TRAINING OF THE SKELETAL-MUSCLE APPARATUS OF SPORTSMEN THROUGH ELECTROVIBROSTIMULATION

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INTRODUCTION

It is often necessary to correct the functional state of the human skeleto-muscular apparatus (SMA) in order to increase the muscle contraction force and the joint mobility as in sports and ballet, for the rehabilitation of invalids and in prolonged space flight to compensate for hypokinesy and -dynamy. For sportsmen it is important to restore their condition after injuries in the shortest possible time. However, traditional methods require a long time to achieve a high functional condition of the SMA. Investigations of the last years showed that electrostimulation is an effective method for the increase of the muscle force and that through vibrostimulation a better joint mobility is achieved.

METHOD

Systematically repeated muscle contractions caused by electrical pulses increase the physiological muscle diameter which results in an increased muscle force. After 20 electrostimulation sessions the maximum of the isometric tension can increase with 40% - 50%. The electrostimulation induces the addressed muscles to deliver work, which results in an hypertrophy of the myofibrils together with a relative decrease of the sarcoplasmic spaces. As the muscle fibres of the gross motor units are located more superficially than the deeper lying fibres of the fine motor units, at the onset of the electrostimulation treatment the gross motor units of the large movements are recruited first, even with a weak electrical stimulation. So those motor units, which are hard to train at will, but which are very important for the development of the muscle force, can be trained easily by the electrical training. The vibrational forces belong to the rhythmical mechanical stimulations, which summon a specific reaction of the neuromusclular apparatus and other body systems. These mechanical impulses and oscillations can play as vibrostimulation the role of the physiological stimuli. The vibrostimulation has a lasting effect on the nervous system, which can stay even during several days after the treatment. Already a short vibro-massage shortens the rehabilitation period of the muscular system of sportsmen. The efficiency to develop the muscle forces of the joint movements or to revalidate the motional functions after trauma and illness is ten and more times higher than in the traditional methods of sports and sportmedicine. The working hypothesis was applied as follows: during the exercises electro- and vibrostimulation were used simultaneously in order to perfect the active movement in the different joints. During a programmed sequence of motions by synergists and antagonists, the vibrostimulation was applied to the antagonists while the electrostimulation was applied to the agonists and synergists. The vibrostimulation elongates the antagonistic muscles, i.e. the zone of the passive insufficiency decreases, whereas the electrostimulation causes the force of the synergistic contraction to increases in the zone of the

active insufficiency. As a result we observe a perfection in the active movement of the human skeletal-muscular apparatus. We suppose, that the simultaneous stimulation of both synergists and antagonists helps to achieve an optimum pattern of the joint movement.

We therefore developed a program-controlled device for the electrovibro-stimulation of the human skeleto-muscular apparatus for applications in medicine, ballet and sport. Separate electro - or vibrostimulators are available but devices for the combined electrovibrostimulation do not exist. The characteristics of the existing devices are not fit for professional use, as a.o. the existing electrostimulators lack a stabilization of the injected muscle current, the pulse frequency range is too limited, the only unipolar pulses cannot remove electric rest charges, and none can give pulse bursts or a modulated pulse sequence. Likewise are the existing vibromassage units not suited for medical purposes, because they are not versatile in their use and the vibro characteristics can only be tuned in a very limited frequency range.

The Laboratory of Biocybernetics of the St.Petersburg State Technical University has invested considerable work into the development of a prototype of a muscle electrovibrostimulator and its experimental testing, the laboratory model having been offered by the Central Scientific Research Institute of Prosthetics in Moscow.

The apparatus consists of three main parts: the electrostimulator, the vibrostimulator and the programmable control and driver unit. The electrostimulator consists of a generator for pulses or pulse trains of selectable frequency, duration, amplitude and shape adapted to the patient's body. The pulse repetition frequency can vary from 1 to 20 kHz. The pulse width can be changed from 1 to 100 μs. The pulse mode can be continuous or amplitude modulated with a modulation by square or sinusoidal voltage pulses from a separate generator. The modulation frequency can be chosen between 10 and 100 Hz. In the sinusoidal modulation mode each pulse train starts from zero amplitude, which makes the electrostimulation softer even for rather large currents. The output stage amplifier of the electrostimulation channel has a strong negative feedback which stabilizes the current to better than +/-1% even under extreme values of the skin-muscle load resistance between the electrodes.

The vibrostimulator is based on an electromotor, whose rotor revolutions are transformed into the linear oscillations of the vibrator. The design of the transformer mechanism allows a continuous variable vibrational amplitude. The vibrator frequency is controlled by selecting the angular speed of the electromotor. Both parameters are electrically controlled so that they can be varied during the electrostimulation following a preset program. Our vibrostimulator allows to regulate the vibrofrequency in the range from 5 to 50 Hz and the vibration amplitude between 0,1 and 10 mm. The device has different exchangeable massage probes which permit the massage of different parts of the patient's body with maximum effect.

