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<th>Name of Authorized Individual (Please type or print):</th>
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<td>Dr. Bernard Lewin, M.D.</td>
<td>Bernard Lewin, M.D.</td>
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Clinical Policy Bulletin:
Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

Number: 0677

Policy

*Please see amendment for Pennsylvania Medicaid at the end of this CPB.*

I. Aetna considers functional electrical stimulation (FES) (e.g., Parastep I System) medically necessary durable medical equipment (DME) to enable members with spinal cord injury (SCI) to ambulate when all of the following criteria are met:

   A. Member has intact lower motor units (L1 and below) (both muscle and peripheral nerve);
   
   B. Member has joint stability to bear weight on upper and lower extremities, and has balance and control to maintain an upright posture independently;
   
   C. Member demonstrated brisk muscle contraction to neuromuscular electrical stimulation and has sensory perception of electrical stimulation sufficient for muscle contraction;
   
   D. Member has the cognitive ability to use such devices for walking and is highly motivated to use the device long term;
   
   E. Member can transfer independently and stand for at least 3 minutes;
   
   F. Member possesses hand and finger function to manipulate the controls;
   
   G. Member is at least 6 months post recovery of spinal cord injury and restorative surgery;
   
   H. Member does not have hip and knee degenerative disease and has no history of long bone fracture secondary to osteoporosis;
   
   I. The member has successfully completed a training program, which consists of at least 32 physical therapy sessions with the device over a 3-month period.

Note: These criteria are adapted from the Food and Drug Administration (FDA) labeling for Parastep I System as well as information provided in published studies.

Aetna considers replacement of a FES for walking medically necessary if the original FES met criteria as medically necessary and is no longer under warranty and cannot be repaired.

Exclusion Criteria:

Functional electrical stimulation for walking (Parastep I System) is specifically contraindicated and has no proven value for members with SCI with any of the following:

   A. Members with cardiac pacemakers; or
   
   B. Members with severe scoliosis or severe osteoporosis; or
   
   C. Members with skin disease or cancer at area of stimulation; or
D. Members with irreversible contracture; or
E. Members with autonomic dysreflexia.

II. Aetna considers neuromuscular electrical stimulators (NMES) medically necessary DME for disuse atrophy where the nerve supply to the muscle is intact and the member has any of the following non-neurological reasons for disuse atrophy:

A. Contractures due to burn scarring, or
B. Major knee surgery (e.g., total knee replacement) when there is failure to respond to physical therapy, or
C. Previous casting or splinting of a limb (arm or leg), or
D. Recent hip replacement surgery before physical therapy begins (NMES is considered medically necessary until physical therapy begins).

NMES are specifically contraindicated and considered unproven in persons with cardiac pacemakers.

Note: More than 2 hours of NMES per day is considered not medically necessary; protocols reported in the literature recommend no more than 2 hours of NMES treatment within a 24-hour period.

III. Aetna considers FES of the upper extremities (e.g., NESS H200 Handmaster NMS1 System) experimental and investigational for all indications, including improvement of muscle strength, reduction of spasticity and atrophy, and facilitation of functional motor movement due to any of the following conditions because its effectiveness for these indications has not been established:

A. Spinal cord injury; or
B. Stroke (cerebrovascular accident/CVA); or
C. Traumatic brain injury; or
D. Other upper motor neuron disorders (e.g., Parkinson's disease).

IV. Aetna considers FES and NMES experimental and investigational for all other indications, including any of the following because its effectiveness for indications other than the ones listed above as medically necessary has not been established:

A. Bell's palsy; or
B. Cardiac conditioning; or
C. Cerebral palsy; or
D. Chronic obstructive pulmonary disease; or
E. Congestive heart failure; or
F. General muscle strengthening in healthy individuals; or
G. Improving ambulatory function and muscle strength for progressive diseases (e.g., cancer, chronic heart failure, chronic obstructive pulmonary disease, multiple sclerosis) in persons without spinal cord injury; or
H. Treatment of denervated muscles; or
I. Treatment of knee osteoarthritis; or
J. Upper extremity hemiplegia.

Note: Aetna considers the FES exercise devices such as the FES Power Trainer, ERGYS, REGYS, NeuroEDUCATOR, STimMaster Galaxy, RT200 Elliptical, RT300 FES Cycle Ergometer (also referred to as a FES bicycle), RT600 Step and Stand Rehabilitation Therapy System, and SpectraSTIM to be exercise equipment. Most Aetna plans exclude coverage of exercise equipment; please check benefit plan descriptions for details. In addition, these stationary exercise devices are considered experimental and investigational to prevent or reduce muscle
Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

atrophy in upper and lower extremities in individuals with hemiplegia or quadriplegia and for all other indications.

V. Aetna considers a form-fitting conductive garment medically necessary DME only when it has been approved for marketing by the FDA, has been prescribed by a physician for use in delivering NMES that is considered medically necessary, and any of the following criteria is met:

A. The member cannot manage without the conductive garment due to the large area or the large number of sites to be stimulated, and the stimulation would have to be delivered so frequently that it is not feasible to use conventional electrodes, adhesive tapes, and lead wires; or
B. The member has a skin problem or other medical conditions that precludes the application of conventional electrodes, adhesive tapes, and lead wires; or
C. The member requires electrical stimulation beneath a cast to treat disuse atrophy, where the nerve supply to the muscle is intact; or
D. The member has a medical need for rehabilitation strengthening following an injury where the nerve supply to the muscle is intact.

Aetna considers form-fitting conductive garments experimental and investigational for all other indications because its effectiveness for indications other than the ones listed above has not been established.

VI. Aetna considers diaphragmatic/phrenic pacing (e.g., the Mark IV™ Breathing Pacemaker System, NeuRx DPS Diaphragm Pacing System, and the NeuRx DPS RA/4 Respiratory Stimulation System) medically necessary for the following indications:

A. For improvement of ventilatory function in stable, non-acute members with SCI when all of the following criteria are met:
   1. Member has high quadriplegia at or above C-3; and
   2. There are viable phrenic nerves; and
   3. Member's diaphragm and lung function are adequate; and
   4. Diaphragmatic pacing will allow the individual to breathe without the assistance of a mechanical ventilator for at least four continuous hours a day.

B. For the treatment of central alveolar hypoventilation when all of the following criteria are met:
   1. Age of 18 years and older; and
   2. Have intact phrenic nerve function; and
   3. Have diaphragm movement with stimulation.

C. For individuals with amyotrophic lateral sclerosis who meet the following criteria:
   1. Age of 21 years old or older; and
   2. Experiencing chronic hypoventilation; and
   3. Have intact phrenic nerve function; and
   4. Have diaphragm movement with stimulation; and
   5. Diaphragmatic pacing is used as an alternative to mechanical ventilation.

Aetna considers replacement of a diaphragmatic/phrenic stimulation system medically necessary if the original diaphragmatic/phrenic stimulation system met criteria as medically necessary and is no longer under warranty and cannot be repaired.

Aetna considers diaphragmatic/phrenic pacing experimental and investigational for all other indications, including for use in individuals whose phrenic nerve, lung or diaphragm function are
not sufficient to achieve adequate diaphragm movement from the electrical stimulation, because its effectiveness for indications other than the ones listed above has not been established.

VII. Aetna considers electrical stimulation of the sacral anterior roots (by means of an implanted stimulator, the Vocare Bladder System) in conjunction with a posterior rhizotomy medically necessary for members who have clinically complete spinal cord lesions (American Spinal Injury Association Classification) with intact parasympathetic innervation of the bladder and who are skeletally mature and neurologically stable, to provide urination on demand and to reduce post-void residual volumes of urine. The following selection criteria must be met:

A. 3 months (female members) after or 9 months (male members) after complete suprasacral spinal cord injury; and
B. A phasic detrusor pressure rise of 35 mm H2O (female members) or 50 cm H2O (male members) on cystometry; and
C. Presence of 3 of the 4 non-vesical sacral segment reflexes (i.e., ankle jerks, bulbocavernous reflex, anal skin reflex, and reflex erection).

Aetna considers electrical stimulation of the sacral anterior roots in conjunction with posterior rhizotomy (Vocare Bladder System) experimental and investigational for all other indications because its effectiveness for indications other than the ones listed above has not been established.

Aetna considers sacral nerve stimulation experimental and investigational for the treatment of chronic constipation because its effectiveness for this indication has not been established.

Note: The Vocare Bladder System, also known as the implantable Finetech-Brindley stimulator, is different from the InterStim device (sacral nerve neuromodulation, see CPB 0223 - Urinary Incontinence Treatments). The Vocare Bladder System is patient-activated and is designed to elicit functional contraction of the innervated muscles. Implantation of the Vocare device is frequently performed in conjunction with a dorsal rhizotomy. The rhizotomy results in an areflexive bladder, limiting incontinence and autonomic hyperreflexia.

VIII. Aetna considers transurethral electrical stimulation experimental and investigational for the management of neurogenic bladder dysfunction and all other indications because its effectiveness for these indications has not been established.

IX. Aetna considers peroneal nerve stimulators (e.g., the ODFS Dropped Foot Stimulator (Odstock), the WalkAide device, the NESS L300 Foot Drop System, and the NESS L300 Plus) experimental and investigational for persons with foot drop in cerebral palsy, multiple sclerosis, traumatic brain injury, stroke or an incomplete spinal cord injury and for all other indications because of insufficient evidence to support their use.

X. Aetna considers threshold (or therapeutic) electrical stimulation experimental and investigational for the management of knee osteoarthritis, cerebral palsy and other motor disorders because its effectiveness for these indications has not been established.

XI. Aetna considers NMES experimental and investigational for the treatment of dysphagia including, but not limited to, Guardian dysphagia dual chamber unit and VitalStim Therapy devices.

XII. Aetna considers combination and sequential units experimental and investigational, including, but not limited to, Empi Phoenix, Kneehab XP, QB1 and RS-4i devices.

XIII. Aetna considers EMG-triggered NMES experimental and investigational, including, but not limited to, Care ETS device.

XIV. Aetna considers phrenic nerve stimulation (e.g., the Remede System) medically necessary for
the treatment of adults with moderate-to-severe central sleep apnea who have failed supplemental oxygen therapy, pharmacotherapy (e.g., acetazolamide or theophylline), and masked-based therapies (e.g., bi-level positive airway pressure or continuous positive airway pressure).

See also CPB 0113 - Botulinum Toxin, and CPB 0362 - Spasticity Management.

Note: The American Spinal Injury Association (ASIA) Impairment Scale is described in the background section below.

Background

Spinal cord injury can (SCI) cause various degrees of neurological impairment depending on the location and severity of the injury. One method of categorizing the degree of injury is by a neurological examination that explores the segments of the cord which are still functional. The most caudal segment of the cord with normal sensory and motor functions is denoted as the neurological level of injury. The American Spinal Injury Association (ASIA) Impairment Scale is a classification system used to describe the extent of SCI.

The ASIA Impairment Scale:

| A Complete: No motor or sensory function is preserved in the sacral segments S4 - S5 |
| B Incomplete: Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4 - S5 |
| C Incomplete: Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3 |
| D Incomplete: Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more |
| E Normal: Motor and sensory function are normal |

Another factor that influences the severity of impairment is the neurological extent of injury, namely the degree of tissue trauma to the spinal cord at the level of injury. If the spinal cord is seriously damaged at the injury site, there is complete loss of sensation and voluntary muscle control below the level of lesion. On the other hand, if the damage is not complete, some sensory and/or motor functions may still be preserved. Thus, a complete injury to the cervical spine will result in quadriplegia, while an incomplete injury to the cervical spine will result in quadriparesis. Similarly, a complete lesion in the thoracic or lumbar spine will produce paraplegia, whereas an incomplete lesion at these levels will produce paraparesis. Spinal cord injury can result in damage to upper motor neurons (UMN), lower motor neurons (LMN), or a combination of both. The cell bodies of UMN originate from the primary motor area of the cerebral cortex and the brain stem, with their axons descending downward and terminating at each segmental level throughout the entire length of the spinal column to synapse with LMN that arise in the spinal cord and connect to a muscle or organ. The brain, through the UMN, exerts an inhibitory influence on the LMN so that they do not become hyperactive to local stimuli. The cell bodies of LMN are located in the central gray matter throughout the entire length of the spinal column, and their axons extend out via the spinal nerve roots and peripheral nerve branches to innervate skeletal muscles throughout the body.

Neuromuscular electrical stimulation (NMES) can be grouped into 2 categories: (i) stimulation of muscles to treat muscle atrophy, and (ii) enhancement of functional activity in neurologically impaired individuals. These devices use electrical impulses to activate paralyzed or weak muscles in precise
sequence and have been utilized to provide SCI patients with the ability to walk (e.g., The Parastep I System). Neuromuscular electrical stimulation used in this manner is commonly known as functional electrical stimulation (FES).

Spinal Cord Injury:

The Parastep I System, a transcutaneous non-invasive and micro-computerized electrical stimulation system built into a battery-powered unit, is controlled by finger-touch buttons located on a walker’s hand-bars for manual selection of stimulation menus. The microcomputer shapes, controls, and distributes trains of stimulation signals that trigger action potentials in selected peripheral nerves. Walker support is used for balance. The patient can don the system in less than 10 minutes. At least 32 training sessions are required.

Klose et al (1997) described performance parameters and effects on anthropometric measures in SCI patients (13 men and 3 women) training with the Parastep I system. Subjects with thoracic (T4 to T11) motor-complete SCI, mean age of 28.8 years, and mean duration post-injury of 3.8 years underwent 32 functional neuromuscular stimulation ambulation training sessions using the Parastep I System. The authors concluded that the Parastep I System enabled persons with thoracic-level SCI to stand and ambulate short distances but with a high-degree of performance variability across individuals. Furthermore, Graupe and Kohn (1998) reported that about 400 patients have used the Parastep I System and essentially all achieved standing and at least 30 feet of ambulation, with a few reaching as much as 1 mile at a time.

In addition to enhancement of walking abilities in SCI patients, other clinical applications of FES include diaphragmatic/phrenic pacing, and spasticity control. Functional electrical stimulation has had some success in improving ventilatory function in adult patients with SCI (Glenn et al, 1984; Carter et al, 1987; Glenn et al, 1988). Hunt et al (1988) reported that diaphragmatic pacing is also helpful for infants and children who need ventilatory support. Furthermore, in a 1992 review on the rehabilitation of children with SCI, Flett (1992) stated that diaphragmatic/phrenic pacing is indicated for children with quadriplegia at C3 or higher if they have viable phrenic nerves and adequate diaphragm and lung function. Candidates for diaphragmatic pacing should be stable and out of the acute phase of injury. The author stated that this approach of assisting ventilation in these patients resulted in psychological benefits to both the children and their families. Currently, bilateral stimulation at low frequency is more frequently used instead of stimulation of only one hemidiaphragm at a time, and adequate ventilation can be attained with 5 to 9 stimuli per minute.

