to think and act in different situations. Motivation is most significant as it shows the children how to strive for success and, finally, achieve the proposed goals. Therefore, even the most insignificant success should get positive support and encouragement from conductors. This will definitely increase the child’s self-esteem.

1.3.1.4. Dynamic proprioceptive correction method (Semenova method)

The dynamic proprioceptive correction method was worked out under the supervision of K. A. Semenova, honored scientist of Russia, in the rehabilitation department for children with cerebral palsy at the Science and Research Pediatric Institute of the Russian Academy of Medical Sciences. K. A. Semenova believes that motor rehabilitation in cerebral palsy and brain trauma can be realized by correcting afferent proprioceptive flow in patients. This flow has an immediate influence on the basic structures of the central nervous system, which control motor activity and the functional antigravitation system as well as monitoring muscle synergies responsible for locomotion and the erect alignment of the body.

K. A. Semenova based her studies on the inabilities of the functional antigravitation system in patients suffering from CP. In 1991, she suggested using “Pingvin” (Penguin), a modified space suit for rehabilitation treatments.

The “Penguin” loading device was designed in the 1970s in the laboratory of space medicine as a measure to counter the effects of long-term weightlessness on the body while in space [Barer A. S., 1972]. It is an established fact that muscle hypotrophy occurs as a result of the absence of loading pressure on bones and muscles in zero gravity conditions. The “Penguin” device imitates gravity
pull on a cosmonaut’s organism using a 40 kilo power load directed length wise along the cephalocaudal axis and so, reduces the negative influence of zero gravity. The invention of the loading suit resolved the problem of a person’s long-term stay in anti-gravity conditions and so, caused a revolution in biological aspects of space travel. The “Penguin” device was then adapted to children and named “Adeli-92”. Utilization and experience of the “Adeli-92” led to the elaboration of a next-generation medical suit, especially intended for the rehabilitation of patients with CP; it also took into account movement specifications of each patient. At the expense of available resources, each patient builds up his own defective system to help him to overcome gravitational force. The medical suit influences tonic reflexes which are essential for forming pathological muscle interaction.

As the suit was directed towards stimulating afferent proprioceptive flow, this new method of treatment was called “dynamic proprioceptive correction” [Semenova K.A., 1999]38.

The reflex-loading device “Gravistat” was developed in 1997; it allows a functional correction of a patient’s posture (illustration 1.3.3). “Gravistat” consists of elastics tension bands which are fixed and counterbalance each other. Tension regulation in these bands allows strictly measured doses of loading pressure to travel along the cephalocaudal axis, thus exerting activity in body muscles and the lower limbs. Rotational elastic pressure corrects the positions of body movement sections. This enhances information flow from receptors of muscles, joints and tendons, and stimulates the central nervous system where movement patterns are shaped.

Neurophysiological research (EEG (electroencephalography), ENG (electroneurography), EMG (electromyography), SSEP (somatosensory evoked potentials) was conducted in 580 patients aged 4 to 25 years suffering from cerebral palsy and 68 patients suffering from consequences of brain trauma with different severity of disease. 55 - 70% of the cases showed substantial improvements in motor activity regardless of illness duration and intensity of brain lesions.
1.3.1.5. The intensive neurophysiological rehabilitation system (The Kozyavkin Method)

The intensive neurophysiological rehabilitation system, widely known as the Kozyavkin Method was invented in the 1980s and has become an important landmark in the developing field of medical rehabilitation. The principles for this rehabilitation treatment were based on research which established a new approach to cerebral palsy and stressed the vertebrogenic component in the etiopathogenesis of this illness. The Kozyavkin Method represents an integral rehabilitation complex, the basis of which is biomechanical correction of the spinal column. This unique method of correcting spinal movements is aimed at eliminating functional blocks of spinal movement segments, improving activities of autochthonic body muscles and directing the flow of proprioceptive information to nerve centers.

Spinal correction using this system is combined with a multimodal complex of treatments, which complete and potentiate each other mutually. The result is a durable normalization in muscle tone, an increase of microcirculation in tissues and bradytrophic structures and a normalization of tissue trophism. This contributes to the formation of a new functional condition, which ensures activation of brain plasticity and compensatory possibilities of the organism.

This new approach to rehabilitating patients with CP takes into account peripheral structures in the etiopathogenesis of lesions and thus, leads to more positive and durable results. Professor Kozyavkin’s method is described more in detail in the second chapter.

1.3.2. Medicamental treatment of CP

Medicamental treatment is applied by neonatologists and pediatricians during a newborn’s critical period of brain lesions, mainly during the first six months. Combating brain oedema and hypoxia constitutes the main aim of this treatment. Later, medicamental treatment is prescribed when seizure syndromes appear, or sometimes, for reducing muscle spasticity and involuntary movements.
On the whole, two groups of medication are used to combat seizures in CP. On the one hand, there is a wide range of anticonvulsants, which rapidly put an end to seizure activity and prevent further repeated outbreaks. Benzodiazepine type preparations constitute the other group of medication. Diazepam is the most widely known. This drug is used in emergency cases of epileptic convulsions.

All antiepileptic drugs should be selected and prescribed according to electroencephalography results, the patient’s individual characteristics and the general clinical picture. Neither medication can be used effectively in all types of seizures. It is often recommended to use two or more antiepileptic drugs during a resistant course of epilepsy.

Medicamental treatments are also prescribed to reduce muscle spasticity in CP, especially after orthopedic interventions. The following drugs are often prescribed: diazepam, which acts as a relaxant; baclofen (lioresal), which blocks motor neuron signals to muscles; dantrolene that has an effect on muscle contraction. Taking drugs in tablet form results in short-term reduction of muscle tone; long-term use of these drugs causes side effects, such as drowsiness and allergic reactions.

Hyperkinetic forms of CP sometimes call for the prescription of medication which can reduce the strength and intensity of involuntary movements. This refers to dopaminergic or anticholinergic agents.

Drugs belonging to the dopaminergic group are widely prescribed in treating Parkinson’s disease; they raise the dopamine level in the brain, which ensures muscle tone reduction and arrests pathological and involuntary movements. Anticholinergic drugs reduce acetylcholine activity, a neurotransmitter, which is responsible for the transmission of nervous impulses in the synaptic gap.

Botulinum toxin type A, sold commercially as Botox and Dysport, is also a medication used in treating CP. Botulinum toxin is a neurotoxic protein produced by the bacterium Clostridium botulinum and one of the most natural toxic substances in the world. Despite its high toxicity, it is used mainly in minute doses to treat muscle spasms and cosmetic defects.

Justinus Kerner (1786-1862), a German physician and poet described this toxin, calling it a “sausage poison” as this bacterium often caused severe poisoning by growing in improperly prepared meat products. J. Kerner first conceived a possible therapeutic use for botulinium toxin.

In the 1950s, it was discovered that minute doses of botulinium toxin type A reduce muscle hyperactivity by blocking the release of acetylcholine at the neuromuscular junction, thus preventing muscles from contracting for a 4-5 month period (Illustration 1.3.4). In time, the excitation transfer to the muscle is restored by means of compensatory sprouting of axon terminal portions. [Park E.S., 2006]39.

This effect is used to treat spastic forms of cerebral palsy, thus reducing muscle spasticity in the limbs and increasing the range for joint movements. Today, there
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is no common viewpoint in regard to the effectiveness and rationality of using botulinum toxin in cerebral palsy treatments.

It is important to emphasize that all the various methods for medicamental treatment of CP are symptomatic and can only be complementary in general rehabilitation programs for patients with cerebral palsy.

1.3.3. Surgical methods for treating CP

Surgery is usually performed in order to remove bone deformities, lengthen muscle tendons, ligaments and fasciae. The operations should improve motor activities of patients who have potential possibilities of being able to walk independently. For children who have no perspective of walking without assistance, surgical interventions are aimed at removing painful syndromes and increasing their abilities for self-help.

The most widely spread operations are directed towards correcting scoliotic deformities of the spinal column, removing dislocations in hip joints, relocating tendon attachments, reducing imbalance of spastic muscles and so on. Osteotomy may be practiced in individual cases in order to correct the biomechanical axis of kinematic links. Today, there is no common viewpoint in regard to optimal periods for conducting surgical treatments. According to existing recommendations, it is necessary to take into consideration the maturity of the nervous system, potentials for developing independent gait as well as the tempo of deformation processes when making a decision about expedient surgery [Murphy N.A., 2006].

The effectiveness of surgical interventions on CP patients remains a controversial subject. During a scientific program of the American Academy for Cerebral Palsy dealing with the effectiveness of various methods of treatment, analyses were conducted in regard to using adductomy as a prophylactic measure for hip subluxation in CP patients [Stott N.S., 2004]. Following an adductomy, a positive effect on hip subluxation was observed in X-rays among 32% of the cases only.
(168 per 530 observations). It was also established that there is no reliable research on actual results of adductomy, which might provide more conclusive information about improving the range of joint movements or bettering the patient’s lifestyle.

Recently, functional neurosurgical procedures have been used more widely together with traditional orthopedic surgery on bones, muscles, joints and tendons. In the USA, selective dorsal rhizotomy has been introduced. During this surgery 70 - 90% of posterior nerve roots L2 - S1 levels are severed [Peacock W.J., 1982]. In some patients with CP, rhizotomy procedures help to reduce muscle spasticity and increase abilities to sit, stand or walk. However, this operation requires careful assessment when applied to patients as complications may arise, namely, weak muscles may decrease a patient’s daily skills and independence.

The baclofen intrathecal pump method, which allows medication to be delivered continuously, also deserves our attention. Baclofen is a derivative of gamma-aminobutyric acid; it connects with gamma-aminobutyric acid receptors and reduces the effects of excitative neurotransmitters.

Baclofen is administered into the subarachnoid space of the spinal cord by an infusion system which includes a pump implanted under the skin covering of anterior abdominal muscles and a catheter placed in the subarachnoid space, but lower than the cone of the spinal cord (Illustration 1.3.5). The pump ensures continuous delivery of medication into spinal cord fluid. Dosage control is carried out by an exterior programmed device. The pump reservoir can be refilled every 3 months by means of a subcutaneous injection. There are many advantages to this method owing to effects of evenly-dosed medication flowing into the spinal cord. However, baclofen intrathecal administration and selective dorsal rhizotomy are sometimes thought to be the most effective only when treating wandering reflex contractures (these appear as a result of hyperspasticity and imbalance of synergetic muscles when
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the patient is in an erect position) and the least effective when treating fixed limb deformities [Lilin E. T., 1999]43.

Current surgical methods for treating cerebral palsy need further research so that evidence and contraindications can be defined more precisely in regard to age and clinical forms of CP. When choosing therapeutic method for children with CP, we should remember the epigraph in the book written by Eugene Bleck, the famous American orthopedist and specialist in surgical treatments for people suffering from CP: “Decision is more important than incision” [Bleck E., 1987]44.

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Theoretical principles of rehabilitation of motor disorders. The Kozyavkin Method
2.1 Phases for establishing theories related to movement systems

CP is a complex and multifaceted pathology caused by organic lesions in the nervous system. Owing to the fact that cerebral palsies are expressed clinically by various speech, movement and mental disorders, this pathology requires early diagnosis and early measures for further rehabilitation treatments. These measures should take into consideration how all the motor systems in the body are organized.

The very first concepts related to motor mechanisms and structures were founded on principles of unconditional reflexes, that is, a movement was evaluated as a natural sequence of ordinary motor reflexes, whereas the reflex arch was considered as the basic element of the complex physiological process. I. M. Sechenov, founder of the theory related to reflex activities in the brain, came to a brilliant conclusion in this field, and successively showed that all voluntary movements and mental processes are mere reflections of objective influence on humans, that is, they are essentially reflex movements.

I.P. Pavlov developed I. M. Sechenov’s ideas and formulated the principles of reflex theory, namely, principles of determinism, structure, analysis and synthesis. Furthermore, he set up rules governing higher nervous activity in humans. Pavlov’s further studies on motor theory were built upon observing conditioned reflexes as the basis for improving movement activity.

As I. M. Sechenov’s reflex theories and I. P. Pavlov’s studies on higher nervous activity were developed even further, they came to reveal a gap between the role played by the periphery and center.
N. Y. Vvedenskiy, a Russian physiologist, displaced biocurrents in human muscles and was the first to listen to neural rhythmic excitability. Thus, he established the importance of frequent rhythmic stimuli in biosystem responses. At the turn of the XIX - XX centuries, studies on local nonfluctuating stimulation were quite unusual. N. Y. Vvedenskiy introduced the idea of “instability” or functional mobility. Nerves and muscles showed reduced excitability and tissue conductivity as a result of excessive stimulation. This led to the elaboration of the parabiosis theory, which stated that living organisms react universally to changing factors in the environment. Vvedenskiy compared parabiosis to an arrested wave of stimulation.

It appeared that excitability may become localized and inhibitions may develop if stimuli exceed the instability level of tissues. In fact, inhibitions actually appear as modifications of excitability. For the first time, the question of the uniformity of fundamental neural processes was raised, namely, stimulation and inhibition.

By proving three-phase reactions of living organisms and the presence of parabiosis in microintervals, it became evident that three fundamental processes, namely, stimulation, inhibition and rest formed a single unit. As a result, the following features became clear: parabiotic inhibition and local nonfluctuating stimulation, inhibition in centers by single stimulation, the ability of weak stimuli to increase tissue readiness for further activity and so on. This greatly influenced the further comprehension of nervous system reactions to stimuli.

N. Y. Vvedenskiy’s student, A. A. Ukhtomskiy developed fundamental studies related to the dominant principal (Latin: dominans - dominant) and established a connection between this new concept and N. Y. Vvedenskiy’s theory of parabiosis. A massive flow of impulses creates a hotbed for stimulating the brain; it then provokes inhibitions of autonomic and other body functions, which do not take part in the main (dominant) program regulating the body. Characteristic features of the dominants are: increased excitability in dominant centers, stabilized stimulation throughout time and possible stimulus summation. By revealing the dominant principal, Ukhtomskiy showed that the final results of reflex reactions in the human organism are not only determined by impulses traveling from receptors to effectors (in accordance to classical concepts about reflex arches); the actual results also depend on the functional condition of the nervous centers. The stimulation hotbed is viewed as the dominant principal; it inhibits all other reflexes as recurrent stimuli, and acts
as a bridge system actively present in the human body and joining together all the nervous centers located in the CNS and the periphery.

The dominant mechanism takes part in forming the central structure of any functional system which is still at the afferent synthesis stage.

It was proved that the dominant is one of the fundamental mechanisms for cerebral activity. The dominant is activated in the organism when there is a motivating stimulation at a given moment. The mechanisms, which form the dominant, are the ascending activating effects located in the hypothalamus and reticular formations. Both features selectively strengthen the stimulation level in the appropriate cells of the cerebral cortex. The descending effects in specific areas of the cerebral cortex selectively facilitate and extend stimuli through nuclei relays in the hypothalamus and reticular formations. In these conditions, any stimuli will provoke summation of all stimuli processes in concrete nervous centers and lead to the organization of a comprehensive activity program, which ensures optimal results for the organism.

Studies related to the dominant principle revealed a natural law that governed all the activities of the integral human organism. It was shown that the stimuli hotbed or any other system do not dominate in natural conditions. This would, in fact, enable the human body to adapt more readily to existing conditions. Later, this system was referred to as the functional system.

Walter Bradford Cannon, an American physiologist conducted studies related to homeostasis, calling it an “autoregulation of physiological processes”. Homeostasis (Greek: homoios - similar + statos - standing still) refers to the relative dynamic constancy of the internal environment and the stability of fundamental physiological body functions. Living cells constitute an active and autoregulating system which is subjected to various environmental
Influences. Cells are capable of renewing themselves; this is one of their essential properties. A multicellular organism is a comprehensive system where cells have various functions. However, complex mechanisms of homeostasis enable the system to sustain a relatively dynamic stability. The corporative activity of numerous cells is one of the most surprising features in any living organism [Hagen G., 2001]. For example, this may be observed in muscle coordination during any locomotor activity. At the beginning of the 20th century, Sherrington referred to these phenomena as muscle synergies.

A child’s organism creates special conditions in order to sustain its internal environment. In fact, homeostasis in a child’s organism is ensured against the background of anabolic processes predominating over catabolic processes. This also constitutes one of the conditions for growth. This phenomenon also determines higher intensity of metabolic processes and greater tension in neuroendocrine systems of regulation, all of which distinguish a child’s organism from an adult’s. As a result, homeostatic disorders can be observed more often in children, especially when the homeostatic functions of the lungs, kidneys and gastrointestinal tract show definite signs of immaturity.

The most significant modifications occur in fluid balance during the first year of a child’s life: the volume of extracellular fluid increases considerably and falls behind the overall increase in body weight. High levels of secretion and liver excretion of aldosterone have a direct influence on tissue hydration in newborns and infants. In children, this neuroendocrine control over homeostasis is combined with highly regulated acid-base balance in the saturation rate of blood with oxygen. This is explained by the comparative predominance of anaerobic glycolysis in the metabolism. Consequently, even moderate hypoxia in the fetus shows that lactic acid accumulates in the tissues. Furthermore, acidogenic functional immaturity in the kidneys creates preconditions for the development of “physiological” acidosis. In newborn infants, some particular features of homeostasis are often connected with disorders which border on the physiological and pathological.

P. K. Anokhin’s studies related to systemogenesis and functional systems were an important landmark in explaining development mechanisms of neuropsychic functions in human ontogenesis. It was established that locomotor activity is not a single reflex, but the result of complex preliminary reasoning together with the
instant integration of various anatomic and physiological systems in order to ensure required results.

The results of this research led to the theory related to “functional systems”.

The functional system is a complex association of body structures; it is directed towards achieving required life-adjustment conditions for the human body. Each functional system works according to several auto-regulation principles, and includes organs and tissues in different anatomic and physiological systems (Illustration 2.1.1).

![Illustration 2.1.1 Diagram of the functional system [Anokhin P. K., 1975]](image)

The components of the human anatomic and physiological systems are formed during the ontogenetic periods. Thus, the nervous system develops according to the following principle: first, earlier evolutionary structures are formed and then, later evolutionary structures develop. The elements of the functional system may have various evolutionary levels and may mature heterochronically, during different ontogenetic periods, combining together to ensure living requirements. Heterochronia, that is, the development and connection of functional systems and their subsystems at an unusual time or out of the regular sequence, is a special feature of a developing organism. The gradual, but consistent maturity of various elements in a single functional system reflects intrasystem heterochronia. Certain distinctions, which occur during the development of individual functional systems, reflect intersystem heterochronia. On the whole, studies on systemogenesis explain
both the development and complications of body functions, as well as the successive phases of a child’s neuropsychic development.

Thus, the combined efforts of many researchers revealed the fundamental mechanisms involved in regulating the functions of the human organism. Their studies also illustrated the diverse adaptive possibilities inherent in the human body, and indicated the means of rehabilitating affected body functions.

Rehabilitation is the key to working with CP patients. It involves an entire complex of medical, social and educational measures, which are all aimed at compensating or rehabilitating affected body functions, restoring a patient’s ability to work and returning him to active social life [Antonov I. P., 1998]. CP rehabilitation is closely connected with secondary prophylactic measures aimed at detecting lesions at an early stage, rehabilitating body functions and preventing complications and relapses. Such tasks cannot be resolved by localized treatments or the rehabilitation of separate systems and functions. However, a particular and very specialized field of medicine and biology was developed during the XX century. It determined a substantially localized approach to therapeutic and rehabilitation problems on the basis of new methods.

In the second period of the XX century, however, there was a general tendency towards interdisciplinary syntheses of all knowledge related to humans. Further studies led to a more systematic approach to analyzing basic foundations in regard to an organism’s vital functions [Anokhin P. K., 1975], [Sudakov K.V., 1987]. In clinical anthropology, such research was based on integrative anthropology, which uses an entire complex of knowledge concerning philo- and ontogenesis, individual and social intercommunication among humans, psycho-biology, the psychomotor system, movement potentials and others [Nikitiuk B. A., 1998]. In integrative anthropology, the elementary analysis is based on integrational systems, which allows partial usage for more comprehensive understanding. Theoretical and practical research revealed that the following factors must be taken into consideration: human changeability in normal and pathological conditions in regard to morphology, individuality and typology, sexuality, age, physiology, psychobiology, ethnic territory and profession. This approach opened new fields of study, especially for such complicated problems as CP.

The “pathological” system concept, laid down by G. N. Kryzhanovskiy, was helped to stimulate further studies in pathology. The pathological process was initially viewed as a result of lesions in existing functional structures. However, it was shown that the process itself does not reflect the total intensity and essence of the situation [Kryzhanovskiy G. N., 1981]. In fact, a new pathological system evolves from elements of damaged physiological systems and creates extraordinary forms of activity and new adaptive mechanisms. Pathological systems are formed under the influence of the hyperactive structure which appears in functionally important sectors of the damaged physiological system; such a hyperactive structure determines the character and effects of the activities in the given pathological
system and so, plays the role of the pathological determinant. The new system works according to new and distinctive regulations.

This concept examines the entire circuit of central neuropathological syndromes, which can be determined by hyperactivity in the system itself. These determining structures play a fundamental role in the activities located in the CNS; their entire concept reveals that these syndromes can be analyzed and then labeled as signs of new hotbeds of stimulation. This also lays the basis for creating adequate pathogenetic models of neuropathological syndromes, and then using them to correct the resulting disorders.

2.1.2 General mechanisms governing the organization of movements in functional systems

When working on the rehabilitation of the human locomotor system, the health professional should be aware of the principles governing the person’s development, organization, and his reserve and adaptive resources in various functioning conditions. It should be clearly understood that the fundamental principles related to structure and functionality in human limb and motor systems contribute to philo- and ontogenesis, special biomechanical features of locomotion and standing erectly on two legs, basic movement coordination, postural conformity and functions of the entire motor system.

Other studies related to the integrative activities of the nervous system contributed largely to improving knowledge in the field of motor coordination. Fundamental and detailed studies on this subject were conducted by Charles S. Sherrington.

Studying the phenomenon of decerebrate rigidity, Sherrington described several principles of reciprocal innervations in antagonist muscles. He proved that afferent muscle innervations and inhibitions of nervous signals were important directive factors for operating organs.

Sherrington demonstrated the role of supraspinal structures in body mechanisms that maintain posture and launch locomotor activity; he explained the role of neural cells in stimulation and inhibition mechanisms; he introduced the synapsis concept; he studied receptive fields and divided receptors into exteroceptors, interoceptors and proprioceptors.
Sherrington also indicated the quantitative superiority of afferent pathways to efferent pathways and predominating inhibitions in nervous signals directed towards operating organs. He formulated one of the fundamental principles of nervous system mechanisms - the principle of a comprehensive pathway. He underlined that the human organism responds to numerous stimuli by producing a small number of movements seen as selected flows in the “terminal comprehensive pathway”.

**Rudolf Magnus** developed new concepts related to the nature of locomotion. Magnus and his students established that the brainstem was the main center for reflex mechanisms involving equilibrium; they also explained reflex mechanisms governing posture and equilibrium.

It was indicated that the brainstem has a complex system of reflex centers, all of which ensure the body’s position in space. Therefore, static reflexes ensure normal posture in standing, sitting and lying, whereas statokinetic reflexes compensate body displacement when the body moves actively or passively.

**Balance reflexes** are invoked by stimulating the inner ear (labyrinth reflex), muscle proprioceptors and neck tendons (tonic tendon reflexes). **Position reflexes** (posture) are directed towards contracting protracted muscles in order to maintain body position. C1 - C3 segments in the spinal cord play a fundamental role in this process.

Muscles and cervical fascia of the spine act as the receptive fields for these tonic neck reflexes. The reflex arch has a polysynaptic character and so, both body and limb muscles are involved in its reaction, whereas eyeball muscles react through centers in the brainstem. This results in a reflex redistribution of muscle tones in the body, limbs and muscles, which control eye position.

**Vestibular reflexes** duplicate tonic neck reflexes. They are connected with receptor stimulation in the vestibular apparatus by means of vestibular nuclei. These reflexes ensure tonic muscle change when the body changes its position in space (position reflexes), favor renewed postural changes (straightening reflexes) and preserve sight orientation in space thanks to eyeball movements.

**Nikolai Bernstein** was the first to analyze movements as an optimal method of perceiving operating patterns in the brain. Studies of human and animal movements were seen as tasks related to managing the complex kinematic system. The task was solved making sensorial corrections and conditioning them to structurizing
required movements. According to Bernstein, the fundamental task facing movement coordination consists in overcoming excessive degrees of freedom.

Various movement tasks can be resolved at different levels in the nervous system. Each level of movement structurization represents a key to resolving definite categories of movement tasks [Bernstein, N. A., 1991].

A key level can resolve any required movement corrections. And so, Bernstein stated that the following concepts were needed: a multilevel organization for movement management, fundamental principles governing the order and sequence of movements, and fundamental levels for regulation. These concepts will then determine the further development of motor functions in ontogenesis beginning at the extrapyramidal systems (Illustration 2.1.2).

N. A. Bernstein was the first to use muscle activity to clarify and explain operational mechanisms in the brain. He laid down the principle of relevance, whereby any arbitrary activity is aimed at achieving a goal, which determines the choice of the act itself. This choice is based on movement conditions and required sensorial corrections. Bernstein was the first to show that the motor neuron is constantly accessible to sensorial corrections. It ensures “repetition without repetition”. The role played by the sensorial correction of movements demonstrated that human motor faculties could be appropriately trained.

*The functional movement system* fulfills its mission by joining the body and limb apparatuses, the life support system and regulation systems. Brain structures carry out and manage the system; they have very high plasticity and are capable of adapting and changing according to specific prevailing conditions. Underdevelopment or damages in some parts of the brain are compensated to some extent by mature or preserved structures. As all other systems, the functional movement system is only a single unit of the entire human organism. They are compounded together dynamically, selectively join central and peripheral formations and are aimed at achieving and exacting adapted activities. [Anokhin P. K., 1975].

This complex system can redistribute afferent impulses dynamically by sustaining their activity at a certain level. The decision phase is the key mechanism governing the entire functional movement system.

Making a decision is a critical stage when freedom of choice must be controlled and complexes of efferent stimulation are organized, all of which are capable of
ensuring the specific act. At this point, the organism should be able to choose one single and unique response among all the numerous possibilities.

The functional movement system is a complex procedure and has not yet been completely identified. It can be analyzed more easily when it is simplified. The motor system can be represented by five fundamental components: 1) rigid link (bone), 2) joint, 3) muscle, 4) motor neuron 5) sensitive nerve ending [Enoka V. M., 1998]. Each component is an important and essential part of the organic link in the comprehensive system.

**The bone component** is the supporting link in the motor system. 206 bones in the body are responsible for stable body support; 85 of these bones form the framework for right-left symmetry. Azygous bones are arranged lengthwise along the body axis and include a series of bones in the skull, spine and sternum. Both the supporting and leverage functions of bones are particularly important in terms of biomechanism. The mechanical properties of the bone depend largely on the interconnection between loading and deformity. It is a well-known fact that the bone responds to deformation by remodeling itself continuously.

