Electrical Stimulation In Stroke And Brain Injury

Abstract: Neuromuscular electrical stimulation (NMES) can be used to augment range-of-motion, strengthening, and facilitation treatment programs of the muscles surrounding the shoulder. The purposes of this article are 1) to describe the uses of NMES around the shoulder joint as developed through our clinical use and 2) to detail the effects of an NMES program on chronic shoulder subluxation as determined by a clinical study. Because of the complexities of this multiarticular joint, NMES is most useful in the initial phase of the ROM, and stimulated contractions are compromised, relatively, as the humerus moves above the 90-degree horizontal plane. The use of NMES to provide scapular stabilization often entails unwanted alteration of the pressures on the spinal column, occasionally making the treatment program unusable. Electrical stimulation to prevent or correct shoulder subluxation, especially in the neurologically involved patient, provides the therapist with a powerful new treatment technique. In a group of stroke patients, shoulder subluxation was reduced significantly (p less than .05) at the completion of a six-week NMES program. Some of the problems, and possible solutions, unique to the development of electrical stimulation programs for the shoulder muscles are discussed.


Abstract: This review demonstrates that neurorehabilitation approaches, based on recent neuroscience findings, can enhance locomotor recovery after a spinal cord injury or stroke. Findings are presented from more than 20 clinical studies conducted by numerous research groups on the effect of locomotor training using either body weight support (BWS), functional electrical stimulation (FES), pharmacological approaches or a combination of them. Among the approaches, only BWS-assisted locomotor training has been demonstrated to have a greater effect than conventional or locomotor training alone. However, when study results were combined and weighted for the number of subjects, the results indicated that there is a gradient of effects from small changes with the immediate application of FES or BWS to larger changes when locomotor training is combined with FES or BWS or pharmacological approaches. The findings of these studies suggest that these neurorehabilitation approaches do play a role in the recovery of walking in subjects with spinal cord injury or stroke. Several factors contribute to the potential for recovery including the site, etiology, and chronicity of the injury, as well as the type, duration, and specificity of the intervention and whether interventions are combined. Furthermore, how these neurorehabilitation approaches may take advantage of the plasticity process following neurological lesion is also discussed.
Abstract: Spasticity treatment must be considered in relation to other impairments with functional goals defined prior to intervention. The effects of muscle co-contraction and involuntary limb movement associated with exaggerated cutaneous reflexes or effort as well as stretch reflex hyperexcitability need to be considered. Exacerbating factors such as pain must be identified. Physical therapy and conventional orthoses are the mainstays of spasticity management during acute rehabilitation. Botulinum toxin shows promise but needs further evaluation in the context of acute rehabilitation. Phenol chemodenervation can produce good results in spasticity refractory to standard treatments. Muscle strengthening exercises may be appropriate in chronic hemiparesis without adversely affecting tone. Electrical stimulation may be a useful adjunct to other spasticity treatments. Difficulty demonstrating functional benefit from antispasticity treatment may imply that interventions directed at single motor impairments whether weakness or spasticity are not likely to result in functional benefit, but it is their combination that is important.

Abstract: Multichannel electrical stimulation was applied in 20 patients with hemiplegia secondary to stroke or head injury using a six-channel microprocessor stimulator-stride analyzer to restore independent gait and to reestablish a normal gait pattern in a two- to three-week therapy period. The therapy was followed up at every session by a stride analyzer incorporated into the stimulator. At the beginning and at the end of the therapy period, each subject's gait was measured with a ground reaction measuring system. Statistical results and observations are presented for the group of 20 subjects, and a detailed description of the results is given for one subject who is representative of the whole group. According to the measured gait characteristics, gait improved significantly in all subjects during the therapy period, resulting in a partly or completely independent gait. The subjects' posture and endurance also improved, and they spontaneously learned how to use a crutch. The measurements and visual assessment of the subjects' progress indicate that the described treatment protocol offers good prospects for faster and more efficient gait rehabilitation in severely impaired patients. To determine the efficacy of gait therapy with multichannel electrical stimulation, a comparative study of conventional therapeutic methods and the method described in this article should be conducted.


Abstract: The beneficial effects of using multichannel functional electrical stimulation (MFES) for gait rehabilitation in nonambulatory hemiplegic patients have already been shown. The methodology of application and the results presented were pooled for the whole group of participants, which blurs the exact picture of each particular subject and many vital details are not presented. The purpose of this article is to focus on a single subject from the study and to present all the details of the treatment. The presented subject participated six weeks in the study, first three
weeks in MFES therapy and second three weeks in conventional therapy. The effects of each therapy were evaluated by the following measures: temporal-distance parameters of gait, ground reaction forces, goniograms in hip knee and ankle, and assessment of the physical status of the patient according to the Fugl-Meyer evaluation scale. An analysis of the measured parameters showed improved performance of the patient during MFES therapy and stagnation or even slight recession during conventional therapy. The patient achieved independent gait during the three weeks of MFES therapy. At 30 months after the beginning of therapy, the patient was still able to ambulate independently without any significant changes in his gait pattern. The accomplishment was mainly attributed to the avoidance of pathological gait pattern development by using MFES assisted gait training and to the high motivation of the patient to walk and exercise during therapy as well as after he was released to go home.


Botte M.J., Bruffey J.D., Copp S.N., and Colwell C.W. (2000) Surgical reconstruction of acquired spastic foot and ankle deformity. Foot Ankle Clin. 5, 381-416. Abstract: With the aging population and improved methods of emergency transport, the number of surviving stroke and brain injury patients continues to increase. Aggressive rehabilitation of appropriate candidates is justified. In the period of spontaneous recovery, efforts are made to prevent fixed contractures using passive mobilization, splinting, nerve blocks, and electrical stimulation. If deformity persists and the patient is no longer recovering, operative management can help alleviate the functional and hygiene problems associated with these limb deformities.

Bowman B.R., Baker L.L., and Waters R.L. (1979) Positional feedback and electrical stimulation: an automated treatment for the hemiplegic wrist. Arch. Phys. Med. Rehabil. 60, 497-502. Abstract: Positional feedback (PF) and electrical stimulation were combined in a new treatment modality for facilitating wrist extension in stroke patients. Thirty adult hemiparetic patients lacking normal voluntary wrist extension were randomly placed in control and study groups. The control group received conventional therapy while the study group received positional feedback stimulation training (PFST) in addition to conventional treatment. At the end of the 4-week program, study patients showed a 280% increase in isometric extension torque when the wrist was positioned in 30 degrees of extension and 70% increase when positioned in 30 degrees of flexion. Control patients showed no significant changes in torque. Study patients made an average 200% gain in selective range of motion over their starting levels while controls made only a 50% increase. Treatment using automated PFST equipment allows controlled repetitive isotonic exercise and facilitation of wrist extension without continuous one-on-one therapist/patient supervision.

Abstract: In collaboration with the College of Engineering the author has developed a laboratory, or clinic, based, battery operated "universal" control system, designed to improve disabled gait in upper motor neuron disabilities, especially stroke, hemiplegia, and cerebral palsy, by applying several channels of FES (Functional Electrical Stimulation) to the lower limb muscles while the patient is walking. The timing of the FES pulses, which can be applied to as many as six of the patient's muscles, is determined by potentiometer controlled one-shot timers, which are triggered by any of three switches in the sole of either shoe. Combinations of inverters, flip flops, AND gates and OR gates in the externally connected logic circuits determine the sequence of delays and pulses applied to the patient's muscles. This paper describes and diagrams some of the logic circuits and as an example of the possible application of the concept of a "universal" control unit reports the modifications of gait induced in a hemiplegic, four year post-stroke, patient. The characteristics of this patient's gait with FES in comparison to its characteristics without FES are demonstrated with motion picture frames, EMG recordings and graphic tracings of her right knee and ankle joint positions. They include more symmetrical timing of her right and left stance and swing phases, increased dorsiflexion of her right ankle in the swing phase, followed by a more distinct heel strike, and improved flexion--extension sequences of the knee and ankle joints and an increased heel rise in the stance phase. The author concludes that the gait characteristics of some hemiplegic patients will improve as they become adapted over a period of weeks or months to a control logic, which lessens their functional limitations by the use of a properly timed and amplified sequence of FES pulses. He suggests that the FES control requirements for individual patients should be determined experimentally with a control system "universally" adaptable to a wide range of disabilities, and that these control parameters could then determine the design of portable units, which may be used on a long term basis. These units would include only the operational options needed to duplicate the gait corrections found to be practicable for each individual patient, by the testing procedure, through a universal logic unit as described in this paper.