Diaphragmatic pacing has also been used to treat patients with central alveolar hypoventilation syndrome. Yasuma and associates (1998) noted that the respiratory assistance by the diaphragm pacemaker or the use of a mechanical ventilator as a backup was highly useful for the home care of a patient with central alveolar hypoventilation. Garrido-Garcia and colleagues (1998) presented a series of patients with chronic ventilatory failure treated with electrophrenic respiration: 13 males and 9 females with a mean age of 12 +/- 11.5 years. The etiology was: 13 tetraplegia, 5 sequelae of surgical treatment of intracranial lesions, and 4 central alveolar hypoventilation. The mean duration of the conditioning period was 3 to 4 months. Eighteen patients (81.8 %) achieved permanent, diaphragmatically-paced breathing with bilateral stimulation and in 4 (18.2 %) patients, pacing was only during sleep. Five patients died (22.7 %): 2 during the hospital stay and 3 at home; 2 deaths had unknown cause and 3 were due respectively to, lack of at-home care, recurrence of an epidermoid tumor, and sequelae of accidental disconnection of the mechanical ventilation before beginning the conditioning period. Two cases were considered failures: 1 patient had transitory neurapraxia lasting 80 days, and the other had an ischemic spinal cord syndrome with progressive deterioration of the left-side response to stimulation.
One patient had right phrenic nerve entrapment by scar tissue and 4 suffered infections. These results demonstrated that complete stable ventilation can be achieved using diaphragmatic pacing and that it improves the prognosis and life quality of patients with severe chronic respiratory failure.

Girsch et al (1996) noted that ventilatory insufficiency due to central hypoventilation syndrome and SCI can be treated even in children with diaphragm pacing, provided the indication for implantation, containing medical and social aspects, was made correctly. Additionally, Flageole et al (1995) stated that pediatric surgeons should be aware of congenital central hypoventilation syndrome (CCHS) because it may be treated with surgically implanted electrodes that allow for pacing of the diaphragm. The technique has an acceptable complication rate, and it can greatly decrease the impact of the disease on the lifestyle and activity of the patient. Shaul et al (2002) stated that diaphragmatic pacing can provide chronic ventilatory support for children who suffer from CCHS or cervical SCI.

Chen and Keens (2004) reported that all patients with CCHS require lifelong ventilatory support during sleep but some will be able to maintain adequate ventilation without assistance while awake once past infancy. However, some CCHS patients require ventilatory support for 24 hours/day. Modalities of home mechanical-assisted ventilation include positive pressure ventilation via tracheostomy, non-invasive positive pressure ventilation (bi-level ventilation), negative pressure ventilation and diaphragmatic pacers. Furthermore, Creasey et al (1996) reported that electrical stimulation has been used for over 25 years to restore breathing to patients with high quadriplegia causing respiratory paralysis and patients with central alveolar hypoventilation. Three groups have developed electrical pacing systems for long-term support of respiration in humans. These systems consist of electrodes implanted on the phrenic nerves, connected by leads to a stimulator implanted under the skin, and powered and controlled from a battery-powered transmitter outside the body. The systems differ principally in the electrode design and stimulation waveform. Approximately 1,000 people worldwide have received one of the three phrenic pacing devices, most with strongly positive results: reduced risk of tracheal problems and chronic infection, the ability to speak and smell more normally, reduced risk of accidental interruption of respiration, greater independence, and reduced costs and time for ventilatory care. For patients with partial lesions of the phrenic nerves, intercostal muscle stimulation may supplement respiration.

Neuromuscular respiratory failure is the cause of death in the majority of patients with amyotrophic lateral sclerosis (ALS). Respiratory muscle dysfunction impacts on quality of life and survival. Yun and associates (2007) noted that closed loop systems may facilitate the implementation of diaphragmatic pacing for the treatment of many indications. They may allow for wider adoption of ventilatory support in central sleep apnea and improve quality of life in diseases of chronic hypoventilation, such as ALS.

Onders and colleagues (2009a) summarized the complete worldwide multi-center experience with diaphragm pacing stimulation (DPS) to maintain and provide diaphragm function in ventilator-dependent SCI patients and respiratory-compromised patients with ALS. It high-lighted the surgical experiences and the differences in diaphragm function in these 2 groups of patients. In prospective Food and Drug Administration (FDA) trials, patients underwent laparoscopic diaphragm motor point mapping with intramuscular electrode implantation. Stimulation of the electrodes ensued to condition and strengthen the diaphragm. From March of 2000 to September of 2007, a total of 88 patients (50 SCI and 38 ALS) were implanted with DPS at 5 sites. Age of patients at implantation ranged from 18 to 74 years. Time from SCI to implantation ranged from 3 months to 27 years. In 87 patients the diaphragm motor point was mapped with successful implantation of electrodes with the only failure the second SCI patient who had a false-positive phrenic nerve study. Patients with ALS had much weaker diaphragms identified surgically, requiring trains of stimulation during mapping to identify the motor point at times. There was no peri-operative mortality even in ALS patients with forced vital capacity (FVC) below 50 % predicted. There was no cardiac involvement from diaphragm pacing even when analyzed in 10 patients who had pre-existing cardiac pacemakers. No infections occurred even with simultaneous gastrostomy tube placements for ALS patients. In the SCI patients, 96 % were able to use DPS to provide ventilation replacing their mechanical ventilators; and in the ALS studies, patients have been able to delay the need for mechanical ventilation up to 24 months. The authors concluded that this multi-center experience has
shown that laparoscopic diaphragm motor point mapping, electrode implantation, and pacing can be safely performed both in SCI and in ALS. In SCI patients it allows freedom from ventilator and in ALS patients it delays the need for ventilators, increasing survival.

Onders and co-workers (2009b) summarized the largest series of surgical cases in ALS during multi-center prospective trials of the laparoscopic DPS to delay respiratory failure. The overall strategy outlined includes the use of rapidly reversible short-acting analgesic and amnestic agents with no neuromuscular relaxants. A total of 51 patients were implanted from March 2005 to March 2008 at 2 sites. Age of patients ranged from 42 to 73 years and the percent predicted FVC ranged from 20 % to 87 %. On pre-operative blood gases, Pco(2) was as high as 60. Using this protocol, there were no failures to extubate or 30-day mortalities. The DPS system increase the respiratory system compliance by decreasing posterior lobe atelectasis and can stimulate respirations at the end of each case. The authors concluded that laparoscopic surgery with general anesthesia can be safely performed in patients with ALS undergoing DPS.

It has not been consistently shown that spasticity decreases with long-term FES. Yarkony et al (1992) claimed that no definitive statement can be made regarding the type, the magnitude, or even the direction of the effect of electrical stimulation on the spasticity of patients with SCI. Current management strategy for this condition ranges from rehabilitative physical therapy, re-education therapeutic exercise, oral medications such as Dantrium, Valium, and Lioresal (baclofen), intra-thecal infusion of baclofen, motor point blocks or nerve blocks, to destructive neurosurgical procedures (Merritt 1981).

Functional electrical stimulation exercise training has been claimed to strengthen and increase endurance of muscles paralyzed following UMN injuries, thereby improving physical fitness and health of individuals with SCI. However, fatigue of electrically stimulated muscles is a principal limiting factor in the applications of FES. Glaser (1986) stated that more research is needed to ascertain the mechanisms of fatigue of this type of peripherally induced exercise, and to substantiate the potential fitness and health benefits of FES exercise training. Sipski et al (1989) examined patient perceptions of FES bicycle ergometry. These researchers suggested that future studies should include a placebo control group. They also found that 6 of 9 patients with a history of neurogenic pain reported an increase in this pain which caused them to drop out of the training program. The cause of this intensification of pain was unclear. Leeds et al (1990) reported that bone mineral density did not increase in quadriplegic men who had undergone 6 months of FES cycle ergometry training. Sipski et al (1993) stated that more research is needed to document the benefits, if any, of the use of bicycle ergometry to justify the use of this equipment. Pentland (1993) claimed that much more research in FES techniques and treatment protocols is needed before this approach can be used widely as a means to provide cardiorespiratory fitness for quadriplegics.

**Stroke Rehabilitation:**

The principal goal of stroke rehabilitation is to improve the functional abilities of these patients, thus affording them greater independence in activities of daily living and improving their quality of life. Conventional modalities of stroke rehabilitation comprise various combination of range of motion (ROM) and muscle strengthening exercises, mobilization activities, and compensatory techniques. Other therapies include neurophysiological and/or developmental based methods in which the therapeutic program incorporates neuromuscular re-education techniques. In this regard, FES has been employed in the rehabilitation of stroke patients. It has been utilized to manage contracture of joints, maintain ROM, facilitate voluntary motor control, and reduce spasticity. However, there is insufficient evidence that FES is effective as a rehabilitative tool for patients who suffered strokes. In particular, there are little data supporting the long-term effectiveness of this modality for stroke rehabilitation.

In a review on the clinical applications of FES, Kumar et al (1995) stated that advances in electrode technology and control and command sources activation systems as well as development of close-loop systems are needed if wide patient acceptance of this modality (FES) is to be ensured. The Agency for
Health Care Policy and Research's clinical guideline on "Post-stroke Rehabilitation" maintains that neither research evidence nor expert consensus adequately supports recommendation concerning the use of FES in the rehabilitation of stroke patients (Gresham, 1995). Furthermore, Hummelsheim et al (1997) reported that repetitive electrical muscle stimulation did not improve biomechanical or functional motor parameters of the centrally paretic hand and arm of stroke patients.

In a randomized controlled study, Yan and colleagues (2005) evaluated whether FES was more effective in promoting motor recovery of the lower extremity and walking ability than standard rehabilitation alone. A total of 46 patients were assigned randomly to one of three groups receiving standard rehabilitation with FES or placebo stimulation or alone (control). They received treatment for 3 weeks, starting shortly after having the stroke. Outcome measurements included composite spasticity score, maximum isometric voluntary contraction of ankle dorsi-flexors and planter-flexors, and walking ability. After 3 weeks of treatment, those receiving FES plus standard rehabilitation did better on several measures of lower limb functioning compared to the other 2 groups. All patients in the FES group were able to walk after treatment, and 84.6 % of them returned home, in comparison with the placebo (53.3 %) and control (46.2 %) groups. However, these authors stated that generalization of the results from this study should be performed with caution because of subject selection criteria, which did not cover all stroke categories or subjects aged younger than 45 or older than 85 years. Further studies are now needed to see whether FES can work with a wide range of stroke patients.

Although a number of studies suggested that electrical stimulation may be effective for reducing shoulder pain and subluxation or improving the function of wrist and finger extensors following stroke (Chantraine et al, 1999; Wang et al, 2002; and Yozbatrian et al, 2006), more research is needed to validate these findings. Chantraine et al (1999) reported that 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. However, they noted that more research addressing the mechanism of the actions of FES on pain and subluxation of the hemiplegic shoulder is needed.

Chae and Yu (2000) critically evaluated the clinical effectiveness of NMES in treating motor dysfunction in hemiplegia. Three distinct applications were reviewed in the areas of motor relearning, shoulder dysfunction, and neuroprostheses. Assessment of clinical effectiveness and recommendations on clinical implementation were based on the weight of published scientific evidence. With respect to motor relearning, evidence supports the use of NMES to facilitate recovery of muscle strength and coordination in hemiplegia. However, effects on physical disability are uncertain. With respect to shoulder dysfunction, NMES 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 effectiveness should be pursued. The authors concluded that the application of NMES for motor relearning and shoulder dysfunction are ready for more rigorous scientific and clinical assessment via large, multi-center, randomized clinical trials.

In a Cochrane review, Price and Pandyan (2000) ascertained the effectiveness of any form of surface ES in the prevention and/or treatment of pain around the shoulder at any time after stroke. These investigators concluded that the evidence from randomized controlled studies 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. The authors stated that further studies are needed.

Turner-Stokes and Jackson (2002) noted that although a wide variety of physical changes are associated with hemiplegic shoulder pain (HSP), these can be categorized into 2 presentations; (i) "flaccid", and (ii) "spastic". Management should vary accordingly; each presentation requiring different approaches to handling, support and intervention. In the "flaccid" stage, the shoulder is prone to inferior subluxation and vulnerable to soft-tissue damage. The arm should be supported at all times and FES
may reduce subluxation and enhance return of muscle activity. In the "spastic" stage, movement is often severely limited. Relieving spasticity and maintaining range requires expert handling; over-head exercise pulleys should never be used. Local steroid injections should be avoided unless there is clear evidence of an inflammatory lesion. The authors concluded that HSP requires coordinated multidisciplinary management to minimize interference with rehabilitation and optimize outcome. They stated that more research is needed to determine effective prophylaxis and document the therapeutic effect of different modalities in the various presentations.

The New Zealand Guidelines Group's guideline for management of stroke (2003) stated that the use of FES and transcutaneous electrical nerve stimulation for post-stroke patients is not recommended. Furthermore, Van Peppen et al (2004) determined the evidence for physical therapy interventions aimed at improving functional outcome after stroke. These researchers reported that while strong evidence was found regarding NMES for glenohumeral subluxation, no or insufficient evidence in terms of functional outcome was found for FES and NMES aimed at improving dexterity or gait performance; orthotics and assistive devices; and physical therapy interventions for reducing hemiplegic shoulder pain and hand edema. Furthermore, in a review on therapeutic orthosis and ES for upper extremity hemiplegia after stroke, Aoyagi and Tsubahara (2004) stated the longer term effectiveness after discontinuation as well as the motor recovery mechanism of ES or robotic devices remains unclear. More research is needed to determine the evidence-based effectiveness of ES or other devices for stroke survivors.

In a Cochrane review on ES for promoting recovery of movement or functional ability after stroke, Pomeroy et al (2006) concluded that "[a]lthough there has been progress in the use of ES for neurorehabilitation, there are still gaps in the evidence base. Research is needed to determine the most effective type, dose and timing of ES for post-stroke rehabilitation".

In a systematic review and meta-analysis, Eraifej and co-workers (2017) evaluated the effectiveness of post-stroke upper limb FES on activities of daily living (ADL) and motor outcomes. A systematic review of RCTs from Medline, PsychINFO, EMBASE, CENTRAL, ISRCTN, ITRP and ClinicalTrials.gov was carried out. Eligibility criteria: included participants greater than 18 years with hemorrhagic/ischemic stroke, intervention group received upper limb FES plus standard care, control group received standard care. Outcomes were ADL (primary), functional motor ability (secondary) and other motor outcomes (tertiary). Quality assessment using GRADE (Grading of Recommendations Assessment, Development and Evaluation criteria). A total of 20 studies were included. No significant benefit of FES was found for objective ADL measures reported in 6 studies (SMD 0.64; 95 % CI: -0.02 to 1.30); total participants in FES group (n = 67); combination of all ADL measures was not possible. Analysis of 3 studies where FES was initiated on average within 2 months post-stroke showed a significant benefit of FES on ADL (SMD 1.24; CI: 0.46 to 2.03; n = 32). In 3 studies where FES was initiated more than 1 year after stroke, no significant ADL improvements were seen (SMD -0.10; CI: -0.59 to 0.38, n = 35). Quality assessment using GRADE found very low quality evidence in all analyses due to heterogeneity, low participant numbers and lack of blinding. The authors concluded that FES is a promising therapy which could play a part in future stroke rehabilitation. This review found a statistically significant benefit from FES applied within 2 months of stroke on the primary outcome of ADL. However, due to the very low (GRADE) quality evidence of these analyses, firm conclusions cannot be drawn about the effectiveness of FES or its optimum therapeutic window. These researchers stated that there is a need for high quality large-scale RCTs of upper limb FES after stroke.

