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Biomechanical Bases of Rehabilitation of Children with Cerebral Palsy

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Abstract. Biomechanical analysis and the study results of children's with cerebral palsy (CP) muscles bioelectrical activity while walking on a flat surface are represented. Increased flexion in the hip and shoulder joints and extension in the elbow joint in children with cerebral palsy were observed, with the movement of the lower limbs had less smooth character in comparison with the control group. Herewith, the oscillation amplitude was significantly increased, and the frequency in the m. gastrocnemius and m. lateralis was decreased. It was shown, that the dynamic stereotype of walking in children with cerebral palsy was characterized by excessive involvement of m. gastrocnemius and m. latissimus dorsi in locomotion. Thus, resulting biomechanical and bioelectrical parameters of walking should be considered in the rehabilitation programs development.

INTRODUCTION

The problem of overcoming social isolation as well as social, physical and psychological adaptation of people with disabilities is of great importance in Russia now. Problem solution depends on availability of higher education for people with disabilities. Today cerebral palsy (CP) has one of the leading places in the structure of children's disabilities. According to the Ministry of Health, there are more than 70 thousand children with cerebral palsy under the age of 14 years in 2010 in Russia, and every year this number increases [1]. However, the majority of children with the pathology of the musculoskeletal system face the problem of physical adaptation to the changing conditions of the modern world. The ability to adapt to the changes in external and internal environment is a unique property of the human body. Biological adaptation is a dynamic oscillatory process, with a reorganization of the functional system of homeostasis to a new level of regulation.

One of the basic biological mechanisms of adaptation is the variability of physiological systems functioning. If we know the patterns of functional system's formation, we can effectively influence its units and accelerate adaptation to changing environmental conditions, i.e. to manage the adaptation process. Restructurisation of the regulatory-adaptive mechanisms and the mobilization of physiological reserves, as well as their inclusion in a variety of functional levels, help to achieve sustainable and perfect adaptation. Normal physiological responses activate first, and then the reaction voltage of the mechanisms of adaptation starts. They require significant energy costs with the use of the reserve capacity of the organism. This leads to the formation of a special functional adaptation system providing specific human activities. The system mechanisms of motor adaptation can be judged only on the basis of a comprehensive set of accounting reactions of the whole organism, including the response from the central nervous system, hormonal and motor vehicles, bodies of movement and circulation of blood analyzers, metabolic and other functional systems. The expression of changes in bodily functions in response to exercise depends primarily on the individual, as well as the type of pathology of children with disabilities.

One of the main physiological components of the normal health development is a motion. It develops all areas of the cerebral cortex, influences coordination of inter-central relations, correction and compensation of deficiencies in

physical and mental development, and forms the physical interaction of analyzer systems and cognitive processes. Motion is a vital condition for the body life-support as well as the means and the method of maintaining health.

One of the main cerebral palsy manifestations is locomotor function violation as the basis of this disease is an organic damage of fetus' nervous system. Locomotor function violations are characterized by abnormal patterns of posture and walk. They are formed on the basis of preserving its pathological activity tonic reflexes [3, 4]. Biomechanical locomotion disorders are associated with muscle's hypertonic, incoordination, contractures in the joints of the lower limbs, and others. Biomechanical structure of patients' walk is changed, which is associated with CNS disorder [6, 7]. Analysis of kinematics, support reactions and muscle function of various body parts clearly shows that during the gait cycle regular change of biomechanical events takes place.

Despite a number of individual characteristics, healthy people's gait has typical and stable biomechanical and innervation structure, i.e., certain spatial and temporal characteristics of movement and muscle function [2]. Research of biomechanical and physiological patterns of performed movements is needed for successful rehabilitation of children with cerebral palsy [5].

As a result of the project a training program for children with disabilities will be developed in order to improve their adaptation to modern conditions.

OBJECTIVE

The study of the gait's biomechanical characteristics of children with cerebral palsy.

MATERIALS AND METHODS

The study group included 20 children (12 boys and 8 girls) between the ages of 8 to 12 years, suffering from cerebral palsy in the form of spastic diplegia, and being in treatment and adaptation in The Regional State Institution "Rehabilitation center for children and adolescents with disabilities" (Closed Administrative-Territorial Entity Seversk). The control group consisted of 10 children (6 boys and 4 girls) of the same age.