**The joint component** is represented by the discontinuous union of bones (in joints) with varying levels of mobility. The number of rotation axes in a joint is determined by the form of its articular surface, whose shapes begins to evolve from the beginning stages of standing and locomotion.
The capsular ligament component ensures stabilized joints. The tension level of the joint capsule, gait and ligament tension direct or confine movements in specific areas. The main elements of articulation can be observed in Illustration 2.1.3

The muscle component ensures targeted movements in the kinematic section, and strengthens joints and tendons. Exrafusal muscle fibers make up the foundation of the skeletal muscle. Intrafusal muscle fibers are disposed in parallel areas, which are arranged in connecting tissue capsules of the muscular spindle. Exrafusal muscle fibers constitute the operational basis of a muscle, whereas intrafusal muscle fibers are the operational basis of the muscular spindle. Working together with the tendinous organ which enlaces tendons, the muscular spindle provides the brain with information about the state of skeletal muscles. Thus, nervous spindle receptors react to muscle contractions, whereas tendinous receptors react to tendon stretching. Exrafusal muscle fibers determine reaction-type answers of the muscle.

An entire group of joint receptors operates together with muscle spindles and tendinous joint organs. Distinguished by structure and arrangement, they send fine information about the state of the motor system. Ruffini end organs detect and inform about internal articular pressure and angular movement velocity, which continue to adapt slowly. Pacinian corpuscles effectively detect and inform about rapid acceleration; they are activated when there are rapid movements independent of their direction. Golgi end organs control tension in ligaments; they are similar to tendinous receptors and also adapt slowly.

Dermal receptors also provide irreplaceable information related to the motor system. These include tactile receptors (Merkel’s disks, Meissner’s corpuscles, Pacinian corpuscles), temperature (Krause’s end bulbs, Ruffini corpuscles) and pain (connected nerve endings, independent nerve endings). Some of them are located
on the surface area (Merkel’s disks, Meissner’s corpuscles), others are found deep within the skin (Ruffini end organs, Pacinian corpuscles). Merkel’s disks are sensitive to vertical pressure and generate rapid, but short-term actions. Pacinian corpuscles are receptors that adapt rapidly and react to rapidly changing tension. Meissner’s corpuscles are sensitive to local tension, but their action potential quickly decreases and ceases. Ruffini end organs react to unidirectional skin stretching. There are very many dermal mechanoreceptors in the bone and foot-sole areas.

Thus, receptors carry information to centers from skin, muscles, tendons, ligaments, joint capsules, fasciae, aponeuroses and others. By integrating all the afferent signals, they also perceive and ensure body position and movement [Moberg E., 1983]. Consequently, the nervous system takes advantage of all accessible information proceeding from receptor apparatuses (Illustration 2.1.4).

These sensorial corrections play an important role in forming and executing movements in the extremities. The quality and conformity of the completed movements are controlled by the CNS and a reverse communication system by means of afferent signals emerging from the muscles. As the number of afferent signals to the brain considerably surpasses the number of efferent signals, the choice of movement in such a situation is dictated by the principle related to “the comprehensive terminal pathway” [Sherrington C.S., 1969]. Sherrington’s “funnel” law is based on a single and unique answer for numerous muscle stimuli. Afferent signals from various receptors flow to the motor neuron of the spinal cord; these signals converge and head for the unique and structurally confined efferent canal. The convergence

Illustration 2.1.4. Diagram of afferent systems which form proprioceptive senses for appropriate movement reactions
mechanism travels through intermediate pathways, gathering signals into a common funnel and finally arrives at its destination (Illustration 2.1.5).

On the whole, the locomotor analyzer is a complex system which treats and transmits information from receptors of the supporting and locomotor apparatuses. It also takes part in organizing and executing movement coordination.

As with other analyzers, the muscle analyzer consists of three sections: stimulus-receiving (peripheral), leading and cortical. Stimulus-receiving sections are located in muscles, tendons, ligaments, joint capsules and the periosteum. Alpha and gamma motor neurons in the spinal cord receive regulating effects from brain structures and transmit orders to the muscles.

These orders are adjusted by proprioceptors of muscles, tendons and joint capsules. When all the nerve structures react together, they ensure and regulate ordinary movements (Illustration 2.1.6).

The process of motor management is undoubtedly more complicated than any other pattern; it includes regulating the systems for muscle tone, support for body balance, current and emergency neuromuscular provisions for body position and movements, and many others. A greater understanding of these complex systems can be reached by simplifying these patterns.

Mastering and improving movements represent a complicated and multidimensional task. All locomotor features are interconnected when a comprehensive locomotor action is to be executed. However, when studying patients with CP, the specialist should pay attention to fundamental movement disorders. It is not only necessary to assist body biomechanisms by mastering and improving required movements, but also to take into consideration future kinematic possibilities.

An athlete becomes thoroughly skilled in sports techniques and improves his muscle sensitivity, sight and hearing acuteness, sense of balance and other specific qualities connected with his specialized field in athletics. In the same manner, locomotor analyzers, which play a major role in actual movement activities, should be specially trained when affected movements in patients with CP are being examined or rehabilitated. This should be kept well in mind; otherwise, any kind
of biomechanical locomotor technique will become a mere formality of movement actions and will not lead to stable and conclusive results [Keller V. S., 1993].

Manual work, heat, apparatuses and other factors have an effect on all types of receptors and take into account their reaction; they also allow the locomotor system to be activated, and thus, constitute one of the key component for success in rehabilitation using the Kozyavkin Method.
2.2. Theoretical principles of therapeutic acts according to the Kozyavkin Method

Organic lesions of the nervous system in patients with cerebral palsy are accompanied by secondary changes in the musculoskeletal and other systems of the body. Muscle hypertonicity and shortening appear as initial disorders of a patient’s neural regulation; these manifestations lead to developing muscle contractures and body asymmetry.

Modifications in the proprioceptive systems, which ensure kinesthetic sensitivity, constitute another important link in CP pathogenesis. Excessive muscle tension decreases the patient’s perception of the surrounding world, raises his blood pressure, limits movements, and heightens the risk of trauma [Larson L.A., 1973].

Functional blockage in the joints in patients with CP also contributes to the distortion of the proprioceptive flow of information to the brain structures. The blockage of joints in the spine maintains pathological afferentation. However, most researchers studying problems related to CP have not paid enough attention to these blockages.

Rod Dishman [Dishman R., 1985] and Charles Lanz [Lanz C. A., 1995] worked out a model of functional blockages in the vertebral motion segments of the spine. They also suggested that an entire complex of changes, including pathological afferentation from the extremities, and muscular, tendinous and vascular disorders would appear if movements in vertebral motion segments (VMS) were limited. Such disorders may cause concomitant and inflammatory reactions, or structural, functional, and biochemical modifications in the body (Illustration 2.2.1).

The immobilization of specific parts of the spine and a loading increase on some functional parts of the joints play a significant role in developing functional blockages in the joints of the spine. Muscle spasticity cause immobility of vertebral motion segments (VMS). High muscle tone contribute to modifications in the configuration of the spine, further disorders in its biomechanical functions, increasingly loaded parts of the body, and overloaded areas in the proximity of the spine.

It has been established that functional blockages are not limited to one single vertebra, but may cover several levels [Kozyavkin V. I., 1996]. Polysegmental blockages in the spine cut off a specific part of the spine, disturb the function of certain vertebrae in the spinal cord and have a negative effect on all the systems connected with the given vertebrae. If functional blockages appear, they can lead to disorders in more important vertical links located near the vertebrae of the spinal cord, namely the trunk, cerebellum, basal ganglia, or the telencephalon cortex.

Therefore, functional blockages in the joints do not cause problems with regard to their actual location, but raise the question of modifications that occur in other
functions of the organism. A child with CP is hampered by movement disorders if he
wants to train his locomotor functions, or his motor development suffers delays at a
certain stage of development. When functional blockages of the spine appear, the
child inevitably displays pathological movement stereotypes. This situation leads to
a vicious circle, which then represents a daunting task for rehabilitation specialists.

There is some cause for optimism, however, as these functional blockages set in
and develop very gradually. And so, Stoddard distinguishes between five levels of
functional blockage - from a zero option with total lack of mobility to the IV level
four more levels of functional blockage with increasing levels of severity. It is a well-
known fact that mild forms of blockage “with reverse efficiency from the starting
point” can be observed in children. Thus, the effects caused by unblocking the
joints can be seen in children before their joint elements start to develop dystrophic
changes. Once again, these phenomena underline the fact that it is both possible
and indispensable to encourage and work out early corrections of functional joint
blockages in children with CP and in other groups of high-risk children.

An innovative method for biomechanical correction of the spine and the extremities
was elaborated so as to correct joint and ligamentary systems in children suffering
from CP [Kozyavkin V. I., 1989]17. This original procedure lays the basis for the
Kozyavkin Method; it eliminates functional blockages in vertebral motion segments,
restores mobility in the joints and opens “the gates” for the flow of proprioceptive information to the CNS.

The positive effects of this procedure are not restricted only to rehabilitating mobility and movement in the joints. Other body systems begin to normalize their work and a new functional condition develops in the organism. The clinical picture shows normalization of muscle tone, increase in blood circulation in the tissues, an activated metabolism and more active tissue trophism. As a result, the child builds up more and more integral capabilities for further motor, cognitive and speech developments (Illustration 2.2.2).

The Kozyavkin Method is built on and evaluated by organizational and functional principles in the human organism, which lay the theoretical grounds and practical application of the said method. Specialists set up tasks for rehabilitating patients with CP by searching for optimal ways to restore the affected structures. They take into account the patient’s age, individual characteristics related to body organization, the actual functioning of different musculoskeletal structures, and above all, the spine.

### 2.2.1. The spine viewed as an object for biomechanical correction

The biomechanical correction of the spine is the basic principle of the Kozyavkin Method for rehabilitation treatments. It takes into account the patient’s age, his
individual characteristics and, most important, his specific body organization and the functional qualities of his spine.

The age of the spine often determines its functional capabilities. The individual characteristics of the spine are directly connected with its further development so, any disorders in the spine may contribute to structural developments of spinal abnormalities. The human spine has a specific feature which is closely associated with the vertical position of the body itself. This feature differentiates the evolution of the spine in humans from that of four-legged creatures and also, its relationship to the terrestrial gravitational field.

The human spine develops around the notochord (dorsal cord) taking its origin from primitive body segments called somites. Somites are divisions distributed along the two sides of the cord and the neural tube. They are divided into three compartments: the dermatome, myotome and sclerotome. The myotome is the intermediate compartment and the source of developing musculature in the body; the dermatome forms the connective tissues of the skin, and the sclerotome, lying adjacent to the neural tube, is responsible for developing bone and cartilaginous tissues. Somites run along the longitudinal axis of the body and are metamerized from the base of the cranium to the caudal vertebra. Metamerism is completed by the 35th gestation day when 43 - 44 pairs of somites are formed and organized in the body [Patten B. M., 1959].

Cell activity in the sclerotome section of the somites, which form the human skeleton, is stimulated by the dorsal and spinal cords. Although sclerotome cells...
possess chondrogenous properties, they can only take part in forming the elements of the human skeleton with the assistance of stimulants from the dorsal cord and the ventral side of the spinal cord [Holtzer H., 1953]. The spinal cord also has an effect on the migration of sclerotome cells. The dorsal cord determines the space orientation of skeletogenic tissues, that is, it imparts significant information to a skeletogenic tissue on its exact position in space and so, acts as an axis which directs skeletogenic tissue differentiation (Illustration 2.2.3).

There is a universal mechanism for all living creatures with regard to organization in space. Here, it concerns the axis along which cells differentiate and the polarity which directs and evaluates positional information [Wolpert L., 1972]. The dorsal cord acts as a master mould of the spine and the primary body axis; it is a provisional structure in humans which dates back to ancestral times and reflects an important biogenetic law developed by Ernst Haeckel, whereby ontogeny recapitulates phylogeny. Some lower vertebrate species have retained the dorsal cord as a permanent axis. Mammals present apertures in their vertebral bodies and only a simple fragment of the dorsal cord is preserved in the central section of the intervertebral disc region (Illustration 2.2.4).

Illustration 2.2.4. Diagram showing the development of vertebral bodies and intervertebral discs. The position of the dorsal cord (black band) displays orientation in space of skeletogenic tissues [Patten B. M., 1959].

This residue of the dorsal cord in the intervertebral discs provides the vertebral pulp in four-legged animals and also, in the human spine during earlier evolutionary stages.

When the initial evolutionary phase has been completed in humans and notochordal cells in the vertebral pulp have been reduced, the internal layer of the annulus fibrosus starts to grow and a new nucleus pulposus with wider functional capabilities develops gradually in the intervertebral region [Sak N. N., 1991].
The ontogenic program must be adhered to very strictly when the human spine is being formed. In this case, the following factors are indispensable: stimulating effects from the spinal cord, an accurate and precise axis orientation of the dorsal cord, and a timely reduction of its elements. Positional and structural abnormalities may appear in the spine if these conditions are disturbed in any way.

Development, which starts at the somites, is reflected further in segmental elements that build up the spine. The vertebral motion segment (VMS) is a structural and functional unit of the spine [Schmorl G., 1932]\textsuperscript{23}. The VMS includes some adjacent vertebrae (“hemivertebrae”), the intervertebral disc which connects vertebral bodies, pairs of zygapophysial (facet) joints which connect articular vertebral processes, the ligament system, groups of paravertebral muscles, vessels and nerves. The interrelation between forming structures is presented in Illustration 2.2.5.

The integrated vertebrae form a curvilinear core called the spine, which constitutes the central axis of the body, and protects both the spinal cord and nerve extremities.

One of the most significant features of the human spine is its ability to bend and flex at the sagittal plane. The spine perceives loading according to the principles governing a multi-flexed coiled spring and a reinforced lever. Spinal flexions evolve as the child learns to sit, stand, and walk; they are finally completed between 10 - 15 years.

The intervertebral discs play a leading role in ensuring these flexions. In normal lordotic curvature, these discs are wedge-shaped and set in a curve that has its convexity anteriorly (in the front).
Various modifications of spine flexions causing scoliosis, kyphoscoliosis and other deformities can be observed in patients suffering from CP. Therefore, rehabilitating normal flexions has become an important therapeutic stage for normalizing the functions of the spine.

The movements of the spine are very similar to those of an elastic shaft attached solidly to a support (Illustration 2.2.6). These movements are guided and controlled by zygapophysial (facet) joints, whereas they are limited by the ribs in the thoracic area.

The degree of movement depends on muscle plasticity and the intervertebral discs, the shape and orientation of the articulated zygapophysial surfaces, and the degree of elasticity in the capsules and adjoining ligaments. It is the orientation of the articulated surfaces in the zygapophysial joints that determines the movements in the different parts of the spine (Illustration 2.2.7); manual therapy can have a direct effect on its orientation [Dvorak J., 1984]26.

The neck and loins are the most mobile and active parts of the body. The general range of flexion and extension of the spine in individuals who are between 20 - 55 years old is estimated to reach 117 degrees on the average (78 degrees - flexion, 39 degrees - extension) [Nikolayev L. P., 1950]27.

The functions of the spine are also associated with the interconnection links between vertebral bodies - the intervertebral discs. The intervertebral disc is the largest avascular structure in the human body with a diffuse type of alimentation. Specific biomechanical features of disc sections provide all types of collagen.

The external spheres are filled with type 1 collagen, which assists stretching movements; the deeper spheres are alimented by type 2 collagen, which possesses
specific elastic properties [Eyre D. R., 2002]. The specific architectonics of the intervertebral disc can also be defined by the unique system of all its interacting components: the annulus fibrosus, nucleus pulposus, and hyaline laminae adjoining the vertebral bodies (Illustration 2.2.8).

Illustration 2.2.7. Graphic representation of the orientation and inclination of joint facets in the vertebrae
a) in the neck region (C4), b) in thoracic regions, c) in lumbar regions of the spine [White A., 1978]28

Illustration 2.2.8. Diagram of the human intervertebral lumbar disc [Sak N. N., 2003]30
Intervertebral discs support axial loading and distribute it towards further tangential efforts; they also act as shock absorbers during locomotion. The structural integrity of an intervertebral disc is an important condition for the spine to function normally. Lesions in an intervertebral disc usually lead to degenerative and dystrophic diseases in the spine.

As a rule, lesions in the spine are connected with its functional activities and the subordinate type of alimentation. The biomechanical properties of the disc are largely connected with the properties of the collagen fibers and the high contents of proteoglycans, which fix water molecules. The direction taken by flowing nutrients is dictated by a complex internal organization of its territorial matrix. The primary nutrient pathway in an intervertebral disc runs laterally along the vertebral bodies. Nutrients are diffused into the disc from adjacent vessels of vertebral bodies through numerous selective barriers located in the hyaline plates [Shibuya K., 1970]. This is the main pathway, but not the only one; diffused nutrients also flow laterally along surface vessels in the periosteum and annulus fibrosus. It is highly probable that these flows run in the opposite direction when the disc undergoes loading and unloading stress (Illustration 2.2.9)

Hemo-synovial barriers operate on the limits of blood vessels and the disc itself, ensuring and selecting the diffusion. They also regulate the flow of required combinations, and protect avascular tissues from alien substances. Capillary endothelial cells constitute the main morphological substratum of these barriers.

A human possesses several distinct characteristics, one of which is erect standing and walking. These features have their own corresponding “key regions” in the spine and include zones of high functional loading. These are segments located in the lordosis vertex and the interjacent regions. Movement directions are modified when
The orientation of joint facets is altered in the interjacent regions (cranial - vertebral transition C0 - C1, cervical - thoracic transition C7 - T1, thoracic - lumbar T12 - L1, lumbar - sacral L5 - S1, and sacral - coccygeal S5 - Co1).

These key regions are functionally important, but dangerous with regard to potential joint blockage or dystrophic lesions in the spine. Therefore, the specialist should be very careful when manipulating the spine.

Other potentially dangerous zones where injuries may occur are located in functionally active areas of the spine, which do not coincide with the transitional zones. Thus, the torsion center in the spine in a reclining position corresponds to level T7 in the vertebra [Lewit K., 1980]33. At this level, the transition is made between turning the superior part of the spine and the shoulder girdle to one side and turning the inferior part of the spine and the pelvic girdle to the other side [Gregersen G. G., 1967]34.

The spine is protected by paravertebral muscles. These autologous and autochtonous muscles are organically connected with the evolution of the spine, and constitute both the main structural and functional elements of the spine, namely its “antigravitational organ” [Popeliansky Ya. Yu., 2003]35. They operate according to their own rules: they relax when they approach the attachment point, and become strained when they move away; when the trunk bends leftwards, the muscles on the right side of the body become strained, whereas the muscles on the left side relax; the opposite occurs when the trunk bends rightwards.

Sudden movements, traumas, or prolonged and uncomfortable body positions make the paravertabral muscles react; spastic muscles disconnect the corresponding vertebral segment from actual movement. The joints function together as protective forces and block all functions. However, if such a state is maintained for a certain period of time, the same protection measures may act in a completely opposite way. Functional rhythm in the disconnected vertebral segment becomes distorted, tissue nourishment starts to be affected, cross arrangements in the vertebral canal and intervertebral foramen are modified, and difficulties arise in the flow of blood and cerebrospinal fluid.

The Kozyavkin Method has been in practice for some years. Specialists use this method to eliminate functional blockage by making use of manual therapy, which repeat and incorporate these joints into ontogenetic stages, from proximal to distal regions of the body. If the joints are successfully unblocked, muscle tone in the intervertebral muscles is corrected, blood vessels, nerves and the brain membrane are normalized, and their interaction is renewed. The flow of blood and cerebral-spinal fluid is restored, tissue trophism starts to increase, proprioceptive impulses are activated in the superior centers of the brain. As a result, the organism develops a new functional condition, which acts as a fundamental support for further rehabilitation treatment.
2.2.2. Morphofunctional principles of rehabilitating bone and joint systems in CP patients

The shape and function of bones are determined by deformities which occur when the bones undergo loading or strain. Functional modifications correspond to certain laws of mechanics and display internal modifications in the internal architecture of the bone [Carter D.R., 1987]. A remodeling process is adapted to the functional modifications in the bone, namely, bone reconstruction, which includes bone rearrangement and resorption of bone structures. Osteogenesis (bone formation) prevails over resorption processes in children and ensures bone development and formation in the body. These two processes should be balanced so that the functional attributes of the bone are entirely preserved. The entire cycle of bone structure modifications in the extremities lasts 10 - 20 years in an adult. Modifications of the compact and spongy substance are a hysto-biomechanical expression of the internal remodeling of the bone.

Bone plates are the elementary vectors for bone tissues; they form compact layers and concentric structures (osteons) in the bone. The osteon has a central canal with a concentric layered system which lies contrariwise to the directed bone plates. Osteons measure a mere 200 µm in diameter, but they allow the bone to sustain very high axial loading (up to 30 kg / mm2). Osteons are considered to be the fundamental structures of strength and solidity, whereas the number and maturity levels of osteons constitute the mechanical strength of the bone. The compact bone contains the largest number of osteons. When the body is subjected to physical strain or loading, the number of osteons increases; when loading decreases, their number is also reduced. When a person's physical activity increases, bones become more mineralized, and they display a higher density and strength; this can be observed especially in athletes [Colletti L., 1989]. Conversely, when loading is reduced, there is a significant loss in bone weight, the number of osteons decreases and the bones become demineralized and weak [Zernicke R.F., 1990].

The spongy bone can also be easily remodeled. Trabeculae in the spongy bone form arches and spirals that correspond exactly to the axial loading. The mechanical properties of the spongy bone structure are very close to those of compact bones. This can be clearly observed in the bones of lower extremities, and especially in the foot (illustration 2.2.10).

A child suffering from CP displays strained and loaded bones. These present internal deformities, the axial fibers are stretched, and the orientation of bone cells, bone plates and bone trabeculae is affected. Myogenic contractures and faulty arrangements in body links can cause internal and external deformities in the bone. If strain and loading are not adequately adapted, the overall adaptive reconstruction of body tissues is severely affected and bones become deformed. Contracting and stretching vectors, which also influence the human skeleton, are modified in patients with CP; they have a damaging and disturbing effect.
However, apart from prolonged loading, there are other unfavorable situations where the bone is underloaded, which may lead to a potentially dangerous demineralization process in the bone tissues or a bone fracture. Nevertheless, bone tissues are highly capable of regenerating themselves. Osteoblasts are cells responsible for bone formation; they are capable of renewing bone defects in the newly-formed bone tissue, reconstructing the bone according to its functional needs, providing reliable fixations for fragments, and modeling the final bone structure.

Bone growth and modeling are genetically programmed, but further development also depends on the work done by the attached muscles and levels of physical loading. Intermittent and pulsating loads greatly activate bone growth although the bone is capable of responding with a burst of growth when bones are stretched for an extended period of time. These factors contributed to forming the basic principles of the compression and distraction method of treating bone fractures founded by Professor G. A. Ilizarov.

Gradual and prolonged distraction can activate bone growth in children with CP. Furthermore, when muscle contractures have been eliminated, the bone seeks to execute its genetic program and responds positively to the burst of growth, both lengthwise and diametrically.

Joint modeling is affected when movements are restricted or completely lacking as the range of movements is greatly confined. Kinematic links are disconnected and so, the evolution of the epiphyseal cartilage and the longitudinal growth of the bone are delayed. Both prolonged physical overloading and underloading amplify dystrophic processes in cartilaginous tissues.

On the whole, modifications of bone, joint, and muscle systems in children with CP have not been adequately researched either in theory or in practice. However, it has been established that such modifications determine the patient’s musculoskeletal apparatus, which limit rehabilitation treatment processes.

Rigidity prevails over paralysis in some forms of CP. Emerging myogenic contractures contribute to bone deformities, and affect the direction and level of the loaded musculoskeletal links. This situation determines bone remodeling processes, modifies the shape and inner bone structure, and usually causes local
overloading in joint cartilages. The most significant clinical manifestations can be observed in overloaded and deformed cartilages, all of which affect the growth the child's longitudinal skeletal bones.

Ischemia develops in the tissues and affects the microcirculation system. In addition, the inner capillary pressure decreases, blood circulates more slowly, and the number of functioning capillaries also diminishes. The number of red blood cells also drops, and some blood-carrying capillaries are transformed into plasmatic ones. Tissues are deprived of oxygen and the patient begins to show signs of hypoxia. Thus, tissue structures are modified, and their mechanical and connective properties, such as elasticity, extensibility, and load resistance are greatly reduced. In this way, the ligaments, fasciae, aponeurosis, joint capsules, and muscle tendons are gradually modified.

The earlier these body modifications undergo rehabilitation treatments, the more successful the outcome will be. If no treatment is applied or if it is started too late, such bone and joint modifications continue to grow and develop, and deformed body structures begin to set in gradually. These manifestations are a mere background for dystrophic structural lesions and its diffusive nourishment, which appear in intervertebral discs and joint cartilages. Therefore, when specialists are faced with the problem of treating children with CP, they should first work on the osteochondrosis symptoms in the spine and dystrophic pathologies in the joints, and also, take into consideration all kinds of methods related to diagnostics, treatment, rehabilitation, and prophylactics.

Prolonged overloading or underloading in the intervertebral discs affects the rhythmic diffusion of its nourishment, and allows tissue hypoxia to develop and set in. Experimental hypokinesis shows that structural modifications occur if the number of capillaries is reduced in the subcartilaginous sections, all of which point to disturbances in metabolic flow and tissue oedema in the intervertebral disc. The volume of vertebral pulp increases, its cells are dispersed through the matrix, fiber plates diverge, and activities in the fermented cell systems of the annulus fibrosus continue to decrease [Sak A. E., 2001]^{19}.

The number of capillary beds located in the vertebral bodies at the extreme ends of the cartilaginous structures is reduced, and the bone marrow content in the medullary space also decreases (Illustration 2.2.11). If blood is not supplied to the vertebral bodies, the diffusion of nourishment in the intervertebral discs becomes affected. As a result, dystrophic lesions appear in the tissues. This reduces the viscoelastic properties inherent to discs and leads to developing rigidity in the spine.

Similar modifications appear in other bradytrophic and connecting tissue structures, such as joint capsules, ligaments, muscle tendons, the fasciae and aponeurosis. Prolonged muscle shortening restricts all joint movements. More specifically, such functional contractures can also be observed in healthy children who have remained in the same position for a certain length of time [Nikolayev L. P., 1950]^{27}.  

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Theoretical principles of rehabilitation of motor disorders. The Kozyavkin Method
2.2.3 Morphofunctional principles of rehabilitating skeletal muscles in CP patients

The human musculoskeletal system is very clearly and distinctly organized; it includes muscles acting as organs, muscular fascicles and muscle fibers. The muscle

Illustration 2.2.11. Bradytrophic tissues in the intervertebral lumbar disc following prolonged experimental hypokinesia. [Sak A. E., 2000].
AF - Annulus fibrosus VP - Vertebral pulp MC - Medullary canal without bone marrow elements

Illustration 2.2.12. Diagram of the sarcomere
fiber is the structural unit of a single muscle. It resembles a muscle cell measuring up to 40 mm in length and 0.1 mm in diameter; it is divided into Z-lines whose segments are called sarcomeres. The sarcomere is a structural and functional unit of the muscle fiber. Contractile protein operating within sarcomeres can be found in muscle fibers (Illustration 2.2.12).