In a systematic review and meta-analysis, Lee and associates (2017) examined the effectiveness of NMES for the management of shoulder subluxation after stroke including assessment of short (1 hour or less) and long (more than 1 hour) daily treatment duration. Medline, CENTRAL, CINAHL, WOS, KoreaMed, RISS and reference lists from inception to January 2017 were the data sources. These researchers considered RCTs that reported NMES for the treatment of shoulder subluxation post-stroke; 2 reviewers independently selected trials for inclusion, assessed trial quality, and extracted data. A total of 11 studies were included (432 subjects); 7 studies were good quality, 4 were fair. There was a
Functional Electrical Stimulation (FES) and Neuromuscular Electrical Stimulation (NMES) are being investigated as potential treatments for subluxation and shoulder pain in individuals with stroke. A meta-analysis of 11 studies found a significant treatment effect of NMES for reduction of subluxation for persons with acute and sub-acute stroke (SMD: -1.11; 95% CI: -1.53 to -0.68) with either short (SMD: -0.91; 95% CI: -1.43 to -0.40) or long (SMD: -1.49; 95% CI: -2.31 to -0.67) daily treatment duration. The effect for patients with chronic stroke was not significant (SMD: -1.25; 95% CI: -2.60 to 0.11). There was no significant effect of NMES on arm function or shoulder pain. The authors concluded that the findings of this meta-analysis suggested a beneficial effect of NMES, with either short or long daily treatment duration, for reducing shoulder subluxation in persons with acute and sub-acute stroke. However, no significant benefits were observed for persons with chronic stroke or for improving arm function or reducing shoulder pain.

**Functional Electrical Stimulation of the Upper Extremities:**

Functional electrical stimulation is being investigated as a means to improve hand and arm function after stroke-related paralysis or spinal cord injury. The NESS H200 hand rehabilitation system (Bioness, Valencia, CA), formerly the Handmaster, is a neuroprosthesis that uses mild ES in an attempt to activate muscle groups in the forearm to produce functional movement patterns in the hand. It is designed to be used as part of a self-administered home-based rehabilitation program for the treatment of upper limb paralysis from hemiplegic stroke, traumatic brain injury or C5 to C6 spinal cord injury. The system contains a custom-fitted orthosis and a control unit. The control unit allows the user to adjust the stimulation intensity and training mode. Exercise sessions can be gradually increased to avoid muscle over-fatigue.

Initial case studies have indicated that the use of FES as an adjunct to physical therapy can improve patient outcomes (Weingarden et al, 1998; Alon et al, 2002; Alon et al, 2003; Berner et al, 2004). However, the studies lacked a control group, involved small study populations with limited periods of follow-up. Thus, it is difficult to ascertain the significance of the treatment effects and their durability.

De Kroon et al (2002) systematically reviewed the evidence for ES to improve motor control and functional abilities of the upper extremity after stroke. The authors reported that "[t]he results suggest that electrical stimulation has a positive effect on motor control, although it is not known if this improvement is clinically relevant." The review stated that "[n]o conclusions can be drawn concerning the effect of electrical stimulation on functional abilities."

Ring and Rosenthal (2005) evaluated the effects of daily neuroprosthetic (NESS Handmaster) FES in sub-acute stroke. Patients were clinically stratified to 2 groups: (i) no active finger movement, and (ii) partial active finger movements, and then were randomized to control and neuroprosthesis groups. Observer blinded evaluations were performed at baseline and completion of the 6-week study. A total of 22 patients with moderate-to-severe upper limb paresis 3 to 6 months after stroke were enrolled in this study. They were in day hospital rehabilitation, receiving physical and occupational therapy 3 times weekly. The neuroprosthesis group used the device at home. The neuroprosthesis group had significantly greater improvements in spasticity, active ROM and scores on the functional hand tests (those with partial active motion). Of the few patients with pain and edema, there was improvement only among those in the neuroprosthesis group. There were no adverse reactions. These investigators concluded that supplementing standard outpatient rehabilitation with daily home neuroprosthetic activation improves upper limb outcomes.

In a systematic review, Meilink et al (2008) evaluated if electromyography-triggered NMES (EMG-NMES) applied to the extensor muscles of the forearm improves hand function after stroke. A total of 8 studies, selected out of 192 hits and presenting 157 patients, were included in quantitative and qualitative analyses. The methodological quality ranged from 2 to 6 points. The meta-analysis revealed non-significant effect sizes in favor of EMG-NMES for reaction time, sustained contraction, dexterity measured with the Box and Block manipulation test, synergism measured with the Fugl-Meyer Motor Assessment Scale and manual dexterity measured with the Action Research Arm test. The authors concluded that no statistically significant differences in effects were found between EMG-NMES and usual care. Most studies had poor methodological quality, low statistical power and insufficient treatment contrast between experimental and control groups. In addition, all studies except 2
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investigated the effects of EMG-NMES in the chronic phase after stroke, whereas the literature suggests that an early start, within the time window in which functional outcome of the upper limb is not fully defined, is more appropriate.

In a retrospective cohort study, Meijer et al (2009) evaluated the short-term and long-term use of a hybrid orthosis for NMES of the upper extremity in patients (n = 110) after chronic stroke. The Modified Ashworth Scale (0 to 5) for wrist (primary outcome) and elbow flexor hypertonia, visual analog scale (0 to 10) for pain, edema score (0 to 3), and passive range of wrist flexion and extension (pROM, degrees) were assessed prior to Handmaster orthosis prescription (T0), after 6 weeks try-out (T1) and a subsequent 4 weeks withhold period (T2). Long-term use was evaluated using a questionnaire. Non-parametric analyses and predictive values were used for statistical analyses. Of the 110 patients, 78.2 % were long-term Handmaster orthosis users. Long-term users showed significant short-term (T0 to T1) improvements on all impairment scores and a significant relapse of wrist and elbow Modified Ashworth Scale (T1 to T2). Non-users showed significant short-term effects on elbow Modified Ashworth Scale and visual analog scale only. Positive predictive values of short-term effects for long-term use varied between 75 % and 100 %, with 85 % (95 % confidence interval (CI): 0.72 to 0.93) for wrist Modified Ashworth Scale. Negative predictive values were low (11 to 27 %). The authors concluded that short-term Handmaster orthosis effects were generally beneficial for hypertonia, pain, edema, and pROM, especially in long-term users and that short-term beneficial effects were highly predictive for long-term use, but not for non-use.

The results of these studies are promising, however, these findings need to be validated by further investigation with more patients and follow-up data.

Rehabilitation Following Ligament/Knee Surgery:

On the other hand, NMES has been shown to be an effective rehabilitative regimen for patients following ligament/knee surgery. It prevents muscle atrophy associated with knee immobilization, enables patients to ambulate sooner, and reduces the use of pain medication as well as length of hospital stay (Arvidsson, 1986; Lake, 1992; Gotlin et al, 1994; Snyder-Mackler et al, 1995).

Bax et al (2005) systematically reviewed the available evidence for the use of NMES in increasing strength of the quadriceps femoris. The authors concluded that limited evidence suggests that NMES can improve strength in comparison with no exercise, but volitional exercises appear more effective in most situations. The authors’ cautious conclusions reflect the general poor quality of the included studies.

Neurogenic Bladder Dysfunction:

Neurogenic bladder dysfunction is due to lesions of the innervation either within the central nervous system or in the peripheral nerves of the bladder and urethra. The Lapides Classification is the scheme most frequently used by urologists to classify patients with neuropathic voiding dysfunction. This classification system is divided into 5 categories: (i) sensory neurogenic bladder, (ii) motor paralytic bladder, (iii) uninhibited neurogenic bladder, (iv) reflex neurogenic bladder, and (v) autonomous neurogenic bladder.

A sensory neurogenic bladder is caused by diseases that selectively disrupt the sensory fibers between the bladder and spinal cord or the afferent pathways to the brain. This is commonly observed in patients with peripheral neuropathies such as diabetes mellitus, tabes dorsalis, folic acid avitaminosis, and pernicious anemia. A motor paralytic bladder is the consequence of diseases/processes that interrupt the parasympathetic motor innervation of the bladder. It can be produced by extensive pelvic surgery or trauma or herpes zoster. An uninhibited neurogenic bladder is due to the absence of cerebral inhibition of the micturition reflex as a result of injury or disease in the cortico-regulatory tract. Cerebral lesions such as stroke, tumors, arteriosclerosis, and traumatic lesions are the most common causes of this type of voiding disorder. A reflex neurogenic bladder is often observed in the post-spinal shock condition existing following the complete transection of the sensory and motor tracts between the sacral spinal cord.
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cord and the brain stem. This is often the result of traumatic SCI and transverse myelitis, but may also occur with severe demyelinating disease or tumor. An autonomous neurogenic bladder is caused by complete motor and sensory separation of the bladder from the sacral spinal cord. Diseases that destroy the sacral spinal cord or cause extensive damage to the sacral roots or pelvic nerves can produce this type of disorder. It should be noted that many patients do not exactly fit into one or another of these categories because of gradations of sensory, motor, and mixed lesions. Thus, the patterns produced after different types of peripheral denervation may vary greatly from those that are classically described (Barrett and Wein, 1991).

Neurogenic bladder dysfunction can also be associated with other neurological diseases including cerebellar ataxia, multiple sclerosis, Parkinson’s disease, and Shy-Drager syndrome. In children, the common causes of neurogenic bladder dysfunction are sacral agenesis, tethered cord syndrome, and myelomeningocele. The main results of neurogenic bladder dysfunction are renal damage and urinary incontinence (UI). The former is due to either high intravesical pressure or the association of vesicoureteral reflux and infection. The mechanisms for UI are multiple including (i) overflow incontinence caused by detrusor atonia with a non-relaxing sphincter, (ii) lack of storage capacity caused by hyperreflexia or poor compliance, and (iii) low urethral resistance caused by denervation of the sphincters. Oftentimes, the causes of UI are mixed (Wein 1992; Fernandes et al, 1994).

The management of patients with neurogenic bladder dysfunction entails clean intermittent catheterization, pharmacotherapy (e.g., oxybutynin, phenoxybenzamine, and anti-cholinergic medications such as tolterodine), and surgical interventions (e.g., urinary diversion or bladder augmentation). Moreover, stimulation of sacral anterior nerve roots in association with posterior rhizotomy has been used in the treatment of patients with suprasacral SCI. The FDA approved the Vocare Bladder System as a humanitarian use device based on a study of 23 patients who received device in association with posterior rhizotomy and were followed for a minimum of 3 months. Comparisons were made with the implanted stimulator turned either on or off; thus patients served as their own controls. The primary outcome measures were improvement in bladder emptying as evidenced by the ability to void more than 200 ml on demand with post-void residual urine volumes of less than 50 ml. Secondary endpoints included reduction in the use of urinary catheters, number and severity of episodes of UI, reduction in incidence of urinary tract infections, and results of a user satisfaction survey.

After 3 months, 90 % of the patients were able to urinate more than 200 ml on demand and 81 % had post-void residual urine volumes of less than 50 ml. A total of 73 % of patients reported fewer urinary tract infections and at 6 months, about 50 % of the patients were using the device exclusively for micturition, and no external devices (e.g., catheters) were needed. The results reported in this study were in agreement with those reported by Van Kerrebroeck et al (1996) as well as Egon et al (1998). The former group of investigators reported on the outcomes of 47 patients who were followed for a minimum of 6 months. Complete continence was observed in 43 of the 47 patients, and 41 of the 47 patients used only the stimulator for bladder emptying. The residual urine volume also decreased to less than 50 ml in 41 patients. The incidence of urinary tract infections also decreased. The latter group of researchers reported on a case series of 93 patients. A total of 83 of the 93 patients used their implants for micturition with residual volumes of less than 50 ml.

Jamil (2001) stated that the Finetech-Brindley stimulator can be recommended to female patients after 3 months and to male patients after 9 months of complete supra-sacral SCI. The presence of 3 of the 4 non-vesical sacral segment reflexes (ankle jerks, bulbo-cavernous reflex, anal skin reflex, and reflex erection) and a phasic detrusor pressure rise of 35 mm H2O in the female and 50 cm H2O in the male on cystometry indicates intact efferent nerve supply to the bladder and consequently the possibility of success of the implanted stimulator.

A less widely used method for the treatment of neurogenic bladder is transurethral electrical bladder stimulation (TEBS). This modality was first introduced in Europe by Katona and Berenyi (1975) to treat patients with myelomeningocele. It was introduced in the United States by Kaplan and Richards
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(1986). This procedure has been utilized with the theory that bladder stimulation promotes new sensory awareness of bladder filling and a restoration of detrusor contractility (i.e., disappearance of uninhibited bladder contractions and replacement with normal contractions). Briefly, this procedure involves the filling of the bladder to approximately half capacity with normal saline via an electrocatheter under sterile conditions. The catheter is then connected to a pressure recorder for continuous monitoring of bladder pressure. A rectal balloon catheter is employed to subtract abdominal pressure and a ground electrode is placed on the leg. Stimulation parameters are as follow: (i) voltage -- 0.5 to 10 mA, (ii) frequency -- 40 to 100 Hz, (iii) duration -- 2 to 8 msec, and (iv) interval -- 1 to 10 sec. Patients undergo one or more series of bladder stimulation. The first series of stimulation begins with an evaluation session, which is followed by 10 to 30 90-min daily sessions. Each of these sessions comprises a 15-min period of monitoring of bladder activity followed by 60 mins of bladder stimulation and then another 15 mins of observation of bladder activity. Between series there is a rest period of 3 to 6 months during which no stimulation is given. Following the rest interval, a subsequent series consisting of 5 to 15 daily sessions will commence (Boone et al, 1992; Kaplan and Richards, 1988; Kaplan et al, 1989).

Although earlier reports (Katona and Berenyi, 1975; Kaplan and Richards, 1986; Kaplan and Richards, 1988; Kaplan et al, 1989) claimed that TEBS is effective in treating patients with neurogenic bladder dysfunction, recent studies (Boone et al, 1992; Decter et al, 1992; Lyne and Bellinger, 1993; Decter et al, 1994) have not been able to replicate such findings. The 2 most relevant outcome measures in assessing the effectiveness of TEBS are restoration of normal detrusor contractility and urinary continence. Lyne and Bellinger (1993) treated 17 patients with neurovesical dysfunction with TEBS. Overall, only 5 (41.7 %) of the 12 patients with fully standardized serial cystometry experienced a durable increase in bladder capacity, and no patient achieved volitional voiding. Decter et al (1992) treated 21 patients with neurogenic bladder dysfunction using TEBS. They found that 20 % of the patients showed an increase in bladder capacity and 30 % experienced a decrease in end filling pressures. However, these effects did not significantly change patients' daily voiding regimens. In a follow-up study, Decter et al (1994) stated that TEBS is a time consuming and labor intensive procedure. Additionally, the limited urodynamic benefits attained by patients have not changed their daily routine of bladder management. Because of the afore-mentioned factors, these investigators are not accepting any new patients in their TEBS program. In an earlier study, Nicholas and Eckstein (1975) reported their findings of TEBS in the treatment of 20 patients with neurogenic bladder dysfunction due to spina bifida. No patient attained bladder sensation and the essential pattern of detrusor activity in these patients was unchanged by TEBS.

Boone et al (1992) performed the only prospective, randomized, sham controlled and blinded clinical trial on the use of TEBS in 36 children with myelomeningocele. Patients were allocated to either a 3-week period of TEBS or sham treatment, which was followed by a 3-month rest period, and then all patients were treated with TEBS for an additional 3 weeks. Bladder capacity, sensation, and compliance as well as continence were evaluated. Transurethral electrical bladder stimulation did not produce any beneficial effects even in patients who had undergone a total of 6 weeks of active stimulation.