Abstract: OBJECTIVE: To measure the effect of the Odstock Dropped Foot Stimulator (ODFS), a common peroneal stimulator, on the effort and speed of walking. DESIGN: A randomized controlled trial. SUBJECTS: Hemiplegic patients who had suffered a single stroke at least six months prior to the start of the trial whose walking was impaired by a drop-foot. INTERVENTIONS: The treatment, functional electrical stimulation (FES) group, used the stimulator and received a course of physiotherapy; the control group received physiotherapy alone. MAIN OUTCOME MEASURES: Changes in walking speed measured over 10 m and the effort of walking measured by physiological cost index (PCI). RESULTS: Thirty-two subjects completed the trial, 16 in the FES group and 16 in the control group. Mean increase in walking speed between the beginning and end of the trial was 20.5% in
the FES group (when the stimulator was used), and 5.2% in the control group. Improvement was also measured in PCI with a reduction of 24.9% in the FES group (when the stimulator was used) and 1% in the control group. No improvement in these parameters was measured in the FES group when the stimulator was not used. CONCLUSION: Walking was statistically significantly improved when the ODFS was worn but no 'carry-over' was measured. Physiotherapy alone, in this group of subjects with established stroke, did not improve walking.


Abstract: In this paper we present an overview of current research into clinical and therapeutic applications of electrical neuromuscular stimulation (NMS). As this is now such a huge subject we have focused our attention on the therapeutic rather than orthotic uses of stimulation and limited the field almost exclusively to upper limb applications in hemiplegia. The evidence that NMS influences motor re-learning and how this may be measured is discussed. We have identified the following as the three most important unresolved issues: 1) an understanding of how NMS modifies the interactions within the nervous system, 2) clinical effectiveness of NMS, and 3) inexpensive, simple to insert and reliable controllable implanted systems. We discuss recent research aimed at resolving these issues and based on this we make some suggestions for future research. To resolve these issues we propose: 1) neurophysiologic research into the mechanism through which NMS interacts with the nervous system; 2) large multicenter randomized controlled trials using rigorous methodology that compare different applications of NMS; 3) continued technical development that is closely linked to clinical applications.


Abstract: BACKGROUND AND PURPOSE: After stroke, many individuals have chronic unilateral motor dysfunction in the upper extremity that severely limits their functional movement control. The purpose of this study was to determine the effect of electromyography-triggered neuromuscular electrical stimulation on the wrist and finger extension muscles in individuals who had a stroke > or = 1 year earlier. METHODS: Eleven individuals volunteered to participate and were randomly assigned to either the electromyography-triggered neuromuscular stimulation experimental group (7 subjects) or the control group (4 subjects). After completing a pretest involving 5 motor capability tests, the poststroke subjects completed 12 treatment sessions (30 minutes each) according to group assignments. Once the control subjects completed 12 sessions attempting wrist and finger extension without any external assistance and were posttested, they were then given 12 sessions of the rehabilitation treatment. RESULTS: The Box and Block test and the force-generation task (sustained muscular contraction) revealed significant findings (P<0.
05). The experimental group moved significantly more blocks and displayed a higher isometric force impulse after the rehabilitation treatment. CONCLUSIONS: Two lines of evidence clearly support the use of the electromyography-triggered neuromuscular electrical stimulation treatment to rehabilitate wrist and finger extension movements of hemiparetic individuals > or =1 year after stroke. The treatment program decreased motor dysfunction and improved the motor capabilities in this group of poststroke individuals.

Abstract: Neuromuscular stimulation may facilitate motor recovery after stroke or brain injury, reduce shoulder pain associated with hemiplegia, and reduce cerebral spasticity. However, the discomfort of surface neuromuscular stimulation significantly limits the clinical implementation of this modality for persons with hemiplegia. The study contained herein tests the hypothesis that stroke and brain injury survivors with chronic hemiplegia (>6 mo) and intact sensation tolerate percutaneous intramuscular stimulation better than surface stimulation. Four stroke and two traumatic brain injury survivors participated in the study contained within this article. Each subject received three pairs of percutaneous and surface stimulations of the paretic finger extensors. The order of the type of stimulation within each pair was randomly assigned. The stimulation parameters for each type of stimulation were normalized to produce the same torque at the metacarpophalangeal joint. Subjects rated their perceived level of discomfort using a 10-cm visual analog scale and the McGill Pain Questionnaire. A blinded evaluator administered the pain measures. Percutaneous stimulation was associated with significantly lower discomfort as reflected by the visual analog scale (0.74 v 3.3; 95% confidence interval of difference, -3.84, -1.28). The McGill Pain Questionnaire produced similar results with percutaneous stimulation associated with a significantly fewer number of words chosen to describe the discomfort (0.87 v 3.30; 95% confidence interval of difference, -3.50, -1.30) and significantly lower Pain Rating Index (1.47 v 6.27; 95% confidence interval of difference, -7.77, -1.83). Data suggest that percutaneous intramuscular stimulation is significantly better tolerated than surface stimulation and that percutaneous stimulation may enhance patient compliance with neuromuscular stimulation treatments.


Abstract: The purpose of this review is to critically assess the clinical efficacy of neuromuscular electrical stimulation in treating motor dysfunction in hemiplegia. Three distinct applications are reviewed in the areas of motor relearning, shoulder dysfunction, and neuroprostheses. Assessment of clinical efficacy and recommendations on clinical implementation are based on the weight of published scientific evidence. With respect to motor relearning, evidence supports the use of neuromuscular electrical stimulation to facilitate recovery of muscle strength and coordination in hemiplegia. However, effects on physical disability are uncertain. With respect to shoulder dysfunction, neuromuscular electrical stimulation decreases shoulder subluxation, at least in the short term. However, effects on shoulder pain and disability are also uncertain. With respect to neuroprosthesis systems, clinically
deployable upper extremity systems must await the development of more sophisticated control methods and greater fundamental understanding of motor dysfunction in hemiplegia. The evidence for clinical feasibility of lower extremity neuroprostheses is stronger, and investigations on clinical efficacy should be pursued. In summary, the application of neuromuscular electrical stimulation for motor relearning and shoulder dysfunction are ready for more rigorous scientific and clinical assessment via large, multicenter, randomized clinical trials. However, additional investigations are needed to demonstrate the clinical feasibility of neuroprostheses applications

Abstract: This case report describes the first survivor with chronic stroke who was treated with percutaneous, intramuscular neuromuscular electrical stimulation (NMES) for shoulder subluxation and pain. The patient developed shoulder subluxation and pain within 2 mo of his stroke. After discharge from acute inpatient rehabilitation, he developed shoulder and hand pain, which was treated with subacromial bursa steroid injection and ibuprofen with eventual resolution. The patient remained clinically stable until approximately 15 mo after his stroke- when he developed severe shoulder pain associated with shoulder abduction, external rotation, and downward traction. The patient could not tolerate transcutaneous NMES because of the pain of stimulation. At approximately 17 mo post-stroke, the patient's posterior deltoid, middle deltoid, and supraspinatus muscles were percutaneously implanted with intramuscular electrodes. After 6 wk of percutaneous, intramuscular NMES treatment, marked improvements in shoulder subluxation and pain, and modest improvements in activities of daily living and motor function were noted. One year after the onset of treatment, the patient remained pain free, but subluxation had recurred. However, the patient was able to volitionally reduce the subluxation by abducting his shoulder. The patient remained pain free for up to 40 mo after the initiation of percutaneous, intramuscular NMES treatment. This case report demonstrates the feasibility of using percutaneous, intramuscular NMES for treating shoulder subluxation and pain in hemiplegia

Abstract: OBJECTIVE: To determine the influence of functional electrical stimulation (FES) on subluxation and shoulder pain in hemiplegic patients. DESIGN: Controlled study of 24 months' duration beginning in the first month after onset of stroke. SUBJECTS AND SETTING: One hundred twenty hemiplegic patients with both subluxed and painful shoulder were followed for rehabilitation before and after discharge between 1989 and 1993. All subjects received conventional rehabilitation based on the Bobath concept. In addition, patients were alternately assigned to a control group or to receive additional FES for 5 weeks on muscles surrounding their subluxed and painful shoulder. MAIN MEASURES: Clinical examinations, including range of motion, pain assessment, and x-rays, were performed at the start of the study, between the second and fourth weeks after onset of stroke, and subsequently at 6, 12, and 24 months. RESULTS: The FES group showed significantly more improvement than the control group in both pain relief (80.7% vs. 55.1%, p<.01) and reduction of subluxation (78.9% vs. 58.6%, p<.05). Furthermore, recovery of arm
motion appeared to be significantly improved in the FES group (77.1% vs. 60.3% in the control group, p<.01). CONCLUSION: The FES program was significantly effective in reducing the severity of subluxation and pain and possibly may have facilitated recovery of the shoulder function in hemiplegic patients

