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Effects of Electrical Stimulation on Individuals with Cerebral Palsy or Spina Bifida

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ABSTRACT

This research paper focuses on the use of neuromuscular electrical stimulation on individuals with spina bifida and cerebral palsy. Field experiments have shown that this type of therapy appears to benefit individuals with these disorders. A description of these two disorders appears in the text of the paper. Specific case studies using electrical stimulation are described, especially one done by Carmick in 1993 which focuses on research done on three young boys with cerebral palsy. Problems with electrical stimulation and a description of its function are also discussed.

INTRODUCTION

Cerebral palsy is a disease which affects the use of muscles in the body to varying degrees. More specifically, cerebral palsy is a manifestation of impaired neurologic function due to aberrant structure, growth, or development of the central nervous system (Denhoff and Robinault, 1960). Neurologic function can be impaired before, during, or after birth (Denhoff and Robinault, 1960). Cerebral palsy manifests itself in the form of convulsions or, in most cases, some motor disfunction. Individuals with cerebral palsy are unable to use their muscles to full potential when there is impairment of motor function. The muscles "work", but not the way they should.

There are several types of cerebral palsy, those which cause the muscles to always be contracted and those which cause them to always be relaxed. The physiologic (motor) classifications of cerebral palsy either involve the spasticity of muscles or their athetosis (Denhoff and Robinault, 1960). Spastic individuals have tighter muscles and a large number of involuntary contractions. Individuals with athetosis display more involuntary motion. There are several subcategories of athetosis, including atonia, which is a total lack of tone and a failure of muscles to respond to volitional stimulation; and rigidity, which is characterized by resistance to slow passive motion of agonist and antagonist muscles (Denhoff and Robinault, 1960). Cerebral palsy can also be categorized according to muscle groups affected (topography) or etiology (Denhoff and Robinault, 1960). Individuals with cerebral palsy who have tight muscles can be treated with physical therapy to keep the muscles moving. The therapist can attempt to loosen the muscles with specialized treatment and exercise. This keeps them from remaining completely immobile. Individuals with cerebral palsy whose muscles are loose and relaxed can also be treated with physical therapy. The therapist works to improve muscular co-ordination, develop the concept of motion, and teach self-help skills (Leaning, 1958). The therapist uses manual treatments and manipulations. This is also beneficial to circulation and reduction of bed sores.

Recently, evidence has been found that electrical stimulation of various body systems can have healing effects (Sisken, Walker, and Orgel, 1993). Endogenous currents present in normal tissues and those that occur after injury were proposed to modify bone structure. It is believed that tissue integrity and function can be restored by applying electrical or mechanical energy to the area of injury (Sisken, et al). Evidently, these currents speed the process of healing bone fractures. Electrical stimulation has also begun to be used on muscles. Studies have shown that neuromuscular electrical stimulation (NMES) and functional electrical stimulation (FES) of particular muscular groups in children can improve muscular control and balance, moreso in younger children (under five or six years of age) (Carmick, 1993). Previously, this had been used almost exclusively on adults (Carmick, 1993).

Physical therapists use neuromuscular electrical stimulation of muscles almost every day. They use it on muscles that are being stretched and treated. It gives the individual more control over the muscle by relaxing very tight (due to injury) muscles (Binder-Macleod, Snyder-Mackler, 1993). It has been used on individuals with cerebral palsy to give them more or at least some control over their muscles. This appears to be a promising treatment, especially when started early and used with a type of task oriented learning (Carmick, 1993). One of the purposes of my research is to find if these studies are being done extensively enough and with enough success that they would be useful to the field of physical therapy in general and could be applied to the treatment of another disease, spina bifida. My research will focus on what has already been done, but I hope to find more evidence that these advances can be used to benefit patients with other muscular conditions other than cerebral palsy, particularly spina bifida. Thus, it would be beneficial for the field of physical therapy to continue research into these possibilities.