Van Balken et al (2004) reviewed the literature on the application of various devices and techniques for the ES treatment of lower urinary tract (e.g., bladder) dysfunction with respect to mechanism of action and clinical outcome. These investigators concluded that randomized clinical trials to compare different techniques and evaluate placebo effects are urgently needed, as are further studies to elucidate modes of action to improve stimulation application and therapy results. The introduction of new stimulation methods may provide treatment alternatives as well as help answer more basic questions on ES and neuromodulation.

Cerebral Palsy:

Cerebral palsy (CP) refers to a wide variety of non-progressive brain disorders resulting from insults to the central nervous system during the perinatal period. Infants born prematurely and full-term infants with low birth-weight have the highest risk of developing CP. Infants whose birth weights are less than
2,500 g account for approximately 1/3 of all babies who later demonstrate signs of CP. Moreover, the rate of CP is about 30 times higher in babies who weigh less than 1,500 g at birth than in full-term babies with normal weight (Kuban and Leviton, 1994). Traditionally, the adverse effects of spasticity are managed by means of pharmacotherapy, physical therapy, bracing, casting, splinting, orthopedic surgeries, and more recently selective posterior rhizotomy. Various forms of ES have also been employed for the management of patients with CP including NMES, which has been used to increase ROM, decrease spasticity, and enhance muscle rehabilitation.

The exact mechanisms by which NMES might improve motor function in children with CP remain unclear. It may be related to its ability to increase ROM, temporarily decrease spasticity, and enhance muscle rehabilitation. Moreover, Pape et al (1993) suggested that NMES applied during sleep might encourage the differential growth of atrophic non-spastic antagonistic muscles. As a result, the decreased imbalance at the end-organ level might improve motor function.

Pape et al (1993) reported their findings regarding the use of NMES for improving motor deficits in children with CP. Six patients with mild ambulatory spastic hemiplegia or diplegia underwent a study of over-night low intensity sub-threshold transcutaneous ES. Only 5 of the 6 patients completed the study. After 6 months of ES, significant improvement was observed on the Peabody Developmental Motor Scales scores in gross motor, locomotor, and receipt/propulsion skills. However, balance and non-locomotor scores showed no significant changes. On the other hand, when ES was withdrawn for 6 months, there was uniform partial regression in scores. Moreover, re-institution of treatment by ES resulted in additional improvement in total gross motor, balance, locomotor, and receipt/propulsion skills, but not for non-locomotor skills. The authors concluded that in selective cases, especially children with mild CP, over-night ES may be a useful adjunct to conventional rehabilitation services. Although the findings by Pape et al appear to be encouraging, this was an uncontrolled study with 5 children who were 3 to 5 years old, a time when rapid changes are expected in these children. More importantly, no attempt was made to standardize physical therapy throughout the study. All but 1 subject continued to receive rehabilitative procedures which may have a confounding effect on the outcome of the study. It is unclear whether these improvements were translated into improvements in activities of daily living. Additionally, there were no data regarding the long-term effects of this treatment modality.

Hazlewood et al (1994) evaluated the effectiveness of ES in treating children with hemiplegic CP. Ten patients were given ES of the anterior tibial muscles by their parents daily for 1 hour for 35 consecutive days in conjunction with their physical therapy (PT) regimen. Ten patients who were matched for age, severity of gait pattern, and for limitation of range of passive dorsiflexion of the ankle served as controls and continued with their current PT program. Active and passive ranges of movement of the ankle, as well as knee and ankle motion during ambulation were recorded by means of electrogoniometers before and after ES. For passive joint-range measurements, there were no significant changes in the range of ankle plantar-flexion, or dorsiflexion with the knee flexed for patients who received tibial muscles ES. However, there was a significant increase in dorsiflexion of the ankle with the knee extended. The mean ranges of the stimulated group of patients for dorsiflexion with the knee extended increased from 40 to 60 % of the range of the non-affected side. For active joint-range measurements, there was a significant difference in the range of voluntary dorsiflexion when the patient was sitting, comparing the experimental and control groups post-test, but no significant differences comparing the pre-and post-changes of the 2 groups. Furthermore, gait analysis and ankle motion showed little change. The authors concluded that because of the complex and diverse pathology associated with CP, the application of ES for the treatment of children with this disorder requires further investigations to determine which types of CP patients are likely to benefit from ES as well as the desired parameters of stimulation before this modality should be used widely in the clinical setting.

Steinbok et al (1997) concluded that therapeutic ES may be beneficial in children with spastic CP who have undergone a selective posterior rhizotomy more than 1 year ago. However, the authors concluded that more research is needed to confirm these results. More importantly, it must be emphasized that these findings can not be extrapolated to the larger population of children with spastic CP who have not undergone selective posterior rhizotomy.
In a systematic review of the literature on ES for CP, Kerr et al (2004) concluded that "[t]here is more evidence to support the use of NMES than TES [threshold electrical stimulation]. However, the findings should be interpreted with caution as the studies had insufficient power to provide conclusive evidence for or against the use of these modalities." An earlier systematic evidence review by Boyd et al (2001) reached similar conclusions about the paucity of evidence for the use of ES for CP.

**Bell's Palsy:**

Acute idiopathic facial paresis is often known as Bell's palsy. Treatment of idiopathic Bell's palsy is still not well-defined. Conservative approaches entail physiotherapies such as facial exercises, massage, and muscle relaxation, which may support rehabilitation and possibly reduce the production of pathological synkinesia. Medical treatments include botulinum toxin type A (Botox) as well as a combined regimen of cortisone, virostatic agents, hemorrhheologic substances, and possibly antibiotics. Moreover, available evidence from randomized controlled trials (RCTs) does not show significant benefit from treating Bell's palsy with corticosteroids (Salinas et al, 2002). Surgical decompression of the facial nerve remains controversial.

Adour (1991) stated that decompression of the facial nerve and electrotherapy are not advised for the management of patients with idiopathic (Bell's) palsy. This is in agreement with Wolf who stated that ES should not be used in the treatment of Bell's palsy. Buttress and Herren (2002) reviewed the medical literature to ascertain whether ES had any advantages over facial exercises in promoting recovery after Bell's palsy. Of the 270 papers reviewed by the authors, only 1 presented the best evidence to answer the clinical question. The authors stated that there is no evidence to suggest that either facial exercises or ES is beneficial to patients with acute Bell's palsy. However, evidence does exist to suggest the use of ES in patients with chronic Bell's palsy, although the study design was not rigorous.

**Foot Drop:**

Individuals with stroke, CP, multiple sclerosis, and SCI/traumatic brain injury may exhibit foot drop, a condition caused by weakness or paralysis of the muscles involved in lifting the front part of the foot. The WalkAide is a product of Myo-Orthotics Technology, a term coined by the manufacturer, Innovative Neurotronics (Austin, TX). According to the manufacturer, it represents the convergence of orthotic technology (which braces a limb) and ES (which restores specific muscle function). The WalkAide device is intended to counteract foot drop by producing dorsiflexion of the ankle during the swing phase of the gait. The device attaches to the leg, just below the knee, near the head of the fibula. During a gait cycle, the WalkAide stimulates the common peroneal nerve, which innervates the tibialis anterior and other muscles that produce dorsiflexion of the ankle. The WalkAide is designed to offer persons with foot drop increased mobility, functionality and independence. It was cleared by the FDA through the 510(k) process. However, there is currently insufficient evidence to support its use for foot drop and other indications. Prospective clinical studies of the WalkAide device are necessary to evaluate whether it improves function and reduces disability compared to standard bracing in persons with foot drop.

Sheffler and associates (2007) reported the findings of peroneal nerve stimulation in patients with hemiplegia. Two chronic stroke survivors who utilized an ankle foot orthosis (AFO) prior to study entry were evaluated at baseline and after 4 weeks of daily use of a surface peroneal nerve stimulator. Participants were assessed without their dorsiflexor assistive device, using the modified Emory Functional Ambulation Profile (mEFAP). The participants demonstrated improvement in all 5 components of the mEFAP relative to baseline. These case reports indicated that enhanced functional ambulation may be an important therapeutic effect of peroneal nerve stimulation. The authors stated that controlled trials are needed to demonstrate a cause-and-effect relationship.

Sheffler et al (2006) found equivalent effects of a transcutaneous peroneal nerve stimulator and an ankle foot orthosis in improving functional ambulation in persons with chronic stroke. The investigators compared the efficacy of the Odstock Dropped-Foot Stimulator (ODFS), a transcutaneous peroneal nerve stimulation device, versus an ankle foot orthosis (AFO) in improving functional ambulation of
chronic stroke survivors. Fourteen chronic stroke survivors with foot-drop participated in the study. Participants received ambulation training under 3 test conditions: 1) ODFS, 2) customized AFO, and 3) no device. Each participant was evaluated using the modified Emory Functional Ambulation Profile under the 3 test conditions. All participants were evaluated with a post-evaluation survey to solicit device feedback and preferences. Functional ambulation with the AFO was significantly improved, relative to no device, on the floor ($P = 0.000$), carpet ($P = 0.013$), and "up and go" test ($P = 0.042$). There was a trend toward significance on the obstacle ($P = 0.092$) and stair ($P = 0.067$) trials. Functional ambulation with the ODFS was significantly improved, relative to no device, on the carpet($P = 0.004$). A trend toward significance on floor ($P = 0.081$), obstacle ($P = 0.092$), and stair ($P = 0.079$) trials was observed. The difference in functional ambulation between the AFO and ODFS showed a trend toward statistical significance on floor ($P = 0.065$) and up and go ($P = 0.082$) trials only. Given a choice between the ODFS and AFO for long-term correction of footdrop, participants indicated a preference for the ODFS. The authors concluded that the AFO and the ODFS may be comparable in their effect on improving functional ambulation as compared to no device. Specific characteristics of the ODFS may make it a preferred intervention by stroke survivors. The authors stated that more rigorously controlled trials are needed to confirm these findings.

A randomized controlled study found no therapeutic effect of an implanted peroneal functional electrical stimulator in patients with chronic stroke and foot drop. In a randomized controlled study, Kottink and colleagues (2008) examined the effect of an implantable peroneal nerve stimulator for 6 months versus an AFO in patients with chronic stroke and foot drop ($n = 29$). The mean time from stroke was 7.3 years (SD = 7.3), and all subjects were community ambulators. The FES group received the implantable stimulation system for correction of their foot drop. The control group continued using their conventional walking device (i.e., AFO, orthopedic shoes, or no walking device). All subjects were measured at baseline and at 4, 8, 12, and 26 weeks in the gait laboratory. The therapeutic effect of FES on the maximum value of the root mean square (RMSmax) of the tibialis anterior (TA) muscle with both flexed and extended knees and walking speed were selected as the primary outcome measures. The RMSmax of the peroneus longus (PL), gastrocnemius (GS), and soleus (SL) muscles with both flexed and extended knees and muscle activity of the TA muscle of the affected leg during the swing phase of gait were selected as secondary outcome measures. A significantly higher RMSmax of the TA muscle with extended knee was found after using FES. No change in walking speed was found when the stimulator was not switched on. A significantly increased RMSmax of the GS muscle with both flexed and extended knees was found after using FES. The authors concluded that functionally, no therapeutic effect of implantable peroneal nerve stimulation was found. However, the significantly increased voluntary muscle output of the TA and GS muscles after the use of FES suggested that there was a certain extent of plasticity in the subjects in this study.

In a randomized trial, Barrett et al (2009) found that exercise provided a greater effect on waking speed and endurance than functional electrical stimulation for people with multiple sclerosis and dropped foot. This two-group randomized trial assessed the effects of single channel common peroneal nerve stimulation on objective aspects of gait relative to exercise therapy for people with secondary progressive multiple sclerosis (SPMS). Forty-four people with a diagnosis of SPMS and unilateral dropped foot completed the trial. Twenty patients were randomly allocated to a group receiving FES and the remaining 24 to a group receiving a physiotherapy home exercise program for a period of 18 weeks. The exercise group showed a statistically significant increase in 10 m walking speed and distance walked in 3 min, relative to the FES group who showed no significant change in walking performance without stimulation. At each stage of the trial, the FES group performed to a significantly higher level with FES than without for the same outcome measures. The investigators concluded that exercise may provide a greater training effect on walking speed and endurance than FES for people with SPMS. FES may provide an orthotic benefit when outcome is measured using the same parameters. The authors stated that more research is required to investigate the combined therapeutic effects of FES and exercise for this patient group.

The NESS L300 Plus is the NESS L300 with a thigh cuff, which supposedly would provide added stability. According to Bioness, the L300 Plus System may help patients develop an even greater sense
of confidence and allow them to enjoy a variety of daily activities. The BioNESS L300 is a wireless electrical stimulation (ES) unit, used to provide peroneal nerve stimulation to promote ankle dorsiflexion after ‘toe off’ and during the swing phase of gait. The system is used to support functional gait in acute and sub acute stroke patients who demonstrate foot drop as a result of first time stroke.

A Queensland Health Technology Assessment team’s Due Diligence (Queensland, 2012) found there is little evidence to suggest that there are major safety concerns related to BioNESS L300, although the long term effects of chronic use of external electrical stimulation devices is unknown. Studies have focused on the use of peroneal nerve stimulation in post-stroke rehabilitation. There were limited available studies that directly compared the new technology with physiotherapist manipulation. The studies that were available were generally not of high quality and often had little statistical power due to small numbers of participants. Of the literature that was assessed, the outcomes were, on the whole more positive than negative. Many studies suggested that more research should be undertaken on larger patient groups to further assess the intervention.

Hausdorff and Ring (2008) reported improved gait and dynamic stability in study of 24 patients experiencing foot drop with chronic hemiparesis. Patients were treated on an outpatient basis with the NESS L300.

van Swigchem et al (2010) evaluated whether community-dwelling chronic stroke patients wearing an ankle-foot orthosis would benefit from changing to FES for the peroneal nerve. Twenty-six patients began wearing the NESS L300. A baseline walking speed was recorded with the original ankle-foot orthosis. Walking speed was also measured at 2 and 8 weeks with both the orthosis and FES. Patients’ satisfaction was assessed with a questionnaire at baseline and at week 8. Results showed patients were more satisfied after the addition of FES. However, measurements of walking speed and physical activity could not objectify the reported benefits of FES. The authors noted additional outcome measures are needed to quantify the FES benefits in this population.

Danino et al (2013) discussed results of 5 hemiplegic patients treated with FES NESS L300 to improve gait. Results found all scores improved when walking with stimulation. However, no significant improvements were noted. At the 1-year follow-up, all patients expressed high satisfaction.

A randomized controlled trial found equivalent improvements with a Bioness L300 foot-drop stimulator and a conventional ankle-foot orthosis for post-stroke rehabilitation (Kluding et al, 2013). Drop foot after stroke may be addressed using an ankle foot orthosis (AFO) or a foot drop stimulator (FDS). The Functional Ambulation: Standard Treatment versus Electric Stimulation Therapy (FASTEST) trial was a multicenter, randomized, single-blinded trial comparing FDS and AFO for drop foot among people ≥ 3 months after stroke with gait speed ≤ 0.8 m/s. Participants (n=197; 79 females and 118 males; 61.14 ± 11.61 years of age; time after stroke 4.55 ± 4.72 years) were randomized to 30 weeks of either FDS or a standard AFO. Eight dose-matched physical therapy sessions were provided to both groups during the first 6 weeks of the trial. There was significant improvement within both groups from baseline to 30 weeks in comfortable gait speed (95% confidence interval for mean change, 0.11-0.17 m/s for FDS and 0.12-0.18 m/s for AFO) and fast gait speed. However, no significant differences in gait speed were found in the between-group comparisons. Secondary outcomes (standard measures of body structure and function, activity, and participation) improved significantly in both groups, whereas user satisfaction was significantly higher in the FDS group than in the control group. The investigators concluded that, using either an FDS or an AFO for 30 weeks yielded clinically and statistically significant improvements in gait speed and other functional outcomes. User satisfaction was higher in the FDS group. Although both groups did receive intervention, this large clinical trial provides evidence that FDS or AFO with initial physical therapy sessions can provide a significant and clinically meaningful benefit even years after stroke.