Abstract: Tilt sensors, or inclinometers have been investigated for the control of Functional Electrical Stimulation (FES) to improve the gait of persons who had a stroke or incomplete spinal cord injury (SCI). Different types of tilt sensors were studied for their characteristics and their performance in measuring the angular displacement of leg segments during gait. Signal patterns of the lower leg with inertial tilt sensors were identified with control subjects and subjects with footdrop who are being stimulated during level walking. To minimize acceleration responses when the foot swings or hits the ground, we use low-pass filtering (1.5-2 Hz). A finite state approach allows the sensor fixed on the shank to effectively detect the step intention in a population of stroke and incomplete SCI subjects and to control the FES. When the lower leg tilts backward, the common peroneal nerve is stimulated to bring the foot up and forward. We have designed a miniature footdrop stimulator with a magnetoresistive tilt sensor built in, so no external sensor cables are required. The thresholds to turn the stimulator on and off can be adjusted, as well as the maximum period of stimulation and the minimum interval between periods of stimulation. This device features several important advantages over traditional AFO's or stimulators controlled by foot switches. Initial trials with stroke and SCI subjects have demonstrated substantial gait improvement for some subjects, while most liked the good cosmesis and ease of using the device with a tilt sensor

Abstract: The use of a functional neuromuscular stimulation (FNS) device can have therapeutic effects that persist when the device is not in use. Clinicians have reported changes in both voluntary and electrically assisted neuromuscular function and improvements in the condition of soft tissue. Motor recovery has been observed in people with incomplete spinal cord injury, stroke, or traumatic brain injury after the use of motor prostheses. Improvement in voluntary dorsiflexion and overall gait pattern has been reported both in the short term (several hours) and permanently. Electrical stimulation of skin over flexor muscles in the upper limb produced substantial reductions for up to 1 h in the severity of spasticity in brain-injured subjects, as measured by the change in torque generation during ramp-and-hold muscle stretch. There was typically an aggravation of the severity of spasticity when surface stimulation reached intensities sufficient to also excite muscle. Animals were trained to alter the size of the H-reflex to obtain a reward. The plasticity that underlies this operantly conditioned H-reflex change includes changes in the spinal cord itself. Comparable changes appear to occur with acquisition of certain motor skills. Current studies are exploring such changes in humans and animals with spinal cord injuries with the goal of using conditioning methods to assess function after injury and to promote and guide recovery of function. A better understanding of the mechanisms of neural plasticity, achieved through human and animal studies, may help us to design and implement FNS systems that have the potential to produce beneficial changes in the subject's central nervous systems
Abstract: We studied the effects of electrical stimulation of the skin on upper extremity spasticity in nine hemiparetic stroke subjects. The effects were quantified by comparing reflex torque responses elicited during ramp and hold angular perturbations of the elbow recorded before and after low-intensity skin stimulation. Electrical stimulation was applied to skin over the biceps muscle for a period of ten minutes at a 20 Hz frequency, pulse duration 0.1 ms, with an intensity level below motor threshold but above sensory threshold. In seven of the nine subjects, stimulation of skin over spastic muscle reduced peak torque responses in both flexors and extensors for at least 30 min. In these seven subjects there were significant increases in mean threshold angle for the onset of reflex torque so that a greater angular rotation was required to initiate the stretch reflex response. This shift occurred without change in reflex impedance. The origins of these long-term changes in reflex torque are unclear, but may reflect synaptic plasticity of spinal circuitry outside the stretch reflex loop

Abstract: We examined spatiotemporal abnormalities in the flexor reflex response in the impaired upper extremity of hemiparetic subjects. Electrical stimulation was used to elicit flexion reflexes in both upper extremities of 8 hemiparetic brain-injured and 6 control subjects. Electromyograms (EMGs) were recorded from 12 arm muscles, and reflex forces and moments were recorded at the wrist with a load cell, and converted to shoulder and elbow torques. We found that the onset of reflex torque and EMG was delayed in the impaired arm and delays were greater at the shoulder than at the elbow. The normal reflex torque response consisted of elbow flexion, shoulder extension, and shoulder adduction. In contrast, in the impaired limb shoulder, flexion torque was observed in 7 subjects and shoulder abduction in 3. The delays in reflex onset and altered torque patterns in the impaired arm may be related to the abnormal movement synergies observed following stroke. &copy 1999 John Wiley & Sons, Inc

Abstract: A newly devised method for electrical stimulation via a wired mesh-glove is described. The stimulation paradigm is novel in that a whole hand is the target of stimulation. Specific standardized stimulation modalities are reviewed. The protocol for mesh-glove stimulation for patients with and without volitional movements, but increased muscle tone is outlined. A sequenced program based on restoration of motor functions is described. The mesh-glove stimulation is well suited for home use. On the basis of our experience working with 40 patients after stroke, head and spinal cord injuries, we concluded that this procedure is beneficial and safe

Abstract: The effects of whole-hand electrical stimulation via a wired mesh-glove upon the residual motor control of the upper extremity are described. Clinical
observations were made in 2 patients with nonfunctional upper limbs, 4 and 2 years after stroke, who had been enrolled in the home mesh-glove program for 6 and 4 months, respectively. The stimulation paradigm is novel and the target of stimulation is the hand. Preliminary results indicate beneficial effects such as reduction in muscle hypertonia and facilitation of isolated hand movements.


Abstract: The purpose of this study was to evaluate the effectiveness of a functional electrical stimulation (FES) treatment program designed to prevent glenohumeral joint stretching and subsequent subluxation and shoulder pain in stroke patients. Twenty-six recent hemiplegic stroke patients with shoulder muscle flaccidity were randomly assigned to either a control group (n = 13; 5 female, and 8 male) or experimental group (n = 13; 6 female, and 7 male). Both groups received conventional physical therapy. The experimental group received additional FES therapy where two flaccid/paralyzed shoulder muscles (supraspinatus and posterior deltoid) were induced to contract repetitively up to 6 hours a day for 6 weeks. Duration of both the FES session and muscle contraction/relaxation ratio were progressively increased as performance improved. The experimental group showed significant improvements in arm function, electromyographic activity of the posterior deltoid, range of motion, and reduction in subluxation (as indicated by x-ray) compared with the control group. We concluded that the FES program was effective in reducing the severity of shoulder subluxation and pain, and possibly facilitating recovery of arm function.


Abstract: BACKGROUND: An estimated 15 million adults in the United States are affected by dysphagia (difficulty swallowing). Severe dysphagia predisposes to medical complications such as aspiration pneumonia, bronchospasm, dehydration, malnutrition, and asphyxia. These can cause death or increased health care costs from increased severity of illness and prolonged length of stay. Existing modalities for treating dysphagia are generally ineffective, and at best it may take weeks to months to show improvement. One common conventional therapy, application of cold stimulus to the base of the anterior faucial arch, has been reported to be somewhat effective. We describe an alternative treatment consisting of transcutaneous electrical stimulation (ES) applied through electrodes placed on the neck. OBJECTIVE: Compare the effectiveness of ES treatment to thermal-tactile stimulation (TS) treatment in patients with dysphagia caused by stroke and assess the safety of the technique. METHODS: In this controlled study, stroke patients with swallowing disorder were alternately assigned to one of the two treatment groups (TS or ES). Entry criteria included a primary diagnosis of stroke and confirmation of
swallowing disorder by modified barium swallow (MBS). TS consisted of touching the base of the anterior faucial arch with a metal probe chilled by immersion in ice. ES was administered with a modified hand-held battery-powered electrical stimulator connected to a pair of electrodes positioned on the neck. Daily treatments of TS or ES lasted 1 hour. Swallow function before and after the treatment regimen was scored from 0 (aspirates own saliva) to 6 (normal swallow) based on substances the patients could swallow during a modified barium swallow. Demographic data were compared with the test and Fisher exact test. Swallow scores were compared with the Mann-Whitney U test and Wilcoxon signed-rank test. RESULTS: The treatment groups were of similar age and gender (\(p > 0.27\)), co-morbid conditions (\(p = 0.0044\)), and initial swallow score (\(p = 0.74\)). Both treatment groups showed improvement in swallow score, but the final swallow scores were higher in the ES group (\(p > 0.0001\)). In addition, 98% of ES patients showed some improvement, whereas 27% of TS patients remained at initial swallow score and 11% got worse. These results are based on similar numbers of treatments (average of 5.5 for ES and 6.0 for TS, \(p = 0.36\)). CONCLUSIONS: ES appears to be a safe and effective treatment for dysphagia due to stroke and results in better swallow function than conventional TS treatment.