Spina bifida is a birth defect in which the vertebral column does not close completely during development, and the spinal cord grows partially outside of it. This causes the individual with the problem to be unable to use his or her muscles from a certain point. Physical therapy for these individuals is used to reduce the speed of muscle atrophy. The more atrophy occurs, the less the individual is able to do on his own. There are many cases where the individual is able to walk at a young age alone or with the help of braces. As they get older and larger, what muscle strength they have will not counteract gravity anymore, and they become dependent on a wheelchair. If this could be prevented, these individuals would have more access to places they want to go, and also they would be healthier. It has been shown that repetitive activation of lower-extremity muscles may allow individuals with spinal cord injuries to ambulate (Binder-Macleod and Snyder-Mackler, 1993).

RESULTS AND DISCUSSION

Electrical Stimulation: a Definition

In clinical situations, electrical stimulation is typically brief electrical pulses grouped together in trains to produce tetanic contractions (Binder-Macleod and Snyder-Mackler, 1993). The stimulation intensity (including pulse amplitude and duration), train frequency and the on/off times of the train are the stimulation variables that have the most impact on muscle fatigue (Binder-Macleod and Snyder-Mackler, 1993). Muscular force can be regulated in two ways during electrical stimulation. Stimulation intensity can be changed, which affects the number of motor units recruited, or the frequency of stimulation can be varied to decrease the speed of muscle fatigue. Trains that go from high to low frequency seem to work best in terms of lessening fatigue and enhancing force output (Binder-Macleod and Snyder-Mackler, 1993). Neuromuscular electrical stimulation is commonly uses as a substitute for a brace to assist with range-of-motion (ROM) exercises and to augment muscle strength.

Case Studies

Lyendecker (1975) observed twenty children with cerebral palsy whose mean age was just over ten years. Ten of these children received NMES treatment with neurodevelopmental therapy (NDT). The other ten received only the NDT. The first group progressed faster than the second, but by the end of the study, the two groups were equal.

The results of a six year study done by Gracanin (1976) were reported on 120 children with cerebral palsy who were given FES. When the peroneal nerve was stimulated during gait in children with varus deformities of the feet, and who exhibited hyperreflexia, the FES had a positive effect. The children's walking ability improved, as well as posture. Some of these improvements lasted after the removal of the FES. The positive effects were seen mostly in the "swing" phase of the child's movement, meaning that it was seen during the motion phase. The FES reduced the number of abnormal elevations, or hikes, and decreased medial rotation of the hip joint, equinovarus, and inadequate dorsiflexion at the ankle joint. The children also displayed improvments during the stance phase, and some were able to touch the floor with the heel (this had not been possible previous to FES).

Dubowitz (1988) reported on the use of electrical stimulation with two three-year-old girls. They had hemiplegia with cerebral palsy, and stimulation was used to determine whether the girls' motor perfomance could be improved. The therapist applied stimulation to the tibialis anterior muscle of the affected leg for an hour three times per day during a time when the children were most active. Gait, motor performance, and balance improved.

Atwater (1991) used electromyography-driven NMES with ten children who had cerebral palsy. The children were aged 5.5 to 16 years. They were given total-body NDT exercise programs and electromyography-driven NMES to either the wrist extensors or the ankle dorsiflexors three times a week for eight weeks. All the children who remained in the study for the full time period (nine of them) showed improvement in general motor function.

In a documented study, Judy Carmick (1993) studied a group of young male children with hemiplegia due to cerebral palsy. She attempted to use neuromuscular electrical stimulation to improve range of motion, temporarily reduce excessive spasticity, facilitate motor control and muscle reeducation, and assist in gait training.

Carmick decided to use NMES as an adjunct to the task-oriented or systems-based model of physical therapy. She worked with both upper and lower extremities of three young boys. NMES was used for muscle education, strengthening, increasing sensory awareness, and evaluation. Use of a Respond II unit that allows two different muscles to be stimulated at the same time or at alternating times, made it easier to decrease overflow of output (Carmick, 1993).

The task-oriented model of learning is one in which stimulation is applied while the child is actually doing something, such as playing with toys or running. During this process, the children are often given concrete directions in order to assist in motor learning. The therapist would have the child perform specific tasks so that the child could learn (aided by the electrical stimulation) how to use specific muscles in certain ways.

