TRAINING OF THE SKELETAL-MUSCLE APPARATUS OF SPORTSMEN THROUGH ELECTROVIBROSTIMULATION

A.V. Zinkovsky1, I.A. Zoubova1, K.P. Schmidt2, K.J. van Zwieten2

1St. Petersburg State Technical University, 195220 St. Petersburg, Grazhdanski Pr. 28, Russia, tel. (812) 534-1364, fax (812) 534-1365, email bioval@mail.imop.csa.ru

2Limburgs Universitair Centrum, Universitaire Campus, B-3590 Diepenbeek, Belgium, tel. (011) 26.81.11, fax (011) 26.82.99, email kschmidt@luc.ac.be

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 hypodynamy. 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 neuromuscular apparatus and other systems of the body. With vibrostimulation, these mechanical impulses and oscillations can act as 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 at least ten times higher than in the traditional methods of sports and sportsmedicine.

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 increase in the zone of the active insufficiency (fig. 1). As a result we observe an improvement in the active movement of the human skeletal-muscular apparatus. We assume, that the simultaneous stimulation of both synergists and antagonists helps to achieve an optimum pattern of the joint movement.

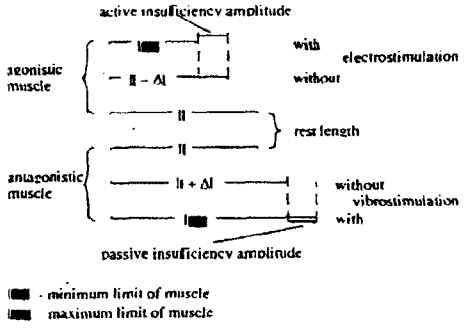


fig. 1: Effects of Muscular Electrovibrostimulation Training

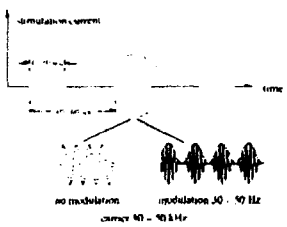
We therefore developed a program-controlled device for the electrovibro-stimulation of the human skeleto-muscular apparatus for applications in medicine, ballet and sport. Separate electro - or vibrostimulators are available but devices for the

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 the existing vibromassage units are not so well adapted to medical purposes, because they are not versatile in application and because the vibro characteristics can only be tuned in a very limited frequency range.

The Laboratory of Biocybernetics of the St.Petersburg State Technical University developed and tested a prototype of a muscle electrovibrostimulator, after the laboratory model had been ordered 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, adaptable to the patient's condition. The pulse lenghth varies between 1 to 10 seconds with 10 to 60 second periods between consecutive bursts. The number of pulses for a single treatment can be chosen between 2 to 11. The pulse bursts consist of a continuous or amplitude modulated 30 - 50 kHz harmonic signal. In the modulated mode the modulation is a 30 - 50 Hz sine wave with 100% modulation depth. In this mode, each pulse train starts from zero amplitude, which makes the electrostimulation softer even for rather large (50 mA) stimulation 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. (fig. 2).

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 continuously variable vibrational amplitude of the vibrator probe of 3 - 6 mm in a frequency range of 15 - 30 Hz. Both parameters are electrically controlled so that they can be varied during the electrostimulation following a preset program. The device has different exchangeable massage probes which permit the massage of different parts of the patient's body with maximum effect.



ig. 2: Characteristics of the Electrostimulation Pulse

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 medicoprofilactic measures.

RESULTS

In order to test 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 was measured during different exercises. 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 formed. In each experimental group one of the stimulation methods 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.

Each 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. In an exercise the athlete performed rythmical movements during which he e.g. tried to lift his leg as high as possible, first without, then with vibrostimulation. With the vibrostimulation switched on, the leg moved higher than without. After several minutes the vibrostimulation was switched off and the athlete should

then keep his leg in the up position as long as possible, at least several seconds. After this phase the vibro- and electrostimulation were applied simultaneously. As a result, the added electrovibrostimulation helped the testperson 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. A quite important observation is, that the electrovibrostimulation effect stays for a considerable 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.
On the other hand, the passive mobility in the hip-joint also improved. Gymnasts who could do the splits before, experienced that it was easier for them to do the splits under electrovibrostimulation. Sportsmen unable to do the splits before, came already after a first electrovibrostimulation session 3-5 degrees nearer to the aim of this exercise. 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 their hip-joint motion in the frontal plane increased with not less than 8-10 degrees.

This shows that the improvement of active leg-lifting under the influence of electrovibrostimulation influences the ability to spread the legs passively as well. In anatomical terms, leg-lifting can be defined as anteversion or flexion of the hip-joint. It is generally known, that anteversion in itself facilitates both abduction (i.e. spreading) as well as rotation of the hip-joint. This can be attributed a.o. to the de-spiralling of the iliofemoral ligament in hip-flexion. Possibly electrovibrostimulation has some influence on this phenomenon too.

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. We assume that vibrostimulation perfects the mobility by reducing the zone of the passsive muscle insufficiency, whereas electrovibrostimulation reduces both, the zone of the passive as well as 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 a better active mobility of the 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 maintains its function and stability because of the increase of the synergistic muscle force. The electrovibrostimulation training also had a positive influence on the rehabilitation of the joint mobility after trauma. In that case, the experiments confirmed the effectiveness of the electrovibrostimulation training for the redevelopment of the muscle force and joint mobility. So our research resulted in the development of a method which improves the functional condition of the human SMA in the zones of the active and passive insufficiencies, especially under extreme loads.

REFERENCES

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Dit artikel bevat elementen uit congresmededelingen, door meerdere van bovenstaande auteurs, in:
a)Proceedings of the XIVth Symposium on Biomechanics in Sports, Lisboa 1996
b)Book of Abstracts of the 10th Conference of the European Society of Biomechanics, Leuven 1996