Abstract: OBJECTIVE: To assess the efficacy of functional electrical stimulation (FES) in the rehabilitation of hemiparesis in stroke. DESIGN: A meta-analysis combined the reported randomized controlled trials of FES in stroke, using the effect size method of Glass, and the DerSimonian- Laird Random Effects Method for pooling studies. SETTING: The included studies were published between 1978 and 1992. They were conducted in academic rehabilitation medicine settings. PATIENTS: In all included studies, patients were in poststroke rehabilitation. The mean time after stroke varied from 1.5 to 29.2 months. INTERVENTION: FES applied to a muscle or associated nerve in a hemiparetic extremity was compared to No FES. MAIN OUTCOME MEASURE: Change in paretic muscle force of contraction following FES was compared to change without FES. RESULTS: For the four included studies, the mean effect size was .63 (95% CI: .29, .98). This result was statistically significant (\(p < .05\)). CONCLUSION: Pooling from randomized trials supports FES as promoting recovery of muscle strength after stroke. This effect is statistically significant. There is a reasonable likelihood of clinical significance as well.


Abstract: This paper reviews recent topics of clinical application of functional electrical stimulation (FES) for the paralyzed extremities in Japan. Transcutaneous and percutaneous FES systems have been clinically used in Japan. Candidates of extremity FES are mostly stroke and spinal cord injury patients. By using percutaneous FES system, all of the joints of the upper extremity including the shoulder have been controlled for activities of daily living in the hemiplegic patient. Simultaneous FES control of the hand and wrist and the bilateral hands have also been achieved in C5 and C6 quadriplegics, respectively. Hybrid FES systems using
percutaneous and surface electrodes, where FES is used in combination with orthoses, have been applied to the paraplegics because they are highly practical for assisting their locomotive activities. Percutaneous FES have been also provided the amyotrophic lateral sclerosis patients with standing up motion. A total implant FES system with 16 output channels is currently developing as a next generation FES system.


Abstract: OBJECTIVE: To gain experience with 'Ness Handmaster Orthosis' treatment in chronic stroke patients, to identify suitable patients, and to study the effects of treatment. DESIGN: Exploratory, uncontrolled trial with measurement of motor functions and muscle tone of the upper extremity prior to, during, upon completion, and six weeks after a treatment period. SETTING: A rehabilitation centre in the Netherlands. SUBJECTS: Eighteen chronic stroke patients (more than six months post stroke), who exhibited upper extremity dysfunction due to spastic paresis. INTERVENTION: A 10-week therapy programme of functional electrical stimulation by means of the 'Ness Handmaster Orthosis'. RESULTS: The results of 15 patients were available for analysis. The differences in motor score and muscle tone before and at the end of treatment were statistically significant (p = 0.008 and 0.021, respectively). The follow-up measurements showed that the effects on motor functions and muscle tone decreased after therapy completion. Stratification of the patients in two subgroups indicated that patients with initial high motor scores benefited most during the intervention period. CONCLUSION: The present study suggests that Handmaster treatment possesses therapeutic opportunities in chronic stroke patients with spastic paresis of the upper extremity.


Abstract: OBJECTIVE: To investigate whether the combined approach of botulinum toxin type A (BtxA) and electrical stimulation was more effective than the toxin alone in the treatment of chronic upper limb spasticity after stroke. DESIGN: Randomized, placebo-controlled study with four treatment groups: 1000 units BtxA (Dysport) + electrical stimulation (A), 1000 units BtxA (B), placebo + electrical stimulation (C) and placebo (D). SETTING: A neurological rehabilitation clinic. SUBJECTS: Twenty-four stroke patients with chronic upper limb spasticity after stroke, six patients in each treatment group. INTERVENTIONS: Intramuscular injection of either toxin or placebo into six upper limb flexor muscles. In group A and C additional electrical stimulation of the injected muscles with surface electrodes, three times half an hour each day for three days. MAIN OUTCOME MEASURES: Muscle tone rated with the modified Ashworth score, limb position at rest and difficulties encountered during three upper limb motor tasks assessed before and 2, 6 and 12 weeks after injection. RESULTS: Most improvements were observed in patients of group A. Cleaning the palm (p = 0.004) differed across groups. Pairwise comparison for this target variable showed that group A differed from group B and D (p <0.01), but not from C. Indicative across-group differences were obtained for elbow spasticity reduction (p = 0.011), and improvement of putting the arm through a sleeve (p = 0.020). CONCLUSIONS: The placebo-controlled trial favours the concept that electrical stimulation enhances the
effectiveness of BtxA in the treatment of chronic upper limb flexor spasticity after stroke


Abstract: The influence of suprathreshold electrical stimulation of the extensor and flexor carpi radialis muscles on biomechanical and functional movement parameters is compared with the effect of a standardized active repetitive training of hand and fingers. Twelve patients suffering from ischaemic lesions in the territory of the middle cerebral artery participated in the study, which was conducted using a multiple baseline design. Following a baseline phase that lasted between one and three weeks all patients received electrical muscle stimulation for 20 minutes twice daily. In a third phase the repetitive training of hand and fingers was conducted for 20 minutes twice daily. Both interventions were applied in addition to conventional occupational therapy and physiotherapy. With the exception of spasticity in hand and finger flexors, repetitive electrical muscle stimulation does not improve biomechanical or functional motor parameters of the centrally paretic hand and arm. The repetitive motor training, however, is appropriate to improve biomechanical and functional movement parameters significantly. Apart from a possible effect on the muscle cell itself, the electrical muscle stimulation is thought to represent a mainly sensory, i.e. proprioceptive, and cutaneous intervention, whereas the active motor training is characterized by a continuous sensorimotor coupling within motor centres of the brain. The underlying neurophysiological mechanisms as well as basic principles concerning the role of afferent input for motor learning and recovery are discussed


Abstract: The purpose of this study is to restore the motion of the paralyzed shoulder caused by upper motor neuron disorders using functional electrical stimulation (FES). Percutaneous wire electrodes were implanted into twelve muscles of the shoulder in six patients with stroke or cervical spinal cord injury. The motion of the paralyzed shoulder was controlled by a portable FES computer system, with the three standard stimulation patterns for restoring motion of 90 degrees flexion to 90 degrees horizontal abduction, 90 degrees flexion to 20 degrees horizontal adduction, and 90 degrees abduction to 90 degrees horizontal adduction. Shoulder movements were repeatedly controlled according to the created stimulation patterns in five of the patients. The two dimensional motion analyzer also confirmed shoulder control over a satisfactorily broad range of excursion. One hemiplegic patient, who was a signboard painter, had his paretic left upper extremity improved by FES, and he drew a large picture on a board with his normal right hand and, with his affected left arm...
against the wall, to support his trunk. This may be a world first case of producing shoulder motion through FES.


Kraft G.H., Fitts S.S., and Hammond M.C. (1992) Techniques to improve function of the arm and hand in chronic hemiplegia. *Arch. Phys. Med. Rehabil.* 73, 220-227. Abstract: We evaluated functional improvement in the upper limb of chronic (more than six months’ duration) stroke patients who received one of two electrical stimulation treatments, conventional treatment, or no treatment. Twenty-two righthanded patients were assigned to one of four groups studied for 12 months posttreatment. Subjects received (1) EMG-initiated electrical stimulation of wrist extensors (EMG-stim), (2) low-intensity electrical stimulation of wrist extensors combined with voluntary contractions (B/B), (3) proprioceptive neuromuscular facilitation (PNF) exercises, or (4) no treatment. Subjects were treated for three months. Before treatment, upon completion of treatment, and three and nine months after treatment, subjects were evaluated by the Fugl-Meyer (FM) poststroke motor recovery test and by grip strength. Subjects also attempted three Jebsen-Taylor hand function tests and a finger tapping test at the same evaluation sessions, but many were unable to complete these tests. During the course of treatment, FM scores of subjects receiving PNF improved 18%, B/B improved 25%, and EMG-stim improved 42%. The aggregate FM improvement of the treated groups was significant from pretreatment to posttreatment, and the improvement was maintained at three-month and nine-month followups (all p less than .005). The treated subjects' improvement in grip strength was also maintained at both followups (p less than .10). In contrast, the control group showed no significant change in FM scores or grip strength. The four treated subjects who were able to perform the hand function tests and finger tapping at all four evaluations also improved on these tests.(ABSTRACT TRUNCATED AT 250 WORDS)

Kralj A., Acimovic R., and Stanic U. (1993) Enhancement of hemiplegic patient rehabilitation by means of functional electrical stimulation. *Prosthet. Orthot. Int.* 17, 107-114. Abstract: This presentation will review briefly the current practice and state of the art in functional electrical stimulation (FES) as applied to stroke, head injured or brain tumour operated patients. A similar application is used in paretic patients following trauma or other aetiology. Over 20 years experience in the application of FES, as practised in Ljubljana, will be highlighted and the devices currently in use will be described. The statistics show the results obtained on 2,500 hemiplegic patients...
examined for FES application during the last 10 years. The statistics and results of
the Slovenian population indicate 0.15-0.20% new cases annually or 1,500 new
cases per million inhabitants. Up to 63% of annual cases are candidates for an FES
based therapeutic locomotion rehabilitation programme. Experience indicates that
60% of hemiplegic patients received single-channel stimulation to correct
equinovarus or foot drop, 30% obtained dual or even three channel stimulation
treatment and only 10% of patients were involved in multichannel FES of four to six
or even eight channels of stimulation. The benefits and outcome of rehabilitation will
be presented and discussed in regard to current trends in the field of FES for
hemiplegic and paretic patients. The partly inactive but very important field of FES
application to the upper extremity in hemiplegic and paretic patients will be
discussed and the relatively modest achievements presented. Future developments
will be presented together with advances foreseen by steadily improving technology.