In a randomized controlled trial, Everaert et al (2013) found that a Walkaide (WA) foot-drop stimulator and a conventional ankle-foot orthosis (AFO) produced equivalent functional gains in walking performance. Individuals with stroke within the previous 12 months and residual foot drop were enrolled in a multicenter, randomized controlled, crossover trial. Subjects were assigned to 1 of 3 parallel arms
for 12 weeks (6 weeks/device): arm 1 (WA-AFO), n = 38; arm 2 (AFO-WA), n = 31; arm 3 (AFO-AFO), n = 24. Primary outcomes were walking speed and Physiological Cost Index for the Figure-of-8 walking test. Secondary measures included 10-m walking speed and perceived safety during this test, general mobility, and device preference for arms 1 and 2 for continued use. Walking tests were performed with (On) and without a device (Off) at 0, 3, 6, 9, and 12 weeks. Both WA and AFO had significant orthotic (On-Off difference), therapeutic (change over time when Off), and combined (change over time On vs baseline Off) effects on walking speed. An AFO also had a significant orthotic effect on Physiological Cost Index. The WA had a higher, but not significantly different therapeutic effect on speed than an AFO, whereas an AFO had a greater orthotic effect than the WA (significant at 12 weeks). Combined effects on speed after 6 weeks did not differ between devices. Users felt as safe with the WA as with an AFO, but significantly more users preferred the WA. The investigators concluded that both the WA and AFO produce equivalent functional gains.

A randomized controlled trial found equivalent results with a Walkaide and an ankle foot orthosis in individuals with post-stroke foot drop (Bethoux et al, 2014). In a multi-center RCT, Bethoux et al (2014) compared changes in gait and quality of life between FES and an AFO in individuals with foot drop post-stroke. A total of 495 Medicare-eligible individuals at least 6 months post-stroke wore FES or an AFO for 6 months were included in this study. Primary end-points were 10-meter walk test (10MWT), a composite of the mobility, activities of daily living/instrumental activities of daily living, and social participation subscores on the Stroke Impact Scale (SIS), and device-related serious adverse event rate. Secondary end-points included 6-minute walk test, GaitRite functional ambulation profile (FAP), modified Emory functional ambulation profile (mEFAP), Berg balance scale (BBS), Timed Up and Go, individual SIS domains, and Stroke-Specific Quality of Life measures. Multiply imputed intention-to-treat analyses were used with primary end-points tested for non-inferiority and secondary endpoints tested for superiority. A total of 399 subjects completed the study. Functional electrical stimulation proved non-inferior to the AFO for all primary end-points. Both the FES and AFO groups improved significantly on the 10MWT. Within the FES group, significant improvements were found for SIS composite score, total mFEAP score, individual Floor and Obstacle course time scores of the mEFAP, FAP, and BBS, but again, no between-group differences were found. The authors concluded that use of FES is equivalent to the AFO. They stated that further studies should examine whether FES enables better performance in tasks involving functional mobility, activities of daily living, and balance.

Meilahn (2013) evaluated the tolerability and effectiveness of the WalkAide neuroprosthesis in a small observational study of 10 children (7 to 12 years old) with hemiparetic CP who used an AFO for correction of foot drop. The children tolerated the fitting and wore the device for the first 6 weeks. The mean wear time was 8.4 hours per day in the first 3 weeks and 5.8 hours per day in the next 3 weeks. Seven children (70 %) wore the device for the 3-month study period, with average use of 2.3 hours daily (range of 1.0 to 6.3 hours/day). Six children (60 %) continued to use the WalkAide device after study completion. Gait analysis was performed, but quantitative results were not included in the report. Although 50 % of the children were reported to have improved gait velocity, mean velocity was relatively unchanged with the WalkAide device. The main drawbacks of this study were the small sample size and self-selection of study subjects based on their willingness to try the device.

A study by Damiano et al (2013) found increases in muscle thickness with use of the WalkAide device, but no permanent improvements in voluntary ankle control. The primary goal of this study was to determine whether repetitive FES (WalkAide) for unilateral foot drop increases TA muscle size compared with an untreated baseline and the contralateral side in children with CP. Secondary goals were to determine whether positive changes in muscle size and gait, if found, accumulated during the 3 intervals during which participants used the device. Of 21 participants selected for the study, 7 were excluded because they either did not complete the entire 10-month study (n = 5) or had poor or missing ultrasound data for 1 or more time-points. The analysis was based upon the 14 remaining participants. Participants were independent ambulators with inadequate dorsiflexion in swing, with a mean age of 13.1 years, evaluated before and after the 3-month baseline, 1-month device accommodation, 3-month primary intervention, and 3-month follow-up phases. The FES device (WalkAide) stimulated the common tibial nerve to dorsiflex the ankle and evert the foot; TA muscle ultrasound, gait velocity, and
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ankle kinematic data for barefoot and device conditions were reported. The authors reported that ultrasound measures of TA anatomic cross-sectional area and muscle thickness increased with the WalkAide compared with the contralateral untreated side. Maximum ankle dorsiflexion decreased at baseline but improved or was maintained during the intervention phase with and without the WalkAide, respectively. Muscle size gains were preserved at follow-up, but barefoot ankle motion returned to baseline values. The authors concluded that the WalkAide device produced evidence of use-dependent muscle plasticity in children with CP, but that permanent improvements in voluntary ankle control after use of the WalkAide were not demonstrated.

In a pilot study, Miller et al (2015) compared the immediate orthotic effect on walking of 2 different devices: (i) the Odstock Dropped Foot Stimulator (ODFS) and (ii) WalkAide (WA). A total of 20 people with multiple sclerosis (pwMS) (10 females, 10 males, mean age of 50.4 ± 7.3 years) currently using ODFS were recruited. Participants walked for 5 minutes around an elliptical 9.5-m course at their preferred walking speed; once with ODFS, once with WA and once without FES on the same day of testing. Gait speed, distance and energy cost were measured. There was a statistically significant increase in walking speed for the ODFS (p = 0.043) and a near to significant increase for the WA (p = 0.06) in comparison to without FES. There were no differences between the ODFS and WA in terms of either walking speed (p = 0.596) or energy cost (p = 0.205). The authors concluded that this was the first study to compare the effects of 2 different FES devices on walking. They stated that further research recruiting a larger cohort of FES naive participants is needed. Implications for rehabilitation FES used for foot drop in MS is effective in improving the speed of walking. The Odstock Dropped Foot Stimulator and the WalkAide have similar orthotic effects on the speed and energy cost of walking in people with MS. They stated that further research is needed to compare FES devices, recruiting treatment of naive participants for a fully powered RCT. The authors noted a number of limitations of this study. Subjects were tested for 5 minutes, so that participants in the study only had limited time to adapt to the different modes. This limitation in the study design could have biased the results in favor of ODFS. Bias may also have resulted from an inability to blind participants and investigators to the devices being administered, particularly where a “new device” is being introduced. The authors stated that future studies comparing FES devices should aim to recruit larger number of subjects naive to FES, evaluating the effect over a longer time frame.

Functional electrical stimulation has been used to correct drop foot following stroke or multiple sclerosis; however, previous studies have shown that a significant minority have difficulty identifying correct sites to place the electrodes in order to produce acceptable foot movement. Recently there has been some interest in the use of “virtual electrodes”, the process of stimulating a subset of electrodes chosen from an array, thus allowing the site of stimulation to be moved electronically rather than physically. Prenton et al (2014) examined the feasibility of unsupervised community use of an array-based automated setup (AS) FES system for foot-drop (ShefStim). Participants' gait, total setup (TS) times and satisfaction were evaluated twice in the gait laboratory. Usage, AS times and problems encountered were recorded during a 2-week period of unsupervised use. Participants (n = 7) with diagnosis of unilateral foot-drop of central neurological origin (greater than 6 months), who were regular users of a foot-drop FES system (greater than 3 months). Main outcome measures included logged usage; TS times for both FES systems and logged AS times for the array-based AS FES system; diary recording of problems experienced; Quebec User Evaluation of Satisfaction with assistive Technology (QUEST 2.0) questionnaire; walking speed; ankle angles at initial contact and foot clearance during swing. All participants were able to use the array-based AS FES system. Total setup took longer with it than participants' own FES systems and AS was longer than in a previous study of a similar system. Some problems were experienced but overall participants were as satisfied with this system as their own FES systems. The increase in walking speed (n = 7), relative to no stimulation, was comparable between both systems and appropriate ankle angles at initial contact (n = 7) and foot clearance during swing (n = 5) were greater with the array-based AS FES system. The authors concluded that this study demonstrated, for the first time, that an array-based AS FES system for foot-drop can be successfully used unsupervised. Despite setup taking longer and some problems users are satisfied with it and it would appear as effective, if not better, at addressing the foot-drop impairment. Moreover, they stated that further product development of this unique system, followed by a larger-scale and longer-term study.
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is needed before firm conclusions about its effectiveness can be reached.

In an acute, open-labelled comparative observation trial, Scott et al (2013) examined if the application of FES improves gait kinematics and walking ability in people with MS who experience foot-drop. A total of 12 patients (3 females and 9 males, EDSS 2-4) with relapsing remitting multiple sclerosis (RRMS; 47.8 years (S.D. 6.6)) who were new users of FES were included in this study. Gait kinematics was recorded using 3D gait analysis. Walking ability was assessed through the 10-m walk test and the 6-min walk test. All assessments were performed with and without the assistance of FES. The effect of FES was analyzed using paired t-tests. Ankle dorsiflexion at initial contact (p = 0.026), knee flexion at initial contact (p = 0.044) and peak knee flexion during swing (p = 0.011) were significantly greater while walking with FES. The increased peak dorsiflexion in swing of nearly 4 degrees during FES-assisted walking approached significance (p = 0.069). The 10-m walk time was significantly improved by FES (p = 0.004); but the 6-min walk test was not. The authors concluded that the acute application of FES resulted in an orthotic effect through a change in ankle and knee kinematics and increased walking speed over a short distance in people with MS who experienced foot-drop. They stated that “The study is limited by the small sample size, and the large standard deviations of the outcome measures indicating a substantial variation among the participants in both walking pattern and performance. However, the study was sufficiently powered to detect statistically significant differences in both gait kinematics and walking performance between the no FES and FES conditions at group level. Future studies are required to evaluate whether the benefit of FES depends on patient characteristics such as type and progression of MS, neuromuscular properties and gait pattern”. They noted that “Further appropriately powered long-term studies into the effects of prolonged use of FES on the gait kinematics of people with MS are required in order to explain the altered gait mechanisms, which result in the long-term orthotic effects in people with MS”.

In a feasibility study, Taylor et al (2014) examined the effect of FES for dropped foot and hip instability in combination with physiotherapy core stability exercises. A total of 28 patients with secondary progressive MS and unilateral dropped foot participated in a randomized cross-over trial. Group 1 received FES for correction of dropped foot for 6 weeks with the addition of hip extension for a further 6 weeks. In weeks 12 to 18, FES was continued with the addition of 8 sessions of core stability physiotherapy with home-based exercise. Functional electrical stimulation and home-based exercise were continued until weeks 19 to 24. Group 2 received the same physiotherapy intervention over the first 12 weeks, adding FES in the second 12 weeks. Functional electrical stimulation improved walking speed and Rivermead Observational Gait Analysis (ROGA) score, whereas physiotherapy did not. Adding gluteal stimulation further improved ROGA score. Both interventions reduced falls, but adding FES to physiotherapy reduced them further. Functional electrical stimulation had greater impact on Multiple Sclerosis Impact Scale, MSIS-29. The authors concluded that the intervention was feasible; FES for dropped foot may improve mobility and quality of life and may reduce falls. Adding gluteal stimulation further improved gait quality. Adding physiotherapy may have enhanced the effect of FES, but FES had the dominant effect. This was a small (n = 28) feasibility study. The authors noted that “A possible confounding effect on this study was the comparability of Groups 1 and 2. While there was not a significance difference in EDSS between groups at recruitment, there was a greater use of assistive devices by Group 2, suggesting that they may have had a greater degree of disability. However, no correlation could be found between EDSS score and either change in ROGA or walking speed at week 24, suggesting that this discrepancy between the groups did not influence the trial results. There is further need for caution in the interpretation of the results of this study due to the small sample size. The study was not powered to produce definitive results”.

In a case-series study, Street et al (2015) determined the effectiveness of FES on foot-drop in patients with MS using data from standard clinical practice. A total of 187 patients (117 females and 70 males, mean number of years since diagnosis 11.7, range of years 1 to 56, age range of 27 to 80, average age of 55 years) with MS who have foot-drop were included in this study; 166 were still using FES after 20 weeks with 153 patients completing the follow-up measures. Intervention was FES of the common peroneal nerve (178 unilateral, 9 bilateral FES users). Outcome measures were clinically meaningful changes (i.e., greater than 0.05 ms-1 and greater than 0.1ms-1) and functional walking category derived...
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from 10-meter walking speed. An increase in walking speed was found to be highly significant (p < 0.001), both initially where a minimum clinically meaningful change was observed (0.07 ms-1) and after 20 weeks with a substantially clinically meaningful change (0.11 ms-1). After 20 weeks treatment responders displayed a 27% average improvement in their walking speed. No significant training effect was found. Overall functional walking category was maintained or improved in 95% of treatment responders. The authors concluded that FES of the dorsiflexors is a well-accepted intervention that enables clinically meaningful changes in walking speed leading to preserved or increased functional walking category. The main drawbacks of this study were the lack of randomization and a control group. The authors also noted that “A further limitation is that the values for a clinically meaningful change in walking speed were derived from a general elderly population. Furthermore, the functional walking categories derived by Perry were from stroke survivors. The cohort from the current study was generally younger and had a disability specific to MS that may have been more profound than that of a general elderly or stroke population. This may suggest that a threshold for a clinically meaningful change may be overestimated in a more disabled population. The final sample consisted of 70% of those assessed for eligibility, providing an indication of the proportion of patients with MS that the findings may be applied to. Further research using appropriate outcome measures could be used to assess the degree of benefit that patients, who are unable to complete the 10-m walking protocol at baseline, may gain from FES as they progress with their treatment”.