Muscle shortening is caused by interacting contractile proteins. At first, it can be viewed as a large and spatial interplay between thick and thin myofilaments. Thick filaments consist primarily of the myosin protein, whereas thin filaments consist primarily of the actin protein. These thick filaments are found in the central part of the sarcomere and are called A-bands (for anisotropic), whereas the thin filaments are found on the lateral sides; they are called I-bands (for isotropic). On the whole, each sarcomere consists of a dark A-band and two surrounding I-bands, and constitutes the basic unit of cross-striated skeletal muscle fibers.

The thick filaments have loose ends (heads); they extend from the Z-line of the sarcomere and bind to the giant protein titin. Titin operates as a molecular elastic, and ensures the structural integrity of myofibrils when muscles contract. One of its heads penetrates through the Z-line and connects with the titin filament of the other half or the sarcomere.

The thin filaments contain actin, tropomyosin, and troponin. Actin is composed of two spiral-like chains of actin filaments (F-actin). The tropomyosin protein resembles a double spiral; it forces its way into a groove situated between two spiral-like binding chains on the F-actin filament. Troponin is attached to certain parts of the protein tropomyosin (Illustration 2.2.13).

The length of the thin filaments is controlled by the actin-binding protein filament called nebulin, which runs from the Z-lines to the free heads of the thin filaments.

Movement activities demand coordinated and concerted work between many muscles so that the body can maintain posture and ensure smooth movements. Attention should be drawn to mechanisms of muscle tone regulation. Two factors determine muscle tone: a) the mechanical and elastic characteristics...
of connective and muscle tissues; 2) the contractility reflex in muscles (tonic reflex for extension).

The first factor is referred to as the “internal rigidity” of muscle tissues; it plays a major role in developing or sustaining spastic hypertonia. To a certain extent, a muscle is similar to a coiled spring whereby its reverse strength of action is proportional to modifications in its length; the spring itself also depends greatly on the elasticity of the material and what material it is made of.

However, the major role in developing and sustaining muscle tone belongs to the functional state of segmental arches in the extension reflex (myotatic reflex). The muscle spindle is the receptor element of the myotatic reflex (Illustration 2.2.14). Each muscle has a certain number of these receptors. The muscle spindle consists of

*Illustration 2.2.14. Diagram of the muscle spindle [Marieb E., 1997]*

intrafusal muscle fibers, which are much thinner than extrafusal muscle fibers, and the nuclear bag, which is wrapped in a spiral-like net of thin nerve fibers; the latter are the primary end buds of sensitivity and excitation.

Some intrafusal fibers have secondary grape-like nerve endings. When intrafusal fibers are stretched, the primary sensory nerve endings intensify the inflow, which travels via leading and fast-moving la-type fibers to the large alpha-1 motoneurons
in the spinal cord. The impulse then continues via other leading and fast-moving alpha-1 efferent fibers to the white extrafusal muscle fibers, which drive the muscles to contract rapidly (phasic reflex). The secondary sensory nerve endings react to muscle tone; afferent inflow is transmitted along the thin II-type fibers via internuncial neurons to small alpha motoneurons, which innervate the tonic extrafusal fibers (red muscle fibers) responsible for body tone and posture.

Intrafusal fibers are innervated by gamma motoneurons located in the anterior horn of the spine. When the gamma motoneurons have been transmitted along the gamma fibers to the muscle spindle, they become stimulated, causing the polar sections of the intrafusal fibers to contract, and the stem body to stretch. The initial sensitivity in the receptors is thus modified, that is, the excitability threshold of the extensor receptors decreases, whereas tonic muscle strain increases.

Gamma motoneurons are affected by central (suprasegmental) actions which are transmitted via the fibers travelling from the motoneurons located in the brain along the pyramidal, rubrospinal, reticulospinal and vestibulospinal tracts. In such a way, muscle tone can be regulated directly by the brain; this is most important for performing arbitrary or spontaneous movements. But, the pyramidal system chiefly regulates the phasic (that is, fast and purposeful) components in arbitrary movements, whereas, the extrapyramidal system facilitates the smoothness of the same arbitrary movements, and “resets” them to determine the task, that is, it mainly regulates tonic muscle innervation.

Neurogenic mechanisms for regulating muscle tone are complex and diversified. The following mechanisms take part in regulating muscle tone: inhibition mechanisms controlled by Golgi receptors located in muscle tendons, and internuncial Renshaw cells situated in the anterior horns of the spine. Renshaw interneurons receive excitatory collateral from stimulated alpha motoneurons and act inversely, that is, they inhibit alpha motoneuron activities. The Golgi tendon receptors send afferent impulses when they stretch or when they are under considerable strain; these impulses are transmitted along the fast type 1b muscle fibers to the spinal cord and inhibit the motoneurons in the anterior horns.

The Golgi tendon organ (illustration 2.2.15) reacts to muscle stretching and other changes in muscle force; it relays information about the stretching muscles back to the brain. This neurotendinous organ is composed of a separate afferent and does not have any efferent endings [Jami L., 1992]. The number of these tendinous organs in the tendons is not very high. Each one is enclosed in a fibrous capsule and, as a rule, is located round the extrafusal muscle fibers joined to the tendons themselves. Up to ten extrafusal muscle fibers are attached to the capsule of the neurotendinous organ; moreover, each one is innervated by different alpha motoneurons.

Collateral fibers are an essential part of tendons; they are also attached to the neurotendinous organ. When the muscle stretches, collateral tendon fibers draw together and compress the Golgi tendon organ receptors, thus potentiating the actual act. A single muscle fiber can activate the neurotendinous organ, but two
newtons are needed to activate the same organ when the muscle stretches passively [Binder M.D., 1977].

Skeletal muscles have a special feature called satellite cells (G1 - myoblasts), which constitute the cambium reserve for muscle tissues. Satellite cells are found between the basement membrane and plasmolemma of individual muscle fibers; the number of their nuclei totals up to 10% of the nuclei in muscle fibers. These cells ensure the lengthwise growth of muscle fibers. Moreover, satellite cells can undergo myogenic differentiation during a person’s entire lifetime, and they take part in restoring skeletal muscles in response to injuries or strain. Embryonic myogenesis is certainly repeated during the reparative regeneration of musculoskeletal tissues.

This particularity of skeletal muscles is an extremely important condition when muscles are being rehabilitated in a patient with CP.

Muscles are modified if muscle functions are missing or if the patient is immobilized for any reason whatsoever (hypokinesia, injuries, space travel). No other body tissue reacts so clearly and distinctly to immobilization as the muscle tissue.

All these modifications can be particularly well investigated when denervation occurs after a nerve has been damaged. Denervated muscle atrophy is manifested by a decrease in muscle weight, atrophy of muscle fibers, decrease in contracting force, tetanic force, arbitrary force, and an increase of fatigue [Duchateau J., 1987]. In cases of full denervation, it has been observed that atrophy develops very quickly in denervated muscles; within a period of two months, both white and red muscle fibers are affected to an equal degree [Stonnington H.H., 1973]. Overall muscle weight drops between 20 - 40% during this period. Muscle fibers are substantially modified at all levels, macro-, micro- and ultrastructural. Enzyme activity decreases, contractions in the muscle fibers slows down, and the correlation between tetanus and contractions also decreases. These phenomena limit movement substantially as all body movements call for a great number of muscles to be included. For example,
when a person takes a step forward, 300 muscles are activated in this process. Furthermore, each muscle has a double efferent innervation from movement nuclei and autonomic ganglions regulating muscle trophism, and is coordinated with double innervations of blood vessels nourishing the muscles. Besides that, the motoneuron determines the contractive activity in muscle fibers, and transmits chemical messages to the fibers. These trophic effects are reciprocal as muscle fibers also exercise a similar influence on appropriate nerves.

The organic interaction between the motoneuron and the muscle fiber is undoubtedly affected in a patient suffering from CP. Hypoplasia and atrophy of some muscle fibers occur in children with CP; they are the result of musculoskeletal denervation. Within a few months, these muscle fibers degenerate even further, and necrosis begins to set in.

Nevertheless, even neural lesions affecting muscles can be directly stimulated. With time, cyclical regeneration and repeated necrosis can be observed in denervated muscles [Schmalbruch H., 1991]45. The denervation processes in muscle fibers are partially or completely reversible when rehabilitation is carried out on innervating and denervating muscles. It is possible to regenerate muscles completely if a synaptic connection is established between the axon and the denervated muscle; partial regeneration can be achieved thanks to collateral ligaments. Axon nodes can form new connections with muscles at terminal or preterminal junctions arriving from Ranvier’s region of constriction [Ulumbekov E. G., 1997]46 (Illustration 2.2.16).

The regenerated axons are thinner and relay impulses more slowly. Schwann cells provide pathways for regenerated axons. When a synaptic connection has been established with the muscles, the diameter of the axis cylinder increases and a thick myelinated envelope starts to grow [Schroder J. M., 1972]47. It is characteristic of trophic nerve actions to have an effect on muscle fiber stretching.

Muscle modifications are potentiated by tissue hypoxia in patients with CP. The filtration of capillary fluid increases in weakened muscles and there is a possibility of developing oedema. Blood flow becomes more difficult in hyperactive and especially, spastic muscles; the capillaries and small vessels are compressed. When muscles become spastic, tissue hypoxia is accompanied by an increasing inability
of the muscle fibers to relax. If these disorders set in for a prolonged period of time, dystrophic processes continue to evolve in the muscles. The expansion of dystrophic processes then limits movement activities in muscle endings and deeper paravertebral muscles.

Children with CP show developmental and growth disorders as well as disorders in bone, joint, and muscle morphogenesis. Muscle organization at the organic level is also affected; this is manifested by the correlation between “muscles and tendons” when tendon length increases. Similar modifications can be seen in muscles suffering under prolonged static overloads [Ivanitskiy M. F., 2003]. Muscle contraction and tendon extension are due to a prolonged state of increased muscle tension. Similar reactions are particularly characteristic for biarticulated muscles in the extremities, namely, shoulder and thigh biceps muscles, and the gastrocnemius muscle. In fact, distal tendons attached to the long head of the biceps brachial muscle may be palpated under the skin; they feel like thin and compact bands or cords that are longer than the muscle by a half. Muscle tone may increase in such cases to reach a stone-like density. All these manifestations are accompanied by a decrease or a complete lack of muscle elasticity.

The preserved muscles, which are closely and functionally associated with the spastic muscles, also undergo certain modifications. Either they become tense and strained, or they show decreased muscle tone. Hypotonic muscles tear the muscle chains apart, and often cause further movement disorders. Hypertonic muscles complicate the general clinical picture as both phasic and tonic muscles can react to increasing muscle tone. The child does not make use of spastic muscles during ambulation; he prefers to substitute other muscles instead, thus provoking his body to adopt forced postural positions and assume a non-physiological type of locomotion.

An important role in the pathogenesis of muscle modification is played by dysfunctional myofascial tissues associated with painful muscle syndromes. One of the causes of pain can be attributed to the hyperirritability of certain tissue regions - trigger zones or trigger points (TP). TP are highly sensitive regions of the body; they are very painful when compressed. Normal muscles do not have a TP; they are not at all painful when compressed and do not display any twitching reactions.

Myofascial tissues have not been adequately explored in children with CP. Nevertheless, it is a well-known fact that TP often develop in children [Bates T., 1977]. Morphological research and neurophysiological investigations related to muscular pains enabled specialists to understand the reasons for these body modifications, and make full use of them in the course of rehabilitation treatments.

Miehlke and his co-authors conducted research on close to 70 biopsies of spinal muscles [Miehlke K., 1960]. These muscles showed clinical signs of extremely active TP, and were found to contain dystrophic modifications in tissues. The muscle fibers lacked a cross-striation, and parts of the muscle fibers had been replaced by adipose and connective tissues. Research studies further demonstrated that muscle compression may be due to glycosaminoglycan infiltrating the tissues [Award E., 1973]. These modifications may be the result of an energy deficit in the zone of...
prolonged ischemia, which is indispensable for a normally functioning metabolism. At present, researchers have traced much finer biochemical modifications in tissue zones affected by ischemia.

Contractile modifications in both muscles and muscle tissues contribute to TP formation. All muscle cells, including contractile cells have actomyosin and chemomechanical transformers. Cells of connective tissues contain myofibroblasts, which possess properties inherent to fibroblasts and smooth-muscle cells; they are able to synthesize smooth-muscle actins and myosins, which may cause contractions in the tissues [Harrison J., 1979]. These factors may explain the spastic modifications in the fasciae, intermuscular septum, joint capsules, ligaments and other fibrous formations. Spastic tissues show increasing signs of hypoxia, which tends to fix these modifications and potential dystrophic disorders in the tissues.

TP related to dermal, ligamentous, periosteal, fascial and myofascial regions of the body are well known. Myofascial TP areas usually show increasing irritability in strained muscle and fascia bundles. Disorders of venous blood flow and a deficit of microcirculation in the muscle contribute largely to provoking myofascial TP. TP formations also reflect certain proprioceptive and autonomic disorders.

Myofascial TP were thoroughly explored by the renowned American doctors, Janet Travell and David Simons [Travell J., 1989]. The authors distinguish several types of myofascial TP: active, latent, primary, associated, satellite, and secondary. Favorable condition for the formation of almost all types of TP can be found in patients suffering from CP.

Associated TP appear when muscles become overloaded due to their heightened activity, which is aimed at compensating inadequate activities in other muscles. Satellite and secondary TP are variants of associated TP. The satellite focus of hyperactivity in the muscles and fasciae is concomitant owing to the fact that it is located in the actual affected zone reflected by another TP. The secondary TP appears in an overloaded muscle, whose functions are closely connected with the muscle affected by the primary TP, that is, either in synergist or antagonist muscles.

 Practically speaking, it is more convenient to distinguish between active and latent TP [Travell J., 1955]. Active TP tend to form in muscles which have been immobilized or shortened for an extended period of time. This kind of TP is very sensitive and prevents the muscle from stretching completely. Latent TP is the focus for increased activity in the muscle or fasciae; it weakens the muscle, hampering extension and limiting movements. It can be palpated by the specialist.

When muscles with TP are required to increase their functional activities, they react weakly and painfully. This pain increases during stress periods for a few minutes, and then, it decreases. Characteristic referred patterns of pain occur when there is kinesthetic (pressure) stimulation of a TP, followed by a localized convulsive response - the muscle twitching symptom. On the whole, TP are immediately
activated when the muscle is acutely overloaded, physically overexerted, injured or cold (Illustration 2.5.17).

These phenomena also appear in patients with CP. The Kozyavkin Rehabilitation Method provides for the consecutive elimination of TP. As a result, pain syndromes decrease, and joint mobility increases. By unblocking the joints in the spine, decreasing muscle tension, this rehabilitation method provides a practical basis for rehabilitation treatments, and aims at eliminating all types of painful TP in patients with CP.

2.2.4. **Morphofunctional principles of rehabilitating viscous and elastic properties in connective tissue structures**

The connective tissue is an important structural component of the body; there are many kinds of connective tissues existing within the body. Up to 50% of the collagen in the adult organism can be found in bone structures and dense connective tissues. The latter forms muscle tendons, the fibrous layer of joint capsules, ligaments, aponeurosis, fasciae and its derivatives (interosseous membranes, the intermuscular septum, tendon retinaculum, and others).

When the pathological condition is prolonged in patients with CP, retractive muscles are accompanied by retractive connective tissue structures, all of which complicate the clinical picture of the existing lesions. The biomechanical properties inherent to fiber structures of the territorial matrix are significant factors which have an effect on the viscous and elastic properties of connective tissue structures.
Collagen fibers represent the strongest structures among all the connective tissues; they are responsible for stability in stretching muscles. These properties are determined by the structural organization of collagen. Basically, collagen is a triple spiral of the tropocollagen molecule, which forms a collagen filament. The collagen fiber consists of several parallel glycoprotein fibrils. When collagen fibers are organized, the tropocollagen molecules first create chains, and then are organized in such a way that each molecule of one chain is displaced by a fourth of its length with regard to the molecule in the adjoining chain (Illustration 2.2.18).

Such specific packing of the tropocollagen molecules determines the fundamental properties of collagen fibers, namely their firmness and stability with regard to stretching muscles and the cross striation of the collagen fibrils; the periodicity of these striations is 65 nm.

Elastin fibers are constructed on another basis. The elastin fibril is created from an elastin molecule joined together by covalent bonds. This network of elastin fibers can expand and contract as a random coil, and so, is capable of restoring initial shapes in a deformed body (Illustration 2.2.19).

Elastin fibers are found in the skin, lungs, cartilage, and blood vessels.

The properties of fundamental fibers in the connective tissues determine the viscous and elastic properties of connective tissues, as well as their abilities to define elastic and plastic deformation. Plastic deformation allows the fasciae and its derivatives to adapt to directional changes and tension, which can be preserved for several hours or even several years. Elastin deformation of the fasciae, ligaments, intervertebral discs and other connective tissues enables them to restore their original shape and properties.
Myofibroblasts, which can synthesize smooth-muscle actins and myosins, are present in all cells of connective tissues; but, they have a tendency to contract and so, additional preconditions appear for retracting all connective body structures.

Prolonged retraction is a result of increased muscle tone or missing functions (for example, generalized hypokinesia and hypodynamicia appear when a segment is immobilized) or, inversely, protracted and intensive physical loading (hyperkinetics and hyperdynamia) lead to disorders in the viscous and elastic properties of the tissues. Such modifications are due to microcirculation disorders in bradytrophic tissues and diffuse nourishment in avascular structures, such as cartilages.

Similar modifications occur in other connective tissue structures: joint capsules, ligaments, muscle tendons, fasciae, and aponeurosis. When the mechanical properties of these structures are modified, disorders in muscle and joint activities appear.

Therefore, by lowering the retraction level of connective tissues in the musculoskeletal system and normalizing their viscous and elastic properties, the specialist uses one of the most significant rehabilitation components when treating children suffering from CP. The Kozyavkin Method emphasizes the principle of rehabilitating connective tissues by working on their physical and mechanical properties, and using all adequate factors at hand.

Thus, despite their rigid structure and organization, collagen cells are responsible for specific muscle contractility and extensibility. Extensibility increases when small and prolonged efforts and temperature conditions prevail. When a person stretches his muscles slowly and easily, he uses more time, but the percentage of elongated tissues is higher after the stretching effort has been completed. Thus, when a person stretches his muscles slowly and easily for a long time, he contributes to an increase in residual plastic deformation and a mechanical relaxation of elongated structures [Warren C.G., 1971]56.

Temperature conditions improve results during stretching and when the stretching effort has been completed. It is best to start stretching after the tissues have been warmed up since higher temperatures decrease the stiffness in the collagen structures and increase their ability to stretch [Laban M.M., 1962]57 [Rigby B., 1964]58. In order to preserve the elongated muscles, it is important to cool the stretched tissues. By cooling the warmed up tissues (that is, restoring the initial temperature) when the stretching effort has been completed, the body enables the collagen to adapt to the newly-acquired length of the tissues [Lehmann J.F., 1970]59.

Therefore, the treatment of CP using neurorehabilitation procedures includes prolonged stretching of all connective tissue structures by applying small amounts of force and warming up the tissues to the required therapeutic temperature. The following procedures are used: massage, mobilizing exercises, kinesiotherapy, and joint immobilization together with wax and paraffin applications.

As a result, the plasticity of joint capsules, ligaments, and fasciae increases, directional fascial force is restored, and the transfer of muscle-to-muscle effort is optimized. The geometrical structure of blood vessels is also normalized,
microcirculation channels of all connective tissue structures are renewed, and the metabolic and trophic functions of the tissues are revived. In fact, connective tissues act as intermediaries in the fore-mentioned functions. On the whole, the rehabilitation of connective tissue architectonics and nourishment is a significant condition for normalizing their viscous and elastic properties.

The Kozyavkin Method has adopted this principle and made it into a priority guideline in its rehabilitation system. Mobility increases in the joints during the course of the rehabilitation treatment; this result is one of the objective criteria when evaluating the effectiveness of on-going rehabilitation procedures.

The fore-mentioned information represents the theoretical grounds on which the principles for the rehabilitation treatment of movement disorders were based. This is especially true for cerebral palsies. Cerebral palsy is an overall complex of syndromes related to motor, cognitive, and speech disorders. It is not possible to create a well-organized and consistent system of rehabilitation treatment if basic and well-grounded knowledge of the pathogenesis of given lesions is not made available, and the special features of the child’s disorders in his early motor ontogenesis are not taken into consideration.

New systems of rehabilitation treatments were based and elaborated by joining together two fundamental principles in medicine - knowledge and practical experience. On the one hand, new achievements in science are geared towards improving practical assistance for the patient. On the other hand, a doctor's practical experience can be directed towards developing new scientific tendencies, or creating new therapeutic and rehabilitation methods.

The new fundamental principles for CP treatment by applying non-conventional methods of manual therapy were introduced into medicine by Doctor V. I. Kozyavkin, who has had long and practical experience in this field. However, practical experience and technology represent mere stepping stones. The Kozyavkin Method draws its inspiration from basic scientific information and knowledge of anatomy, neurophysiology, biomechanics, neurology, orthopedics and many other disciplines.
2.3. Conceptual principles of the Kozyavkin Method

Children suffering from cerebral palsy differ substantially from their peers when their motor, mental and social developments are considered. Each case of CP is unique and the ethiopathogenetic mechanisms are so different and varied that a standardized method of physical rehabilitation for children with CP does not exist.

Applying only classical methods does not by any account lead to obtaining the desired results. Therefore, specialists need to refer to a combination of traditional and non-traditional methods of treatment. By combining different rehabilitation methods, medical professionals will be more successful in treating this complex pathology. This basic principle lays the grounds for several rehabilitation systems for children suffering from CP. One such approach is the multi-modal system of intensive neurophysiological rehabilitation founded by Professor V. I. Kozyavkin.

The Kozyavkin Method is based on developing a new functional state in the child’s organism by activating brain plasticity and stimulating compensatory abilities in the body. This is achieved by combining complex activities that open new horizons for the child’s further mental and physical development. In the end, the Kozyavkin Method aims at improving the patient’s quality of life.

The new rehabilitation system has been very successful and has achieved significant results. Consequently, it has also been recognized as an effective model all over the world. More than 17 thousand patients from 52 countries have been treated at the International Clinic of Rehabilitation in Truskavets and the “Elita” Rehabilitation Center in Lviv (Ukraine) (Illustration 2.3.1).
2.3.1. Historical creation and development of the Kozyavkin Method

The Kozyavkin Method was created and developed in the latter years of the past century. In fact, it began in the late eighties. The founder of this method is Volodymyr Kozyavkin, a neurologist, who specialized in applying complex treatments to patients with pathologies of the spine and the nervous system; Professor Kozyavkin then applied his own methods utilizing manual therapy in further treatments. His many years of practical experience enabled Doctor Kozyavkin to discover that specific techniques of mobilizing the spine resulted in normalized muscle tone in patients suffering from CP. This practical experience laid the grounds for the biomechanical correction of the spine and normalization of muscle tone in children suffering from different types of cerebral palsy.

However, the anatomical and physiological features of the child’s spinal column required Professor Kozyavkin to adapt classical methods of manual therapy to pediatric practice. Consequently, he developed an original technique involving polysegmental biomechanical correction of the spinal column, which was specifically adapted to the child’s body.

In 1989, lectures about the rehabilitation method for CP were delivered at the Congress on Manual Therapy in London and the All-Union Research Conference on child neurology and psychiatry in Vilnius [Kozyavkin V. I., 1989]. Doctors and researchers from the former Soviet Union expressed their interest in the new method. In the same year, a commission of experts from the Moscow Clinical Hospital No.18, headed by Professor K. A. Semenova, had previously examined a group of patients with cerebral palsy who had been treated with this method. They all confirmed the effectiveness of the new rehabilitation guidelines employed for treating this severe neurological pathology.

On May 4th, 1990, the modern Rehabilitation Center, “Elita” was founded in Lviv, Ukraine to accommodate the new rehabilitation method. The Center began treating patients from Ukraine and the other Soviet republics.

Information about the new rehabilitation
method spread to neighboring European countries. The first group of patients from Germany and France arrived in Lviv in 1991. Both stable and positive results in rehabilitation treatments have since led to a steady stream of patients of various ages. Since 1993, groups of patients have been arriving regularly by special charter flights from Germany twice a month in order to benefit from rehabilitation treatments applying the Kozyavkin Method.

The Cabinet of Ministers of Ukraine passed Resolution No. 622-p on August 20th, 1993 whereby the Kozyavkin Method was officially recognized in Ukraine and recommended for wider application by Ukrainian rehabilitation institutions.

A new Institute for Medical Rehabilitation was founded in 1996 in order to allow for more scientific research, improve the method itself, and develop new rehabilitation programs. A branch of the Kyiv Faculty of Rehabilitation and Physiotherapy at the P. Shupik National Medical Academy for Post-Graduate Studies was opened to encourage and broaden further advanced studies in the field of rehabilitation. More than 350 Ukrainian and foreign doctors from various fields of medicine have attended follow-up courses and seminars and become acquainted with the intensive neurorehabilitation program for patients suffering from brain lesions.

Positive results and the high effectiveness of the new rehabilitation method have enhanced its reputation both in Ukraine and abroad [Del Bello F., 2000]^{61}.

Describing modern conservative methods for treating children with CP, the leading German orthopedist, Professor Fritz Niethard includes the Kozyavkin Method in his encyclopedic edition on child orthopedics and refers to it as one of the four most effective methods for rehabilitating this complex disease [Niethard F.U., 1997]^{62}.

In 1999, a group of researchers and doctors headed by Professor Kozyavkin received the State Award of Ukraine in the field of science and technology for major achievements in rehabilitation medicine. In 2001, Professor Kozyavkin, the founder of the new rehabilitation method, was awarded the title of Hero of Ukraine.

The International Clinic of Rehabilitation was established in June, 2003 in order to widen the range of possibilities for future developments and improvements in the rehabilitation field.
2.3.2. Fundamental units of the rehabilitation system

The rehabilitation system according to the Kozyavkin Method consists of two fundamental subsystems: the intensive correction subsystem and the subsystem aimed at stabilizing and potentiating effects.

Intensive correction is carried out at the rehabilitation center and lasts two weeks. The treatment period indicated for stabilizing and potentiating the effects is continued at home according to doctors’ recommendations. This period usually lasts from 6 to 12 months. Then patient is re-admitted to the center for the next course of intensive treatment if so instructed [Kozyavkin V. I., 1995].

The intensive rehabilitation system is a multi-modal approach of applying various active methods, that is, when one active method complements and potentiates another.

The main complex of therapeutic programs includes: biomechanical correction of the spine, mobilization of extremity joints, reflexotherapy, mobilizing physical exercises, special massage system, rhythmic exercises, apitherapy and mechanotherapy (Illustration 2.3.5).
Biomechanical correction of the spine

The intensive rehabilitation system was elaborated by Professor V. I. Kozyavkin; it is based on the polysegmental correction of the spine and aimed at eliminating functional blockages in the vertebrae and rehabilitating their normal functions [Kozyavkin V. I., 1992].