Abstract: Perceptual problems such as tactile neglect are important features of
stroke and strong predictors of a poor outcome. Although new methods of treatment
have been described, documentation of the effects of such treatment is inadequate,
mainly because satisfactory methods of quantifying tactile neglect are unavailable.
We describe a device for quantifying neglect based upon the principle of the Bender
test which uses double or simultaneous bilateral stimulation to determine neglect.
The device, which is computer driven to ensure uniformity of test protocols,
determines the cutaneous perceptual threshold to controlled- current electrical
stimulation using surface electrodes. The effect of rival contralateral stimulation on
the perceptual thresholds on the affected side of the patient's body is a quantitative
measure of tactile neglect. The device was evaluated in normal young and
neurologically normal elderly subjects and in stroke patients with clinical evidence of
tactile neglect. It was shown to distinguish reliably between normal subjects and
those who had tactile neglect. The device will be suitable for use in trials of
treatments for tactile neglect and in tracking the natural history of this symptom.

Stimulation of the peroneal nerve synchronized with the swing phase of gait of


on the spastic hand opened by electrical stimulation. Neurorehabil. Neural Repair 14,
199-205.
Abstract: The purpose of this study was to investigate the effects of ipsilateral arm
movement and contralateral hand grasp on the spastic hand opened by open-loop
electrical stimulation. The major problem of applying proper electrical stimulation is
variable spasticity, the intensity of which changes with posture and movements of
other parts of the body. Electrical stimulation was applied to extensor digitorum
communis and ulnar nerve to open the affected hand. Different procedures were
then used to assess the effects of moving the ipsilateral forearm and contracting the
contralateral normal hand. Electrical stimulation opened the spastic hand in more
than 95% of trials in all subjects, whether stimulation was applied before or after the
movement of the forearm. Moving the ipsilateral forearm did have an effect on opening the hand, and making adjustment of stimulation intensities was necessary in all subjects. The stimulation opened the spastic hand during the contraction of the contralateral normal hand. Electrical stimulation could open the spastic hands most of the time, in the presence of ipsilateral forearm movement and contralateral normal hand contraction. If electrical stimulation was applied before the ipsilateral forearm was moved toward the target, stimulation intensities needed to be adjusted.


Abstract: BACKGROUND AND PURPOSE: Subluxation is a significant problem in poststroke hemiplegia, resulting in pain and loss of function. Current treatments are not proved and not considered effective. It has been demonstrated that cyclical electrical stimulation of the shoulder muscles can reduce existing subluxation. The purpose of this study was to determine whether electrical stimulation could prevent subluxation in both the short and long terms. METHODS: A prospective, randomized controlled study was used to determine the efficacy of electrical stimulation in preventing shoulder subluxation in patients after cerebrovascular accidents. Forty patients were selected and randomly assigned to a control or treatment group. They had their first assessment within 48 hours of their stroke, and those in the treatment group were immediately put on a regimen of electrical stimulation for 4 weeks. All patients were assessed at 4 weeks after stroke and then again at 12 weeks after stroke. Assessments were made of shoulder subluxation, pain, and motor control. RESULTS: The treatment group had significantly less subluxation and pain after the treatment period, but at the end of the follow-up period there were no significant differences between the 2 groups. CONCLUSIONS: Electrical stimulation can prevent shoulder subluxation, but this effect was not maintained after the withdrawal of treatment.


Abstract: A patient is presented who suffered a lateral brainstem infarction which selectively abolished pain and temperature sensitivity in the lower right limb. One year later central post-stroke pain had developed in the affected limb with touch and cold allodynia. P40m dipoles calculated from magnetoencephalographic fields after electrical stimulation of both tibial nerves were localized in SI as is seen in normal subjects. However, stimulation of the affected side caused deep pain sensations and elicited a large N80m component, best explained by an additionally active dipole in cingulate cortex. This early co-activation in a limbic structure suggests peripheral Abeta-fiber mediation and lemniscal projection. Abnormal link to the pain system may be due to sensitization and reorganization above the level of nociceptive deafferentation.


Abstract: Short, intensive multichannel electrical stimulation therapy was evaluated in 14 hemiplegics after stroke or head injury. The stimulation of the peroneal nerve,
soleus, quadriceps, hamstring, gluteus maximus, and triceps brachii muscles with individually preprogrammed sequences was applied by surface electrodes at the beginning of gait rehabilitation. The patients started walking with the support of a therapist, gradually increased the walking distance and all reached independent ambulation with a crutch after an average of 14 stimulation sessions. A portable microprocessor six-channel stimulator/stride analyzer enabled the collection of gait parameters and recording of statistical mean values of stride time, gait symmetry, right and left stance times, and their standard deviations. Without additional equipment, several hundred stimulated strides were measured during each stimulation session.


Abstract: A dual-channel electrical stimulation system with a stimulator and a programmer/stride analyzer was designed for clinical rehabilitation of gait and for subsequent daily use as an orthotic aid. The stimulator, with controls to adjust amplitude only (50 mA), adapts chosen stimulation sequences to the walking rate of a patient. Pulse duration (50-500 microseconds), frequency (5-120 Hz), shape (symmetrical biphasic, monophasic), stimulation sequences (16 stride segments) and their cycle (2-12 sec), and right/left foot-switch choices are selected for each patient and programmed into a separate unit. The programming unit also statistically processes the foot-switch data collected by the stimulator. The device was evaluated with regard to the programmable parameters, effectiveness during gait, and feasibility in clinical use. It was applied to 11 stroke patients and 10 brain injury patients during gait, stimulating 22 combinations of peroneal nerve and hamstring, quadriceps, triceps brachii, and gluteus maximus muscles. Forces on both feet, equinovarus, knee extension and hyperextension, elbow flexion, and hip extension were corrected. Selection of the stimulation sequences, their adaptation, range of pulse duration, and valid statistics were verified. Improved forces and joint angles were recorded together with significant changes in the stride time, length, and velocity by the stimulation.


Abstract: Three partially paralyzed patients were unable to walk even after maximal rehabilitation attempts at a major rehabilitation center. One 36-year-old man had transverse myelitis, a 57-year-old man had had a stroke, and the third patient, a 35-year-old man, had incurred a traumatic brain injury. The three patients were unable to flex the hips, had adductor spasm and weak hip and knee extension, and lacked ankle dorsiflexion. Intramuscular stainless steel wire electrodes activated by timers were placed in the quadriceps, hip flexors, extensors, and abductors, as needed. Muscle force and foot contact evaluations were done using the Cybex and the Cleveland Veterans Administration Gait Laboratory. After implantation of intramuscular electrodes, all three patients had improved function but still desired some supervision in walking. A ten-fold increase in knee torque was noted in one patient, thereby providing him with nearly normal strength. No implant complications were noted. The study demonstrated the feasibility of functional neuromuscular stimulation (FNS) gait augmentation in a previously nonwalking patient outside the
laboratory. Further improvements will require the development of an implantable, multichannel, programmable microprocessor-controlled stimulator.


Abstract: Deep vein thrombosis (DVT) and subsequent pulmonary embolism (PE) is a major source of mortality and morbidity in stroke patients. This study was designed to determine the effectiveness of different prophylactic treatments in the prevention of DVT after a stroke in patients undergoing rehabilitation. An additional objective was the identification of risk factors for DVT in stroke in patients during rehabilitation. Three hundred and sixty patients, over a 3-year period, were randomly assigned to one of four groups: adjusted dose heparin, intermittent pneumatic compression (IPC), functional electrical stimulation (FES), or control. There was no significant difference in the development of DVT by treatment group. Patients with DVT on admission (prevalent, n = 61) were compared with the study patients (n = 360). Time interval (from stroke to admission) and lactic dehydrogenase (LDH) concentration were significant risk factors, as well as predictors, for development of DVT (p < .000). These results suggest that the longer a patient remains without DVT prophylaxis after a stroke, the greater the risk of developing DVT and this supports early prophylaxis before rehabilitation.