In a systematic review and meta-analysis, Miller and colleagues (2017) reviewed the effectiveness of FES used for foot drop in people with MS on gait speed in short and long walking performance tests. A total of 5 databases (Cochrane Library, CINAHL, Embase, Medline, and PubMed) and reference lists were searched. Studies of both observational and experimental design where gait speed data in patients with MS could be extracted were included. Data were independently extracted and recorded; methodological quality was assessed using the Effective Public Health Practice Project tool. A total of 19 studies (described in 20 articles) recruiting 490 patients with MS were identified and rated as moderate or weak, with none gaining a strong rating. All studies rated weak for blinding. Initial and ongoing orthotic and therapeutic effects were assessed regarding the effect of FES on gait speed in short and long walking tests. Meta-analyses of the short walk tests revealed a significant initial orthotic effect (t = 2.14, p = 0.016), with a mean increase in gait speed of 0.05 m/s, and ongoing orthotic effect (t = 2.81, p = 0.003), with a mean increase of 0.08 m/s. There were no initial or ongoing effects on gait speed in long walk tests and no therapeutic effect on gait speed in either short or long walk tests. The authors concluded that FES used for foot drop has a positive initial and ongoing effect on gait speed in short walking tests. Moreover, they stated that further fully powered RCTs comparing FES with alternative treatments are needed.

Diabetic Neuropathy:

The American Association of Neuromuscular and Electrodiagnostic Medicine, the American Academy of Neurology, and the American Academy of Physical Medicine & Rehabilitation (Bril et al, 2011) developed a scientifically sound and clinically relevant evidence-based guideline for the treatment of painful diabetic neuropathy (PDN). The basic question that was asked was: “What is the efficacy of a given treatment (pharmacological: anticonvulsants, antidepressants, opioids, others; non-pharmacological: electrical stimulation, magnetic field treatment, low-intensity laser treatment, Reiki massage, others) to reduce pain and improve physical function and quality of life (QOL) in patients with PDN”? A systematic review of literature from 1960 to August 2008 was performed, and studies were classified according to the American Academy of Neurology classification of evidence scheme for a therapeutic article. Recommendations were linked to the strength of the evidence. The results indicated that pregabalin is established as effective and should be offered for relief of PDN (Level A). Venlafaxine, duloxetine, amitriptyline, gabapentin, valproate, opioids (morphine sulfate, tramadol, and oxycodone controlled-release), and capsaicin are probably effective and should be considered for treatment of PDN (Level B). Other treatments have less robust evidence, or the evidence is negative. Effective treatments for PDN are available, but many have side effects that limit their usefulness. Few studies have sufficient information on their effects on function and QOL.
Functional Electrical Stimulation/Neuromuscular Electrical Stimulation for Ambulatory Function in Patients with Multiple Sclerosis:

In a case-series study, Wahls et al (2010) examined if NMES would improve gait disability in patients with secondary progressive multiple sclerosis (SPMS) or primary progressive multiple sclerosis (PPMS). Participants were treated using NMES coupled with a home-exercise program (HEP) to treat MS-related gait disability. Between June 2007 and June 2009, a licensed physical therapist used NMES coupled with a HEP to work with patients who had SPMS/PPMS and MS-related gait disability. All of the cases in which an NMES test session of NMES was conducted were included in the case series. Data regarding MS symptoms, treatment, gait, and function were abstracted from the PT clinic notes. Results of assessment with the expanded Kurtzke Disability Status Scale (EDSS) at presentation and at most recent visit were abstracted from the clinical record by the treating physical therapist. A total of 9 patients (7 with SPMS and 2 with PPMS) met inclusion criteria for review. Mean of years of diagnosis was 10.4 (range of 4 to 15), and mean EDSS score at presentation was 5.9 (range of 4.5 to 6.5). Mean of days of NMES was 140 (range of 22 to 495). Mean EDSS scores improved by 0.78 (range of 0 to 2.0). The authors concluded that NMES was associated with measurable gains in ambulatory function in patients with gait disability associated with SPMS and PPMS. Moreover, they stated that additional studies are needed.

In a systematic review, Springer and colleagues (2017) evaluated the literature describing the orthotic and therapeutic effects of FES on gait in patients with MS. The PubMed, CINAHL, and ProQuest databases were searched. Included were studies that evaluated therapeutic and/or orthotic effects of FES in patients with MS with at least 1 outcome measure related to gait. Methodology was assessed using the Downs and Black checklist. A total of 12 relevant studies were reviewed; their methodological quality ranged from 14 to 21 of 28; 11 studies reported the effects of peroneal stimulation. Most found a significant orthotic effect (measured during stimulation), mainly on walking speed. Only 3 assessed the therapeutic effect (carry-over), which was not significant. The authors concluded that the evidence presented in this review suggested that FES has a positive orthotic effect on walking in patients with MS. Yet, more robust clinical trials are needed to substantiate this finding. They stated that therapeutic effectiveness of FES was not demonstrated, and almost all studies tested a single channel peroneal stimulator; future studies involving FES technological innovations with advanced clinical approaches might contribute to a carry-over effect from FES and increase the percentage of patients with MS who might benefit from this technology.

Neuromuscular Electrical Stimulation for Knee Osteoarthritis:

Giggins et al (2012) evaluated the effectiveness of surface NMES in the treatment of knee osteoarthritis. A systematic review and meta-analysis of RCTs and controlled clinical trials was performed. Studies were identified from databases (MEDLINE, EMBASE, CINAHL, Sports Discus, PEDro and the Cochrane Library) searched to January 2011 using a battery of keywords. Two reviewers selected studies meeting inclusion criteria. The methodological quality of the included studies was assessed using the Thomas Test and the strength of the evidence was then graded using the Agency for Health Care Policy and Research guidelines. Data were pooled and meta-analyses were performed. A total of 9 RCTs and 1 controlled clinical trial, studying a total of 409 participants (n = 395 for RCTs, and n = 14 for controlled trial) with a diagnosis of osteoarthritis were included. Inconsistent evidence (level D) was found that NMES has a significant impact on measures of pain, function and quadriceps femoris muscle strength in knee osteoarthritis. The authors concluded that the role of NMES in the treatment of knee osteoarthritis is ambiguous. Thus, future work is needed in this field to clearly establish the role of NMES in this population.

Threshold Electrical Stimulation:

Threshold electrical stimulation (also known as therapeutic electrical stimulation) entails the use of of low-intensity ES, usually at night. For patients with CP, threshold electrical stimulation (TES) aims to (i) strengthen muscles weakened by non-use and (ii) to increase joint mobility, thus, resulting in improved
voluntary motor function.

In a randomized, controlled, cross-over trial, Sommerfelt et al (2001) evaluated the effect of TES applied to antagonists of spastic leg muscles on gross motor function in children with spastic diplegic CP. A total of 12 children between 5 and 12 years of age completed a 24-month cross-over study in which 6 were randomly assigned to receive TES for the first 12 months and the remaining 6 for the last 12 months. Physiotherapy and a home training program were not altered. All were evaluated blindly in terms of tests of motor function and video recordings at the start and at 12 and 24 months. At the end of the study parents/carers gave a subjective assessment of the effect of TES. No significant effect of TES on motor or ambulatory function was found on the blinded evaluation, but parents of 11 of the 12 children stated that TES had a significant effect. The authors concluded that it is unlikely that TES has a significant effect on motor and ambulatory function in children with spastic diplegia CP.

In a randomized, double-blind, placebo-controlled clinical trial, Dali et al (2002) studied whether a group of stable children with CP (36 boys, 21 girls; mean age of 10 years 11 months with a range of 5 to 18 years) would improve their motor skills after 12 months of TES; 2/3 received active and 1/3 received inactive stimulators. The primary outcome was change in summary indices of the performance measurements in a set of motor function tests. Tests were videotaped and assessed blindly to record qualitative changes that might not be reflected in performance measurements. Fifty-seven of 82 subjects who were able to walk at least with a walker, completed all 12 months of treatment (hemiplegia n = 25; diplegia n = 32). There was no significant difference between active and placebo treatment in any of the tested groups, nor combined. Visual and subjective assessments favored TES (non-significant), whereas objective indices showed the opposite trend. The authors concluded that TES in these patients did not have any significant clinical effect during the test period.

In a randomized placebo-controlled study, Kerr et al (2006) examined the effectiveness of NMES and TES in strengthening the quadriceps muscles of both legs in children with CP. A total of 60 children (38 males, 22 females; mean age of 11 years [SD 3 years 6 months]; age range of 5 to 16 years) were randomized to one of the following groups: NMES (n = 18), TES (n = 20), or placebo (n = 22). Clinical presentations were diplegia (n = 55), quadriplegia (n = 1), dystonia (n = 1), ataxia (n = 1), and non-classifiable CP (n = 2). Thirty-four children walked unaided, 17 used posterior walkers, 6 used crutches, and the remaining 3 used sticks for mobility. Peak torque of the left and right quadriceps muscles, gross motor function, and impact of disability were assessed at baseline and end of treatment (16 weeks), and at a 6-week follow-up visit. No statistically significant difference was demonstrated between NMES or TES versus placebo for strength or function. Statistically significant differences were observed between NMES and TES versus placebo for impact of disability at the end of treatment, but only between TES and placebo at the 6-week follow-up. The authors concluded that further evidence is needed to show whether NMES and/or TES may be useful as an adjunct to therapy in ambulatory children with diplegia who find resistive strengthening programs difficult.

In a systematic review with meta-analysis of randomized trials, Scianni et al (2009) examined if strengthening interventions increase strength without increasing spasticity and improve activity, and if there is there any carry-over after cessation in children and adolescents with CP? Children with spastic CP between school age and 20 years were included in this analysis. Strengthening interventions involved repetitive, strong, or effortful muscle contractions and progressed as ability changed; and they included biofeedback, ES, and progressive resistance exercise. Strength was measured as continuous measures of maximum voluntary force or torque production. Spasticity was measured as velocity-dependent resistance to passive stretch. Activity was measured as continuous measures, e.g., 10-m Walk Test, or using scales e.g., the Gross Motor Function Measure. A total of 6 studies were identified and 5 had data that could be included in a meta-analysis. Strengthening interventions had no effect on strength (standardized mean difference [SMD] 0.20, 95 % CI: -0.17 to 0.56), no effect on walking speed (MD 0.02 m/s, 95 % CI: -0.13 to 0.16), and had a small statistically-significant but not clinically-worthwhile effect on Gross Motor Function Measure (MD 2 %, 95 % CI: 0 to 4). Only 1 study measured spasticity but did not report the between-group analysis. The authors concluded that in children and adolescents with CP who are walking, the current evidence suggests that strengthening interventions
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are neither effective nor worthwhile.

Cauraugh et al (2010) performed a systematic review and meta-analysis using the International Classification of Functioning to determine the summary effect of ES on impairment and activity limitations relevant to gait problems of children with CP. These researchers identified 40 CP and ES studies, and 17 gait studies qualified for inclusion. Applying enablement classification methods to walking abnormalities created 2 subgroups: impairment (n = 14) and activity limitations (n = 15). Overall, 238 subjects experienced ES treatments and 224 served as a no stimulation control group. Calculations followed conventional data extraction and meta-analysis techniques: (a) individual standardized mean differences, (b) summary effect size, (c) I² heterogeneity test, (d) fail-safe N analysis and (e) moderator variable analyses. The authors cited reservation about recommending ES as an effective intervention for individuals with CP. Outside of the laboratory-testing experiments, "no quantitative, functional immediate or longitudinal effects beyond the testing situations were reported in the studies. Thus, long-term effects of various types of electrical stimulation on gait challenges in children with cerebral palsy would advance our understanding".

Negm et al (2013) examined if low frequency (less than or equal to 100 Hz) pulsed subsensory TES produced either through pulsed electro-magnetic field (PEMF) or pulsed electrical stimulation (PES) versus sham PEMF/PES intervention is effective in improving pain and physical function at treatment completion in adults with knee osteoarthritis (OA) blinded to treatment. The relevant studies were identified by searching 8 electronic databases and hand search of the past systematic reviews on the same topic till April 5, 2012. These investigators included RCTs of people with knee OA comparing the outcomes of interest for those receiving PEMF/PES with those receiving sham PEMF/PES. Two reviewers independently selected studies, extracted relevant data and assessed quality. Pooled analyses were conducted using inverse-variance random effects models and standardized mean difference (SMD) for the primary outcomes. A total of 7 small trials (459 participants/knees) were included. PEMF/PES improves physical function (SMD = 0.22, 95 % CI: 0.04 to 0.41, p = 0.02, I(2) = 0 %), and does not reduce pain (SMD = 0.08, 95 % CI: -0.17 to 0.32, p = 0.55, I(2) = 43 %). The strength of the body of evidence was low for physical function and very low for pain. The authors concluded that current evidence of low and very low quality suggested that low frequency (less than or equal to 100 Hz) pulsed subsensory TES produced either through PEMF/PES versus sham PEMF/PES is effective in improving physical function but not pain intensity at treatment completion in adults with knee OA blinded to treatment. Moreover, they noted that methodologically rigorous and adequately powered RCTs are needed to confirm these findings.

Improvement of Ambulatory Function/Muscle Weakness in Individuals with Progressive Diseases:

Pereira et al (2012) conducted a systematic review on the effectiveness of FES in improving lower extremity function in chronic stroke. Multiple databases (PubMed, CINAHL, EMBASE, and Scopus) were searched for relevant articles. Studies were included for review if (i) greater than or equal to 50 % of the study population has sustained a stroke, (ii) the study design was a RCT, (iii) the mean time since stroke was greater than or equal to 6 months, (iv) FES or NMES was compared to other interventions or a control group, and (v) functional lower extremity outcomes were assessed. Methodological quality was assessed using the PEDro tool. A standardized mean difference (SMD ± SE and 95 % CI) was calculated for the 6-min walk test (6MWT). Pooled analysis was conducted for treatment effect of FES on the 6MWT distance using a fixed effects model. A total of 7 RCTs (PEDro scores 5 to 7) including a pooled sample size of 231 participants met inclusion criteria. Pooled analysis revealed a small but significant treatment effect of FES (0.379 ± 0.152; 95 % CI: 0.081 to 0.677; p = 0.013) on 6MWT distance. The authors concluded that FES may be an effective intervention in the chronic phase post-stroke. However, its therapeutic value in improving lower extremity function and superiority over other gait training approaches remains unclear.

In a Cochrane review, Maddocks et al (2013) evaluated the effectiveness of NMES for improving muscle strength in adults with advanced disease. The secondary objective of this study was to examine the
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acceptability and safety of NMES, and changes in muscle function (strength or endurance), muscle mass, exercise capacity, breathlessness and health-related quality of life. Studies were identified from searches of The Cochrane Library, MEDLINE, EMBASE, CINAHL and PsycINFO databases to July 2012, citation searches, conference proceedings and previous systematic reviews. These investigators included RCTs in adults with advanced chronic obstructive pulmonary disease (COPD), chronic heart failure, cancer or human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) comparing a program of NMES as a sole or adjunct intervention to no treatment, placebo NMES or an active control. They imposed no language restriction. Two review authors independently extracted data on study design, participants, interventions and outcomes. They assessed risk of bias using the Cochrane Collaboration's tool; and calculated mean differences (MD) or standardized mean differences (SMD) between intervention and control groups for outcomes with sufficient data; for other outcomes these researchers described findings from individual studies. A total of 11 studies involving 218 participants met the inclusion criteria across COPD, chronic heart failure and thoracic cancer. Neuromuscular ES significantly improved quadriceps strength by a SMD of 0.9 (95% CI: 0.33 to 1.46), equating to approximately 25 Newton meters (Nm) (95% CI: 9 to 41). Mean differences across various walking tests, favoring NMES, were 40 m (95% CI: -4 to 84) for the 6MWT, 69 m (95% CI: 19 to 119) for the incremental shuttle walk test and 160 m (95% CI: 34 to 287) for the endurance shuttle walk test. Limited evidence was available for the assessment of other secondary outcomes. The authors concluded that NMES appears an effective means of improving muscle weakness in adults with progressive diseases such as COPD, chronic heart failure and cancer. Moreover, they stated that further research is needed to clarify its place in clinical practice, by determining the optimal parameters for a NMES program, the patients most likely to benefit, and its impact on morbidity and service use.