Hardware-software system, included a video camera Phantom Miro EX2, was used for movement's biomechanical analysis.

Special markers were attached to the testee's temporal bone, shoulder joint, elbow joint, wrist joint, hip joint, knee joint, ankle joint. Then they were prompted to walk on a flat surface. Shooting was conducted at a speed of 100 frames per second. Quantitative analysis of the movements' biomechanical characteristics and motions' mathematical modeling were processed using the program StarTraceTracker 1.1 VideoMotion®.

Bioelectric activity analysis was carried out via the multifunction computer electroneuromyography "Neuro-MEP-4". Electrodes were superimposed symmetrically on the following muscles: m. gastrocnemius (caput mediale); m.vastus lateralis; m. biceps femoris; m.latissimus dorsi.

Factual data are presented in the form of «mean ± error» ($M \pm m$). The significance of differences between the groups was assessed using a nonparametric Mann-Whitney.

RESULTS

Elemental analysis shows that during the locomotor cycle regular change of phases with different characteristics of biomechanical processes occurs.

The cycle consists of two main phases: supporting and portable. In turn, the supporting phase is divided into three intervals: reliance on the heel, on the entire foot and on the sock. Also, doubly supporting phase it distinguished.

Gait's multivariable analysis allows splitting the locomotor cycle into six biomechanical phases. Delimited by the extreme values of the dynamic parameters.

During the study of the hip angle changes while walking on a flat surface, it was shown that the angle in children with cerebral palsy was significantly ($p < 0.05$) higher, with extreme increase in the angle value up to 216.45° was observed in phase 4 (Fig. 1). The study results of knee joints were similar in both groups (Fig. 2).

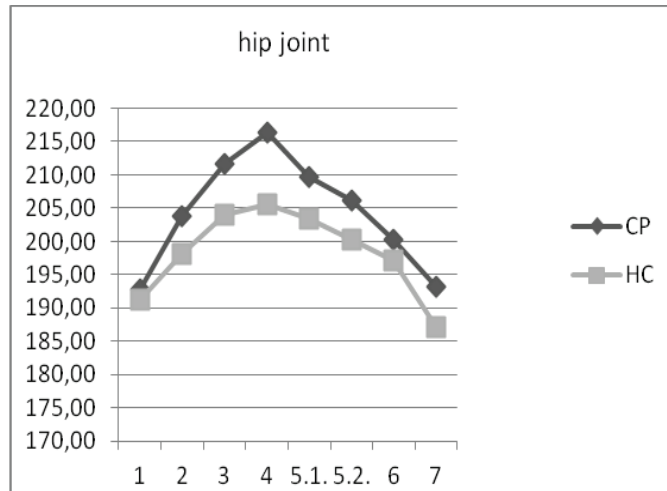


FIGURE 1. The angles' value of the lower limbs walking on a flat surface.
CP - Children with cerebral palsy; HC - Healthy children

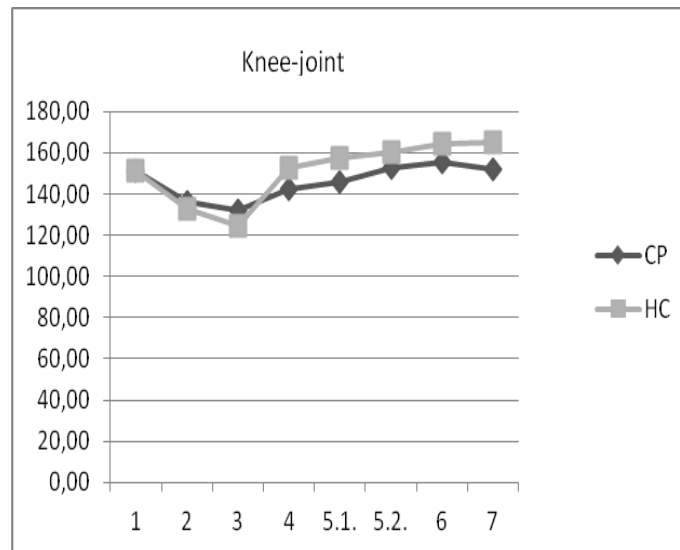


FIGURE 2. The angles' value of the lower limbs walking on a flat surface.
CP - Children with cerebral palsy; HC - Healthy children

The shoulder joint angle in CP group was significantly greater ($p < 0.05$), where in during the movement index was smoothly changing compared to the control group. Whereas, changes of the elbow angle had lower values than in the healthy children's group (Fig. 3). Thus, children with cerebral palsy while walking carried out smooth movements of upper extremity, bending arms at the shoulder and straightening the elbow (Fig. 3).