Abstract: OBJECTIVE: To study the effects of electrical stimulation (ES) on flexion contractures in the hemiplegic wrist. DESIGN: The investigation was carried out following an OFF (two weeks with rehabilitation only)-- ON (two weeks with ES treatment and rehabilitation)--OFF (two weeks rehabilitation only) fixed protocol. SETTING: A stroke ward and an outpatient stroke service. SUBJECTS: Eleven hemiplegic subjects with reduced range of extension and increased resistance to passive movement at the wrist. MAIN MEASURE: Quantitative measures of the hemiplegic posture at the wrist, passive range of extension and resistance to passive extension of the wrist. Measurements were taken at the start of the study and then at two-weekly intervals. Two extra measurements were taken at the end of the ON period. RESULTS: Following two weeks treatment with ES the posture of the wrist improved and the passive range of extension increased. However, there were no significant changes in the resistance to passive movement. These benefits appeared largely to be lost two weeks after ES was discontinued. CONCLUSIONS: Short-term ES gives temporary improvements in contractures at the wrist in poststroke hemiplegia.

Abstract: This pilot study investigated the effect of oral electrical stimulation on swallow function in stroke patients with chronic dysphagia. The purpose was to determine whether an innovative technique could make an improvement in swallow function that might be developed as a potential treatment for patients with persistent dysphagia. Four stroke patients with chronic dysphagia were recruited on the basis of videofluoroscopic findings of a delayed swallow reflex. A single case design was used. Oral electrical stimulation of swallowing was carried out using a palatal prosthesis starting at an output pulse of 0.5 mA, with a fixed duration of 200 microsec, repeated at 1-sec intervals. Barium paste (1 x 5 ml) was introduced at the level of the patient's maximum tolerance of stimulation and any effect on swallow function was recorded by videofluoroscopy. The findings from the pilot study indicated that oral electrical stimulation resulted in an improvement in swallow function in 2 of the 4 patients. The stimulation was well tolerated in all cases with no serious adverse effects. These early results are promising, but further research is needed.


Abstract: Dantrolene sodium or dantrolene1 is 1([5-(nitrophenyl)furfurylidend] amino) hydantoin sodium hydrate. It is indicated for use in chronic disorders characterised by skeletal muscle spasticity, such as spinal cord injury, stroke, cerebral palsy and multiple sclerosis. Dantrolene is believed to act directly on the contractile mechanism of skeletal muscle to decrease the force of contraction in the absence of any demonstrated effects on neural pathways, on the neuromuscular junction, or on the excitable properties of the muscle fibre membranes. Controlled trials have
demonstrated that dantrolene is superior to placebo in adults or children with spasticity from various causes, as evidenced by clinical assessments of disability and daily activities, and by muscle and reflex responses to mechanical and electrical stimulation. It is somewhat less effective in patients with multiple sclerosis than in those with spasticity from other causes. There has been a general clinical impression in controlled trials that dantrolene caused less sedation than would have been expected from therapeutically comparable doses of diazepam. In 2 controlled trials, there was no significant difference between dantrolene and diazepam in terms of reductions in spasticity, clonus, and hyperreflexia, but side-effects such as drowsiness and inco-ordination occurred significantly more frequently on diazepam. Long-term studies have indicated continuing benefit for patients taking dantrolene, though the incidence of side-effects has often been high and there has been a suggestion of exacerbation of seizures in children with cerebral palsy. Dantrolene may be of value in the medical treatment of spasm of the external urethral sphincter due to neurological and non-neurological disease, and animal studies suggest a potential use in the management of malignant hyperpyrexia. Chemical evidence of liver dysfunction may occur in 0.7 to 1% of patients on long-term treatment with dantrolene, with symptomatic hepatitis in 0.35 to 0.5% and fatal hepatitis in 0.1 to 0.2%. The drug commonly causes transient drowsiness, dizziness, weakness, general malaise, fatigue and diarrhoea at the start of therapy. Muscle weakness may be the principal limiting side-effect in ambulant patients, particularly in those with multiple sclerosis, and therapy could be hazardous in patients with pre-existing bulbar or respiratory weakness. The dosage of dantrolene has been fixed in most controlled trials, though long-term studies have indicated the need for individualisation of dosage. The initial dose is usually 25mg once daily, increasing to 25mg two, three or four times daily, and then by increments of 25mg up to as high as 100mg two, three or four times daily. The lowest dose compatible with optimal response is recommended.


Abstract: The effect of afferent cutaneous electrical stimulation on the spasticity of leg muscles was studied in 20 patients with chronic hemiplegia after stroke. Stimulation electrodes were placed over the sural nerve of the affected limb. The standard method of cutaneous stimulation, TENS with impulse frequency of 100 Hz, was applied. The tonus of the leg muscles was measured by means of an electrohydraulic measuring brace. The EMG stretch reflex activity of the tibialis anterior and triceps surae muscles was detected by surface electrodes and recorded simultaneously with the measured biomechanical parameters. In 18 out of 20 patients, a mild but statistically significant decrease in resistive torques at all frequencies of passive ankle movements was recorded following 20 min of TENS application. The decrease in resistive torque was often (but not always) accompanied by a decrease in reflex EMG activity. This effect of TENS persisted up to 45 min after the end of TENS. The results of the study support the hypothesis that TENS applied to the sural nerve may induce short-term post-stimulation inhibitory effects on the abnormally enhanced stretch reflex activity in spasticity of cerebral origin.

Abstract: BACKGROUND AND PURPOSE: It has been suggested that cyclic neuromuscular electrical stimulation (ES) may enhance motor recovery after stroke. We have investigated the effects of ES of the wrist extensors on impairment of wrist function and on upper-limb disability in patients being rehabilitated after acute stroke. METHODS: We recruited 60 hemiparetic patients (mean age, 68 years) 2 to 4 weeks after stroke into a randomized, controlled, parallel-group study comparing standard rehabilitation treatment with standard treatment plus ES of wrist extensors (3 times 30 minutes daily for 8 weeks). Isometric strength of wrist extensors was measured using a device built for that purpose. Upper-limb disability was assessed with use of the Action Research Arm Test (ARAT). Observations were continued for 32 weeks (24 weeks after the finish of ES or the control intervention phase). RESULTS: The change in isometric strength of wrist extensors (at an angle of 0 degrees extension) was significantly greater in the ES group than the control group at both 8 and 32 weeks (P=0.004, P=0.014 by Mann Whitney U test). At week 8 the grasp and grip subscores of the ARAT increased significantly in the ES group compared with that in the control group (P=0.013 and P=0.02, respectively); a similar trend was seen for the total ARAT score (P=0.11). In the subgroup of 33 patients with some residual wrist extensor strength at study entry (moment at 0 degrees extension >0), the ARAT total score had increased at week 8 by a mean of 21.1 (SD, 12.7) in the ES group compared with 10.3 (SD, 9.0) in the control group (P=0.024, Mann Whitney U test); however, at 32 weeks the differences between these 2 subgroups were no longer statistically significant. CONCLUSIONS: ES of the wrist extensors enhances the recovery of isometric wrist extensor strength in hemiparetic stroke patients. Upper-limb disability was reduced after 8 weeks of ES therapy, with benefits most apparent in those with some residual motor function at the wrist. However, it is not clear how long the improvements in upper-limb disability are maintained after ES is discontinued.


Abstract: BACKGROUND: Shoulder pain after stroke is common and disabling. The optimal management is uncertain, but electrical stimulation (ES) is often used to treat and prevent pain. OBJECTIVES: The objective of this review was to determine the efficacy of any form of surface ES in the prevention and / or treatment of pain around the shoulder at any time after stroke. SEARCH STRATEGY: We searched the Cochrane Stroke Review Group trials register and undertook further searches of MEDLINE, EMBASE and CINAHL. Contact was established with equipment manufacturers and centres that have published on the topic of ES. SELECTION CRITERIA: We considered all randomised trials that assessed any surface ES technique (functional electrical stimulation (FES), transcutaneous electrical nerve stimulation (TENS) or other), applied at any time since stroke for the purpose of prevention or treatment of shoulder pain. DATA COLLECTION AND ANALYSIS: Two reviewers independently selected trials for inclusion, assessed trial quality and extracted the data. MAIN RESULTS: Four trials (a total of 170 subjects) fitted the inclusion criteria. Study design and ES technique varied considerably, often precluding the combination of studies. Population numbers were small. There was no significant change in pain incidence (Odds Ratio (OR) 0.64; 95% CI 0.19 to 2.14) or change in pain intensity (Standardised Mean Difference (SMD) 0.13; 95% CI -1.0 to 1.25) after ES treatment compared to control. There was a significant treatment effect in favour of ES for improvement in pain-free range of passive humeral lateral...
rotation (Weighted Mean Difference (WMD) 9.17; 95% CI 1.43 to 16.91). In these studies ES reduced the severity of glenohumeral subluxation (SMD -1.13; 95% CI -1.66 to -0.60), but there was no significant effect on upper limb motor recovery (SMD 0.24; 95% CI -0.14 to 0.62) or upper limb spasticity (WMD 0.05; 95% CI -0.28 to 0.37). There did not appear to be any negative effects of electrical stimulation at the shoulder. REVIEWER'S CONCLUSIONS: The evidence from randomised controlled trials so far does not confirm or refute that ES around the shoulder after stroke influences reports of pain, but there do appear to be benefits for passive humeral lateral rotation. A possible mechanism is through the reduction of glenohumeral subluxation. Further studies are required.