Phrenic Nerve Stimulation for Central Sleep Apnea/Ventilator-Dependent Respiratory Failure:

In a prospective, multi-center, non-randomized study, Abraham and colleagues (2015) evaluated the safety and effectiveness of chronic, transvenous, unilateral phrenic nerve stimulation (PNS) in the treatment of central sleep apnea (CSA). A total of 57 patients with CSA underwent baseline polysomnography followed by transvenous PNS system implantation and follow-up. Feasibility was assessed by implantation success rate and therapy delivery. Safety was evaluated by monitoring of device- and procedure-related adverse events (AEs). Effectiveness was evaluated by changes in the apnea-hypopnea index (AHI) at 3 months. Quality of life at 6 months was evaluated using a sleepiness questionnaire, patient global assessment, and, in patients with heart failure (HF) at baseline, the Minnesota Living With Heart Failure Questionnaire. The study met its primary end-point, demonstrating a 55 % reduction in AHI from baseline to 3 months (49.5 ± 14.6 episodes/hour versus 22.4 ± 13.6 episodes/hour of sleep; p < 0.0001; 95% CI for change: -32.3 to -21.9). Central apnea index, oxygenation, and arousals significantly improved. Favorable effects on quality of life and sleepiness were noted. In patients with HF, the Minnesota Living With Heart Failure Questionnaire score significantly improved. Device- or procedure-related serious AEs occurred in 26 % of patients through 6 months post-therapy initiation, predominantly due to lead re-positioning early in the study. Therapy was well-tolerated. Effectiveness was maintained at 6 months. The authors concluded that transvenous, unilateral PNS appeared safe and effective for treating CSA. Moreover, they stated that these findings should be confirmed in a prospective RCT.

Costanzo and associates (2015) stated that the remede System (Respicardia, Minnetonka, MN) is a new physiologic treatment that uses transvenous PNS to contract the diaphragm, thereby stabilizing gas exchange and restoring normal breathing throughout the sleep period. This is a prospective multi-center randomized trial with blinded end-points evaluating the safety and effectiveness of the remede System. Up to 173 patients with CSA will be randomized 1:1 to remede System therapy initiated at 1 month after implantation (treatment) or to an implanted remede System that will remain inactive for 6 months (control). Primary effectiveness end-point is the percentage of patients who experience a reduction in AHI by a greater than or equal to 50 % at 6 months (responder analysis). Primary safety end-point is freedom from serious AEs through 12 months. Secondary end-points include sleep-disordered breathing parameters, sleep architecture, Epworth Sleepiness Scale score, and Patient Global
Assessment. The authors stated that this study is the first RCT of the safety and effectiveness of the Remede System for the treatment of CSA.

Zhang et al (2017) stated that CSA is common in patients with HF and is associated with poor quality of life and prognosis. Early acute studies using transvenous PNS to treat CSA in HF have shown a significantly reduction of CSA and improvement of key polysomnographic parameters. In a prospective, non-randomized study, these researchers evaluated the safety of and effectiveness of chronic transvenous PNS with an implanted neurostimulator in HF patients with CSA (n = 8). The stimulation lead, which connected to a proprietary neurostimulator, was positioned in either the left peri-cardiophrenic or right brachiocephalic vein. Monitoring during implantation and 6-monthly follow-ups were performed; 6 of the implanted 8 patients completed the study (1 was lost to follow-up; 1 died from pneumonia). Neither side effects nor AEs related to stimulation occurred. During the 6-monthly follow-ups, 1 patient had a lead dislodgement in the first month and the lead was subsequently re-positioned. No additional lead dislodgements occurred. There were no significant changes in sleep habits, appetite, bleeding or infections. Compared with the parameters before stimulator implantation, there were significant improvement in AHI, central apnea index, left ventricular ejection fraction and 6-min walk distance (all p < 0.01). The authors concluded that the use of chronic transvenous PNS appeared to be safe and feasible in HF patients with CSA. Moreover, they stated that large multi-center clinical trials are needed to confirm safety and effectiveness in this population.

Furthermore, an UpToDate review on “Central sleep apnea: Treatment” (Badr, 2015) does not mention phrenic nerve stimulation as a therapeutic option.

Jagielski and colleagues (2016) evaluated the 12-month clinical outcomes of patients with CSA treated with unilateral transvenous PNS in the prospective, multi-center, non-randomized Remede System pilot study. A total of 47 patients with CSA were treated with the Remede System for a minimum of 3 months. Sleep-disordered breathing parameters were evaluated by polysomnography (PSG) at 3, 6, and 12-month follow-up. Sleep symptoms and QOL were also evaluated; 41 patients completed all follow-up PSGs and were included in the analysis. At 12 months, there was sustained improvement compared with baseline in the AHI (49.9 ± 15.1 versus 27.5 ± 18.3 events/hour, p < 0.001) and central apnea index (28.2 ± 15.0 versus 6.0 ± 9.2 events/hour, p < 0.001). Sustained improvement in the oxygen desaturation index (46.1 ± 19.1 versus 26.9 ± 18.0 events/hour, p < 0.001), rapid eye movement (REM) sleep (11.4 ± 6.1 % versus 17.1 ± 8.0 %, p < 0.001), and sleep efficiency (69.3 ± 16.9 % versus 75.6 ± 17.1 %, p = 0.024) were also observed. There were also continued favorable effects on sleepiness and QOL; 3 deaths unrelated to Remede System therapy and 5 serious AEs occurred over 12 months of follow-up. The authors concluded that the findings of the present study demonstrated that in patients with CSA, unilateral transvenous PNS is associated with sustained improvement in key sleep parameters, sleep symptoms, and QOL over 12 months of follow-up.

In a prospective, multi-center, RCT, Costanzo and co-workers (2016) evaluated the safety and effectiveness of unilateral neurostimulation in patients with CSA. These investigators recruited patients from 31 hospital-based centers in Germany, Poland, and the USA. Participants had to have been medically stable for at least 30 days and have received appropriate guideline recommended therapy, be aged at least 18 years, be expected to tolerate study procedures, and willing and able to comply with study requirements. Eligible patients with an AHI of at least 20 events/hour, tested by PSG, underwent device implantation and were randomly assigned (1:1) by a computer-generated method stratified by site to either stimulation (treatment) or no stimulation (control) for 6 months. The primary effectiveness end-point in the intention-to-treat population was the comparison of the proportions of patients in the treatment versus control groups achieving a 50 % or greater AHI reduction from baseline to 6 months, measured by a full-night PSG assessed by masked investigators in a core laboratory. The primary safety end-point of 12-month freedom from serious AEs related to the procedure, system, or therapy was evaluated in all patients. Between April 17, 2013, and May 28, 2015, these researchers randomly assigned 151 eligible patients to the treatment (n = 73) or control (n = 78) groups. In the analysis of the intention-to-treat population, significantly more patients in the treatment group (35 [51 %] of 68) had an AHI reduction from baseline of 50 % or greater at 6 months than had those in the control group (8 [11 %])
of 73; difference between groups 41 %, 95 % CI: 25 to 54, p < 0.0001; 138 (91%) of 151 patients had no related-serious AEs at 12 months; 7 (9 %) cases of related-serious AEs occurred in the control group and 6 (8 %) cases were reported in the treatment group; 7 patients died (unrelated to implant, system, or therapy), 4 deaths (2 in treatment group and 2 in control group) during the 6-month randomization period when PNS was delivered to only the treatment group and was off in the control group, and 3 deaths between 6 months and 12 months of follow-up when all patients received neurostimulation; 27 (37 %) of 73 patients in the treatment group reported non-serious therapy-related discomfort that was resolved with simple system re-programming in 26 (36 %) patients, but was unresolved in 1 (1 %) patient. The authors concluded that transvenous PNS significantly reduced the severity of CSA, including improvements in sleep metrics, and was well-tolerated. The clinically meaningful effects of the therapy were supported by the concordant improvements in oxygenation and QOL, making transvenous PNS a promising therapeutic approach for CSA.

Fox and associates (2017) noted that sleep-disordered breathing (SDB) and Cheyne-Stokes respiration (CSR) are associated with shorter survival in patients with HF. A novel treatment method for this patient group is unilateral PNS by the Remede system, which has recently been studied in a large RCT. Previous literature has shown efficacy and safety of the treatment with this 1st-generation device, but hardly any data are available on long-term clinical parameters, the Remede device's battery lifetime, device exchangeability, lead position stability, surgical accessibility, and manageability. These researchers performed Remede device replacements in consecutive patients for battery depletion, and documented clinical parameters, longevity, operation procedure, complications, and difficulties. All patients were on neurostimulation treatment by PNS when device replacement became necessary; AHI (from 45 ± 4/hour to 9 ± 4/hour), oxygen-desaturation index (from 35 ± 7/hour to 7 ± 6/hour), and time spent with oxygen saturation of less than 90 % (T < 90 % from 5 ± 7 % to 0 ± 0 %) were improved and improvements remained constant throughout the 4-year follow-up. Mean battery life was 4.2 ± 0.2 years and mean replacement procedure time was 25 ± 5.1 minutes. Apart from conventional X-ray documentation of stable lead positions in a long-term setting, no radiation or contrast dye usage was needed and no major complications occurred. In addition, clinical exercise capacity and sleepiness symptoms improved. The authors concluded that the novel Remede device showed sustained therapy efficacy and safety in terms of stable lead positions over 4 years. They stated that long-term PNS therapy for central SDB/CSR appeared feasible in a clinical routine setting.

Germany (2017) stated that CSA is common in HF and contributes to morbidity and mortality. Symptoms are often similar to those associated with HF and a high index of suspicion is needed. Testing is typically done in the sleep laboratory, but home testing equipment can distinguish between central and obstructive events. Treatments are limited. Mask-based therapies have been the primary treatment. Oxygen has some data but lacks long-term studies. Neurostimulation of the phrenic nerve is a new technology that has demonstrated improvement.

On October 6, 2017, the FDA approved the Remede System for adult patients who have been diagnosed with moderate-to-severe CSA. The Remede System is an implantable device that stimulates the phrenic nerve to stimulate breathing. The Remede System is comprised of a battery pack surgically placed subcutaneously in the upper chest area and thin wire leads that are inserted into the veins near the phrenic nerve that stimulates breathing. The system is programmed using an external System Programmer and Programming Wand. It monitors the patient’s respiratory signals during sleep and stimulates the nerve to move the diaphragm and restore normal breathing. The FDA evaluated data from 141 patients to assess the effectiveness of the Remede System in reducing AHI. After 6 months, AHI was reduced by 50 % or more in 51 % of patients with an active Remede System implanted; AHI was reduced by 11 % in patients without an active Remede System implanted. The most common AEs reported included concomitant device interaction, implant site infection, and swelling and local tissue damage or pocket erosion. The Remede System should not be used by patients with an active infection or by patients who are known to require magnetic resonance imaging (MRI). This device is not intended for use in patients with obstructive sleep apnea (OSA).

Examples of NMES devices include Empi 300 PV, NexWave, and R2i muscle stimulator.
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Care ETS device is an electromyography (EMG) triggered NMES. This device is designed to detect any EMG signals (nerve impulses from the brain to the muscles) that are supposed to stimulate a muscle contraction but are too weak to do so. When the device detects these signals, it applies stimulation to the muscle and induces a contraction, to purportedly retrain the brain and muscle to properly coordinate contractions and movement. This device is also proposed for use for relaxation of muscle spasms and prevention or retardation of disuse atrophy.

VitalStim Therapy is a type of NMES that uses a mild electrical current that is intended to treat dysphagia by re-educating the muscles and improving swallowing. Guardian dysphagia dual chamber unit is proposed for use for muscle re-education by application of external stimulation for pharyngeal contraction.

Empi Phoenix is a combination NMES and TENS device. QB1 powered muscle stimulator is a combination NMES and TENS device. RS-4i sequential stimulator (also referred to as a combination unit) initially provides an interferential treatment followed by the muscle stimulation. Kneehab XP is a combination NMES and TENS device designed for the knee.

Garara and colleagues (2016) noted that intramuscular diaphragmatic stimulation using an abdominal laparoscopic approach has been proposed as a safer alternative to traditional PNS. It has also been suggested that early implementation of diaphragmatic pacing may prevent diaphragm atrophy and lead to earlier ventilator independence. These investigators reviewed the safety and effectiveness of intramuscular diaphragmatic stimulators in the treatment of patients with traumatic high cervical injuries resulting in long-term ventilator dependence, with particular emphasis on the effect of timing of insertion of such stimulators. The Cochrane database and PubMed were searched between January 2000 and June 2015. Reference lists of selected papers were also reviewed. The inclusion criteria used to select from the pool of eligible studies were: (i) reported on adult patients with traumatic high cervical injury, who were ventilator-dependent, (ii) patients underwent intramuscular diaphragmatic stimulation, and (iii) commented on safety and/or effectiveness. A total of 12 articles were included in the review. Reported safety issues post insertion of intramuscular electrodes included pneumothorax, infection, and interaction with pre-existing cardiac pacemaker. Only 1 procedural failure was reported. The percentage of patients reported as independent of ventilatory support post-procedure ranged between 40% and 72.2%. The mean delay of insertion ranged from 40 days to 9.7 years; of note the study with the average shortest delay in insertion reported the greatest percentage of fully weaned patients. The authors concluded that although evidence for intramuscular diaphragmatic stimulation in patients with high cervical injuries and ventilator-dependent respiratory failure is currently limited, the technique appears to be safe and effective. Earlier implantation of such devices does not appear to be associated with greater surgical risk, and may be more effective. They stated that further high quality studies are needed to examine the impact of delay of insertion on ventilator weaning.

Sieg and associates (2016) noted that case reports, case series and case control studies have examined the use of PNS in the setting of high SCIs and CHS dating back to the 1980s. These researchers evaluated the evidence related to this topic by performing a systematic review of the published literature. Search terms "phrenic nerve stimulation", "phrenic nerve and spinal cord injury", and "phrenic nerve and central hypoventilation" were entered into standard search engines in a systematic fashion. Articles were reviewed by 2 study authors and graded independently for class of evidence according to published guidelines. The published evidence was reviewed, and the overall body of evidence was evaluated using the grading of recommendations, assessment, development and evaluations (GRADE) criteria. The initial search yielded 420 articles. There were no class I, II, or III studies; there were 18 relevant class IV articles. There were no discrepancies among article ratings (i.e., kappa = 1). A meta-analysis could not be performed due to the low quality of the available evidence. The overall quality of the body of evidence was evaluated using GRADE criteria and fell within the "very poor" category. The authors concluded that the quality of the published literature for PNS is poor. The available literature suggests that PNS is a safe and effective option for decreasing ventilator dependence in high SCI and central hypoventilation; however, the authors stated that they were left with critical questions that provide crucial directions for future studies.
**Functional Electrical Stimulation/Neuromuscular Electrical Stimulation for Chronic Obstructive Pulmonary Disease:**

In a randomized double-blind, placebo-controlled trial, Maddocks and associates (2017) evaluated the effectiveness of NMES as a home-based exercise therapy for patients with severe COPD. These researchers randomly assigned (1:1) adults with COPD, a forced expiratory volume in 1 s (FEV1) less than 50 % predicted, and incapacitating breathlessness (Medical Research Council dyspnea scale greater than or equal to 4) to receive active or placebo NMES, daily over a 6-week period.