The spiral-like rotatory technique is used to rehabilitate movements in key regions of the spinal column. The INRS (intensive neurophysiological rehabilitation system) includes polysegmentary manual therapy which is applied to the vertebrae in a non-conventional rotatory direction (“dorsal rotation”) [Kozyavkin V. I., 1996]. The technique is based on reverse torsions (that is, the direction is inverted) which are applied to the spinal column. First and foremost,
specialists work on internal muscle spirals as these muscles are the most likely to remain in a hypertonic state.

The correction of the intervertebral joints is conducted in consecutive order in the neck, thoracic and lumbar regions of the body (Illustration 2.3.6). A manual diagnosis is drawn up by the doctor; the patient is suitably prepared and follows special exercises for relaxing his muscles [Kozyavkin V. I., 1993].

Correction of the neck region is carried out by provoking movements on trajectories, which unblocks most of the segments simultaneously, starting from the lower neck segments to the C0 - C1 segments. Corrections in the thoracic region are conducted one after another, starting from the upper regions down to the lower areas; the specialist applies specific impulse techniques when the patient exhales. Manipulation is carried out in the lumbar region on all blocked movements simultaneously. Finally, the mobilizing impulse method is used on blocked iliosacral joints.

These combined exercises are aimed at rehabilitating functions of the spinal column, normalizing muscle tone, restoring the flow of blood, lymph, and cerebrospinal fluid, as well as activating respiration [Lun G. P., 1996].

Rehabilitating movements in thoracic joints is a most important phase during the exercises as their functions are all connected with the spine. The spinal column, breastbone and ribs form a whole unit from the embryogenic point of view. The functions of the spinal column may be affected if joints located in the thoracic cage are modified. Furthermore, rib and spinal joints may become blocked due to respiratory disorders, or inversely, respiratory disorders may, in turn, potentiate changes in the rib and thoracic joints.

When movements in spinal joints and other connected joints have been rehabilitated, the doors are open to further rehabilitation activities based on the functioning capabilities of the patient’s body [Kozyavkin V. I., 1992].

Mobilization of extremity joints

By mobilizing joints in the extremities, health specialists restore joint mobility, eliminate the imbalance between muscles and joints, improve trophism in tissues, and prepare the patient for new movements. Mobilization starts at the large joints and then, gradually move to the smaller joints located in the hands and feet [Gordiyevych S. M., 2000].

The Kozyavkin Method includes both classical and original techniques of joint mobilization. Specialists use simultaneous unblocking of joints, passive joint techniques, and active work-outs involving joint movements [Kozyavkin V. I., 1992] (Illustration 2.3.7).

Traction mobilization is used when rehabilitating body movements, and especially in large joints. Rhythmic exercises are used more often when the neighboring muscles
have been affected by hypertonia. The patient can relax more slowly and painlessly, as rehabilitation exercises broaden the range of movements in the joints. The technique is fairly safe and painless, but requires painstaking control and accuracy on the part of health specialists when it is applied to a patient with CP [Margosiuk I. P., 1999].

The sessions of manual therapy are concluded by position mobilization which combine manipulative activities, rhythmic mobilization, and postisometric relaxation.

If speech disorders in the form of spastic or hyperkinetic dysarthria appear, the temporomandibular joints are mobilized. These work-outs are combined with massages of the masticatory and mimic musculature, all of which eventually leads to improved articulation.

Reflexotherapy

Reflexotherapy serves to intensify the effects provoked by relaxed muscles, decreases activities in the myofascial trigger zones, and normalize somatic and autonomic interaction [Lisovich V. I., 1997]. Classical reflexotherapeutic exercises are applied together with new and original methods. A most effective effect is produced by transmitting low electrostimulating impulses into biologically active points of the body. The device is applied to points located along the classical meridian, as well as along tendon meridians and trigger zones. A portable device is used to carry out electrostimulation (Illustration 2.3.8). The entire procedure does not have any contraindications; it is virtually painless, easy to use, and completely accepted by our smaller patients [Lisovich V. I., 2000].

The postisometric relaxation method can be used to restore muscle tone (PIR). PIR is an active and effective way of reducing muscle hypertonia and eliminating painful muscle spasms [Lewit K., 1980].

Other procedures aimed at rehabilitating muscle tone should precede PIR; these include massage, mobilizing exercises, and reflexotherapy. The relaxation technique is combined with exercises activating soft muscles and gradually stretching contracted muscles. The intensity of PIR should be measured accurately, as excessive relaxation due to force, time or repeated sessions may reduce the overall effects. In some
cases, it may even provoke negative consequences, such as a decrease in muscle strength, pain due to the redressment of connective tissue elements, etc.

Postisometric relaxation is adapted to the special features of the child’s muscular pathology. In individual cases, it enables the doctor to normalize muscle tone, eliminate muscle pains, and remove residual muscle deformation. However, this method has its peculiarities and restrictions when applied to children with CP. The following information should be taken into account: as soon as the lesions have been diagnosed, the patient’s clinical history, the extent of his muscle hypertonia, and the acuteness of contracture modifications in the joints should be recorded. The PIR technique requires the patient to take an active part in the procedures; therefore, if the patient is unable to adapt to certain relaxation exercises, and this is especially true in very young patients, he will not benefit from any applied exercises.

Mobilizing physical exercises

Mobilizing physical exercises are based on classical kinesiotherapeutic principles. They fit into a logical sequence in the rehabilitation program, but they must be conducted in a special and particular way when patients with CP are being treated. This program is aimed at developing existing motor functions, forming new motor patterns, and mastering more suitable forms of locomotion and everyday movement skills (Illustration 2.3.9)

The “centre-periphery” principle constitutes the framework for the mobilizing exercises; rehabilitation movements are induced in the joints of the trunk and extremity girdles and then continued in distal joints. First, the specialist applies simple motor skills and then, moves on to more complicated patterns [Lisovich V. I., 1995].

Each session includes exercises that work on the joints located in the spinal column and extremities; they are aimed at increasing their mobility and strengthening the
muscles. It is most important for the specialist to execute the movements accurately, encourage the patient to breathe correctly, and continuously control how the patient feels. The rehabilitation training schedule is drawn up according to the child’s somatic health and the intensity of apparent pathological reflexes and synkinesis.

New movement patterns are created and consolidated over the two-week rehabilitation course. It is most important to continue the training schedule if it is to be successful. Therefore, parental participation in the sessions is widely encouraged; in fact, the parents learn and assimilate the principles related to all individual exercises with the child, and then apply them at home.


**Special massage system**

Massage is an important therapeutic method applied to patients with CP; it is aimed at normalizing osteoarticular, nerve and muscle functions in the body, improving the blood and lymph flow, and activating tissues trophism. Massage is used within the framework of the rehabilitation program in order to redress ligaments and capsules of joints, tendons and aponeuroses, activate hypotonic muscles, relax spastic muscles, eliminate muscle hypertonia, and remove myofascial trigger zones.

The special massage system includes classical, segmental, and periosteal massage techniques combined with postisometric and postisotonic relaxation (illustration 2.3.10).

Hypotonic muscles are activated by tonic massage treatments. Relaxation massage techniques allow the specialist to prepare the patient’s osteoarticular and muscle systems for further biomechanical corrections of the spinal column. Inhibitory acupressure removes painful and compressed muscles, and reduces activity in the myofascial trigger zones. Classical massage is widely applied to relieve spastic muscles.
Segmental massages are applied to paravertebral zones in order to stimulate blood flow and provoke reflex reactions in internal organs and other regions of the body. Periosteal massage may be painful, so it is only performed on children suffering from severe muscle contractures or showing apparent modifications in capsular ligaments and joints [Kozyavkin V. I., 2004]75.

This type of massage is especially effective when it is applied to the muscles together with warming up procedures. In fact, by warming up the muscles and maintaining a stable warm temperature, the specialist can reduce the viscosity and tone in the muscles.

Favorable preconditions are thus created for further and successful correction of the spine and joint mobilization.

**Rhythmic exercises**

Rhythmic exercises are aimed at improving the child’s motor faculties and developing his social skills. Rhythmic exercises are conducted in relevant age groups according to the children’s mental and locomotor development. They are based on play and game techniques together with music and dancing. They encourage the child to interact socially, communicate with other children, stimulate his motivation towards recovery, and reinforce his faith in himself [Kozyavkin V. I., 1993]76.

Parents are encouraged to take an active part in the rhythmic exercises. The instructor’s approval, parental encouragement, and suitable music enhance the child’s positive emotions, helping him to create new communicative and locomotor skills [Kachmar O. O., 2003]77.

**Apitherapy and wax and paraffin applications**

Wax and paraffin applications, as well as apitherapy, that is, treatments using bee venom, are used to stimulate the child’s immune system, improve blood circulation, and activate metabolic processes in the tissues.
Wax and paraffin applications are used to wrap up different muscle and joint groups warmly. The warming effect joins together with the influence of biologically active substances [Lun G. P., 1993]

An allergenic test composed of various bee products is conducted on the patient prior to actual apitherapy. Bee venom is administered into joint spaces, trigger points, body areas showing attached spastic muscles, and painful, periosteal zones. The most common regions for applying bee venom are located in the spine, large joints, as well as hand and foot joints. The bee sting is removed beforehand from the bee with tweezers; it is used to measure the dose of bee venom and relieve the child’s anxiety when he is faced with a real bee.

**Mechanotherapy**

Mechanotherapy is used to strengthen muscles, improve movement coordination, and form correct movement stereotypes.

Lever-type equipment is used to train muscles in the lower extremities. The instructor first draws up an optimal training schedule; he then selects and adjusts levers, weights, and the number of repeated exercises (Illustration 2.3.11).

Block devices are used primarily for developing strength and endurance in the muscles located in the upper extremities. The instructor may also use correcting devices such as vibroextensors, which transmit measured doses of heat, vibration and mechanical massage to the paravertebral zones; this action naturally mobilizes all the joints in the spinal column.

Treadmills and cycling equipment are used to correct faulty body posture, form suitable stereotypes, and develop movement coordination (Illustration 2.3.12).

Ambulant patients can exercise on a mechanical treadmill. Electric treadmills are used for patients with severe cases of CP; the patient is suspended over the running treadmill as the weights are gradually reduced. This process helps the patient to
learn how to walk and enables him to form suitable locomotor movements.

A qualified physiotherapist controls and monitors all mechanotherapy sessions.

2.3.3. Therapeutic programs included in the Kozyavkin Method

Rehabilitation according to the Kozyavkin Method constitutes a highly effective therapeutic system for treating children suffering from various forms of cerebral palsy, but also other patients with vertebral pathologies, consequences of injuries, and organic lesions of the nervous system.

Owing to extensive scientific and practical research and studies, this rehabilitation system is being continuously improved and broadened. A new component called the program for biodynamical movement correction was developed and introduced in 1999. A new functional state was previously attained by the patient when he underwent the entire complex of treatments. The new program is aimed at using the patient’s new functional state to destroy old pathological stereotypes, and form new and required functional movements [Voloshyn B. D., 2003].

The program is based on the principle of dynamic proprioceptive movement correction, which is applied by a biodynamic corrector in the form of a specially designed suit called the “Spiral”. The suit provides for additional external efforts, which correct movements in the limbs and body posture, and activate the flow of proprioceptive information [Kozyavkin V. I., 2001]. The program is described more in detail in the third chapter of this book.

Another program called “Early Rehabilitation” was also worked out. It is aimed at improving the quality of assistance provided to high-risk children (during a difficult pregnancy, problems at childbirth, or neonatal pathologies). The program was approved in 2004 and put into practice at the “Elita” Rehabilitation Center in Lviv (Ukraine).

Many years of experience and the successful application of the intensive neurorehabilitation system proved the effectiveness of this new technology, and
led the specialists to the conclusion that an early start was indispensable when introducing rehabilitation treatments.

The early rehabilitation of children with perinatal lesions is aimed at providing prophylactic methods for maximal or even minimal organic lesions of the nervous system. If treatment is started in the course of the first year, that is, immediately following acute perinatal strokes or trauma, severe neurological disabilities can be prevented in very many cases. This is definitely a motivating factor in our society as the State can reduce certain expenses related to the social needs of disabled children [Moiseyenko R. O., 2003]81.

The “Early Rehabilitation” program was initially based on the intensive neurophysiological rehabilitation system, but then, it was modified to fit the morphological and functional features of one-year-old children. The fundamental task of the program lies in overcoming motor, mental and speech delays in the growing child. The program includes many consecutive rehabilitation activities aimed at activating blood flow and CSF circulation, eliminating concomitant disorders in the somatic and autonomic spheres, and normalizing all body functions [Kozyavkin V. I., 2005]82.

The intensive rehabilitation program is continued over a period of 5 days for children aged three months to one year. Further treatment is carried out at home by the parents and according to doctors’ recommendations. If necessary, the therapeutic cycle for a one-year-old child is repeated monthly until all the symptoms of organic lesions in the nervous system have been removed. Older children follow a two-week outpatient cycle of intensive rehabilitation, but the frequency of the actual sessions is determined by the severity of the patient’s condition. It is highly recommended to carry out two to four cycles every year. The overall program includes outpatient rehabilitation treatments as well as two distinct units of treatment – diagnosis and medical therapy [Kozyavkin V. I., 2005]83.

The diagnostic unit includes anamnestic data and the actual examination of the patient. Special attention is paid to hereditary impairments, the parents’ health, the course of the pregnancy, and both childbirth and post-childbirth periods. The child is examined according to a diagnostic scheme; the gross motor functions are monitored by video, the patient’s physical, mental, motor, and speech statuses are evaluated, and finally, his social development is determined. The international developmental screening tests, DENVER II and PEDI are used.

The DENVER II Test enables the health professional to monitor and evaluate the patient’s motor, mental, and social abilities [Frankenburg W. K., 1992]84. The PEDI Test (Pediatric Evaluation Disability Inventory) is given to children aged six months to 7 ½ years old; standardized norms enable the specialist to evaluate the child’s abilities according to three parameters: self-reliance, mobility, and social functions [Berg M., 2004]85.
**The therapeutic unit** includes the biomechanical correction of the spinal column, reflexotherapy, special logopedic massages, breathing exercises, therapeutic physical exercises, and wax and paraffin applications (Illustration 2.3.13). The child’s organism creates a new functional state when all these treatments have been applied. Clinically speaking, muscle tone and limb movements are normalized, respiratory functions improve, and body symmetry is restored. All these factors enable the child to develop his motor, mental, social, and language functions more adequately.

The presence of parents or close relatives is greatly encouraged during early rehabilitation sessions. They learn to understand the on-going treatment, get answers to their questions from the doctor, and become more familiar with the practical skills that will be needed for working with the child at home.

During the sessions, the doctors explain what may cause brain lesions in children; they also describe modern methods that are used to treat patients suffering from this complex neurological pathology. The parents are warned of early symptoms which should draw their attention to the disease. These symptoms may include the following: the child’s body posture is modified (the body becomes asymmetric, the head and extremities maintain fixed positions; the trunk straightens or bends excessively, apparent movement disorders (paresis, violent movements, twitching, and others), and the child does not develop his motor and language skills according to his age. The parents should be able to identify several external signs of this disorder, namely, ever-increasing head circumference, or inversely, the head circumference decreases; the child becomes nervous and irritable, or else he reacts weakly and passively to external events. These symptoms should alert the parents, who should then turn to specialists immediately, ask for an in-depth investigation, and if needed, carry on with active rehabilitation treatments.
The effectiveness of early rehabilitation was evaluated in 2004-2005 when several year-old children followed this special program at the “Elita” Rehabilitation Center [Kozyavkina O. V., 2005]. 20% of the children were under the age of one; 40% of the children in this age group followed a single treatment course; 22% - 2 courses; 38% - three or more. 26 clinical histories of children who had followed more than 3 treatment courses were chosen and analyzed (Illustration 2.3.14).

The clinical evaluation was also based on dynamic results showing the patient’s locomotor, mental and speech evolution, and his adaptation to society. Analyses of pregnancies and childbirth presented a considerable number of complications, which were identified during the perinatal and postnatal periods.

The Apgar scale with a range of 6 - 7 - 8 scores is used to assess the health of newborn children. 23% of the newborns were premature; 12% of these infants were transferred from maternity wards to in-patient wards so that they could benefit from the second phase of treatment for premature newborns. Due to severe health complications, or intrauterine infections in the mother’s womb, 27% of the newborn infants were transferred to pediatric in-patient wards for intensive care.

All the children who were admitted to further treatments were diagnosed with one of the following complications: hypoxic - ischemic or hypoxic - traumatic lesions of the CNS. 20% of the cases presented syndromes related to the flow of cerebrospinal fluid, hypertension, or hydrocephalic disorders; 80% of the children showed delays in motor development or locomotor disorders; 15% of the latter group were classified in the cerebral palsy group.

Daily clinical supervision of these children, analyses of video recordings of their motor functions, supplementary paraclinical examinations, and PEDI test results showed substantial improvements in the patient’s motor, mental, speech, and somatic conditions. It was also observed that the patient was able to adapt and
adjust more readily to his surroundings, becoming more self-reliant and independent (Illustration 2.3.15).

Locomotor, mental, and speech delays disappeared in 46% of the children. These children underwent regular therapeutic sessions at the rehabilitation center, and within a year, they were able to compete with their peers.

33% of the patients showed marked improvements in their locomotor development; emotional and autonomic disorders decreased; the children could sleep normally; somatic pathologies dropped substantially. The children’s appetite was restored; their diaphragmal respiration, digestion, and kidney functions improved greatly. As blood circulation was restored, cyanosis of the mucous membranes and distal extremities was reduced, and tissue turgor increased. The children reacted vocally, and began

<table>
<thead>
<tr>
<th>Complications</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Complications during pregnancy</td>
<td></td>
</tr>
<tr>
<td>toxicosis during the first and / or second period of pregnancy</td>
<td>11%</td>
</tr>
<tr>
<td>threat of miscarriage</td>
<td>34%</td>
</tr>
<tr>
<td>mother’s illness (somatic or infectious)</td>
<td>35%</td>
</tr>
<tr>
<td>II. Complications during childbirth</td>
<td></td>
</tr>
<tr>
<td>premature birth</td>
<td>46%</td>
</tr>
<tr>
<td>precipitated labor</td>
<td>15%</td>
</tr>
<tr>
<td>artificially stimulated childbirth</td>
<td>34%</td>
</tr>
<tr>
<td>caesarean section</td>
<td>4%</td>
</tr>
<tr>
<td>obstetric assistance</td>
<td>30%</td>
</tr>
</tbody>
</table>
They also showed more interest in their surroundings, and reacted more promptly to light and sound stimulants around them.

Repeated treatment sessions enabled 21% of the children to achieve positive results. This refers to the group of one-year-olds with signs of cerebral palsy due to complications arising in the perinatal period, premature birth, and/or difficult childbirth. By activating the blood circulation, normalizing muscle tone, reducing spasticity in the muscles and postural reflexes, rehabilitation specialists were able to overcome developmental delay and restore proper functioning of main systems of the body.

Therefore, if any symptoms of organic lesions in the brain are detected at an early stage and treatment is started immediately, the early rehabilitation program can be considered to be highly effective. By applying this program as early as possible, the specialist reduces neurological disorders in his patients, gives them a fighting chance to overcome their physical disabilities, and enables them to adapt to their environment.

2.3.4. Algorithm for correcting disorders of movement and posture

Movement disorders are the leading clinical manifestations of CP. Consecutive and step-by-step actions involving all the elements in the functional motor system should be applied if these disorders are to be corrected. These ideas are reflected in the algorithm for rehabilitation activities according to the Kozyavkin Method.

The rehabilitation algorithm is represented schematically as a five-pointed star that connects all body links together. The center of the star represents the spinal column and the spinal cord (block A), whereas the astral points symbolize the other sections of the body, that is, the upper astral point represents the head and the brain; the lateral points represent the upper extremities, and the lower points refer to the lower extremities in the body (Illustration 2.3.16).

Each astral point representing body extremities (limbs) consists of fundamental structures such as muscles, bones, joints, blood vessels, and nerves. The large proximal joints, gross muscle groups, blood vessels and nerves are located closer to the center of the star. Small distal joints, as well as their corresponding muscles, blood vessels and nerves are situated at the very tips of the astral points. The upper astral point symbolizes the head; it includes the philogenetically older structures in the brainstem, subcortex, as well as the brain cortex itself—a newer distal structure that monitors all higher mental and motor functions.

All the above-mentioned structures must interact closely if the human body is to develop normally. Moreover, this interaction is fed by sensorial (from the periphery to the center) and locomotor flows of information (from the center to the periphery). CP patients may be affected by sensorial or locomotor disorders, or they may show disorders in their sensorial and locomotor movements [Kozyavkin V. I., 1994]87.
Functional blockages in the vertebral motion segments constitute one of the most important causes of dysfunctional interactions. Such blockages limit movements in the joints and affect the ascending flow of proprioceptive information. Thus, such blockages in the rehabilitation algorithm can be interpreted as dysfunctional interactions between all the astral points.

The topographical representation of the rehabilitation algorithm is used to guide the specialist when he must apply and carry out the different stages of the rehabilitation system. The scheme clearly defines the successive stages for rehabilitation, and lays down the principle of rehabilitation work starting at the center and moving towards the periphery. Such clear and concise consecutive actions in rehabilitation conform to developing movement functions at the ontogenetic stage. Motor skills and simple reflex reactions are mastered towards the distal directions in the body according to cranio-caudal gradients of development [Patten B.M., 1959]. Each preceding link of the chain should be rehabilitated as the messages move from one block to the next. In fact, messages and movements can only be transmitted effectively if they successfully pass through one link of the chain before proceeding to the next. This principle of “trail blazing” (going into new territory with no marked paths) has proved to be most effective in practical therapy.

Rehabilitation treatments start at the first block of the rehabilitation algorithm (see block A in the Illustration), that is, in the spinal column and its joints. First and foremost, functional blockages in the vertebral motion segments should be eliminated. Consequently, muscle tone is normalized, movements are restored in the joints and vertebrae of the spinal column, and trophism and blood circulation improve greatly. All these modifications reflect a new functional state in the body.
The patient expresses his new condition by creating new mental and motor skills, and activating and expressing his motivations and emotions.

Professor Kozyavkin has called this phenomenon the “awakening” of the patient. Indeed, the new functional condition opens new possibilities for further and more effective influences to be applied to body structures and functions.

Next, successive acts are performed on the proximal structures of the shoulder and pelvic girdles (block B). Here, specialists use various techniques such as joint mobilization, physical exercises and special massages. The rehabilitation specialist then moves on to further acts and exercises executed on the intermediate joints (block C), and finally, on all the distal joints (block D). Functional, but finer formations of mobility in the “distal” sections can be made possible only when the preceding and “proximal” functions have been restored.

It follows that more and more movements become involved and such functions as balance, language, and other more complex functions continue to develop. Some exercises and tasks are conducted at home according to our doctors’ recommendations.

2.3.5. Assessing the effectiveness of treatments using the Kozyavkin Method

Currently, there are countless systems and methods for rehabilitating children with CP. Health professionals and parents need objective and reliable information about available treatment methods, especially with regard to the strong and weak points of each method. Such information can only be obtained by analyzing and examining scientific and research publications. However, general standards and methodology are lacking in this field, making it very difficult to compare and assess the results. And so, standardized evaluations should be applied to given clinical studies.

Analyses and results are classified according to the International Classification of Functioning, Disability and Health (ICF) at the International Clinic of Rehabilitation [World Health Organization (WHO), 2001]. This classification is a standardized description of health-related indicators and criteria at both individual and population levels. It was worked out by the WHO and approved on 22nd May, 2001 in the 54th session of the WHO Assembly; it was endorsed for use in the Member States as the international standard to describe and measure health and disability. It is also recommended for use in all clinical studies. The ICF supplements the International Classification of Diseases, 10th edition (ICD-10).

The ICF includes four fundamental domains*: 1) individual body functions, 2) body structures, 3) activity and participation, 4) environmental factors. Each domain is itself separated into divisions and subdivisions.

* Domain - a practical and important set of interconnected physiological functions, anatomical structures, and daily actions, tasks, and activities.
When conducting analyses and applying the Kozyayvkin Method in rehabilitation treatments for patients with cerebral palsy, we placed special emphasis on learning how the body functions. We especially acknowledged muscle tone functions (b735 in the ICF classification), mobility of joint functions (b710), and control of voluntary movement functions (b760). They are all included in the chapter dealing with “Neuromuscular, skeletal and movement-related functions”, and constitute the most informative indicators for working with children suffering from cerebral palsy.

The evaluation of the intensive neurophysiological rehabilitation system was based on the information stored in our special software database [Kachmar V. O., 2001]. 12,256 electronic medical histories filed in the database were analyzed by our specialists [Kozyavkin V. I., 2003]. Results showed that, as of July 1st, 2002, 89% of the patients were affected with different types of cerebral palsy, 6% suffered from vertebrogenic pathologies, 3% from consequences of organic lesions in the nervous system (strokes, skull and brain injuries), 2% from other illnesses. In the CP group, 73% of the patients were affected with spastic tetraparesis, 6% suffered from spastic diparesis, 7% from spastic hemiparesis, 2% from atonic - astatic syndromes, and 2% from hyperkinetic forms of the illness (Illustration 2.3.17).

For the purpose of analysis, all the patients were divided into age groups: under 4 years of age, between 4 and 7 years old, between 7 and 14, between 14 and 20, and over 20 years of age (Illustration 2.3.18).

The largest group (36%) was composed of patients aged 7 to 14 years and only 3% of children were under 4 years. These statistics encouraged us to create the “Early Rehabilitation” program for very young children under 1 year.

The duration of the rehabilitation treatment according to the Kozyayvkin Method and the number of attended courses constituted two significant factors in establishing the overall analysis.
Only 37% of the patients underwent a rehabilitation course for the first time; 26% had already had two treatments, 14% - three treatments, whereas 14% of the children had gone through their fifth course of treatment or even more (Illustration 2.3.19).

Muscle spasticity is one of the main clinical symptoms of CP, so it was treated as an individual condition, which is dependent on the rate of increased tonic reflexes in
response to muscle stretching. This is accompanied by major tendon reflexes in the foot, as well as the inability to control volitional movements [Lance J. W., 1980].

Patients with complications due to spasticity can be classified into two groups. The first group suffers from pathological sensory afferentation, inadequate movement coordination, pathological movement stereotypes, increasing fatigue, the need to overcome muscle resistance, muscle stiffness, tense and strained limbs, and the loss of basic functional independence. The second group suffers from pains and contractures in the joints, which limit their self-reliance, and also, from major psychological problems.

In clinical practice, the specialist often determines muscle spasticity according to the resistance level in the muscles when they are passively stretched. There are various biomechanical and electrophysiological methods in use in specialized scientific institutions. We preferred to use the Modified Ashworth Scale in order to measure and assess muscle tone (Diagram 2.3.20). It also allowed us to make quantitative evaluations of muscle spasticity in the body [Bohannon R. W., 1987].