Price C.I. and Pandyan A.D. (2001) Electrical stimulation for preventing and treating post-stroke shoulder pain: a systematic Cochrane review. Clin. Rehabil. 15, 5-19. Abstract: BACKGROUND: Shoulder pain after stroke is common and disabling. The optimal management is uncertain, but electrical stimulation (ES) is often used to treat and prevent pain. OBJECTIVES: The objective of this review was to determine the efficacy of any form of surface ES in the prevention and/or treatment of pain around the shoulder at any time after stroke. SEARCH STRATEGY: We searched the Cochrane Stroke Review Group trials register and undertook further searches of Medline, Embase and CINAHL. Contact was established with equipment manufacturers and centres that have published on the topic of ES. SELECTION CRITERIA: We considered all randomized trials that assessed any surface ES technique (functional electrical stimulation (FES), transcutaneous electrical nerve stimulation (TENS) or other), applied at any time since stroke for the purpose of prevention or treatment of shoulder pain. DATA COLLECTION AND ANALYSIS: Two reviewers independently selected trials for inclusion, assessed trial quality and extracted the data. MAIN RESULTS: Four trials (a total of 170 subjects) fitted the inclusion criteria. Study design and ES technique varied considerably, often precluding the combination of studies. Population numbers were small. There was no significant change in pain incidence (odds ratio (OR) 0.64; 95% CI 0.19-2.14) or change in pain intensity (standardized mean difference (SMD) 0.13; 95% CI -1.0-1.25) after ES treatment compared with control. There was a significant treatment effect in favour of ES for improvement in pain-free range of passive humeral lateral rotation (weighted mean difference (WMD) 9.17; 95% CI 1.43-16.91). In these studies ES reduced the severity of glenohumeral subluxation (SMD -1.13; 95% CI -1.66 to -0.60), but there was no significant effect on upper limb motor recovery (SMD 0.24; 95% CI -0.14-0.62) or upper limb spasticity (WMD 0.05; 95% CI -0.28-0.37). There did not appear to be any negative effects of electrical stimulation at the shoulder. REVIEWERS' CONCLUSIONS: The evidence from randomized controlled trials so far does not confirm or refute that ES around the shoulder after stroke influences reports of pain, but there do appear to be benefits for passive humeral lateral rotation. A possible mechanism is through the reduction of glenohumeral subluxation. Further studies are required.

muscles either to produce hand-grasp or to open the hand. When the glove is
donned, conductive areas on its inside surface automatically make contact with self-
adhesive electrodes on the skin. SETTING AND PATIENTS: This report concerns
nine people with SCI who have used the device in their daily lives for up to a year or
more. Measurements were made at clinics in Edmonton, Miami, and Chicago as part
of a multicenter clinical trial. OUTCOME MEASURES AND RESULTS: The mean
peak force of tenodesis grasp in the nine subjects increased from 2.6N (passive) to
11.3N (glove active). Active force was significantly greater than passive grasp force
even when muscles were fatigued after repetitive grasp-release cycles. Most manual
tasks improved significantly with the use of the glove, as judged by the number of
tasks completed in a minute or the subjects’ qualitative ratings of task difficulty.
CONCLUSION: The Bionic Glove can provide significant improvement of hand
function in people with C6-C7 SCI

muscle responses to stimulation of the motor cortex induced by peripheral nerve

86.
Abstract: The basic problem following a cerebrovascular accident is that the normal
inhibitory regulating mechanism, the cerebral motor cortex, is damaged to a variable
extent. This releases primitive peripheral reflex activities resulting in aberrant
function of limbs and restricted motion in joints. The sensory cortex can equally be
damaged and careful assessment of sensory appreciation in the stroke patient has
to be made. The initial treatment of patients after a stroke consists of a variety of
physiotherapy techniques, the rationale of which is to reduce the power of dominant
aberrant reflex activities and build the strength in the antagonistic group of muscles.
The potential for the efficacy of physiotherapy is somewhat restricted, but there is a
place for appropriate bracing. A certain number of patients exist, however, for whom
physiotherapy cannot achieve the desired results and for whom bracing is either
ineffective or unacceptable. The only alternative for these patients is functional
electrical stimulation or reducing the activity in the deforming muscles. This can
either be done by direct inactivation of the motor nerve or by actually lengthening the
muscle tendon unit to reduce the power of the muscle group. An alternative is to
transfer tendons

Rose F.C., Jones R, Vrbova G (1989) Neuromuscular Stimulation: Basic Concepts and
Clinical Applications. New York, Demos.

Abstract: Dysphagia is a common and potentially fatal complication of acute stroke.
However, the underlying pathophysiology, especially the relative importance of motor
and sensory dysfunction, remains controversial. We conducted a case control study
of 23 acute stroke patients (mean age = 72 yr) at a median of 6 days post-stroke and
15 healthy controls (mean age = 76 yr). We used novel methods to assess
swallowing in detail, including a timed videoeendoscopic swallow study and oral
sensory threshold testing using electrical stimulation. Vocal cord mobility and
voluntary pharyngeal motor activity were impaired in the stroke group compared with
the controls (p = 0.01 and 0.03). There was a delay during swallowing in the time to
onset of epliglottic tilt in the stroke group, particularly for semisolids (p = 0.02) and solids (p = 0.01), consistent with a delay in initiation of the swallow. Sensory thresholds were not increased in the stroke group compared with controls. We conclude that pharyngeal motor dysfunction and a delay in swallow initiation are common after acute stroke. Vocal cord mobility is reduced, and this may result in reduced airway protection. We found no evidence to support the hypothesis that oropharyngeal sensory dysfunction is common after acute stroke.


Abstract: 24 hemiplegic patients completed patterned functional electrical stimulation (PFES) upon the afflicted arm and leg. The multichannel PFES program was mathematically derived from the EMG agonist/antagonist pattern recorded from each subject’s unaffected limbs during a series of monitored, voluntary movements. The average improvement in volitional range of motion for the group’s paralyzed limbs was 90% for the upper extremities and 69% for the lower extremities. For partially paralyzed limbs, there was an average increase in range of movement of 68% for the upper extremities and 26% for the lower extremities. These findings support the relearning-based, PFES open-loop theory which uses individualized therapeutic PFES-derived from EMG coordination patterns modeled from specific, ballistic limb movements to rehabilitate patients who have been immobilized after stroke.


Abstract: Nonsustained ventricular tachycardia (VT) in the late period (7 to 21 days) after myocardial infarction (MI) is reported to be a predictor of sudden death. Patients with 3-beat VT on Holter monitoring in the late infarction period would be suspected to demonstrate electrical instability on electrophysiologic studies. Forty-seven patients were identified as having at least 3-beat VT on Holter monitoring. Eighteen patients refused electrophysiologic studies or were not referred. Eight patients died; 3 were sudden deaths in 13 +/- 5 months, a 17% incidence. Twenty-nine patients underwent invasive electrophysiologic studies and 28 had inducible VT, 18 sustained and 10 nonsustained. Lorcainide prevented VT induction in 21 of the 28 patients, whereas 12 of the 22 patients studied on procainamide were protected. Lidocaine, tested in 21 patients, prevented VT induction in only 5. Lorcainide and procainamide prolonged refractoriness in those patients protected at programmed electrical stimulation (PES), whereas the QT interval was prolonged in patients in whom VT could still be induced. Twenty-seven of the 28 patients were placed on drugs predicted to be effective by PES studies, 19 on lorcainide. After a mean follow-up of 12.5 +/- 4 months the patient with noninducible arrhythmia is alive and 26 of the 28 patients with inducible arrhythmia are alive and well. Two patients died, 1 of stroke and 1 of pump failure after a second MI. No sudden deaths were observed in this group. Two patients had breakthrough arrhythmias and were treated by alternative antiarrhythmic therapy that was also effective on initial electrophysiologic studies. (ABSTRACT TRUNCATED AT 250 WORDS)