The module of the programmable driver unit allows manual selection of the parameters for electro- and vibrostimulation, and automatic control of the action of the electrovibrostimulator with given amplitude, frequency and duration. The electronic circuits of the electrovibrostimulator and the control unit use the IC

technology in MSI, which is a fair compromise between a good reliability of the apparatus under field conditions and a reasonable price of the unit.
The broad adaptation range of the pulse parameters of the combined apparatus allows an optimum application in order to ensure for every patient the maximum efficiency of the medical and medico-profilactic measures.

RESULTS

For the test of the developed electrovibrostimulator two series of experiments were set up. In the first series the separate influence of vibrostimulation and electrostimulation on the improvement of the joint movement under different exercises was measured. By the second series the effect of the combined method of the muscular electrovibrostimulation in the physical training of athletes was experimentally determined. Therefore three experimental and three control groups were organized. In each experimental group one of the stimulation methods for the perfection of the joint movement was tested: in the first group the electrostimulation, in the second the vibrostimulation, in the third the combined electrovibrostimulation. In total more than 100 top athletes took part in the experiments, among them 10 world qualification masters of sport and 20 masters of sport. The other athletes were candidates of master of sport and sportsmen of the 1st class. Also took part in our experiments the Honoured Masters of Sport A. Ditjatin and E. Davidova, two winners of gold at the XXII Olympic Games in Moscow.
Every group had 25 training sessions. During these trainings the athletes did special exercises with electrostimulation, vibrostimulation or with combined electrovibrostimulation. During each training session we defined and registered the level of development of the movements of the trained joints. The stimulation treatment was applied once a day every second day, always in combination with the ordinary training. The whole experiment lasted for 6 weeks.
A neccessary condition of the experiment was the active participation of the sportsman. During an exercise the athlete should perform rythmical movements together with vibrostimulation, at the same time trying e.g. to lift his leg as high as possible. With the vibrostimulation switched on, the leg involuntarily moved higher. The athlete then should keep his leg in the up position as long as possible. The electrovibrostimulation helped him to lift the leg 6-10 cm higher than his normal height limit.
During all the time of the electrovibrostimulation we perceived a tendency to increase the amplitude of the movement. With clear statistical significance this increase of the active mobility at lifting the leg was observed for all sportsmen. Most important is the fact, that the electrovibrostimulation effect stayed for a long time: from 1 month till 1,5 months. During this time the repetition of that specific exercise without the electrovibrostimulation proved the effectiveness of our method.
At the same time the passive mobility in the hip-joint improved. Gymnasts who could do the splits before, told that it was very easy for them to do the splits under electrovibrostimulation. Sportsmen who did not do the splits before, came already after a first electrovibrostimulation session nearer to the aim of this exercise (3-5 degrees better). Sportsmen who had never done the splits before started to do it completely after 5-7 electrovibrostimulation trainings. Only three sportsmen from

the experimental group could not perform the splits completely. However, the amplitude of the hip-joint motion in the frontal plane increased with not less than 8-10 degress. The results of these experiments show that the combined electrovibrostimulation gives in a shorter time a better effect for the training of the active and the passive mobilities in the hip-joint and confirm the superiority of the electrovibrostimulation training in attaining the optimum joint mobility. The vibrostimulation perfects the mobility by reducing the zone of the passsive muscle insufficiency, whereas the electrovibrostimulation not only reduces the zone of the passive, but also the zone of the active insufficiency. Vibrostimulation elongates the antagonistic muscles, so that the range of the passive insufficiency decreases. Electrostimulation increases the contraction force of the agonistic-synergistic muscles in the zone of the active insufficiency resulting in the perfection of the active mobility of the sportsman's locomotor system. The simultaneous stimulation of synergists and antagonists creates the optimum mobility structure in the joint.

CONCLUSIONS

Research in our laboratory of Biocybernetics of the St.-Petersburg State Technical University showed that the results of the combined electro- and vibrostimulation are better than those obtained after a separate application of both. With a programmable device for the combined electrovibrostimulation we achieved an increase of the concentrical and eccentrical muscle contraction force, a substantial decrease of the zones of active and passive muscle insufficiency and an increase of the joint mobility. The experimental data show that after the electrovibrostimulation the increase of the active and the passive mobility in the joints goes practically parallel. This means that notwithstanding a considerable increase of the mobility because of the stretching of the antagonistic muscles, the joint keeps its durability because of the increase of the synergistic muscle force. The electrovibrostimulation training had a big effect on the rehabilitation of the joint mobility after a trauma. The experiments confirmed the effectiveness of the electrovibrostimulation training for the redevelopment of the muscle force and joint mobility. The result of the research consists in the creation of a method which allows to improve the functional condition of the human SMA in the zones of the active and passive insufficiencies, especially under extreme loads.

REFERENCES

A.V. Zinkovsky, V.V. Kuznetsov et al., (1987). Authors' Certificate 1344356.