*Diagram 2.3.20. Ashworth scale (modified version)*

<table>
<thead>
<tr>
<th>score</th>
<th>Evaluation criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No increase in muscle tone</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in muscle tone with minimal resistance at the end of the range of movement</td>
</tr>
<tr>
<td>1+</td>
<td>Slight increase in muscle tone with some muscle strain and minimal resistance throughout the remainder (less than half) of the range of movement</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in muscle tone throughout most of the range of movement; passive movements are easily executed</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in muscle tone; passive movements become more difficult</td>
</tr>
<tr>
<td>4</td>
<td>Affected muscles and limbs are strained and rigid in flexion or extension positions</td>
</tr>
</tbody>
</table>

When the intensive neurophysiological rehabilitation course had been completed, the muscle tone was analyzed in 10,793 patients suffering from spastic forms of CP. 94% of them showed decreased muscle tone and only 6% of the patients showed muscle tone which had not changed. No increases in muscle tone were recorded during the rehabilitation process in patients with spastic forms of CP (Illustration 2.3.21).
Goniometry is a technique commonly used to assess the limitations of a patient’s range of active and passive movements in the joints. In our clinic we are using traditional zero position method to assess the range of active and passive movements in the shoulder, elbow, wrist, hip, knee, and ankle joints when they are in the flexed or extended position (along the transverse axes of rotation). It is also used to measure the pronator and supinator movements in the combined radioulnar joints when they are in the proximal and distal positions (along the vertical axis).

After the intensive rehabilitation course had been completed, 91% of the 10,793 examined patients showed an increase in the range of passive motions, and 84% in the range of active motions. The range of motion did not change for 8% and 15% of the patients respectively. Only 1% of all the patients showed a decrease in the range of active and passive movements (Illustration 2.3.22).
In order to assess the degree of motor development in children suffering from cerebral palsy, we created a video-recording method that controls the gross motor functions. The video camera records all successive movement exercises executed by the patient before and after each rehabilitation course [Kachmar O. O., 1997]. The video recordings enable us to store unique information regarding the child’s motor development and assess his progress during the entire rehabilitation treatment. The therapist also fills in a special “Scale of the gross motor functions” where he indicates the results of the patient after he has completed an individual motor exercise (Illustration 2.3.24).

While studying the patient’s musculoskeletal structure, the therapist asks him to perform many exercises on his back, stomach, on his knees, and in the sitting and standing positions. Various other tasks are also evaluated, namely, side-to-side rotations, crawling, getting up, standing (on one foot and on both feet), jumping, and walking. Each subtest is composed of several tasks, which are then assessed on a three-point scale. Twenty minutes are needed to evaluate one patient. The points of each test are then added up, and a total sum is presented at the end of the session. This method enables health professionals to assess the general development of the patient’s musculoskeletal and locomotor systems, as well as the progress of the different motor functions in his body.

The analytical results related to the gross motor functions in 12,256 patients with CP, who went through the entire rehabilitation course according to the Kozyavkin Method, are represented in Illustration 2.3.23. As a result of these intensive treatments, 75% of the patients were able to maintain control of their head when in the prone position. This had not been possible prior to treatment. 62% of the children were able to maintain a sitting position. 28% were able to crawl; 41% learned how to stand alone, and 19% learned how to walk.

Illustration 2.3.23. Changes of gross motor functions after rehabilitation (the figures showing modifications to motor functions are quoted as a percentage ratio with regard to the condition of the patients who were not able to perform the given motor function before the actual treatment process)
12, 256 patients
### Conceptual principles of the Kozyavkin Method

#### Scale showing the gross motor functions

<table>
<thead>
<tr>
<th>Supine position</th>
<th>Good +/- no</th>
<th>Crawling</th>
<th>Good +/- no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifts his head up from the mat</td>
<td></td>
<td>Crawl using his elbows and knees</td>
<td></td>
</tr>
<tr>
<td>Lifts his right leg</td>
<td></td>
<td>Can stand on all fours</td>
<td></td>
</tr>
<tr>
<td>Lifts his left leg</td>
<td></td>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
</tr>
<tr>
<td>Moves his right arm easily</td>
<td></td>
<td>Holds his head up when standing on all fours</td>
<td></td>
</tr>
<tr>
<td>his left arm</td>
<td></td>
<td>Raises his arm when standing on all fours</td>
<td></td>
</tr>
<tr>
<td>Sitting on the floor</td>
<td></td>
<td>Uses the non-alternating crawl</td>
<td></td>
</tr>
<tr>
<td>Sits on the floor</td>
<td></td>
<td>Uses the alternating crawl</td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
<td>Moves backwards</td>
<td></td>
</tr>
<tr>
<td>Sits on the floor without using his hands</td>
<td></td>
<td>using the non-alternating crawl</td>
<td></td>
</tr>
<tr>
<td>Can grasp an object lying alongside</td>
<td></td>
<td>using the alternating crawl</td>
<td></td>
</tr>
<tr>
<td>when in a sitting position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can sit up from the supine position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can sit up from a reclining position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without using his hands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral rotations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation rightwards onto the stomach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation rightwards onto the back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation leftwards onto the stomach</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotation leftwards onto the back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prone position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifts his head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lift his head and his chest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - support on the forearms - support on hand)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sits on a chair using his feet for support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can clap his hands when</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in the sitting position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can lift his right foot when in the sitting position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can lift his left foot when in the sitting position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - less than 60 degrees - more than 60 degrees)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can lift his arms simultaneously when in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the sitting position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>right arm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left arm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(elbow &lt; upper arm - &gt; upper arm - arm straightened out)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets up from the chair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - using his hands - without using his hands)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right leg when standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left leg when standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(on the toes - on toes and metatarsus - on the feet)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squats without support</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no, - on his knees +90 - &lt;90)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picks up an object from the floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crawling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crawls using his elbows and knees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can stand on all fours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holds his head up when standing on all fours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raises his arm when standing on all fours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses the non-alternating crawl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses the alternating crawl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moves backwards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>using the non-alternating crawl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>using the alternating crawl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kneeling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can kneel and maintain this position</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - yes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moves forwards on his knees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moves backwards on his knees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing up and erect standing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets up from the floor near an assistive device</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets up from the floor alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gets up - without using his hands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands near a wall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walks when holding onto another person’s both hands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>one hand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walks alone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt; 5 steps - &gt; 5 steps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walks sideways</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walks and stops when ordered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walks forwards with his back facing forwards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right leg when walking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left when walking (on the toes - on toes and metatarsus - on the whole foot)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jumping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can execute a jump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can execute a long jump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On one foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands on the right foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands on the left foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no - &lt;5 sec. - &gt;5 sec.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hops on the right foot</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hops on the left foot</td>
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<td></td>
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</tr>
</tbody>
</table>

Illustration 2.3.24. Scale of gross motor functions
It is most important to compare the effectiveness of rehabilitation in patients belonging to different age groups. Criteria and assessment were based on the progressing development of certain motor functions during the rehabilitation process.

The results of the analysis testify to the fact that the patient’s age often determines how successful the treatment may be. Thus, 68% of the patients under the age of 4 mastered the sitting position, whereas only 55% of the patients over 14 were able to maintain this position (Illustration 2.3.25).

Forming and developing **manual functions of the hand** is most important for patients with CP so that they can become self-reliant and independent. As a matter of fact, hand movements are commonly used in daily life; these include such tasks
as “grasping an object + activity + releasing the object”. Children suffering from cerebral palsy cannot perform any one of the foregoing tasks with their hands.

The grasping function provides the therapist with the most information for further diagnosis. In order to examine this function, we applied the modified version of the Sollerman Method [Sollerman C., 1995]94. It includes several ways of grasping an object with each hand, and four types of pinch grasping (two-finger pinch; key grasp; three-finger pinch; five-finger pinch) and four types of palmar grasps (diagonal, transverse, spherical, and flat plane) (illustration 2.3.27).

87% of the patients with hand function disorders showed active and fine hand mobility after rehabilitation treatments; 13% of the patients conserved their former degree of hand mobility (Illustration 2.3.26). Not one patient displayed a decrease in his grasping function [Voloshyn B. D., 2001]95.

Finally, the most significant aspect of our studies concerns the stability of the overall results. In fact, the patient completed the intensive rehabilitation course and then, continued his treatment at home.

Results showed that 45% of the patients developed their gross motor functions even further at home; 47% of the patients maintained the motor functions that had improved during rehabilitation; only 8% lost what they had attained, but this was usually connected with other illnesses or injuries (Illustration 2.3.28).

Both the new rehabilitation program and optimal organization of the overall rehabilitation process have contributed to producing such good results in rehabilitating patients with CP.
By applying modern IT technology, the specialist can organize the entire therapeutic process in the clinic in a very rational way; he can continuously monitor the patient’s condition, and control all the necessary technological processes provided at the institution.

2.3.6. Monitoring system in therapeutic rehabilitation

A unified medical IT system was introduced at the International Clinic of Rehabilitation in order to ensure a valid functioning method, comprehensive development, and improvements in both diagnostic and rehabilitation processes, as well as in scientific research and educational work. It provides a steady flow of medical information and enables our health professionals to systematize the circulation of documents [Kozyavkin V. I., 2005]96.

The electronic medical card constitutes the main component of the IT system. It contains all the information about the patient: passport data, medical examinations, anthropometry, journals, clinical histories, and multimedia information (X-rays, photographs) [Kachmar V. O., 2004]97.

At the same time, the fundamental medical information, the results of medical examinations, and the results of all treatments, are recorded on the electronic card according to standardized medical terminology, which was elaborated by our medical experts. All applied terms are organized into a graded “tree” which counts 2,126 knots, and represents a master model for examining the patient. Here, we have taken advantage of standardized medical information, which was started in many countries of the world more than 40 years ago. The most popular programs were developed in the USA, namely, the unified medical language system - UMLS [UMLS, 2006]98 and the systematized nomenclature of medical-clinical terms - SNOMED [SNOMED, 2006]99. Unfortunately, a standardized system of medical terminology in Ukrainian, which could be applied to IT systems, is still at a rudimentary stage.

Illustration 2.3.28. Changes in the patients’ condition between rehabilitation courses

<table>
<thead>
<tr>
<th></th>
<th>Further improvement</th>
<th>Stabilized Condition</th>
<th>Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>7,727</td>
<td>7,727</td>
<td>7,727</td>
</tr>
</tbody>
</table>

By applying modern IT technology, the specialist can organize the entire therapeutic process in the clinic in a very rational way; he can continuously monitor the patient’s condition, and control all the necessary technological processes provided at the institution.
These master models set a recommended sequence for the doctor to follow when he examines the patient, and they offer variable solutions to on-going problems.

The doctor does not need to compose the text by hand; he may select the required answers from all the variants offered by the program. This allows him to input the data quickly and effectively, and also to adhere to a certain progressive sequence.

The patient’s electronic medical record also has the advantage of making all the outgoing documents available and automatic. The data is recorded and excerpts from patient’s clinical history are registered automatically in the form of a connected text. The standardized multilingual terminology enables the specialist to write in different languages, and each language has its own linguistic pattern. At present, the IT system is being prepared to produce documents in four languages - Ukrainian, Russian, English, and German.

A monitoring system was elaborated in order to evaluate all changes in the patient’s condition during the actual rehabilitation process; it analyzes all the indicators that are recorded on the patient’s electronic card [Kozyavkin V. I., 2005]100. A general operational picture of the patient’s condition is provided when the specialist can analyze the neurological, somatic, and orthopedic modifications, evaluate changes in muscle tone, the gross motor functions, anthropometric indicators, hand function, and independent skills. This information is needed to correct the rehabilitation program, and determine what effect the treatment has on the patient.

Recording required medical information is also an essential part of the monitoring system. The information is recorded on the patient’s electronic card by our medical specialists; then, the specially adapted subprogram assesses whether the given information is timely and complete.

If these medical IT systems are to function correctly, it is necessary to share and exchange information with the patients and with other institutions by means of telemedicine. As of autumn, 2004, regular telemedical sessions have been conducted via the Internet between the International Clinic of Rehabilitation in Truskavets, the “Elita” Rehabilitation Center in Lviv, and other medical institutions.

These sessions enable our specialists located in different cities and regions to deliberate and debate amongst themselves, and carry out medical examinations on patients via the Internet. These examinations are aimed at solving various problems concerning expedient rehabilitation programs, controls of the patient’s condition after treatment, and the doctors’ recommendations with regard to further rehabilitation treatments.

Analyzing the infrastructures in the clinic constitutes one of the most significant components of the monitoring system. The latter records the arrival time of all our workers and collaborators, the number of telephone calls in each office, the number of visitors staying in our hotel complex, the supplies of electricity, water and heating, access control system of the clinic, and many others.

In such a way, highly-efficient technologies in medical rehabilitation combined with modern informatics allow us to raise the entire process of rehabilitation treatments to a new and high-principled level.
Literature:


Program for biodynamic movement correction
General information about the program

One of the most important tasks for rehabilitating patients with cerebral palsy is the correction and rehabilitation of affected motor functions and the correction of pathological locomotor stereotypes.

Rehabilitation configurations according to Kozyavkin’s Method are being constantly expanded and improved. The method is based mainly on a polymodal approach with the application of various interventions, which are all complementary and potentially active in attaining a final result. An important link in this rehabilitation system is the organism’s ability to create new functional conditions, which include the normalization of muscle tone, an increased range of passive and active movements in the joints, a trophism increase in tissues and the activation of mental processes. This new functional condition opens up new possibilities for rapid motor development in patients with CP [Kozyavkin V.I., 1995].

In order to determine the tasks for developing a child’s motor functions according to Kozyavkin’s method, a program for biodynamic movement correction was included in the rehabilitation system. It called for assisting the patient to eliminate irrational movement models and form adequate movement stereotypes [Kozyavkin V.I., 2001].

Recent research results were used to work out this program for motor correction, namely research studies carried out by Professor K. A. Semenova’s school at the Scientific Research Institute for Pediatrics by the Russian Academy of Medical Sciences [Semenova K.A., 1999]. Researchers proved that special suits could be effectively applied and used for patients with CP; the former had been worn by cosmonauts to prevent their organism from reacting unfavorably in zero-gravity conditions [Barer A. S., 1972]. Basing their work on these theoretical grounds, researchers developed foundations for dynamic proprioceptive movement correction, and then, created the “Adeli” suit for movement correction. Henceforth, this suit was modified and adapted for CP patients into the reflex-loading device “Gravistat”.

While working on our program for biodynamical movement correction, we took advantage of information related to structural and functional fundamentals regarding muscle interaction in various body positions and movements. It is known that muscles function together in groups when executing movement tasks, that is, longitudinal muscle integration and muscle spirals, which ensure muscle work coordination. Muscle spirals are especially important for motor tasks, whereby both the body and limbs work together successfully, particularly when performing complex movements [Tittle К., 1974].
Muscle spirals cross over from one side of the body to the other, thus joining the right and left sides together. They ensure bilateral symmetry of the body and provide support for a normal postural position within the gravitational field. Moreover, muscle spirals act as powerful shock absorbers, which cushion body impacts during locomotion, ensure cross-coordination between thoracic and pelvic girdles during locomotion, and execute many other important tasks. Each task is entirely determined and guaranteed by exact brain control, which “chooses” a specific set of muscles and combines them into muscle chains.

Pathologies of brain structures in patients with CP are accompanied by functional deformations of muscle layers, as a result of which irrational muscle combinations and pathological muscle chains are formed in the body.

Therefore, one of the main tasks of rehabilitating patients with motor disorders is renewing optimal muscle cooperation, normalizing muscle work and forming correct movement stereotypes. The following chapter deals more thoroughly with principles related to functional muscle integration for ensuring body position and movements.

Our studies and research led us to create a suit designed for correcting movements. It was specially designated for reconstituting spiral-like pulls with the assistance of external corrective forces. The suit was a biodynamic corrector called “Spiral”; it enables additional external forces to imitate muscle spiral pull. Thus, the positions of the body and the limbs are corrected and normal conditions for muscle cooperation are created. This external assistance to weakened muscles activates the flow of proprioceptive information to the brain [Voloshyn B. D., 2003].

As the patient wearing the suit continued to engage in various activities, the program was transformed into an entire scheme of biodynamic movement correction, which was directed towards structuring movement stereotypes similar to their physiological counterparts.

An important component of the program for biodynamic movement correction is raising the patient’s motivation towards therapeutic processes and drawing him more deeply and emotionally into the actual rehabilitation process. Our institute has worked out specialized training equipment and computer games with virtual reality elements, which are all employed towards these purposes.
3.1 Anatomic and physiological reasons for movement corrections

3.1.1. General mechanisms of the human morphological structure

Cerebral palsies are expressed in apparent motor deficiencies, which are accompanied by changes in body shapes and positions as well as operational changes in many life-supporting organic systems. Efforts to correct these disorders are based on fundamental regulations governing the human body, namely: 1) uniaxiality, 2) metamerism, 3) antimerism.

A uniaxial structure is manifested by the equal distribution of parts along a single axial direction in the body skeleton – from the head to the coccyx whereby the spinal column acts as the central axial link.

Metamerism is manifested by the constitution of body parts similar to the structure of repeated segments, which was determined by somite segmentation (primal body divisions discernible at the embryonic stage). Metameric (segmentary) structures are inherent to the spinal column, short body muscles, spinal cord, nerve roots, spinal brain nerves, blood vessels and others.

Antimerism is manifested by bilateral (right and left-sided) body symmetry relative to the central sagittal plane. This principle can be observed in the human body by the even binate distribution of most organs; bones, skeletal muscles, and most parts of the internal organs. Binate organs are discernible at early stages of development. The dorsal cord is the axis of guide for body symmetry. Symmetrical means absolute; any disorders in body symmetry will be unfavorable for the organism. Therefore, body symmetry is a permanent sign of good health.

All these general principles relative to constituting a healthy body (uniaxiality, metamerism and antimerism) are used to evaluate the body morphology of a patient with cerebral palsy. Any detected anomalies in body constitution and rehabilitation possibilities of a patient’s deformed body can be appraised and treated further by employing the intensive neurophysiological rehabilitation system.

Rehabilitation of movement functions begins with the normalization of the spinal column, the central body axis, which ensures pre-requisite conditions for human verticalization and erect walking.
3.1.2. Biomechanical features of posture and movements of the human body in the gravitational field

The formation of morphological and functional principles of erect walking in humans is a complex and lengthy process which begins in the early embryonic genetic stage. There is information that body straightening is specific to the most initial stages of human embryonic development [Yurovskaya V. Z., 1983]7. Maturation terms for human systems are prolonged in time; a newborn’s somatic development is considerably slower than the newborn monkey’s. The results of this prolonged growth are observed in the great brain; further development and maturation continue after birth.

In most animals, the longitudinal axis of the body is positioned horizontally, perpendicular along the gravitational vector field and balance is retained by means of four leg supports [Tank V., 2004]8. Hereby, there is a reflex reaction in managing postural actions, most likely with minimal participation of the upper sections of the nervous system (Illustration 3.1.1).

The human body holds a special position in relation to the terrestrial gravitational field: it is perpendicular to the terrestrial plane, which may seem contradictory to laws of motion. The human longitudinal body axis is parallel to the gravitational vector field, whereas the fundamental masses of body links are concentrated within relatively small distances [Gurfinkel V. S., 1965]9. The support area is small, the central body mass is situated high above the support area, and centers of gravity of all body links are directed towards the supports (Illustration 3.1.2).

The vertical position of the body is distinguished by its extreme instability. Great coordination and precision in the interactivity of many kinematic pairs and skeletal muscles are needed for human movements in space and using distal supports. Nevertheless, it is virtually impossible to maintain body position by mere muscle reflex contraction. Therefore, all parts of the locomotor apparatus need to function in order to maintain the erect (orthograde) position. These mechanisms were included during the evolutionary process when upper limbs were liberated and a new effective operational system, “brain to hand”, was formed. This system expanded fields of body interaction with the external environment.
Furthermore, essential changes in human body structure occurred in accordance with axial loads. Features of body structure are not only connected with new characteristics, but also with a recapitulation of distant ancestors’ characteristics. Thus, many structures which are characteristic of human ancestors are subject to involution (the cord, branchial arches, pharyngeal recesses, some parts of the coccygeal vertebrae and others).

In addition, structural features appear and consolidate favorable vertical movements. Indicators for erect walking include spinal column flexions and foot arching, both of which absorb vertical loading. Voluminous aeriferous pockets are important for results and conditions for erect walking; they alleviate skull weight, collar bone curvature, consolidate the hand’s lateral extremity (radialization) and the leg’s medial extremity (tibialization). Positions (frontal) of shoulder blades and sacrum are realigned in response to axial loading. Long limb bones are subject to torsions and twisting as a result of muscle pull. During the assimilating and mastering processes of walking, the terminal phalanx of the foot widened; its shape has become one of the most important taxonomic indicators of erect walking and has been accepted in classification and systematization theories [Khrisanfova E. N., 1978].

Having assumed a vertical position, the human body became similar to a solid spring just waiting to straighten out and convert its surplus of potential energy into kinetic energy movements. An important role in body verticalization is played by the spinal column, which adapts to axial loading at the expense of the vertebrae, joint and disk structures. A special “melody” for the spinal column is created by the configuration of vertebral bodies and intervertebral disks as functional spinal curvatures are carried out on the sagittal and frontal planes.

Fundamental dislocations of the spinal column are possible around the vertical axis due to deeper flexures and modeling of intervertebral disks, around the transversal axis with flexure changes in the sagittal plane and around the sagittal axis with lateral modeling of the spinal column (Illustration 3.1.3).
Orthograde posture has determined a relative limit for potential gravitational energy necessary for any human movement, which itself includes movement of the whole body in relation to the external environment, body links in relation to one another and deformation of tissues, organs and systems. Mechanical energy is necessary for locomotion; it comes from the outside as well as the inside. Energy from the outside is provided by outer forces; inside energy arises when chemical energy is changed into mechanical. Deformations occur when posture and body link positions change; this, in turn, weakens or strains muscles and other tissues, and irritates internal forces. During movement, the potential energy of the stretched muscle is transformed into kinetic energy. This cyclical process is executed with minimal loss of energy [Laputin A.N., 1999].

At the same time, energy exchange and transformation in the multi-layered systems of the organism are carried out on various levels: 1) atomic and molecular, 2) cellular and tissue, 3) pertaining to organs, and 4) organismal. The leading role at the third and fourth levels is held by the terrestrial gravitational field. Gravitational energy is one of the most convenient kinds of energy and can be used for artificial reproductions of a non-equilibrium state and the detection of energetic resources in the external environment.

Functions governing body equilibrium and human body verticalization may be observed through gravitational interaction [Gurfinkel V. S., 1965]. From this viewpoint, the body’s morphological perfection is observed as part of a cosmic program of gravity, whereas actual human posture is regarded as an entire campaign of the organism’s gravitational interactions in regard to the external environment [V. A. Kashuba, 2003]. Thus, on the one hand, gravitational forces act as modulators of body shape and, on the other hand, they are permanent inhibitions in regard to body growth and development.

The bone lever is one of the most effective links in the locomotor apparatus; it is capable of accumulating, recreating and transferring gravitational energy. Bone levers detect gravitational energy and then transfer it to the organ’s systems by means of muscles. This allows the levers to work and operate more effectively by
means of creating artificial conditions for their functional operations whereby the organism could regulate the loss of energy resources.

Creating new programs and means for optimal movement activity is a most effective way to use gravitational energy. This has been realized in sports by gravitonics, a new system of physical exercises using weights [Laputin A. N., 2000]13. This system has also been tested for rehabilitating movement functions in children suffering from various forms of motor disorders, and especially, cerebral palsy.

Original trends towards rehabilitating vertical body postures and functional movements in children with cerebral palsy were elaborated at the Institute for Medical Rehabilitation as components of the intensive rehabilitation system [Kozyavkin V. I., 1995]14. The most important element in this system is the rehabilitation of skeletal muscles, joints and connective tissue formations. This is achieved by an entire complex of rehabilitation activities, the most important being a stable and durable correction of the spinal column as the body’s central axis. This system is described more in detail in the second chapter.

3.1.3. Muscle provisions for human erect posture and walking

Provisions for erect posture require a complex reflex process, which includes different sections of the brain. Neurons from different levels of the CNS take part in providing and supporting posture (Illustration 3.1.4). Among them are spinal centers, nuclei in the extrapyramidal system and cortical zones.

Neurons in the extrapyramidal systems receive impulses from associative cortical zones and send them to gamma motor neurons of the anterior horn of the spinal cord. Impulses are then directed from the gamma motor neurons to intrafusal fibers in muscle spindles; this action arouses their sensitivity. Impulses then travel along gamma afferent pathways from the spindles and finally spread to the alpha-motor neuron segment of the spinal cord. As a result, extrafusal muscle fibers respond to center commands and contract.

In this rehabilitation system, special emphasis is placed on specific muscles which ensure movement and maintain posture. Among all postural muscles (posture muscles), the most important role is played by body extensors and lower limb muscles, all of which provide support for the body.

Erect walking required changes in muscle pull in the terrestrial gravitational field; this was attained by altering muscle insertion zones and levels of development. Body and lower limb muscles were especially concerned in this process.
Role played by body muscles in determining vertical body posture in humans

Trunk stabilization is an important condition for long-lasting stability of the entire body. An important role in maintaining the trunk is played by spinal muscles, both those which directly connect the vertebrae and paravertebral muscles, which support lateral body sections.

Evolutionary changes to trunk muscles in the animal world, which accompanied erect walking, were connected with the tail and tail muscle reductions, shortening and widening of the trunk, expansion of the greater pectoral muscle on the ribs, and alterations in many other muscle insertions. **Trapezius muscles** and especially their clavicular areas became stronger; a levator scapulae muscle was formed (this muscle is inherent only to anthropoids and humans). The **rhomboid muscle** lost its insertion in the occipital bone; similarly, the **anterior serratus muscle** lost its insertion on the cervical vertebrae. The **pectoralis major muscle** in humans supplanted many muscles from the ribs; abdominal muscles were reduced whereas clavicular muscles were developed. Muscle insertion to the humeral bone was displaced proximally; as a result, shoulder movements were given more freedom of movement.

**Paravertebral muscles** play an essential role in maintaining erect body posture. They include muscles which were displaced from other parts of the body, as well as...
“their own” **autochtonous muscles**, which form deep layers in the dorsal surface of the spinal column. Autochtonous back muscles form two longitudinal muscle tracts: **the medial tract** made up of short segmentary muscles situated between the vertebrae, and **the lateral tract** made up of long muscles situated between transverse processes of the vertebrae and costal angles (Illustration 3.1.5).

Paravertebral muscles have multifunctional properties and also an organic connection with the spinal column; these muscles are not only functional, but also structural elements of the spinal column. Deprived of these elements, the spinal column’s strength would be minimal [Bernstein N. A., 1926]16.

Paravertebral muscles functionally resemble the opposing cables or ropes holding a ship’s mast and so, determine the stability of the spinal column [Popelianskiy Ya. Yu., 1974]17. Paravertebral muscles work and function according to particular regulations; they relax when insertion points draw closer to one another and become tense. Insertion points withdraw from one another in the following situations: a bending leftwards action exerts tension on paravertebral muscles situated to the right of the spinal axis whereas the muscles located to the left, relax; a bending rightwards action produces the opposite effect. These muscles also have a peculiar reaction during breathing phases. Most muscles become tense when we inhale and relax when we exhale. However, paravertebral muscles react in an opposite way; they relax when we inhale and become tense when we exhale.

When a human is in an erect position, the paravertebral muscles help to maintain an erect position and then relax one after another when a person bends over more than 10 - 15 degrees [Popelanskiy Ya. Yu., 1997]18. Paravertebral muscles take an active part in protecting the spinal column; they perform and function together with muscles which form the abdominal prelum.