The children used in the lower extremity experiment were ages 1.6, 6.7, and10. The youngest child showed (as expected) the greatest improvement. When he first came in for treatment, he walked on his toes and could only lead with his right side when walking. The therapist used NMES on his tibialis anterior muscle at 21 months of age. This did not appear to affect his gait, so they added the triceps surae muscle when he was 26 months. They alternately stimulated these two muscles using a remote-controlled device. Finally, at 29 months of age, the therapist only stimulated the triceps surae, and the child's foot became plantigrade immediately. The next step was to stimulate the gluteus maximus muscle to strengthen the child's gait. They also eventually had to correct the compensating trunk rotation which kept him leading with his right side by applying NMES to the medial hamstring. He was able to walk and run much better after this treatment. Carryover lasted for at least four weeks, because the child had learned to maintain the skill.

The second child was 6.7 years of age and had previously received NDT physical therapy, which had not been very effective. The tibialis and the triceps surae muscles were stimulated alternately while the child walked about. His Physiological Cost Index (PCI) showed a factor of four reduction, which means that his locomotor efficiency improved. Range-of-motion also improved greatly, and the child could ride a bike without training wheels after his therapy. Previous to the NMES, he could not maintain his balance well enough to ride a bike. Carryover continued for a year.

The third child was 10 years of age. The tibialis anterior and triceps surae muscles were the focus of the NMES. After two months of treatment, the child's PCI showed a factor of two improvement. He obtained a smoother gait and a more symmetrical posture. He no longer vaulted on his right foot, his lateral trunk deviation was gone, and his balance improved (Carmick, 1993).

In the upper extremity experiment, the two younger boys were used again. The youngest was unable to creep when he came in for treatment, due to the fact that his left arm was not strong enough to hold him up. NMES was applied to the triceps brachii muscle, and the child immediately began to creep around the room. Carryover occurred immediately also. His wrist extensors and finger flexors were also targeted, because the child could not let go of things once he was holding onto them. This also worked immediately, and the child was able to use both hands together. Eventually, the therapist stimulated the thumb extensors and abductors so the child could use his thumb with more efficiency. Immediate effects were observed.

The second child had a nonfunctional left hand which had atrophied a great deal. NMES was applied to the same muscles as on the first child. After several sessions, spontaneous use of the hand improved.

Various physicians and researchers have noticed that for children with cerebral palsy, motor gains usually reach a plateau or cease between the ages of six and seven (Bleck, 1987). The NMES used in this study appeared to improve motor function and balance in two children of ages 6.7 and 10. This use of NMES showed important functional changes in children with cerebral palsy. Preliminary findings seem to suggest that NMES may be a useful physical therapy tool when it is used with this particular model of learning (Carmick, 1993).

A study has also been done on individuals with spina bifida. Pape, 1990, states that the use of therapeutic electrical stimulation (TES) on spina bifida patients improved motor function, bowel control, and bladder control. Research is very new, but it looks promising.

Problems with Electrical Stimulation

There can be a problem with NMES when it is not used properly, and that is muscle fatigue. The right combination of factors must be used or the treatment will fatigue the muscle and become ineffective. Fatigue can be defined as a decrease in the force-generating ability of a muscle resulting from recent activity. During electrical stimulation, the rate of fatigue of skeletal muscle is much greater that that seen during volitional contractions. There are several reasons for this. The first is that the order of motor unit recruitment during volitinal contractions selects the most fatigue-resistant motor units for low-force contractions. During NMES contractions, the more rapidly fatiguable motor units are recruited first, even at low stimulation intensities. Secondly, higher frequencies are used during NMES, and higher frequencies result in more rapid fatigue. Thirdly, the central nervous system is not involved, and therefore cannot vary the use of motor units and modulate their discharge rates in order to maintain a targeted level of force. Therapists must be very careful when selecting frequency and intensity of pulses to avoid fatiguing the muscle (Binder-Macleod and Snyder-Mackler, 1993).

CONCLUSION

The studies that have been examined in this paper appear to show support in the medical community and valid medical reasons for the use of neuromuscular stimulation in the treatment of cerebral palsy and spina bifida. As long as therapists continue to study its effects and monitor for muscular fatigue, NMES could become an even more powerful tool in the field of physical therapy. This technology should be researched so that individuals with spina bifida, cerebral palsy, and other neuromuscular disorders can live fuller lives with proper treatment.

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