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 K., 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]. 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]. 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]. 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]. 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]. 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).

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]\textsuperscript{23}.

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.

Lev Petrovich Nikolayev was one of the first to study muscle integration of human in a practical sense [Nikolayev L. P., 1950]\(^{24}\). Principles of eiloid integration were developed in the field of sports [Tittle K., 1974]\(^{5}\); [Sak N. N., Sak A. Ye., 2001]\(^{25}\), and observed in constitutional features of both healthy and ill bodies [Kadyrova L. A. and others, 1991]\(^{26}\). Many authors studied anatomic bases for muscle spirals and their mutual interaction [Khoroshkov Yu. A., 1985]\(^{27}\), [Shaparenko P. F., 1988]\(^{28}\). Research on muscle spirals conducted on patients with cerebral palsy are of indisputable interest [Kozyavkin V. I., 2001]\(^{29}\).

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.

Illustration 3.2.3 Diagram of muscle spirals in the body [Title K., 1974]\(^{5}\)
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
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] and patients suffering from CP [Kozyavkin V. I., 1996].

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 rhythmical 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 possesses 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 an 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
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]8. They consist of muscle interaction between various rotator axes: 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
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 decussation or scalariform syndromes, as well as others [Ivanichev G. A., 1997].

Upper decussation syndrome

“The upper decussation 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.

**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, 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.

Illustration 3.3.2 Main (posterior) axial spiral
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

Illustration 3.3.3. Anterior axial spiral
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]47.

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.
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.

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.

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 arm-rest, 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.

[Image: Illustration 3.4.1. Hand manipulator]

[Image: 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]50.
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
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]51.

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]52. 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]53.

The “motivation” concept in therapeutic rehabilitation can be interpreted in two ways [Maclean, N., 2000]54. 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]. 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]. 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]. 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].

Illustration 3.5.1. Fundamental components of the motivation program leading the patient towards recovery [Gordiyevych S. M., 2003].

Correction of limb movements with the assistance of computer games
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:


Program for biodynamic movement correction


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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.