SWIMMING EXERCISES AS A METHOD TO TREAT CHILDREN WITH SCOLIOSIS

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KEY WORDS: scoliosis, non-surgical treatment, physical exercises

INTRODUCTION: Idiopathic scoliosis is a disease, which is characterized by three-dimensional deformation of the spine, leading to instability of this structure. The main clinical symptom is the curvature of the frontal plane. This curvature is as a rule combined with a torsion along the axis of the spine and the occurrence of a lumbar kyphosis. It occurs in childhood, and the juvenile and the adolescent periods are the most critical phases. Any damage to the spinal structure leads to deviations from the normal degrees of freedom of all joints, different in degree and strength. Three lateral complexes consist of inter-vertebral discs, which includes the adjoining vertebral bodies and the bilateral symmetrical frontal joints, whose orientation is different in the different parts of the spine and permits different degrees of rotation. The muscles that move the spine are divided into internal and external muscles. In this case, a biomechanical kinematic model of the spine is studied. The forces that act on the model are divided into internal and external:

External forces:

- drag forces.
- driving forces.
- ground reaction.
- inertial forces.
- gravitational forces.
- equipment reaction forces.
- forces exerted by another person.
- artificially created forces.

METHODS: We shall study the influence of the internal forces more closely. When studying the biomechanical kinematic model of the spine, not taking into consideration the external forces, the internal forces are: posterior and lateral disc shear forces S_p and S_l; erector spinae muscle force F_m; disc compression force F_c; abdominal pressure resultant force F_a; rectus abdominus force A; and vertical and horizontal components of the lateral abdominal wall muscle forces V_r, H_r, V_l and H_l on the right and the left sides. These forces are expressed by the following equations /Schultz 1982/:

$$S_l = F_x \quad ; \quad H_l + H_r + S_p = F_y$$

$$F_c + F_a - F_m - A - V_l - V_r = F_z \quad ;$$

$$\overline{A_{ac}} - F_a\overline{bc} - F_m\overline{dc} = M_x$$

$$V_l cf - V_r\overline{ce} = M_y \quad ; \quad H_l\overline{cf} - H_r\overline{ce} = M_z$$

It is assumed that there are no antagonistic muscle actions, that the value of the abdominal pressure effect F_a is empirically predicted and that muscles act only in tension: $P_a = 10^{-4}\left[43 - 0.36\left(\theta_h^{'} + \theta_t^{'}\right)\right]^2\left[M_H^{1.8}\right]$

These assumptions allow certain forces to be selectively zeroed, based on the following partitioning inequalities:

If $M_x \rhd 0$, then $F_m = 0$ (no erector spinae); If $M_x \lhd 0$ then $A = 0$ (no rectus abdominus) If $M_y \lhd 0$, then $V_r = 0$ (no left lateral flexors); If $M_y \lhd 0$, then $V_l = 0$ (no right lateral flexors) If $M_z \rhd 0$, then $H_r = 0$ (no right rotators); If $M_z \lhd 0$, then $H_l = 0$ (no left rotators)

The six forces included in the solution depend on the direction of the moments resulting from given input load and posture conditions. The solution used assumes that the muscles that generate the smallest growing force of compression on the lumbar segment will be the first to contract with a growing intensity and will create a reactive moment, necessary to balance the external loading moment.

Having in mind the specifics of the scoliotic disease, the biomechanical kinematic model in use is of a spine with a second degree of lumbal scoliosis: /Single major thoracic curve/, the apex lies within the thoracic spine and the upper end vertebra is T5 and the lower end vertebra T12. To solve the problem, it is necessary to determine the functional values of the muscles acting directly on the spinal segments in section T5 - T2. To avoid arbitrariness, the study is made on the base of electromyographic records of the biopotentials of the muscles in motion. In terms of the present muscle model, the degree of muscular excitation is represented by the relative number, $n(t)$, of stimulated motor units and the normalized average stimulation rate $v(t)$ or, at the level of individual motor units, by their discharge intervals $\tau_i(t)$. However, n is related to the cumulative relative cross-sectional are u of stimulated units by: $u = u_0 \exp\left(\bar{c}\, n\right) = \exp\left[\bar{c}(n-1)\right], 0 \lhd u_0 \leq u \leq 1$

while $v(t)$ is defined /Hatze, 1981/ by

$$v(t) = \int_0^{\bar{c}\, n(t)} \left[\exp(x) / \hat{v}(x) \tau(x,t) \right] dx \Big/ \left[\exp\left(\bar{c}\, n(t)\right) - 1 \right], \tau(x,t) \approx \tau_i(t)$$

with $\tau(x,t) \approx \tau_i(t)$ denoting the discharge interval at time t of the i-th motor unit in the n - population of stimulated units [1].

The necessity of using rehabilitation in a water environment, starting at an early juvenile age is especially underlined. The reasons that call for this lie in the close relation between the kinematic mechanism under study (the spine) and the laws of biorheology. It is known that the logistic principle of growth represents an important rule in biometry. It was assumed that the growth of all living organisms corresponds to this principle. The equation of the logistic curve is as follows:

$$y = \frac{a}{1 + be^{-ct}}$$

where a, b and c are the parameters of this function [2].