Normalizing functions of body muscles is an important condition for renewing body posture and movement in patients with cerebral palsy. These autochtonous back muscles made a considerable contribution to body verticalization and walking during ontogenetic stages. Renewing the functional operations of these muscles in rehabilitation systems is important not only for the patient’s
erect posture, body equilibrium and locomotion, but also for eliminating concomitant disorders in both respiratory and cardiovascular systems, both of which are basic requirements for the organism’s vital activities.

**Role played by limb muscles in determining vertical body posture in humans**

Limb muscles underwent a complex evolutionary transformation in order to carry out new functions dictated by human erect posture. Muscle insertion areas were reduced in the limbs; muscle insertion points were displaced proximally; distal tendons lengthened. All these features caused increased tension on joints and limb muscles.

Changes in human upper limbs occurred due to loss of support functions and more freedom in arm movement, especially lateral and rotatory movements. The human leg acted as a push and shove support; many muscles were reduced, but others were strengthened, namely, muscles which prevented the body from falling forward. **The gluteus maximus muscle** is connected with maintaining the trunk in erect posture; it has additional support from the iliac crest. Muscle insertion was displaced upward, making the muscle a powerful extensor for the femur bone and a support for vertical body posture. As the gluteus maximus muscle developed, another muscle gained considerable importance, namely, the tensor fasciae latae; it bends the femur and, by transferring pull from the gluteus maximus and the gluteus medius, strengthens the knee joint, flexure and supination of the shins [Lesgaft P. F., 1951].

The mass in muscles belonging to the posterior group in the femur (bicep muscles of the thigh, semitendinous muscles, and **semimembranosus muscles**) was reduced; the muscle insertion points were also displaced proximally. Part of the human semimembranosus muscle merged with the adductor magnus. **The biceps femoris muscle** evolved with a short head.

As the role of extensor movements in the shins increased, the mass in the **quadriceps femoris muscle** increased. The rectus femoris muscle in humans (as opposed to inferior apes) was extended additionally in the anterior inferior iliac spine.

In the shins, the muscle part of the **gastrocnemius muscle** was displaced proximally; heel tendons lengthened considerably. The mass of the **soleus muscle** increased due to increased plantar flexure in the foot; this muscle was strengthened additionally in the interosseous membrane of the leg and tibia.

Thus, limb muscles in humans acquired a specific structure and continued to develop according to new functional demands imposed by erect walking conditions. The structural axis in the foot was displaced from the third toe to the second toe; muscle tendons lengthened and phalanges gained more strength. The plantar aponeurosis
began to play an important role in supporting the arch of the foot; in humans and anthropoids, it starts at the tuberosity of the calcaneus.

On the whole, when considering human lower limbs, the greatest development can be observed in extensor muscles of the femur and shins and flexor muscles of the heel. All these transformations led to anatomic and functional features of human muscles as opposed to animal muscles (Illustration 3.1.6).

In four-legged erect-walking animals, the main limb joints are in a half-bent position. Humans, whose position developed into erect posture, have joints which are very close to the extensor position. The vertical line of the center of mass (CM) passes behind the rotation center of the hip joint and before the rotation center of the knee and ankle joints. In a comfortable posture, CM projection passes at 7.5 mm behind the trochlear notch and 8.7 mm before the kneecap and 42.1 mm before the ankle joint [Gurfinkel V. S., 1965].

And so, this stance calls for muscle lengthening, which takes place in front from the transversal axis of rotation in the hip joint, and behind from rotation axes in the knee and ankle joints. Continuous activity of antigravitational muscles is necessary to ensure erect posture; these include femur and shin extensors, and foot flexors. The latter maintain and support the foot. The pelvis and thighs are also maintained by iliac psoas muscles and the capsular ligamentous apparatus, namely, iliofemoral ligaments of hip joints.

Lower limb muscles take an active part in the entire verticalization process of the child’s body. Thus, they not only stabilize and lock joints, but also create functional morphogenesis in the skeleton, namely, changes in form and position of distal segments corresponding to conditions for erect posture and walking. Child’s age of 6 to 12 month is critical for the development of lower extremity muscles [Elder G.C.B., 1993].

Pelvic muscles play a particular role in determining the biomechanics of erect posture and walking. Interacting with hip (thigh) muscles, they are functionally indispensable for adapting and restructuring thigh bones (femur). Erect posture is
conditioned by reducing the anti-flexion angle in the femoral neck and increasing its retroflexion angle. The latter does not appear in newborns, but it can be observed at 4 - 5 degrees in children between 5 - 6 years; it varies between 0 to 28 degrees in adults [Gafarov Kh. Z., 1990].

The iliopsoas muscle is one of the key muscles related to statics; it takes part in adapting the body to vertical posture. It works as a powerful flexor of the thigh at the hip joint; this power exceeds the weight in the lower limbs. At the same time, muscle pull changes the shape in the neck-shaft area, reducing the anteflexion angle in the femoral neck. The retroflexion angle increases simultaneously. These actions allow the CM of the body to be gradually displaced backwards. Such changes call for adaptive restructuring of superposed sections; they can be observed in hip anteflexion and formation of lumbar lordosis, which compensate CM displacement and maintain equilibrium.

An adaptive restructuring of shins and heels is no less important as it is essential to erect walking. There is a functionally expedient restructuring whereby the shin evolves away from the vertical as its proximal extremity moves inwards, its distal extremity outwards. The posterior section of the foot rotates outwards, whereas the anterior section moves inwards. Muscle pull and static load in the erect position, and locomotion play a leading role in these restructuring processes.

In newborn children, transversal axes in condyles of the femur and tibia bones form a 14 - 15 degree angle in the frontal plane. During internal torsions, these axes coincide with the frontal plane, but then they cut through the plane, moving backwards from the front at a 4 - 8 degree angle. Distal segments in the shin twist outwards and variate laterally, which ensures physiological valgus in the knee joint. This, in turn, determines projection of biomechanical axes of the shin onto the ball of the ankle joint and its axis. Finally, it results in an equal load being distributed onto tarsal articulations. This is a condition for normal development of the foot, formation of its support and shock-absorbing systems.

Thus, muscles create necessary conditions for modeling the human skeleton and its various functions from a newborn’s first days. This modeling is determined by muscle pull, which is transmitted from one group of muscles to the next within the muscle spiral system.

Therefore, it is necessary for patients with motor disorders to simulate these forces during rehabilitation procedures as they determine biomechanical and rational morphogenesis in the human skeleton and without which normal erect posture would be impossible. In addition, the rehabilitation of limb muscles is a condition for normal locomotion. The center of mass position changes during any kind of movement. In order to perform the planned movement adequately, limb muscles must act and ensure preventive stabilization of all kinematic links and take into account inertial effects of future movements of the head, trunk and arms.
3.2. Principles governing functional integration of skeletal muscles

In order to execute a concrete movement task, it is indispensable to have operational muscle integrations, all of which have different properties. Temporary and spatial synchronization of their work ensures flexible adaptation to environmental conditions. All of these muscle integrations have their own structural fundamentals.

3.2.1. Structural fundamentals of muscle integration

The structural fundamentals of physiological synergy are found in muscle integration, which include muscle pairs, longitudinal muscle groups and muscle spirals.

Integrations of longitudinal muscle are formed along the central body axis. They are represented by twin muscular bands on the ventral, dorsal and lateral surfaces of the body (Illustration 3.2.1).

Illustration 3.2.1. Diagram of integration of longitudinal muscles in the dorsal area [Title K., 1974]³

The muscles situated more ventrally from the spinal column are regarded as flexors; the muscles situated more dorsally from the spinal column are viewed as extensors. Simultaneous contraction of homolateral, ventral and dorsal groups complements the activity of the lateral metameric muscles, which ensure lateral bending of the spinal column.

Integration of longitudinal muscle allows for the preservation of body symmetry and movements of the axial skeleton. Phylogenetically, these forms of integration
can be seen as earlier configurations of muscle interaction; they predominate in the aquatic ancestors of terrestrial spinal primates who required only two levels of freedom for locomotion, namely, the dorsoventral and bilateral. In humans, the integration of longitudinal muscles is an important link in muscle harmony which ensures posture and movement. However, these muscles are only a small part of other forms of muscle integration.

**Muscle pairs** are forms of muscular integration which ensure stabilization and movement of kinematic body links around a defined axis of rotation [Leutert G., 1975].

Twin integration reflects the principle of reciprocal muscle interaction. Antagonist muscles act in such a way, for example, flexors and extensors, abductors and adductors, supinators and pronators (Illustration 3.2.2). All of these groups have operational agonist muscles, but their functions are continuously being controlled by opposing antagonist muscles. As they go about their concessive work, antagonist muscles ensure the conformity and flow of each movement. If antagonist muscles are excluded from their work, this may lead to discontinuity or gradation of movement.

3.2.2. **Muscle spirals**

"The extremity of any segment of a human body, whether it be the head, hand, foot or trunk should not portray sharp angles in space, but sinuous lines, which may closely resemble contours of an ellipse, the figure eight or a spiral"

*George Demeni*

Muscle spirals represent the functional integration of muscles, which ensures rotational and forward movements. Eiloid integration of muscles appeared in terrestrial spinal primates who adapted to more complicated posture and movements. The spiral is a universal form in space organization, the highest configuration of all living things, beginning even with the DNA molecule. When observing the grass snake simply and rationally, the ideal picture presents right-sided and left-sided muscle
spirals from the very top of the head to the bottom extremities; these ensure agility and velocity in locomotion. Particular differentiation of spiral muscular integration was reached in humans.


The basis for muscle spirals is found in the chain of skeletal muscles; their essential function is transferring efforts or force from one link to another. Spiral muscles are composed of other muscles which take part in forming spatial decussation. This ensures relative structural and functional independence as opposed to directional spirals. Muscle spirals can be divided into two categories: regional and organismal.

**Regional integration of muscles** includes the muscle spirals of kinematic links in the body. These can be referred to as the “proper” muscle spirals belonging to the trunk and limbs.
The muscle spirals located in the trunk provide for the maintenance of internal organs, determine particular movements of the spinal column, the thoracic cage and the coordinated operations of respiratory muscles (Illustration 3.2.3).

Beginning in the neck region, spirals consecutively deliver muscular tension from one level to another. As it decussates with the spiral arriving from the opposite side, each muscle spiral winds around the trunk and proceeds to the other half of the body.

Muscle spirals in limbs are used to execute rotational movements in the kinematic links around the longitudinal axis. Another important function of these spirals is shock absorption and damping impact waves during locomotion and falling (Illustration 3.2.4).

Eiloid integration of limb muscles includes flexor and extensor muscles, pronator and supinator muscles, and abductor and adductor muscles.

The interaction between limb spirals reflects the biomechanical fundamentals related to the functioning of joints. Thus, the “graphs” of muscle work in the hip joint during the support phrase bring to mind the inverted “graphs” in the ankle joint [Gurfinkel V. S., 1985]: the muscle tension in the anterior muscle group of the shin combines with tension in the pelvic muscles and the posterior group of muscles in the thigh and conversely. Hereby, the spirals governing external rotations of the segments in the lower limbs prevent them from executing internal rotations.
Organismal muscle spirals are formed by integrating regional spirals into a single and unique system, which delivers force along the muscle chain [Title K., 1974]; [Shaparenko P. F., 1988]. As a result of this, skeletal musculature appears as an incomplete quantity of curvilinear structures or successively joined spiral trajectories. As they cross over from one side of the body to the other and join the right and left halves of the body together, muscle spirals create an indivisible muscle system with diverse functions. In this system, muscles execute local and general (as part of spiral groups) functions. General functions include the preservation of bilateral body symmetry in the terrestrial gravity field, particular movements of the spinal column and limbs, coordinated forward and rotational movements of the trunk and limbs, decussating coordination work in the fascia of upper and lower limbs during the walking process. Muscle spirals also act as reliable shock absorbers and utilize concessive muscle work for damping impacts and jolts, which occur during locomotion. The different processes of standing, walking, external respiration, blood and lymph flow are optimized at the expense of the spiral integration of muscles.

The transfer of force into spirals is carried out by connective tissue structures – the fasciae, aponeurosis, ligaments, joint capsules, muscle tendons and the soft skeleton of the muscles. None of these structures are passive; on the contrary, they are active elements capable of contracting. However, the basis for spirals can be found in skeletal muscle chains, which transfer tension from one link to another. Each spiral uses a determined collection of muscles. Individual muscles take part in spiral actions aimed at different purposes. General spirals wind around the body and include internal and external spirals (Illustration 3.2.5).

Internal spirals begin in the sternocleidomastoid muscle regions and move along the ventral surface obliquely downwards, to the opposite side of the trunk. The spirals envelope the trunk and then the lower limb and finally reach the

Illustration 3.2.5 Diagram of muscle spirals in the body [Shaparenko V. S., 1988]
anterior surface of the toes. As a result, internal spirals bend the trunk and extend the foot (dorsal flexion).

External spirals begin in the splenius muscles of the neck and head and move along the ventral surface of the body obliquely downwards, to the opposite side. As they bend the trunk and lower limb, the spirals reach the plantar surface of the toes. External spirals extend the trunk and bend the feet (plantar flexion). As a result, external and internal chains are formed, which in turn, create right and left-directed spirals. Each spiral has its own mirror image; the body is secured by spirals arriving from opposite circinate integration of muscles, which conveys force and strength from the finger extremities to the toes, both of which are situated at opposite ends of the body.

Thus, general eiloid integrations envelope the body in mirror images of right and left spiral-like patterns, and so create the fundamental principles for posture and movement. External spirals begin on the posterior surface of the body, whereas internal spirals start on the anterior surface. The spirals terminate their journey in the phalanges of the feet: the internal spirals on the dorsum of the foot, extending
and supinating the foot; the internal spirals on the sole of the foot, bending and pronating the foot.

Nevertheless, attempts have been made to determine which muscles belong to spiral groups and convey force and strength to the body; these attempts are quite provisional so far as muscle pull consistently changes at the expense of their own interchangeability. Muscles are arranged in many layers. Andreas Vesalius (1514 - 1564), a Padua doctor and anatomist, distinguished up to seven layers of dorsal muscles running in different directions (Illustration 3.2.6).

Therefore, the muscle ensemble does not represent a rigidly organized system, but a chain of interchangeable links where muscle structure can change in accordance with the new required work task. The brain “selects” spiral structures which will provide adequate motor reaction required for maintaining posture, ensuring walking, running and jumping. When muscle groups are absent (for example, this can be observed in patients suffering from paralyses), then other muscles can team up together in order to ensure posture and movement. These muscles normally acted as supporting, neutralizing or stabilizing muscles in the kinematic link. This action conforms to fundamental theoretical principles related to functional systems, according to which individual physiological functions have multicomponent provisions, and the most important factor is the ultimate result. In particular, it has been demonstrated that provisions for just one of these functions can be accomplished by composing with one or the other physiological indicators and often by using their various and quantitative integrations [Shydlovsky V. A., 1982]31. This action is also extended to structural provisions for movements. Therefore, peculiar features of motion reactions can be carried out at the ontogenetic stage by systems which provide useful, adaptive and self-organizational results in the organism.

Even though attempts to limit spirals by using a concrete group of muscles are always conditional, generalized patterns of decussation and spirals indicate the direction for general pull and lay the basis for more detailed analyses of each particular case. These patterns allow us to simplify what is complex and assist us when we begin the actual analysis (Illustration 3.2.7).

Whatever structure the muscle spirals may have, their basis is the chain of skeletal muscles, whereas the functional substance lies in the transfer of muscle force from one link to the next through connected tissue structures. At each moment, spirals use a given set of muscles, which changes in conformity with the constantly changing tasks related to statics and locomotion.

Spiral muscle chains are biologically and economically expedient systems, a basis for rational body adaptation to conditions of statics and dynamics. Concerted pull of muscle groups can be added into the general pull exercised by variable acts, which help to maintain vertical body posture in the erect position and are conducive to rotational movements in the joints.

Eiloid integration of muscles reflect the interaction between the right and left sides of the body; they are foundations for muscles and enable them to absorb shock
during erect standing and walking; they show a way of adapting to gravitational forces and muscle pull; they are the basis for muscular and fascial formation in the uterine cavity, which help to protect and maintain internal organs. Muscle spirals support the bone skeleton, fix the head position in a dynamic way and preserve physiological bending movements in the spinal column, take part in respiratory inhalations and exhalations of the thorax and create the basis for positioning, which is required for following movements.

Twin spirals, but differently oriented, are conditional for normal statics. If the interaction between twin spirals is altered, then the bilateral symmetry of the body is disturbed. This can be observed especially in patients suffering from CP.

Muscle integration is also a basis for muscle synergy, a semi-continuous interaction of muscle groups, which are formed when a person has mastered his movements. Muscle synergies are subsystems belonging to the general system of muscle interaction and are therefore, interdependent and controlled.

In practice, manual therapy applied to individual muscles may not give lasting results if the interaction between the given muscles and other muscles in the general spiral integration pattern is not restored. These facts have been confirmed by clinical observations of patients suffering from intervertebral osteochondrosis [Kadyrova L. A. and others, 1991][26] and patients suffering from CP [Kozyavkin V. I., 1996][32].

Analysis of fundamental stages in the formation of these muscle integrations help us to understand the principles related to neuromuscular integration.
3.2.3. Main phases of formation of muscle integration

Executing movements calls for complex neural control, which includes motivation, awareness of the decided movement and muscle stimulation.

The history of muscular and neural interaction begins at the early stages of the prenatal period, long before actual birth, when the connection between muscles and nerves has been firmly established. The developmental levels of the neuro-muscular system, which is progressively taking shape, is reflected in embryonic movements [Carlson B., 1983]. The embryo passively changes its position in the amniotic fluid until the 6th week, whereas, from the 7th week on, it is capable of reacting by bending its neck feebly when hairs come in contact with its lips or nose. This testifies to closures of initial functional curves. From the 12th week on, spontaneous and irregular movements are replaced by more purposeful reflex reactions.

The very first spontaneous movements appear at the end of the second month, namely jerking actions moving from one side to the other, which indicate the functional maturity of the muscular body walls. At the beginning of the third month, reflex contractions of facial muscles and hand-grasping movements appear. In addition, flexor muscles join in earlier than extensor muscles under the influence of signals from the red nuclei. Swallowing movements as well as rhythmic thoracic movements appear during this period.

Weak respiratory movements also become apparent up to the 4th month of fetal development. Simple movements are consolidated even further, whereas more complex reflex movements appear and sense organs begin to develop. By the end of the third month and after the appearance of general dermal sensitivity, taste and vestibular functions emerge, followed by audition and vision functions [Criley B.B., 1969].

Illustration 3.2.8. Stages of prenatal development of the human embryo.

a) the embryo at the 9th week of the gestation period; 3cm in length
b) the embryo at the 14th week of the gestation period; 6cm in length
c) 20-week-old fetus; 19cm in length [Marieb E., 1997]
Later, faculties for movements and simple reflex reactions extend to distal areas according to the cranial and caudal gradient, which is reflected in the descending myelinization process of movement pathways.

Thus, the transfer of force and strength from one muscle to another appears even before birth itself. Initial connections are established between muscle flexors; the actual embryo assumes a characteristic curved position, which is manifested on the spinal column by a primary kyphotic curvature (Illustration 3.2.8).

Further functional muscle changes are reflected in the sequence process of neural myelinization, which ensures specific motor, sensory and vegeto-trophic functions.

The peripheral nerve is formed when axons begin to grow gradually from motoneurons located in the anterior horns of the spinal cord. An axon terminal extends in the shape of a growth cone with many projections called filopodium. Filopodium posses contact orientation and so, search to attach to the innervating substratum [Patten B. M., 1959].

Sensory and motor nerve fibers reach the innervating region before differentiation has been completed. Large motoneuron axons establish a link to the myotubes of developing muscles. Thus, neural and muscle combinations (motor endplates) of axons and muscle fiber groups are formed and consequently, a muscle motor unit is created. Later, sensory projections of some neurons induce the formation of muscle spindles, whose receptors are stimulated when the given muscle contracts. Golgi tendon organs are formed in the muscle tendons: they are activated when muscle tendons are extended [Carlson B. M., 1983].

Spinal nerves begin to form when the large motoneuron axons in the anterior horns of the spinal cord start to grow. Their sensory parts form and grow from spinal ganglion cells. Proximal neuron projections are included in spinal cord pathways or connect with associated neurons, closing reflex arches. Consequently, the embryo begins to react to peripheral sensory stimuli.

Further development is accompanied by active neural myelinization. Myelinization is ensured by specific cells: macroglia cells or oligodendrocytes supply myelin to cells of the central nervous system and Schwann cells supply myelin to peripheral neurons. Schwann cells intertwine with developing nerves wrapping them into a layered lipid sheath (Illustration 3.2.9).

The myelinization process of nerve fibers in the CNS continues to the age of three and completes the formation period of white matter in the brain. Myelin performs an insulating function for nerve fibers, and increases the speed at which impulses propagate.

In phylogenesis, the myelinization process takes place much later; it is more characteristic of somatic nerves.

In a autonomic nervous system, less myelinated nerve fibers propagate impulses at a lower speed; overall adaptive trophic functions remain intact in this system. The development of the somatic nervous system appears to be more advanced than the
autonomic system and the speed whereby the impulse is propagated along the myelinated somatic nerve reaches 100 mm per second or more.

Forming somatic nerves provide for the innervations of head, neck, trunk and limb muscles. Furthermore, limb muscles have unilateral innervations and the diameter of their nerves exceeds the nerve diameter in other parts of the body. Body muscles have bilateral innervations and so, suffer less in hemiparesis disorders.

Decussations of muscle fibers also begin to form during the intrauterine period, but are finally completed after birth. One of the earliest muscle decussations is formed in facial and mastication muscles. Decussations of muscle fibers are particularly well expressed in actions of both mastication and sucking muscles.

The formation of the nervous system and especially of neural myelinization continues after childbirth. Many functional changes reflect a process sequence which ensure specific functions required for the development of a small child [Carlson B., 1983]. Generalized myofixation conditioned by underdeveloped cortical centers of movement regulation can be observed in newborns: the child is born with “locked” body muscles extending from the surface to the deepest parts of the body. Flexor myofixation does not apply only to muscle groups which ensure movements in head and hip joints. On the average, flexor muscles and pronators clearly dominate extensor muscles and supinators when the body and limbs are flexed. The child can turn his body onto the side without the help of pectoral and pelvic arch. Unconditioned reflexes provide for such slow-moving actions.

Muscles are slowly disconnected from myofixation as in-born, unconditioned and tonic reflexes, which close their reflex arches from the neck and trunk to the dorsolumbar area, gradually vanish [Magnus R., 1913].

The tonic neck reflex appears more often during the child’s first three months. By the end of the third month, the labyrinthine righting reflex has more and more

Illustration 3.2.9. Axon myelinization in the Schwann cell: a) cross-section of a Schwann cell surrounding the axon; b) axon surrounded by numerous Schwann cells, which are protected by a continuous coating of melanin [Enoka R.M., 1998]
influence on maintaining normal posture. As a result, flexor myofixation is reduced, whereas the position of the head has less influence on muscle tone level.

During the following three months, many unconditioned reflexes are slowed down and labyrinthine reflexes clearly dominate. As a result, the primitive righting neck reaction gives place to differentiated body movements with rotatory elements, excluding head movements. It can be affirmed that surface body muscles are unlocked and muscle spirals, which provide for rotatory body movements, come into play; the child masters the action of turning onto his stomach and back over.

Muscles are slowly disconnected from myofixation as in-born and tonic reflexes gradually vanish. Muscles situated in all layers of the body, from surface to deep muscles, are released successively, the movements of the spinal column increase as three, then five, then even more efferent spinal segments join in the movements. Myelination of the pyramidal pathway begins; by the beginning of two months, the axons of the lateral pyramidal pathway have been myelinated to level C1 - C4. Extensor muscles related to the head are gradually included in movement activities. The child begins to control and maintain his head. Extensor muscles related to the head, such as sternal, clavicular and mastoid muscles, where internal muscle spirals begin their journey, are activated.

By 4 - 5 months, the myelination process of pyramidal pathways has reached level C5 - T2; the in-born unconditioned grasping reflex disappears. The child begins to control his movements, starting from the shoulder girdle, and then the humerus. Hand support reactions appear. Furthermore, both individual muscle contraction and the relaxation of many muscles, which are ensured by clear-cut muscle interaction, are important signals for leaving the nervous system. Muscle integrations are formed in order to provide for movements of the body and kinematic links [Ivanitskiy M. F., 2003]. They consist of muscle interaction between various rotator axes: 1) flexor - extensor movements; 2) abductor - adductor and 3) pronator and supinator movements.

Decussations in neck, spinal and upper limb muscles are formed as control of the head and sitting skills are mastered. The volume of movement increases, ligaments of upper limbs are established and hand movements directed towards a given object appear. By four months, muscle spirals of upper limbs have begun to take shape. Reciprocal interaction between internal and external spirals is established, most likely by the child’s fourth month.

Basic sitting skills are put into place after rotatory righting movements from the back onto the stomach have been mastered. The sitting position calls for specific postural muscles, which fix and stabilize the position of the body. Sitting with support becomes possible by six months of age, whereas sitting with bent hips and shins can be mastered by 7 - 8 months. Furthermore, muscle tone symmetry appears, whereas muscle tone asymmetry at the age of 2 - 4 months was connected with the dominating influence of asymmetrical tonic neck reflexes.
Improving and perfecting hand movements can be viewed as the most important stage of motor development. The in-born grasping reflex disappears by the age of four months and the hand begins to execute arbitrary grasping movements. After the age of 6 months, the child learns to use the opposing force of his thumb, which is the basis for exercising a precise grasping movement.

Crawling constitutes a necessary stage in forming locomotor functions; the child begins to crawl between the ages of 6 - 8 months and improves his movements continuously in the course of the following two months. These movements include crawling on the stomach with the help of arm muscles and small rotatory body movements and crawling on all fours with the help of arm, body and leg muscles. Decussations of thorax and spinal muscles improve at the beginning of the crawling stage. All these stages reflect phases of development and the functional inclusion of all muscle interactions; muscle spirals of lower limbs are the last to join the general functional scenario of coordination.

By the age of 7 - 8 months, muscle interaction in the body and lower limbs appears; the child is able to maintain an erect position with the help of some sort of a support; he also makes use of the muscle strength in his upper limbs to stand up. Subsequently, leg support functions take shape, which will become satisfactory and complete after the muscles of kinematic body links have been fixed. By the age of ten months, functional interconnections between extensor and flexor muscles are established; the child crawls around more easily and stands up with some support.

By the end of his first year, the child overcomes gravitational forces, adopts erect posture more readily and starts to walk. During the standing position and locomotion activities, the child uses a whole arsenal of possibilities in order to increase the stability of the body, which actually finds itself in an extremely unstable position. The child increases body stability by extending support areas; he expands the distance between his feet, decreases the CG location point, inclines his head or his body, flexes his leg joints and projects the CG onto the frontal part of the foot by moving his hands forward. Moreover, he takes short steps when walking, which reduces the time spent on support areas. All these factors allow the child to overcome the most complicated features of adapting the body to erect gait, which demands skeletal modeling and activation of postural muscles.