Abstract: OBJECTIVE: To determine the perceived benefit, pattern and problems of use of the Odstock Dropped Foot Stimulator (ODFS) and the users' opinion of the service provided. DESIGN: Questionnaire sent in a single mailshot to current and past users of the ODFS. Returns were sent anonymously. SETTING: Outpatient-based clinical service. SUBJECTS: One hundred and sixty-eight current and 123 past users with diagnoses of stroke (CVA), multiple sclerosis (MS), incomplete spinal cord injury (SCI), traumatic brain injury (TBI) and cerebral palsy (CP). INTERVENTION: Functional electrical stimulation (FES) to correct dropped foot in subjects with an upper motor neuron lesion, using the ODFS. MAIN OUTCOME MEASURES: Purpose-designed questionnaire. RESULTS: Return rate 64% current users (mean duration of use 19.5 months) and 43% past users (mean duration of use 10.7 months). Principal reason cited for using equipment was a reduction in the effort of walking. Principal reasons identified for discontinuing were an improvement in mobility, electrode positioning difficulties and deteriorating mobility. There were some problems with reliability of equipment. Level of service provided was thought to be good. CONCLUSION: The ODFS was perceived by the users to be of considerable benefit. A comprehensive clinical follow-up service is essential to achieve the maximum continuing benefit from FES-based orthoses.


Abstract: OBJECTIVE: To assess the clinical effectiveness of the Odstock dropped foot stimulator by analysis of its effect on physiological cost index (PCI) and speed of walking. This functional electrical stimulation (FES) device stimulates the common peroneal nerve during the swing phase of gait. DESIGN: A retrospective study of patients who had used the device for 4 1/2 months. SUBJECTS: One hundred fifty-one patients with a dropped foot resulting from an upper motor neuron lesion. SETTING: A medical physics and biomedical engineering department of a district general hospital specializing in the clinical application of FES and a
neurophysiotherapy department at a separate hospital. MAIN OUTCOME MEASURES: Changes in walking speed and effort of walking, as measured by PCI over a 10-meter course. RESULTS: There was a 92.7% compliance with treatment. Stroke patients showed a mean increase in walking speed of 27% (p<.01) and reduction in PCI of 31% (p<.01) with stimulation, and changes of 14% (p<.01) and 19% (p<.01), respectively, while not using the stimulator. Multiple sclerosis patients gained similar orthotic benefit but no "carry-over." CONCLUSIONS: The measured differences in walking with and without stimulation were statistically significant in the stroke and multiple sclerosis groups. In this study use of the stimulator improved walking. Those with stroke


Abstract: OBJECTIVE: To reduce the triceps surae stretch reflex by electrical stimulation of the deep peroneal nerve. DESIGN: Intervention study. SETTING: Research institution. PARTICIPANTS: Sample of convenience of 10 spastic stroke individuals. INTERVENTION: After the deep peroneal nerve was stimulated between 0.9 and 4 times tibialis anterior motor threshold, the triceps surae was stretched to elicit a reflex. MAIN OUTCOME MEASURE: The triceps surae stretch reflex was quantified by the amplitude of the reflex electromyography (EMG) in soleus and medial gastrocnemius muscles and mean ankle moment. Paired t test and the Wilcoxon signed rank test (p < .05) were used to evaluate the effect of conditioning stimulation. RESULTS: The soleus stretch reflex EMG was reduced significantly (p < .001) by stimulating the deep peroneal nerve to 25%+/-6% (standard error) of the unconditioned value (relaxed triceps surae). The optimal interval between stimulation and stretch was 141+/-15 msec. The velocity threshold increased significantly (p = .006) from a median value of 8 degrees per second to 33 degrees per second and the area under the stretch velocity/stretch reflex relation decreased significantly (p < .001) (soleus EMG). CONCLUSIONS: The stretch reflex of relaxed triceps surae in persons with spastic stroke can be extensively reduced by stimulating the deep peroneal nerve at several times motor threshold of the tibialis anterior

Abstract: Functional movements can be restored after stroke by portable neuroelectric stimulator controlled by the patient. This field of activity is called functional electrical stimulation (FES). A common example of FES is electric stimulation of the peroneal to prevent dropfoot. A more sophisticated multichannel enables stimulation of more than one paralyzed muscle of the leg. This system is used temporarily to facilitate recovery of muscle function following stroke. Upper extremity FES systems have proven more difficult to develop than lower extremity systems designed to improve walking. A single-channel hand stimulator is available to assist finger movements


Waters R.L., Campbell J.M., and Nakai R. (1988) Therapeutic electrical stimulation of the lower limb by epimysial electrodes. Clin. Orthop. 44-52. Abstract: The problem of inadequate hip stability prevents many patients with head trauma, stroke, or spinal injury from balancing on one limb in order to take a step. There is no adequate orthotic substitute for hip instability, and electrical stimulation with surface electrodes cannot effectively activate the deep hip muscles. This report describes a clinical program in which electrical stimulation via surgically placed electrodes is combined with routine tendon lengthening and transfers and physical therapy. The electrodes are fixed to the epimysium and the leads directed subcutaneously to exit the skin at a common site for attachment to a commercially available stimulator. Preliminary results indicate that functional muscle contractions of the deep hip muscles can be obtained with epimysial electrodes and that stimulation can be used to augment walking ability. The results demonstrate the safety and effectiveness of percutaneous electrical stimulation and contribute to the development of a practical, implanted stimulation system for patients who do not regain hip instability after an upper motor neuron lesion.


limb has been designed to allow for ease of use in the home as a daily treatment modality, as well as offer the opportunity for function enhancement. In a pilot study, the system was used by ten patients with chronic stable hemiparesis secondary to cerebral vascular accident and head injuries. The patients were referred by their treating physicians or therapists after meeting the inclusion criteria of good general health, being greater than one year after head injury, or being ten months post-stroke, with no observed neurologic changes in the prior six weeks. Each of these patients had received prolonged physical therapy, either continuous from the initial inpatient rehabilitation treatment or on an intermittent basis over a period of years. The baseline status for factors related to increased muscle tone, i.e., passive range of motion at the wrist and elbow, posture at rest, posture immediately following activity, and spasticity were quantified before the treatment protocol with the functional electrical stimulation orthosis. Active range of motion and tests of functional use of the involved upper limb were also assessed. The patients were instructed in the protocol, trained in the use of the system, and then used the electrical orthosis at home for up to several hours per day. Follow-up assessments were at six months. A statistically significant improvement was noted in all muscle tone/spasticity parameters measured. A separate report will describe the effects on voluntary motion and functional capabilities.


Abstract: To assess the efficacy of electrical acupuncture in the rehabilitation of patients with hemiplegia in stroke, we randomized 128 patients within 2 wk of stroke onset to receive either comprehensive rehabilitation plus electrical acupuncture (n = 59) or comprehensive rehabilitation only (n = 59). Electrical acupuncture was administered by electrical stimulation of acupuncture points through adhesive surface electrodes five times per week. Neurological status (Brunnstrom's stage) and the Chinese version of the Functional Independence Measure were assessed before treatment and at discharge. Patients treated with electrical acupuncture had a shorter duration of hospital stay for rehabilitation and better neurological and functional outcomes than the control group had, with a significant difference in scores for self-care and locomotion (P = 0.02). This result did not postulate the previous study that acupuncture therapy for stroke patients should depend on needle manual and "de qi" response. We suggest that electrical acupuncture through adhesive surface electrodes in conjunction with current optimal rehabilitation programs is a convenient and effective therapy for stroke patients.


Abstract: The function of ipsilateral cutaneous reflexes was studied with short trains of stimuli presented pseudorandomly to the superficial peroneal nerve (SP; innervates the top of the foot) during treadmill walking in neurologically intact (NI) subjects and subjects who had had a stroke. Ankle and knee joint angles together with electromyograms (EMG) of tibialis anterior (TA), soleus (SOL), medial gastrocnemius (MG), vastus lateralis (VL), and biceps femoris (BF) muscles were recorded. Net reflex EMG and kinematic responses to stimulation were quantified in each of the 16 parts of the step cycle and responses compared between the stroke and NI subjects. Stimulation strongly suppressed extensor muscles throughout stance in the stroke subjects. TA muscle showed a significant suppression during
swing phase that was correlated with reduced ankle dorsiflexion in both stroke and NI subjects. BF reflexes were facilitatory during parts of swing and VL reflexes were suppressive throughout stance in the stroke subjects. There was a significant correlation between BF facilitation and knee flexion during swing, which was stronger in NI subjects. We conclude that only part of the stumble correction to foot dorsum electrical stimulation observed in NI subjects is maintained after stroke, and that new, suppressive responses are seen.