The above calculations represent a good basis for working out the rehabilitation complexes with maximum precision.

RESULTS: The early and precise diagnosis of scoliosis is of crucial importance for the implementation of contemporary and adequate rehabilitation systems. Rehabilitation exercises in water stimulate and activate the organism. The skeletal musculature is activated and the functional capacity of the muscles increases.

Children with idiopathic scoliosis can be divided into 4 categories according to their age:
- Children from 3 to 5 years old with idiopathic scoliosis (1 and 2 stage).
- Children from 6 to 10 years old with idiopathic scoliosis (1 and 2 stage).
- Children from 11 to 13 years old treated with braces.
- Children from 14 to 16 years old treated with surgical methods.

The experimental exercises with children from the above four groups took place for 4 months. Each of the 4 complexes of exercises is constructed considering the requirements of the corresponding category of children it is designed for.
The results of the rehabilitation process (changes in muscle strength) are evaluated considering the following parameters:
-strength (maximum amplitude of fulfilling the exercise); speed (maximum speed while running a certain distance); endurance (maximum time for holding a certain position); Rehabilitation is evaluated by a three mark system:
- very good - decrease in the angle of curvature of more than 5°; good - change of the angle of curvature within the boundaries of +/- 5°; poor - increase in the angle of curvature of more than 5°. The results of the experiments that were carried out are illustrated by the following diagrams /1,2,3/. Control checks and evaluation of the indicator of the medium value for strength, speed and endurance are made at the end of the month. This indicator is projected on the vertical axis of the coordinate system.

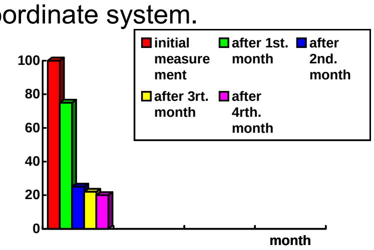

Fig. 1. *The results achieved by children from the first and second, after four months of swimming pool rehabilitation.*

The children of the first and second risk groups differ only in age. This makes it possible to combine the results of these two groups in Fig. 1. The children have a minor form of scoliosis (1st and 2nd stage of injury). This is why the children in both groups have similar basis data. The results from Fig. 2 show a rapid increase in the general physical condition of the children after the first and the second months. In the third, fourth and succeeding months there is a slowdown in rate of improvement of the children's condition compared to the previous months. This is due to the improvement of the general physical condition after the first two months, which provides an opportunity for concentrating the work upon the injured nerve-muscle links. There is more time for special rehabilitation of each of the injured groups and for this reason the results are steady.

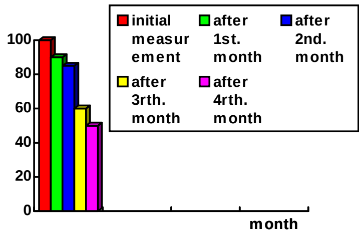

Fig.2. *The results achieved by children from the* third group *after four months of swimming pool rehabilitation.*

The first period (2- 3 months) of rehabilitation of the children treated with splints is extremely difficult. There is large structural deformation of the spine, of the inter-vertebral discs, almost atrophied muscles and existence of great muscle stress with a coefficient greater than normal (Fig. 2). After the third month there is intensive acceleration of the work tempo. The difference between this and the other two groups is in the period for improvement of general physical condition, which in this case includes the first five months. The main handicap is the psychological burden on the children.

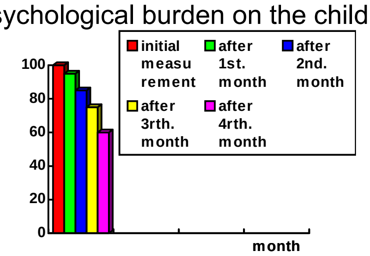

Fig. 3. *The results achieved by children from the fourth group after four months of swimming pool rehabilitation.*

The rehabilitation of the children from the third group is very slow (Fig. 3). For this group the first two months are used solely for the psychological preparation of the children. This preparation is required as a basis for later work. The improvement of general physical condition starts at the third month. After the sixth month the rehabilitation of the injured muscle groups can begin.

DISCUSSION: Our proposal for special complexes of exercises performed in a swimming pool is based on the proposition of greater freedom of human body movement in water. The gymnastics performed in a swimming pool causes complex and beneficial influences on the general physiological condition of the human organism. These certain complexes of exercises improve the tone of specific muscle groups. Along with this, the treatment gives an opportunity for a constant, complex and equally applied strain on the whole skeletal-muscular system, which is specific for the body in a water environment. Another advantage is the fact that the most considerable forces, such as air pressure and gravity-lifting force, are equal per cm^2 of the human body. Swimming pool exercises as treatment help to overcome the psychological injuries of children with spinal deformations. In a swimming pool it is easier to overcome the problems caused by the low mobility of children with scoliosis, such as their inferiority complex, because of the free movement provided by the water environment.

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