When the body is in the erect position, its location in space is constantly modified in connection with the CG, which is conditioned by respiratory phases, the circulation of blood, lymphatic fluid, cerebrospinal fluid, exhaustion and so on. This is determined by the intermittent activity of skeletal muscles, which reduces static moments when body masses are displaced. It is possible that a differentiated activity of deep and surface spinal muscles exists; deep muscles control reciprocal positions of the spinal column, whereas surface muscles maintain the equilibrium of the whole body [Morris L. M., 1962].

A one-year-old child starts to use the rear impact of his lower limbs when walking. Due to the push impact, the leg extends or straightens out in the hip and knee...
Principles governing functional integration of skeletal muscles

joints and flexes in the ankle joint. With time, muscle mass grows, leaving structural changes in hip extensors (especially in the gluteus muscle), shin (tibia) extensors (quadriceps muscle of thigh) and foot flexors (triceps muscle of calf and others) which ensure repulsion from the support. A functional band of muscles (ligaments) is created, which reflects operational needs for erect walking.

The quality of walking improves over the following three years. A tighter functional interconnection between flexor and extensor muscles is established. The child moves into the erect position more precisely by transferring his CG onto the support area and maintains his equilibrium by moving his body, thus, altering the angles for body stability.

After the age of three, the high cortical levels of regulation are activated. A functional interconnection of external and internal muscle spirals appears: when walking, the child uses rotatory body movements, but from the age of 4 - 5 years, he includes decussated and coordinated movements of upper and lower limbs. These actions reduce excessive body rotation and increase gait speed [Ivanitskiy M. F., 2003].

Push impacts are applied in running, which illustrates how muscles attain an optimal developmental level of muscle interaction. As soon as the child’s foot pushes away from the support area, muscle circuits perform a gigantic task when they overcome gravitational forces, i.e., during the pushing off phase, they gather the body together into a spiral, fix this position and as soon as the foot meets the ground, they proceed with their next task, ensuring shock absorption.

On the structural level, adaptation to erect posture and erect gait is completed by specific skeletal reconstructions and improvements to neural and muscle interactions. All muscle spiral integrations allow decussated and coordinated movements of upper and lower limbs to be included, create reliable shock absorption during locomotion activities, and protect the body from vertical overloads, shocks or jolts. Decussated coordination with multi-directed rotations of the pelvic and shoulder girdles reduces excessive rotatory body movements, increases reliable and rapid body locomotion during both single and double support phases of gait.

Shoulder and pelvic girdles are mastered individually as movement pathways mature; movement is directly activated through the pyramidal system and indirectly activated through the extrapyramidal system.

The quality of the child’s movements is conditioned by the maturity and adaptive capacity of the nervous and musculoskeletal systems. A striking example of this phenomenon can be observed in multifunctional movements of distal limb areas. The expansion and differentiation of cortical fields played a particular role in the evolutionary process of the human hand, and so, altered the motor and tactile functions of the hand [Khrisanfova Ye. N., 1978]. The most important functions of the human hand are found in sagittal plane movements when the thumb exerts an opposing force and so, sets up the “precise grasp” mechanism.
The child’s motor skills improve gradually as he familiarizes himself with the surrounding environment. As the upper cortical level of movement regulation is included, the child progressively and actively masters the surrounding environment and improves conscious movements, both of which are prerequisites for attaining professional skills. All these movements are effectuated by using all variants of muscle integration - both general and regional.

3.2.4. Certain variants of disorders in functional muscular interactions

Maintaining vertical body posture demands clear and precise interaction between all kinematic body links within the terrestrial gravitational field, which can only be achieved by taking into account all skeletal muscles. Disorders in muscle interactions are manifested by muscular imbalance, whose causes and consequences are diverse and complex.

Muscular imbalance may affect body symmetry and posture, modify movements, restrict respiration, cause difficulties in blood circulation and the outflow of lymphatic fluids, and reduce the capacity of muscles for work. Theoretically, disorders of body structures can arise in any area. Modifications to frontal (scoliotic deformities) and sagittal (lordosis and kyphosis of sections of the spinal column) planes are significant for clinical reasons.

In order to maintain a correct postural position, the symmetry plane of a body in movement should coincide with one of countless symmetry planes. Nature made use of bilateral symmetry for highly-developed creatures, which provides for optimal interaction of the body with the surrounding environment. Disorders of this type of symmetry have been fairly well researched. However, disorders of body posture in sagittal planes due to muscular imbalance have not been so extensively explored.

Specific body posture during erect gait is determined by irregular load or tightness of muscles and their integrations; therefore, muscular imbalance can be manifested by such disorders as decussion or scalariform syndromes, as well as others [Ivanichev G. A., 1997].

Upper decussion syndrome

“The upper decussion syndrome” is characterized by a double muscular imbalance of the frontal and rear surfaces of the body. The first imbalance is due to overloaded extensors of the neck and head (as well as fixators of the shoulder girdle) on the one hand, and to weakened deep flexors of the neck, on the other hand. The second imbalance is due to overloaded thoracic muscles on the ventral surface of the body and weakened interscapular muscles on the dorsal surface (Illustration 3.2.10).
Imbalance may be associated with individual muscles being overloaded, or their disposition to hypertonicity, during reciprocal inhibitions of antagonist muscles. Muscle tension is frequently located in the superior region of the trapezius muscle, which activates the shoulder blade (scapula), scalene and greater pectoral muscles. Pain or defense reactions due to muscle overload or tightness in the pectoral muscles or the shoulder girdle can result when these same muscles are activated. The initiating agents may also be fatigue or physical, psychological and emotional stress. Therefore, stress reactions often appear as muscles of the shoulder girdle and anterior chest wall activate defense mechanisms by making the shoulders elevate and retract. These actions result in postural disorders and may lead to further movement disorders. The sagittal profile of the spinal column is modified resulting in severe curvature of the neck (lordosis) and thorax (kyphosis). Problems are aggravated when movement segments of the neck and the upper thoracic vertebrae become locked and muscle sclerosis sets in.

As the upper decussation syndrome progresses, neck lordosis and stooped posture become worse. Imbalance may be caused by weak and flaccid muscles (interscapular group and neck muscles), as well as by muscles which tend to be hypertonic, namely, scalene and greater pectoral muscles and superior regions of the trapezius muscle.

Lower decussation syndrome

The lower decussation syndrome is due to the imbalance of ventral muscles and muscles of dorsal surfaces of lower body limbs, as well as pelvic and hip muscles. The syndrome is manifested by functional overloads of body extensors in the pelvic
region (the anterior lumbar quadrate muscle which straightens the body) connected with weak abdominal muscles. Other components of “decussation” are related to hypertonic muscles, which assist in flexing the hips (the greater psoas muscle and the rectus muscle of thigh) when gluteus muscles are weakened. These muscle phenomena produce anteflexion in the pelvis and consequently, severe lumbar curvature (lordosis) (Illustration 3.2.11).

Activation of the greater psoas muscle defines the deepening curvature in lumbar lordosis. Deep and often asymmetrical impressions near the spinal column may appear in the insertion region of the great psoas muscle. Lumbar hyperlordosis is characterized by stretched and strained rectus and oblique muscles of the abdomen, which finally results in abdominal protuberance.

Further activation of the great psoas muscle leads to further fixation of lumbar hyperlordosis. Lumbar hyperlordosis tends to develop when the body adjusts to overstrained pelvic muscles in pregnancy or an increase in body mass with trophic factors in the abdominal region. Thus, the centre of gravity is moved forwards onto the forefoot. Overload and tension in weaker parts of the forefoot produces transverse platypodia (flatfoot).

**Scalene syndrome**

The scalene (multi-storied) syndrome is manifested by muscle imbalance of the dorsal surface area of the body; these muscles run in cranial caudal directions. Overloaded and strained muscle groups alternate with groups of weak muscles among dorsal, pelvis and hip muscles. And so, activated and tight upper fixators
in the shoulder blades are followed by stretched interscapular muscles, then by overloaded and tight extensors in the lumbar spine, then flaccid gluteus muscles and then again, hypertonic muscles belonging to the posterior group of the hip (Illustration 3.2.12).

Restoring bilateral body symmetry and functional muscle interactions, which are both responsible for general harmony in the spinal column, constitutes one of the most important tasks for rehabilitation specialists treating patients with cerebral palsies.

**Principles governing functional integration of skeletal muscles**

Illustration 3.2.12. Diagram of scalene syndrome [Sak N. N., Sak A. Ye., 2002]42

**Imbalance of limb muscles**

This group includes unbalanced muscles which determine targeted movement in the joints. Imbalance is connected with disorders to the reciprocal interaction of antagonist muscles. The following are the most widespread:

1. Flexor - extensor muscle imbalance:
   1.1. Flexor - extensor imbalance of muscles providing for movements in the elbow joint
   1.2. Flexor - extensor imbalance of muscles in the knee joint
   1.3. Flexor - extensor imbalance of muscles in the talocrural (ankle) joint.

2. Abductor - adductor muscle imbalance:
   2.1. Abductor - adductor imbalance of muscles in the shoulder joint
2.2. Abductor – adductor imbalance of muscles in pelvic and hip joints

3. Supinator - pronator imbalance:
   3.1. Supinator - pronator imbalance of muscles in the shoulder joint
   3.2. Supinator - pronator imbalance of muscles in forearm joints
   3.3. Supinator - pronator imbalance of muscles in pelvic and hip joints
   3.4. Supinator - pronator imbalance of muscles in ankle joints
   3.5. Supinator - pronator imbalance of muscles in foot joints.

The above-mentioned imbalances are manifested by disorders in the interrelation between internal and external spiral extremities. Imbalances are fairly wide-spread and appear as nonphysiological adjustments of extremity segments.

Thus, flexor - extensor imbalance of muscles in the elbow joint may appear as a flexor adjustment in the forearm (when brachial and biceps muscles of the shoulder are overloaded) or, on the contrary, an extensor adjustment (when triceps muscles are predominate).

The development of imbalance of muscles in the pelvic and hip joints may be due to chronic muscle tightness, which does not take into account extended (stretched) abductor muscles (gluteus medius and gluteus minimus muscles and the assisting lumbar quadrate muscle). Such phenomena are especially observed in people whose professional activities put constant strain on the adductor muscles of the hip.

3.2.5 Disorders of muscle interaction in CP

Muscle imbalance is an organic manifestation of clinical CP. It is often accompanied by chronic muscle overload and vertebrogenic lesions of the peripheral nervous system (PNS) (scalene syndrome, upper and lower decussation syndromes). There may also be an imbalance in muscles which ensure movement in large joints. Muscle imbalance in cerebral palsy is caused by weakness in one muscle group and rigidity in another group (spastic variants) [Kozyavkin V. I., 1999].

These modifications become more and more fixed with time and so, tissues tend to react less and less to rehabilitation treatment. Therefore, well-timed and active rehabilitation activities for weakened or hyperactive muscles are of utmost importance for rehabilitation.

One of the most important conditions for rehabilitating patients with cerebral palsy is renewing functional muscular interaction. We should be guided by the idea that muscle groups are not permanent and can change according to each movement task. It is this variability of components of muscular integrations that make muscle groups so reliable and effective. In fact, it is not a catastrophe for total muscle integration if one muscle fails to function; the organism can react and choose another structure in the muscle chain.
It is most important to remove all signs of pathological synergies which tend to create excessive levels of freedom during the rehabilitation program. A conflict between the old system of adaptation and new possibilities is inevitable as the new program of adaptation is slowly mastered. New movement tasks are ensured by specific work which targets the activation of movements in individual joints and the rehabilitation of statics and dynamics of the whole body.

Most patients with CP suffer from movement disorders with mixed characteristics. Disorders of movement functions at all stages of locomotor development are observed, namely, control of the head position, crawling, sitting, standing and walking. However, the predominating form of disorder will determine the severity and particularity of the pathology, both of which should be taken into consideration when treatment strategies are developed.

**Spastic diparesis** is a form of CP whereby lower extremities suffer more than upper extremities. Lesions may vary, from mild to severe palsy. The child builds up particularly distinct pathological synergies for movement. He replaces the modified muscles with healthier muscle groups and consequently, creates original and adapted forms of standing and gait whereby he can maintain balance and proceed with gait by resorting automatically to compensatory reactions.

As muscle tone and tendon reflexes increase, the child adopts characteristic body posture where the legs can be observed in a decussated position, crossed over at the knees and gait becomes more difficult and unsteady (Illustration 3.2.13).

One of the characteristics of body posture in a child suffering from spastic diparesis is the internal rotation of upper extremities combined with the internal rotation of lower extremities. Such a combination of spiral-like muscle integrations dominate in the given pathology and are normally used only in individual movements.

The prolonged and simultaneous predominance of internally rotating spirals of upper and lower extremities can be associated with disorders of normal muscle interaction in the body. Restricted movements in the pelvic arch are combined with static overload of paravertebral muscles.

In order to maintain balance and gait, patients automatically make use of compensatory reactions, which cannot restore static and dynamic disorders, but can assist in gait. Thus, body stability increases as the CG location (the semi-flexed position of joints in the lower limbs) and the rotation axis in
leg joints draw nearer to the vertical CG pathway of knee joint positions. The patient reduces any risk of falling during ambulation by reducing the time spent on a single support and increasing the support area in double support periods. The support area increases due to the valgus position of the lower leg when a “third support point” is created at the level of the knee joints.

Thus, a new pathological system emerges from physiologically damaged systems, which creates unconventional forms of gait and new adapted mechanisms.

**Spastic hemiparesis** is caused when one side of the brain is affected and disorders of statics and body and limb movements continue to develop. A new pathological system requiring correction is formed due to hyperactive structures. The following can be observed on the affected side of the body: the shoulder is adducted, the forearm is flexed, the hand is clenched into a tight fist, the hip is bent and prone, the lower leg is extended, the toes are also extended (dorsal flexion) and the extended toes are used as support areas in walking. When analyzing such peculiar body posture, specialists can testify to the fact that there is a functional predominance in flexors of the upper extremities and extensors of the lower extremities. This is due to one-sided muscle hypertonicity of internal spirals and muscle weakening and stretching, which are formed by external spirals (Illustration 3.2.14).

One-sided disorders of reciprocal interrelations between internal and external body spirals are accompanied by curvature of the spinal column, body asymmetry and deformities. However, despite one-sided body disorders, patients are fairly active and completely ambulatory.

**Spastic tetraparesis** is the most severe form of CP. Patients suffering from this form of CP often are not able to walk; they cannot sit or stand without support. Developing muscles as well as external and internal body spirals undergo considerable modifications. As CP develops, these modifications are mostly manifested in initial spiral links (head, neck and upper limb muscles). High muscle tone becomes apparent and appears in the form of developing contractures in the joints as well as body deformities. Static rehabilitation and development of locomotor functions are very complex for this form of CP. The child can expect certain improvements in his condition only if there is an early and energetic comprehensive program of treatment. (Illustration 3.2.15).
Atonic and astatic forms of CP are characterized by an inadequate development of righting reflexes, deficiency of balance reactions and disorders of movement coordination against a background of muscle hypotonia, which in itself excludes the possibility of normal body statics. As a result, movements are uncertain and uncoordinated; the patient is able neither to maintain his head correctly nor to sit or stand. Weakened muscles are not capable of transmitting tension or force to the skeleton and adjacent muscles. Therefore, skeletal bones do not receive impulses for adapted changes in conformity with gravitational force demands, whereas skeletal muscles are not capable of forming functional muscle integrations, which ensure normal body and locomotor positions.

Hyperkinetic forms appear when extrapyramidal systems are affected; they are manifested by various changes in movements depending on the severity of subcortical lesions. These changes call for individual treatment, depending on the type of lesions (athetosis, choreoathetosis, twisted dystonia). These changes are most evident in muscles of the head, neck and distal sections of extremities; they are accompanied by disorders of body symmetry and even body deformities. The diagnosis and analysis of disorders in the locomotor system are very complex and can be done only by combining spasticity with athetosis or ataxia. Muscle dystonia, violent and forced movements, spastic muscle changes create particular difficulties when such patients are being treated.

Practically all forms of cerebral palsy can be successfully treated if there is an early rehabilitation program. Delayed rehabilitation causes priorly formed adaptations for standing and gait to be destroyed.

Therefore, the doctor faces a difficult choice if the patient turns to him very late. He must break the inherent compensation system or leave it the way it was and so, not risk harming the patient in any manner.

The application of the biodynamic program for movement correction can help the doctor to choose an active program without inflicting harm on the patient. The perfected system of complex activities enables doctors to make a favorable choice with a certain guarantee of ultimate success.
3.3 “Spiral” - a suit for movement correction

The Kozyavkin Method is a multidimensional action which provides for new functional conditions in the patient’s organism; moreover, it enables the child to develop his motor capacities more rapidly by means of normalizing muscle tone, increasing the volume of active and passive movement in the joints, improving tissue trophism, and activating neural and mental processes. All these improvements are used in the course of an intensive program of movement instruction and patient re-education [Kozyavkin V. I., 1995].

The biodynamic program for movement correction, which is used within the framework of the Kozyavkin Method, enables specialists to eliminate primitive and pathological movement models and construct rational movement stereotypes [Voloshyn B. D., 2003]. In order to re-educate the patient effectively, it is imperative to take the following recommendations into consideration.

1. The development of movements can only be effective if the patient’s body is in an optimal position. Patients suffering from CP need external corrective actions, which should be sustained at a certain level during all phases of work with the patient himself.

2. The designed movement should not hamper the patient’s locomotor activities.

3. All phases of rehabilitation involving movement correction should be carried out on the basis of an individualized program, which takes into account the characteristics of each patient’s disorders.

The “Spiral” suit was created to provide a biodynamic program for movement correction; it takes into account the biomechanical principles of movements in the human body, which are based on an anatomic analysis of functional interaction in the skeletal muscles. The suit is simple and does not cause the patient to react negatively; it is comfortable and can be applied to natural human ambulation and exercises on a treadmill, with game devices, exercises in mobilizing gymnastics, mechanotherapy and ordinary movement activities [Kozyavkin V., 2004], [Kozyavkin V. I., 2005].

The suit for movement correction consists of a system of resilient elastic straps that are wrapped around the body and extremities in a spiral-like fashion and attached to special support elements, such as vests, shorts, knee-and-elbow-pads, cut-off gloves and half boots. The suit is chosen according to the patient’s body morphology; it can be securely fastened owing to its collapsible and compressible qualities and lateral attachments. The entire surface of the support elements is made of special material suitable for fastening the elastic straps. There are no rigid parts in the support elements, which considerably widens the range of possibilities for mobilizing gymnastics.

The patient should be wearing close-fitting, thin and non-synthetic clothes (a T-shirt or a thin sports suit) before actually putting on the support elements. As
the patient puts on these support elements, we should find out whether he feels
comfortable or whether the suit elements are too tight. When the patient has been
dressed, special attention should be paid to the symmetry and accuracy of the
support elements, as well as all the attachments and adjustments.

The elastic tension of the suit provides the required corrective force to the
muscles. The suit has a special surface whereby tension straps can be adjusted
and attached to the support elements in any place. In addition, the specialist can
choose the direction and target point where actual force will be exerted, depending
on the movement disorders and the objectives set out in the designated phase of
treatment.

This system of elastic tension and force consists of an axial spiral, the main
spirals of extremities and additional forces. When the support elements have been
attached, elastic force is then applied to the axial spiral.

3.3.1. The Axial Spiral

The Axial Spiral is one of the fundamental components of the “Spiral” suit. When
using the Axial Spiral, the specialist aims at correcting the position and movements
of the trunk, and shoulder and pelvic girdles. The Spiral suit is attached to the vest
and shorts.

Illustration 3.3.1 The “Spiral” suit for movement correction
All versions of the Axial Spiral suit are based on double figure-of-eight spiral straps. When choosing a suit, the specialist should take into account the characteristics of disorders in body position and movement biomechanics [Kozyavkin V. I., 2005].

The following variants of the axial spiral have been developed:

- Main axial spiral (with two posterior crossings)
- Anterior axial spiral (with two anterior crossings)
- Combined axial spiral (with one anterior and one posterior crossing)
- Two-leveled axial spiral (with separate upper and lower correctors).

**Main (posterior) axial spiral**

This spiral is used most often on CP patients in clinical practice. The force exerted by the suit structure provides dynamic correction to the position and movements of the trunk, and shoulder and pelvic girdles. The main spiral activates muscle activity in the spine and so, is indicated for correcting the position of the shoulder girdle (shoulder blades and clavicle) and the upper arm, as well as eliminating pelvic torsion and excessive rotation in the hips.
The main axial spiral consists of two posterior crossing bands. The spiral effect is created by applying symmetrical elastic bands on both sides of the trunk.

The spiral band travels upwards from the left armpit and along the posterior spinal surface to the region above the right shoulder; then it moves downwards along the anterior shoulder surface to the right armpit. Encircling the armpit and then moving along the back, the band travels upwards and obliquely to the region above the left shoulder. Then, the tension band travels downwards along the anterior surface of the shoulder to the left armpit. At this point, it crisscrosses along the back and moves downwards and to the right, to the posterior superior iliac spine of the hipbone. Then, it continues along the gluteus muscles, encircles the external anterior surface of the hip just below the inguinal fold and moves to the anterior superior iliac spine of the hipbone. Then, the band travels from the back to the front and continues horizontally along the abdomen below the navel (between the navel and the pubic symphysis); it finally arrives at the anterior superior iliac spine of the left hipbone. The band located below the inguinal fold encircles the left hipbone (from the front to the back - inwards and forwards) and travels forwards. From this point, the band moves encircles the anterior and lateral surface of the left hip, travels upwards along the gluteus muscles and then, obliquely along the back to the right armpit.

In summary, the course of the main axial spiral begins at the left armpit, crisscrosses twice on the back region and finishes at the right armpit.

The anterior axial spiral

The anterior spiral begins at the left armpit. From this point, the band travels obliquely and upwards along the anterior surface of the thorax to the opposite right shoulder region located in the central area of the clavicle. The band then encircles the right shoulder joint and continues down to the right armpit and once again, onto the anterior region of the thorax; then it travels obliquely to the left region of the shoulder. The anterior superior crossing of the band is applied in such a manner.

The band moves from the back and encircles the left shoulder; from the left armpit it travels obliquely downwards and to the right along the surface of the abdomen to the anterior superior iliac spine. Then, the band moves towards the back along the lateral side of the right hip, along the gluteus muscles and the internal surface of the thigh; from there, it travels along the anterior and lateral surface of the thigh to the right iliac crest. Then, the band moves horizontally along the back to the opposite side as far as the left iliac crest. Then, the band travels downwards along the anterior and lateral surface of the thigh; it turns inwards and continues along the internal surface, towards the back and along the gluteus muscles as far as the anterior superior iliac spine of the left pelvic bone. From this point, the band travels obliquely upwards and to the right along the abdomen to the right armpit. The anterior inferior crossing of the strap is applied in such a manner.
Combined axial spiral

The combined axial spiral has two crossings: one is situated on the anterior surface of the trunk and the other on the posterior surface. The upper part of the combined spiral resembles the main axial spiral; however, here, the elastic bands crisscross on the anterior surface of the trunk and not on the posterior side.

The elastic bands are arranged in such a manner so that more force and tension can be created, adding to the initial force exerted by flexor muscles in the trunk. These actions strengthen the prelum abdominale muscle and correct lumbar hyperlordosis. The combination spiral also enables the specialist to modify the force and tension in the individual bands and thus, restore body symmetry. This is achieved when positional differences of the shoulder blades and pelvic bones are eliminated.

The combined axial spiral starts at the left armpit, travels upwards along the anterior surface of the shoulder to the middle of the left clavicle. The band moves over to the back area, travels obliquely downwards and to the right as far as the right armpit. It encircles the right shoulder from below and then continues upwards to the
middle of the right clavicle. From this point, the band travels to the back and then along the back, moving downwards and to the left as far as the left armpit. Then, the band continues along the anterior surface of the abdomen, travelling obliquely and to the right as far as the anterior superior iliac spine of the iliac bone.

It encircles the right hipbone from the front to the back and then moves along the gluteus muscles and towards the internal surface of the thigh. Then, the band travels forward along the inguinal fold, along the lateral surface of the right hip, arriving at the crest of the right pelvic bone. Then, it continues horizontally along the back to the opposite side reaching the crest of the left pelvic bone. Then, the band encircles the left hip from the external side and comes out on the anterior surface, travels downwards to the internal side of the left hip, and moves along the gluteus muscles to the anterior superior iliac spine of the iliac bone. From this point, the band continues obliquely and to the right along the anterior surface of the abdomen as far as the right armpit.

In summary, the course of the combined axial spiral begins at the left armpit; the band then crisscrosses on the back and on the abdomen and finishes at the right armpit.
Two-layered axial spiral

This spiral resembles the main axial spiral, but there are no connections between the elastic bands in the regions of the shoulder girdle and the hip. Thus, the given spiral can be used when the patient adopts various positions, including the sitting position. In such a manner, the two-layered spiral enables the specialist to apply individual corrections on two levels.

If necessary and with the help of additional force loads, which imitate the force and tension exerted by flexors or extensors of the trunk, the specialist can connect the elastic bands of the shoulder girdle and the hip.

The two-layered axial spiral consists of two figure-of-eight bands: an upper system and a lower system. The upper spiral system is used to correct the position of the shoulder girdle; the lower system is applied to hip and pelvic positions.

The upper part of the two-layered axial spiral has many variations. It can be used to correct anterior or posterior displacements of the shoulder girdle, depending on the situation at hand. The posterior superior spiral is used to correct shoulder protraction, whereas the anterior superior spiral is used to correct shoulder retraction.
The posterior superior part of the suit (with the bands crisscrossing in the back). The spiral starts at the left armpit. The spiral band travels obliquely and upwards along the back to the region situated above the right shoulder, right in the middle of the clavicle; it moves along the anterior surface of the shoulder and arrives at the armpit. The band then continues through the armpit onto the back, moving upwards and obliquely to the region just above the left shoulder, right in the middle of the clavicle. Then, the band travels downwards along the anterior surface of the shoulder to the left armpit.

The anterior superior part of the suit (with the bands crisscrossing in the front). The spiral starts at the left armpit. From this point, the band travels upwards and to the right along the anterior surface of the trunk to the area situated just above the right shoulder, right in the middle of the clavicle. It then moves downwards along the posterior surface of the right shoulder to the armpit. The band continues through the armpit onto the anterior surface of the trunk and then, makes its way upwards and obliquely to the area just above the left shoulder, right in the middle of the clavicle. Finally, the band travels downwards along the posterior surface of the shoulder to the left armpit.

The lower part of the two-leveled spirals is used to correct the internal and external rotation of the hips, and pelvic torsion and inclination.

The band of the lower part of the suit starts at the left anterior superior iliac spine of the pelvic bone, moves along the gluteus muscles to the internal surface of the left thigh. It passes through this area and continues to the anterior surface of the inguinal region, along the external surface of the hip as far as the left hipbone. From this point, the band travels horizontally along the back to the right side as far as the right hipbone. Then, it encircles the hip on the external side and continues to the anterior surface of the hip. It then travels downwards to the inner surface of the right thigh, along the gluteus muscles and finally, arrives at the anterior superior iliac spine of the right iliac bone.