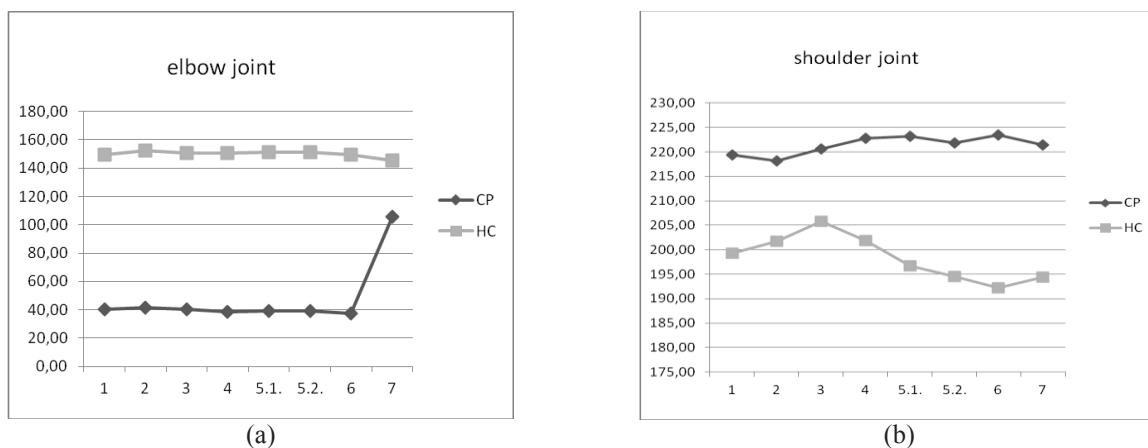


FIGURE 3. The angles' value of the upper limbs walking on a flat surface.
 (a) – elbow joint; (b) – shoulder joint
 CP - Children with cerebral palsy; HC - Healthy children

In the study of bioelectrical activity of the m. gastrocnemius in children with cerebral palsy a significant ($p < 0.05$) increase in the average amplitude of the oscillation (844 ± 164) (uV), compared to the group of healthy children (405 ± 57) (uV). Also, there was a significant ($p < 0.05$) increase in the total oscillation amplitude by 37% and amounted to (268 ± 44) (mV/s), compared to the control group (195 ± 30) (mV/s). While the maximum oscillation amplitude and frequency of the oscillations was reduced ($p < 0.05$), compared with healthy children. Thus, increase in the amplitude-frequency index in children with cerebral palsy was revealed. Similar results were obtained in the study of the m.vastus lateralis. The bioelectrical activity of the m.latissimus dorsi in children with CP characterized by an increase in the maximum and the total oscillation amplitude, the average amplitude compared to the control group.

The main differences between the dynamic stereotypes of walking in children with cerebral palsy, according to the electromyographic analysis, are as follows:

- changes in the bioelectric activity of the m. gastrocnemius are most significantly expressed;
- we observed a significant increase in the amplitude of the oscillations in combination with a reduction in the frequency in children with self-locomotion;
- the amplitude of the oscillations decreases and the frequency increases significantly in children, moving only with the support. Excessive activity this muscle group was not associated with synchronization in a group of children moving with support;
- in both groups of children with cerebral palsy was observed excessive activity of the m. the m. latissimus dorsi as compared with the control group;
- the activity of the m. vastus lateralis was increased in both groups of children with cerebral palsy. The activity m. biceps femoris was decreased in both groups of children.

CONCLUSION

Increased flexion in the hip and shoulder joints and extension in the elbow joint in children with cerebral palsy were observed, with the movement of the lower limbs had less smooth character in comparison with the control group. There was a significant increase in the oscillation amplitude and decrease in the frequency of bioelectrical activity in the m. gastrocnemius and the m. vactus lateralis. Thus, resulting biomechanical parameters of walking should be considered in the rehabilitation programs development.

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