3.3.2. Main spirals of the extremities

Spirals of the extremities are another important component of the suit for movement correction. These spirals continue and supplement the axial spirals by modeling force and tension vectors on extremity segments [Kozyavkin V. I., 2005].

The elastic bands form the extremity spirals; they are attached to several support elements, which in turn reinforce their position on the patient’s body and enable various vigorous and directional forces or tension to develop and act on different parts of the body.
Main spirals of the upper extremities

Three kinds of basic hand spirals are applied, depending on the specific features of movement disorders and the type of deformities affecting the upper extremities: 1) external rotation spiral of the upper arm and forearm, 2) internal rotation spiral of the upper arm and forearm, 3) internal rotation spiral of the upper arm and external rotation spiral of the forearm.

Illustration 3.3.6 Main spirals of upper extremities
1 - external rotation spiral of the upper arm and forearm,
2 - internal rotation spiral of the upper arm and forearm,
3 - internal rotation spiral of the upper arm and external rotation spiral of the forearm
The name of each spiral reflects the targeted direction of each corrective activity, which, as a rule, should be contrary to the patient’s deformity.

**External rotation spiral of the upper arm and forearm**

This spiral is aimed at correcting the internal rotation of the upper arm and flexor contractures in the elbow joints, as well as reducing the internal rotation of the forearm and the pronate position of the bone.

The external rotation spiral of the upper arm and forearm starts at the vertebra prominens (seventh cervical vertebra), where the elastic band is attached to the vest. The band travels along the back and the scapular spine to the upper arm; it intersects the deltoid muscle and moves on to the anterior surface of the upper arm, just below the greater tubercle of the humerus. The band slants gently and encircles the upper arm from the outside towards the inside. It continues to travel from above the internal epicondyle of the humerus to the olecranon of the ulnar bone.

From this point, the band slants gently and encircles the upper arm, moves across the lateral edge to the anterior surface of the upper arm and then, arrives at the head of the ulna bone. Then, the band folds over the ulnar edge of the bone and emerges on its back surface, where it is fastened to the cut-off gloves.

**Internal rotation spiral of the upper arm and forearm**

This spiral is aimed at reducing the external rotation of the upper arm and forearm. The internal rotation spiral of the arm starts at the vertebra prominens (seventh cervical vertebra), but slightly away from the line of the spinous process of vertebra, where the elastic band is attached to the vest. The band travels along the back, intersects the scapular spine and continues towards the axillary region. It then encircles the medial edge of the arm, emerges on its anterior surface and continues to the external epicondyle of the humerus. Then, the spiral slants gently and encircles the forearm, first around the rear surface and then over the medial edge as it continues to travel along the anterior surface of the forearm. It then moves downwards to the styloid process of the radius bone, then onto the dorsum of the hand and is finally fastened to the cut-off gloves.

**Internal rotation spiral of the upper arm and external rotation spiral of the forearm**

The internal - external rotation spiral is applied by combining the external rotation of the upper arm with the internal rotation of the forearm and a pronated adjustment of the bone. The course of internal - external rotation spiral in the
upper part resembles the course set out by the internal rotation spiral. The elastic band starts at the paravertebral line of the vertebra prominens (seventh cervical vertebra), where it is attached to the vest. The band intersects the scapular spine and travels to the axillary region, where it encircles the medial edge of the arm and emerges on the anterior surface. The band continues its way slightly above the external epicondyle of the humerus and emerges onto the posterior surface of the hand. When the band arrives at the point situated between the olecranon of the ulnar bone and the internal epicondyle of the humerus, it is fastened to the elbow pad and then, continues its journey in the opposite way. First, the band encircles the lateral surface and then the anterior surface of the forearm, arriving at the head of the ulna bone. Then, the band folds its way over the ulnar edge of the bone, emerges onto the opisthenar (the back surface of the hand) and is fastened to the cut-off gloves.

Main spirals of the lower extremities

Four kinds of basic leg spirals are applied, depending on the specific features of movement disorders and the type of deformities affecting the lower extremities: 1) external rotation spiral of the hip and shin, 2) internal rotation spiral of the hip and shin, 3) internal rotation spiral of the hip and external rotation spiral of the shin, 4) external rotation spiral of the hip and internal rotation spiral of the shin.

External rotation spiral of the hip and shin

The spiral is applied by combining the internal rotation and bringing the hip in line with internal rotatory deformities of the shin. The external rotation spiral starts in the region of the sacral bone, where it is attached to the shorts. Then, the elastic band travels obliquely along the buttocks, below the greater trochanter of the femoral bone and slants gently along the lateral side of the hip, encircling the anterior and internal surfaces of the thigh. It continues obliquely downwards to the internal epicondyle of the femoral bone. Below the popliteal space, the band slants gently downwards and encircles the posterior surface of the shin and arrives at the lateral malleolus along its lateral side. Here, the band is fastened to the half boots.

Internal rotation spiral of the hip and shin

The internal rotation spiral of the leg is used to exercise the external rotation of the hip and shin. Such leg positions can often be observed in patients who have been operated on riders’ muscles. The spiral starts at the crest of the pelvic bone, where it is attached to the shorts. From this point, the band travels downwards and inwards.
along the gluteal fold to the internal surface of the thigh. It encircles the anterior and external surfaces of the thigh and arrives at the lateral epicondyle of the femur; then, the band encircles the posterior surface of the shin and arrives at the medial bone, where it is fastened to the half boots.

Illustration 3.3.7. Main spirals of the lower extremities
1 - external rotation spiral of the hip and shin, 2 - internal rotation spiral of the hip and shin, 3 - internal rotation spiral of the hip and external rotation spiral of the shin, 4 - external rotation spiral of the hip and internal rotation spiral of the shin.
External rotation spiral of the hip and internal rotation spiral of the shin

The external and internal rotation spiral is applied to patients whose hip position displays pronated adductor muscles combined with the external rotation of the shin and foot. This pathology can be observed in patients who have been operated on the ischiocavernous group of muscles or following an achillotomy. The spiral band for the external and internal rotation is attached to the shorts near the sacral bone. It travels obliquely along the buttocks, below the greater trochanter of the femoral bone to the lateral edge of the thigh. The band slopes gently and encircles the external lateral edge of the thigh; it then continues to the anterior surface and is fixed between the medial epicondyle of the thigh and the kneecap. Here, the spiral band modifies its course; it slopes gently, moving just below the kneecap along the anterior surface of the shin. The band then encircles the lateral edge of the shin and continues along the posterior surface of the shin to the medial bone, where it is fastened to the half boots.

Internal rotation spiral of the hip and external rotation spiral of the shin

This spiral is used in patients suffering from clubfoot and bow-legged deformities by combining the external rotation of the hip and the internal rotation of the shin and foot. The spiral starts at the crest of the pelvic bone, where it is attached to the shorts. Then, the band travels downwards and inwards along the gluteal fold to the internal surface of the thigh. It encircles the anterior surface of the thigh and is fixed between the lateral epicondyle of the thigh and the kneecap. Here, the band modifies its course; below the kneecap, it continues downwards and obliquely along the anterior surface of the shin to the internal edge of the shin. Then the band slopes gently, encircles the shin, continues to travel downwards along its posterior surface and arrives at the lateral bone, where it is fastened to the half boot.

Additional force and tension are applied to individual joints whenever it is necessary to correct other movement disorders. The targeted direction of this force should reflect initial muscle vectors whose movements are to be transmitted along the spiral band.
3.3.3 Morphofunctional principles for rehabilitating and preserving morphological symmetry when using the “Spiral” corrector

The “Spiral” biocorrector enables a specialist to rehabilitate body symmetry and preserve positive results achieved in the rehabilitation system.

We have been very successful when applying the “Spiral” biocorrector to correct pathological body positions, including decussation and scalariform syndromes. Clinical presentations should be taken into consideration when decussation syndromes are to be corrected.

The upper decussation syndrome is characterized by stooped and round-shouldered posture with increased neck lordosis and pectoral kyphosis, divergence in the shoulder bones, elevated shoulders and frequent body asymmetry. The syndrome is caused by muscle imbalance in the ventral and dorsal surfaces of the upper parts of the trunk; it expresses a mismatch between weakened flexors and hyperactive extensors of the cervical region of the spinal column, as well as an inadequate connection between weakened interscapular and hyperactive pectoral muscles. This syndrome is also accompanied by force and tension imbalance in the upper and lower parts of trapeziform muscles with predominating activity in the upper portions (illustration 3.2.10).

In these cases, the corrector aims at creating additional force loads, which will enable the patient to restore the physiological position of the trunk. The patient can achieve better posture by increasing his efforts to lower his shoulder blades and bring them back together, relaxing hyperactive pectoral muscles and training weakened muscles.

These tasks can be achieved by using the main axial spiral of the corrector. An additional force load is placed in the elastic bands, which strengthens the action in the lower portions of the trapeziform muscles and in muscles belonging to the interscapular group. This action eliminates the elevated position of the shoulder blades and the clavicle, restores trunk symmetry with regard to the vertical body axis. Pectoral muscles tend to relax when interscapular muscles are strengthened. The main axial spiral ensures a gradual redressment of connective tissue structures and reduces tone in hyperactive pectoral muscles. As a result, trunk posture, shoulder and pelvic girdle positions with regard to frontal and sagittal planes can be corrected. Harmony in posture and the spinal column are restored when severe disorders of pectoral kyphosis and neck lordosis can be reduced.

All these achievements should be consolidated in further activities involving therapeutic gymnastics.

The lower decussation syndrome is characterized by lordotic posture with significant curvature of lumbar lordosis, pelvic antiflexion and general overload in
the frontal parts of the foot. The syndrome is characterized, on the one hand, by weakened gluteus maximus muscles due to shortened hip flexors and, on the other hand, by weakened abdominal muscles due to hyperactive trunk extensors located on the posterior surface of the body (Illustration 3.2.11).

This syndrome is often accompanied by an imbalance between the lumbar quadrate muscle (shortening) and the gluteus medius muscle (floppiness). These muscle disorders make it difficult for the patient to maintain his hips correctly when walking without support and also, create overload in hip adductors, thus contributing to “goose” gait. In these cases, more force and tension should be applied to these muscle regions in order to strengthen muscle activity in gluteus muscles, floppy abdominal muscles and abductor hip muscles.

Such corrections can be achieved by using the combined axial spirals of the suit. In these cases, force and tension stretching from the armpit to the anterior superior iliac spine take on a significant meaning; they strengthen abdominal muscles and reduce lumbar lordosis. Additional force and tension stretching from the internal surface of the thigh to the anterior superior iliac spine can be applied in order to stimulate abduction and supination of the hip.

Due to the fact that decussation syndromes in CP are not isolated, but often combined with other disorders of body movements and positions, each program for biodynamic correction is applied according to the situation at hand. The ultimate condition for using the corrector successfully is defined by a clear-cut individualization of techniques together with distinct calculations of all required efforts.

Therefore, when using the correction suit, the specialist widens the range of rehabilitation possibilities for patients suffering from cerebral palsy. The suit allows the specialist to potentiate the specific therapeutic effects of the Kozyavkin Method, produce positive results during the two-week rehabilitation course, and preserve the positive results achieved by the overall rehabilitation system.
3.4. Correction of limb movements with the assistance of computer games

One of the most important tasks when rehabilitating children with cerebral palsy resides in creating functional and adequate movements in the limbs. So, apart from therapeutic exercises and activities, mechanical training devices are used in order to expand movement volume and build up movement strength, speed and coordination. The majority of medical establishments are equipped with specialized training devices that enable the patient to overcome resistance force and perform the required movement. Unfortunately, these devices have an ineffectual aspect as they may become monotonous for the child and demotivate him from executing prolonged and regular activities.

Both collaborators and employees at the International Rehabilitation Clinic suggested associating useful but monotonous training sessions with interesting and fascinating computer games. In fact, are there any children who do not like playing computer games?

And so, specialized training devices were invented. They were equipped with detectors registering the patient’s specific movements: flexion and rotation of the hand, trunk inclination, flexion of the foot and others. The information is detected, transmitted to the computer and used to conduct the computer game. The patient’s hand, trunk and foot movements adjust and relocate the figure in the computer game. The attached devices are equipped with regulators which measure movement resistance and dose force and tension during the game [Kozyavkin V. I., 2002].

Thus, specialized computer games were also developed for activities using various training devices. The general scheme of the game was created so as to stimulate the patient constantly, expand the volume of his movements and increase the speed and accuracy of the given movements. As the game progresses, the tasks become more and more complicated so that more thorough and absolute movements are expected at each turn. Interesting and clever game figures stimulate the patient and help him to carry out accurate exercises, and increase the speed and amplitude of movements. As a result, the child develops his own reactive speed and improves his movement coordination.

At the same time, software programs perform a diagnostic function. During the game, the specialist can measure and display important indicators on the monitor, including the range and speed of the patient’s movements and the effectiveness of the game itself. The given information is saved and used for the future when the patient’s achievements and progress are to be analyzed [Kozyavkin. V. I., 2005].

Virtual reality techniques are used to intensify the patient’s emotions and relay sensitive influences. Thus, images are viewed through virtual reality glasses, whereas the sound is transmitted through stereo headphones.
Over the past years, numerous game devices for training movements have been developed at the International Rehabilitation Clinic: a hand manipulator, a training chair and a universal game device. All these devices can be hooked up to a personal computer and do not require specialized computer skills or techniques.

These activities based on game devices are part of the program for biodynamic movement correction and an important component of the Kozyavkin Method [Kozyavkin V., 2004].

3.4.1 Hand manipulator

The hand manipulator is the first in this series of devices; it is intended to improve hand movements. The movements in the wrist joint can be trained depending on the actual hand position, namely, flexion – extension, abduction – adduction of the hand. During the activity, the patient’s forearm is fixed to an armrest, which can be adjusted to the required height. The requisite force is set up as a resistance regulator; the first exercises are conducted with very little resistance, which increases slowly and gradually as the game progresses (Illustration 3.4.1).

Two specialized games have been developed for the hand manipulator: “The Bee” and “The Cossacks”.

“The Bee” game is aimed at exercising rotations in the forearm and hand. The actual game is based on the adventures of a bee that gathers honey from various flowers growing in a green glade. The child uses his hand movements as he moves the bee around the field.

Illustration 3.4.1. Hand manipulator

Illustration 3.4.2. A screen image of “The Bee” game involving exercises of hand rotations leftwards and rightwards
When the bee lights on a flower, a drop of honey is added to the small bucket. As soon as the container is full, the bee moves on to the next game level. On all the game levels, the bee tries to escape from flies and bumblebees and avoid falling raindrops (Illustration 3.4.2).

“The Cossacks” game is aimed at exercising flexors and extensors in the joints of the hand. In order to guide the boat correctly, steer clear of rocky islands, and deal with enemy ships, the child should extend and flex his hand continuously. At the next game level, the child becomes a horseman who rides around the field and defeats his adversaries (Illustration 3.4.3).

Every child has his own movement capacities and limitations, so it is indispensable to build up and define game parameters before the first training session so that the entire range of the patient’s movements is taken into account. Further information about initial game parameters and result data after each game level are stored in the database and can be used to analyze the results of all the training sessions.

In order to evaluate the effectiveness of computer game devices, pilot research programs were conducted at the International Rehabilitation Clinic on a group of 30 children suffering from spastic hemiplegia. Results showed that the hand manipulator was applied effectively in the overall complex of physical rehabilitation; it contributed to increasing the volume of active movements in the joints of the hand, strengthening muscles and improving the grasp function of the hand [Kozyavkin V., 2004].
3.4.2 Training chair

A training chair was invented to develop movement coordination in the trunk and improve posture control. The detector system defines the position and movements of the trunk on three planes: flexor – extensor movements, lateral inclinations, and rightward and leftward rotations. Information about trunk movements is transmitted to the computer and consequently used for administering the game itself. “The Bee in the Park” is a three-dimensional game used for activities involving the training chair.

The back of the training chair is attached to the patient’s back during the training session. As the child leans forwards, backwards, to the side, and as he rotates his trunk, he attempts to control the figure moving about in a three-dimensional virtual world.

As the player continues to wander around the park and execute the game tasks, he must try to compete with other figures - a spider, bumblebee or caterpillar. Jumping over bushes, escaping from lurking enemies and overcoming different obstacles, he tries to find as many flowers as possible. The training chair allows the child to improve the volitional control of his body movements more effectively and strengthen his muscles so that he can continue exercising and applying therapeutic physical training.
3.4.3 The universal game device

Our newest invention is called the universal game device; it can be used to exercise movements in different joints. It is a very simple device, which is attached just above or below the actual joint of the given extremity and transmits information on movements to the computer. The device can be used to perform exercises in the ankle, knee, shoulder and wrist joints. Therapeutic results can be improved during therapeutic physical training sessions by applying two devices and controlling movements of both extremities.

We have elaborated a game about the adventures of a dragonfly that enjoys travelling around a tropical island. As the dragonfly tries to find its way around, it follows specific directions and attempts to escape from hidden adversaries. When it finally finds the coconut, the dragonfly must direct its extremities (limbs) repeatedly towards the coconut in order to smash it open and win the prize.

The game combines several exercises involving two types of movement - smooth and coordinated movements, which the child needs to master in order to move around the playing field, and rapid, frequent and wide movements needed to attain the target.

Computer game devices are an important component of the program for biodynamic movement correction. Significant and long-lasting results are obtained by associating therapeutic physical training with computer games and so, combining various movement activities and raising the patient's motivation.
3.4.4 The training simulator “Pavuk” (Spider)

The training simulator “Pavuk” (Spider) constitutes one of the components of the program for biodynamic movement correction. It is a large metal cage measuring 2x2x2 m where the patient is positioned right in the middle. One end of the elastic force band is fastened to the support structures of the cage, whereas the other end is attached to the patient’s body by means of support straps. Force loads are fastened to the patient’s body by means of various support elements, that is, cuffs of different sizes.

The force load can be regulated and attachments can be selected at will; thus, the specialist can choose the direction and load volume according to each patient’s needs. This also enables him to substantially expand the field of therapeutic physical training. And so, having ensured the requisite force load or unload on certain parts of the body in the training simulator, the specialist can conduct exercises aimed at developing the patient’s balance and control of body posture, expanding the range of active and passive movements and mastering required movement skills.

Groups of weakened muscles can be selected and exercised by using additional loads and pulley systems, which are attached to the cage. Such exercise activities enable muscle groups to improve and function in a better way. The patient’s movement capacities are developed by applying antigravitational activities, even going as far as exercises involving complete suspension in space. Even passive patients seem to

Illustration 3.4.8. Exercise session in the training simulator “Spider”
be attracted and reassured by the security measures and effective training sessions, and more than often express their willingness to take part.

Training sessions in the “Spider” simulator are particularly effective for patients suffering from cerebral palsy, neural and muscular illnesses, cerebrovascular strokes and craniocerebral injuries. Contraindications to activities in the simulator can take the form of repeated epileptic seizures and mental disorders, which makes it extremely difficult to maintain contact with patients.

3.5 Motivations for CP rehabilitation

Psychological influences and social factors play a significant role in rehabilitating patients suffering from organic brain lesions. One of the most important factors is motivation, as it is the most difficult to form and develop during the therapeutic course of treatment [O’Gorman G, 1975].

Observations have shown that, even during the first days of rehabilitation treatments according to the Kozyavkin Method, patients become more active, seem to take a more active part in the rehabilitation process, and begin to express interest in their environment. This “waking up” phenomenon develops slowly and influences the final results of rehabilitation. When the “waking up” phenomenon is associated with the overall complex of psychological and social activities, the patient becomes more interested and motivated, thus contributing to optimal final results.

At present, the generally accepted term “motivation” does not exist in rehabilitation. A. Schopenhauer was the first to use the word “motivation” in his article “On the Fourfold Root of the Principle of Sufficient Reason” [Schopenhauer A., 1813]. Later on, this term became part of common psychological practice explaining the causality of human and animal behavior. At the same time, motivation is interpreted as a mental phenomenon appearing as a combination of factors that direct and determine behavior, or a combination of causes or impulses that make the organism react more actively and determine the ultimate direction [Ilin Y. P., 2000].

The “motivation” concept in therapeutic rehabilitation can be interpreted in two ways [Maclean, N., 2000]. Some researchers evaluate motivation as an individual’s internal characteristic and do not take any social influences into consideration at all. Others emphasize the significance of these social factors as they will determine the extent of the patient’s involvement in the rehabilitation program. The truth may lie somewhere in the middle.

The International Rehabilitation Clinic has had many years of experience in dealing with patients suffering from cerebral palsy. Therefore, specialists at the clinic have elaborated an overall complex program for motivating a patient towards recovery by applying social and individual factors.
The program includes: 1) creating a favorable atmosphere for rehabilitation; 2) coordinating the doctor’s and patient’s value systems; 3) adopting new social contacts; 4) understanding and applying new motor abilities acquired during treatment on the part of the patient [Gordiyevich S. M., 2003]

The most important factor of our program lies in creating a favorable atmosphere for rehabilitation at the therapeutic establishment itself. A good ambience inevitably has a positive influence on the patient and so, raises his motivation towards recovery. Everything starts with the psychological atmosphere created by the entire rehabilitation team of workers. All contacts between the patient and rehabilitation specialists should be positive, encourage affirmative relations and mutual trust. It is most important to refer to the patient continuously and encourage him to take an active part in the rehabilitation process.

Another important factor in creating a positive atmosphere for rehabilitation can be found in the actual environment. By using environmentally friendly and clean materials on the premises, specially selected music and other factors, we can help the patient to feel comfortable psychologically at home.

All the above-mentioned factors were taken into account when the premises of our clinic were planned and constructed in the neo-secession style, that is, a characteristic expressiveness in architectural composition transcending old traditions and dogmas.
Coordinating the patient’s value systems with that of the rehabilitation team of workers is an important factor for motivating a patient towards recovery. One of the most practical means of doing this is by including the patient and his family in the organization and decision-making plans related to rehabilitation tasks [Payton O., 1990]²⁵. Therefore, both patients and parents take an active part in elaborating individual rehabilitation programs according to the Kozyavkin Method. Their opinions and wishes are all taken into consideration and the final aims of medical treatment are outlined together.

In order for the program to be successful, the patient should be well informed about all rehabilitation measures, anticipated results in case of intervention, the actual rehabilitation course and general prognosis [Jeffrey D.L., 1981]²⁷. The patient should receive information before arriving at the clinic from the doctors, the medical staff and our specialized publications. Internet sites and other mass media information are also very useful. The rehabilitation team should also receive timely return information from the patient regarding the course of the rehabilitation process, execution of tasks and the patient’s physical and mental health.

The patient tends to react more positively, understand the various approaches to the activities, and play a more active part in rehabilitation treatments if he and his family are allowed to take part in organizing the tasks and setting up the final goals for the rehabilitation program. In fact, the patient becomes more responsible for his own rehabilitation results [Baker S.M., 2001]²⁸. Such an approach can very well satisfy the patient, his parents, and even the rehabilitation specialists with regard to the final results of the treatments.

New social contacts, a new awareness, and personal interests provide other important stimuli for the patient. In fact, motivation is tightly associated with the patient’s social integration [Thompson S.C., 1989]²⁹.

Illustration 3.5.1. Fundamental components of the motivation program leading the patient towards recovery [Gordiyevych S. M., 2003]²⁵
During intensive rehabilitation activities, we try to establish new contacts among the patients in every possible way; we conduct various group activities, and remind the patient about the aims set out in real life, beyond the walls of the rehabilitation clinic. During their stay at the clinic, patients can spend their leisure time with other children and play together in specially equipped rooms. Excursions and trips are regularly planned so that the children can interact within a collective group.

During the course of the rehabilitation program, the patient begins to understand and apply the newly acquired movements; this constitutes one of the main motivation components of the Kozyavkin Method. The patient expresses his desire to be actively included in the rehabilitation process and continue to master his newly acquired movement functions. The more he realizes and understands this fact, the more he strives to achieve during the program.

An entire complex of measures has been worked out for the motivation program in rehabilitation treatments; all members of the rehabilitation team have been concerted and their activities coordinated. Psychotherapeutic assistance is available during all treatment procedures and at all informal meetings with the patient; the patient is constantly encouraged to take an active part in rehabilitation acts and comment on his achievements, etc.

Many methods are applied to awaken motivation in a patient and help him to establish social contacts, such as, rhythmic gymnastics, Olympiad competitions for children, parties and meetings, concerts and excursions.

Rhythmic gymnastics are conducted in groups; they are based on game methods applied to music and dance [Kozyavkina N. V., 2003]. The patient masters new motor and communicative skills. The active participation of parents in these groups provides a very positive emotional background for the children [Kachmar O.O., 2003].

Another special feature of group activities can be found in Olympiad competitions for children; they stimulate the patient and motivate him towards recovery and social integration. Sports and games take place in a cheerful atmosphere, which creates a positive and emotional charge for the children, widens their social contacts and encourages them to believe in themselves. Winning is not emphasized during these “Olympic Games” for children, but more attention is paid to mutual and individual achievements in locomotor and mental developments.

Music therapy, art therapy and many other rehabilitation acts have a great effect on the patient’s motivation.

In summary, one of the most significant new components of the Kozyavkin Method can be found in the complex program aimed at heightening the motivation factor towards recovery and drawing both the patient and his parents actively into the rehabilitation process. If a patient is constantly motivated and expresses the desire to recover, there will definitely be substantial progress in locomotor and cognitive development, and the child will also take his place in society.
Literature:


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Conclusion

You have just completed reading the book about the fundamental principles for motor disorders in children suffering from cerebral palsy according to the new method developed by Professor Kozyavkin - a system of intensive neurophysiological rehabilitation. The given rehabilitation system is ultimately aimed at improving the child’s quality of life, which is seen as the most important and most meaningful problem faced by modern rehabilitation medicine.

This particular system was started in Ukraine in the 1980ies, when Professor Kozyavkin, the founder of this method, concluded that an important role is played by peripheral vertebrogenic components in the ethiopathogenesis of cerebral palsies.

The newly created system of medical rehabilitation was based on the Professor Kozyavkin’s method of biodynamic correction of the spinal column. The method itself aims at eliminating functional blocks in spinal motor segments, rehabilitating the activity of autochthonous muscles in the trunk and directing the flow of proprioceptive information towards centers of the body. Thus, the patient forms and develops a new functional state that allows reserve and restored processes in the organism to be activated.

The correction of the spinal column is closely combined with a multimodal complex of therapeutic acts that all complement and potentiate each other. The final results can be observed in stable and normalized muscle tone, an increase in microcirculation in the tissues and bradytrophic structures of the locomotor apparatus, and normalized trophic levels in the tissues.

Finally, we were able to determine and define problems related to rehabilitating movements and muscle tone - the leading pathogenic links in CP, as well as determine many problems involving the entire organism, such as, restoring body symmetry, normalizing respiratory and cardio-vascular systems, eliminating numerous problems in vegetative and endocrine systems, accelerating the child’s motor and mental development and encouraging his adaptation and integration into society.

Stable, long-lasting and positive results have been attained by applying such a new approach to rehabilitating patients with cerebral palsy, namely, by taking into account the peripheral structures in the ethiopathogenesis of lesions.

We hope that this book has been both interesting and useful. We expect that Professor Kozyavkin’s Method will attract new supporters and followers, and will help many more children suffering from cerebral palsy to lead a full life in society.