Randomization was by an independent system using minimization to balance age, GOLD stage, and quadriceps strength. subjects and outcome assessors were masked to group allocation. The primary end-point was change in 6MWT distance at 6 weeks. Analysis was by intention-to-treat. Between June 29, 2012, and July 4, 2014, these researchers enrolled 73 subjects, of whom 52 participants were randomly assigned; 25 to receive active NMES and 27 to placebo NMES. Change in 6MWT distance was greater in the active NMES group (mean 29.9 [95 % CI: 8.9 to 51.0]) compared with in the placebo group (-5.7 [-19.9 to 8.4]; MD at 6 weeks 35.7 m [95 % CI: 10.5 to 60.9]; p = 0.005). Sensitivity analyses for complete-cases and adjustment for baseline values showed similar results. 6 weeks after stopping the intervention the effect waned (7.3 m [95 % CI: -32.5 to 47.0]; p = 0.50). The proportion of participants who had AEs was similar between groups (5 [20 %] in the active NMES group and nine [33 %] in the placebo group); 2 participants, 1 from each group, reported persistent erythema, which was considered to be possibly related to NMES and the use of adhesive electrodes. The authors concluded that NMES improved functional exercise capacity in patients with severe COPD by enhancing quadriceps muscle mass and function. They stated that these data support the use of NMES in the management of patients unable to engage with conventional pulmonary rehabilitation; however, more work is needed to study how to maintain the effect. They stated that future work should consider trialing longer programs of NMES, potentially those that use improvements in function to dovetail into pulmonary rehabilitation, or add behavioral change and education components to NMES to enhance health status and QOL. Once optimized, the effect of an NMES-based approach on outcomes pertaining to patient independence and health service use could be evaluated.

The authors noted that this study had several drawbacks: These investigators were not able to mask the nurses and physiotherapists who were involved in recording of AE data, although events were classified without unmasking of group allocation. The authors perceived their placebo model to have been successful, but they could not totally rule out an anabolic effect, and incidental features of NMES such as dedicated time for self-management might have affected participant behavior. The sample size was informed by effect estimate data from a pilot study and an established minimally important difference for COPD, and the expected difference of 54 m was not reached. Nonetheless, the homogeneous sample and well standardized assessments contributed to between-group differences that were significant and exceeded updated minimally important differences for the primary end-point. The study was not powered to detect small changes in health status that might be expected following this modest intensity training. These researchers noted a small number of hospital admissions during the short trial period. Although the number of exacerbations, hospital admissions, and courses of oral corticosteroids was higher in the placebo group than in the active group, this was unlikely to account for the differences in functional exercise capacity, which remained stable, and was enhanced following active NMES.

In a meta-analysis, Chen and colleagues (2016) examined the controversial topic of whether NMES is effective in patients with moderate-to-severe COPD. These investigators pooled data from 9 trials published between January 9, 2002 and January 4, 2016 across PubMed, Embase, Cochrane Central Register of Controlled Trials, Google Scholar, and relevant websites for RCTs. In these trials, patients with moderate-to-severe COPD were randomly allocated to receive NMES. Primary outcomes were quadriceps strength and exercise capacity; secondary outcome was health-related QOL. These researchers extracted data from 276 patients; NMES contributed to statistically improved quadriceps strength (SMD 1.12, 95 % CI: 0.64 to 1.59, I² = 54 %; p < 0.00001) and exercise capacity, including longer exercise distance (WMD 51.53, 95 % CI: 20.13 to 82.93, I² = 90 %; p = 0.001), and longer
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exercise endurance (SMD 1.11, 95 % CI: 0.14 to 2.08, I² = 85 %; p = 0.02). There was no significant difference in St George's Respiratory Questionnaire scores (WMD -0.07, 95 % CI: -2.44 to 2.30, I² = 56 %; p = 0.95). The authors concluded that NMES appeared to be an effective method of enhancing quadriceps strength and exercise capacity in moderate-to-severe COPD patients. Moreover, they stated that further research is needed to clarify its effect on other outcomes and determine the optimal parameters for an NMES program.

This study had several drawbacks: (i) the subgroup analysis with small sample size led to insufficient evidence, (ii) the diversity of measurement could have led to heterogeneity correspondingly, and (iii) NMES with different parameter settings or programs may lead to different physiological effects and outcomes.

Sacral Nerve Stimulation for the Treatment of Chronic Constipation:

In a Cochrane review, Thaha et al (2015) evaluated the effects of SNS using implanted electrodes for the treatment of FI and constipation in adults. These investigators searched the Cochrane Incontinence Group Specialized Register, which contains trials identified from the Cochrane Central Register of Controlled Trials (CENTRAL), Medline, Medline In-Process, ClinicalTrials.gov, the World Health Organization (WHO) ICTRP and hand-searched journals and conference proceedings (searched February 5, 2015), Embase (January 1, 1947 to 2015 Week 5), and the reference lists of retrieved relevant articles. All randomized or quasi-randomized trials assessing the effects of SNS for FI or constipation in adults. Two review authors independently screened the search results, assessed the methodological quality of the included trials, and undertook data extraction. A total of 6 cross-over trials and 2 parallel group trials were included; 6 trials assessed the effects of SNS for FI. In the parallel group trial conducted by Tjandra, 53 participants with severe FI in the SNS group experienced fewer episodes of FI compared to the control group who received optimal medical therapy (mean difference (MD) -5.20, 95 % confidence interval (CI): -9.15 to -1.25 at 3 months; MD -6.30, 95 % CI: -10.34 to -2.26 at 12 months). Adverse events (AEs) were reported in a proportion of participants: pain at implant site (6 %), seroma (2 %) and excessive tingling in the vaginal region (9 %). In the parallel group trial carried out by Thin, 15 participants with FI in the SNS group experienced fewer episodes of FI compared with the percutaneous tibial nerve stimulation (PTNS) group (MD -3.00, 95 % CI: -6.61 to 0.61 at 3 months; MD -3.20, 95 % CI: -7.14 to 0.74 at 12 months); AEs were reported in 3 participants: mild ipsilateral leg pain during temporary testing (n = 1); and stimulator-site pain following insertion of neurostimulator (n = 2).

In the cross-over trial by Leroi, 7 of 34 recruited participants were excluded from the cross-over due mainly to complications or immediate device failure; 24 of the remaining 27 participants while still blinded chose the period of stimulation they had preferred. Outcomes were reported separately for 19 participants who preferred the 'on' and 5 who preferred the 'off' period. For the group of 19, the median (range) episodes of FI per week fell from 1.7 (0 to 9) during the 'off' period to 0.7 (0 to 5) during the 'on' period; for the group of 5, however, the median (range) rose from 1.7 (0 to 11) during the 'off' period compared with 3.7 (0 to 11) during the 'on' period; 4 of 27 participants experienced an AE resulting in removal of the stimulator. In the cross-over trial by Sorensen and colleagues, participants did not experience any FI episodes in either the 1-week 'on' or 'off' periods. In the cross-over trial by Vaizey, participants reported an average of 6, and 1, episodes of FI per week during the 'off' and 'on' periods respectively in 2 participants with FI. Neither study reported AEs. In the cross-over trial by Kahlke, 14 participants with FI experienced significantly lower episodes of FI per week during the stimulator 'on' (1 (SD, 1.7)) compared with the 'off' period (8.4 (SD, 8.7)); AEs reported include: hematoma formation (n = 3); misplacement of tined lead (n = 1); and pain at stimulator site (n = 1). Two trials assessed SNS for constipation. In the Kenefick trial, the 2 participants experienced an average of 2 bowel movements per week during the 'off' cross-over period, compared with 5 during the 'on' period. Abdominal pain and bloating occurred 79 % of the time during the 'off' period compared with 33 % during the 'on' period. No AEs occurred. In contrast, in the trial by Dinning with 59 participants, SNS did not improve frequency of bowel movements and 73 AEs were reported, which included pain at site of the implanted pulse generator (n = 32), wound infection (n = 12), and urological (n = 17) events. The authors concluded that limited evidence from the included trials suggested that SNS can improve continence in a proportion of patients with FI. However, SNS did not improve symptoms in patients with constipation. In addition,
AEs occurred in some patients where these were reported. Moreover, they stated that rigorous high quality randomized trials are needed to allow the effects of SNS for these conditions to be assessed with more certainty.

In a pilot study, Iqbal et al (2016) assessed the effectiveness of transcutaneous electrical stimulation directly over the sacral nerve roots in chronic constipation. The study was conducted of transcutaneous sacral stimulation given over a 4-week period for 12 hours a day. Patients were assessed using the Patient Assessment of Constipation Symptoms, the Patient Assessment of Constipation Quality of Life, and the Cleveland constipation tool. A Global Rating of Change measure and a 1-week bowel diary was kept for the final week and compared with baseline. Of the 20 patients recruited (16 women, median age of 38.5 years), 80 % (16) completed the trial; 5 (31 %) patients reported at least a point reduction in the Patient Assessment of Constipation Symptoms score, 4 (25 %) deteriorated, and 7 (44 %) improved by less than 1 point. Median (interquartile range [IQR]) Patient Assessment of Constipation Symptoms scores were 2.33 (2.34) at baseline and 2.08 (2.58) at follow-up (p = 0.074). Median scores for the Patient Assessment of Constipation Quality of Life and Cleveland systems were 3.00 (1.64) and 17.15 (18) at baseline and 2.22 (3.04) and 15.31 (12) at follow-up (p = 0.096 and 0.111); 1/3 of patients reported a positive Global Rating of Change measure, although 68 % required concurrent laxatives during the trial. The authors concluded continuous transcutaneous sacral stimulation in the short-term appeared to be ineffective for chronic constipation. They stated that larger well-powered studies with intermittent stimulation regimens are needed to investigate this further. This was a pilot study and was limited by its small sample size (n = 20).

Patton et al (2016) evaluated the long-term effectiveness of SNS in patients with scintigraphically confirmed slow-transit constipation. At the 1- and 2-year post-randomized controlled trial (RCT), the primary treatment outcome measure was the proportion of patients who reported a feeling of complete evacuation on greater than 2 days per week for greater than or equal to 2 of 3 weeks during stool diary assessment. Secondary outcome was demonstration of improved colonic transit at 1 year. A total of 53 patients entered long-term follow-up, and 1 patient died. Patient dissatisfaction or serious adverse events (AEs) resulted in 44 patients withdrawing from the study because of treatment failure by the end of the 2nd year. At 1 and 2 years, 10 (OR = 18.8 % (95 % CI: 8.3 % to 29.3 %)) and 3 patients (OR = 5.7 % (95 % CI: -0.5 % to 11.9 %)) met the primary outcome measure. Colonic isotope retention at 72 hours did not differ between baseline (OR = 75.6 % (95 % CI: 65.7 % to 85.6 %)) and 1-year follow-up (OR = 61.7 % (95 % CI: 47.8 % to 75.6 %)). The authors concluded that in these patients with slow-transit constipation, SNS was not an effective treatment.

Zerbib et al (2017) stated that open studies have reported favorable results for SNS in the treatment of refractory constipation. These investigators examined its effectiveness in a double-blind cross-over RCT. Patients with at least 2 of the following criteria were included: (i) fewer than 3 bowel movements per week; (ii) straining to evacuate on more than 25 % of occasions. Response to therapy was defined as at least 3 bowel movements per week and/or more than 50 % improvement in symptoms. Responders to an initial 3-week peripheral nerve evaluation were offered permanent implantation of a pulse generator and were assigned randomly in a cross-over design to two 8-week intervals of active or sham stimulation. At the end of the 2 trial periods, the patients received active stimulation until the final evaluation at 1 year. A total of 36 patients (34 women; mean (s.d.) age of 45(14) years) underwent peripheral nerve evaluation; 20 responded and received a permanent stimulator. A positive response was observed in 12 of 20 and 11 of 20 patients after active and sham stimulation periods respectively (p = 0.746). Pain related to the device occurred in 5 patients and wound infection or hematoma in 3, leading to definitive removal of the pulse generator in 2 patients. At 1 year, 11 of the 20 patients with an implanted device continued to respond. Stimulation had no significant effect on colonic transit time. The authors concluded that these results did not support the recommendation of permanent implantation of a pulse generator in patients with refractory constipation who initially responded to temporary nerve stimulation.

Sreepati G, James-Stevenson (2017) stated that FI and constipation are common gastro-intestinal (GI) complaints, but rarely occur concurrently. Management of these seemingly paradoxical processes is
challenging, as treatment of one symptom may exacerbate the other. These researchers reported the case of a 51-year-old female with lifelong neurogenic bladder secondary to spina bifida occulta who presented with progressive symptoms of daily urge FI as well as hard bowel movements associated with straining and a sensation of incomplete evacuation requiring manual dis-impaction. Pelvic floor testing showed poor ability to squeeze the anal sphincter, which indicated sphincter weakness as a major contributor to her FI symptoms. Additionally, on defecography she was unable to widen her posterior anorectal angle or relax the anal sphincter during defecation consistent with dyssynergic defecation. A sacral nerve stimulator was placed for management of her FI. Interestingly, her constipation also dramatically improved with sacral neuromodulation. The authors concluded that this unique case highlighted the emerging role of SNS in the treatment of complex pelvic floor dysfunction with improvement in symptoms beyond FI in a patient with dyssynergic-type constipation. Moreover, they stated that while SNS is increasingly being used in patients with refractory FI, its role in treatment of refractory constipation is unclear. The findings of this case suggested that SNS may have benefit in the dyssynergic subtype of constipation; further studies evaluating SNS in this specific subset of constipation sufferers are needed.

Chen et al (2017) noted that GI motility disorders are common in clinical settings, including esophageal motility disorders, gastroesophageal reflux disease, functional dyspepsia, gastroparesis, chronic intestinal pseudo-obstruction, post-operative ileus, irritable bowel syndrome, diarrhea and constipation. While a number of drugs have been developed for treating GI motility disorders, few are currently available. Emerging electrical stimulation methods may provide new treatment options for these GI motility disorders. These investigators presented an overview of electrical therapies that have been, and are being developed for GI motility disorders, including gastroesophageal reflux, functional dyspepsia, gastroparesis, intestinal motility disorders and constipation. Various methods of gastrointestinal electrical stimulation were introduced. A few methods of nerve stimulation have also been described, including spinal cord stimulation and SNS. Potentials of electrical therapies for obesity are also discussed. PubMed was searched using keywords and their combinations: electrical stimulation, spinal cord stimulation, sacral nerve stimulation, gastrointestinal motility and functional gastrointestinal diseases. The authors concluded that electrical stimulation is an area of great interest and has potential for treating GI motility disorders. However, further development in technologies (devices suitable for GI stimulation) and extensive clinical research are needed to advance the field and bring electrical therapies to bedside.

Maeda et al (2017) noted that sacral neuromodulation (SNM) has been reported as a treatment for severe idiopathic constipation. These researchers evaluated the long-term effects of sacral neuromodulation by following patients who participated in a prospective, open-label, multi-center study up to 5 years. Patients were followed up at 1, 3, 6, 12, 24, 36, 48 and 60 months. Symptoms and quality of life were assessed using bowel diary, the Cleveland Clinic constipation score and the Short Form-36 quality-of-life scale. A total of 62 patients (7 men, median age of 40 years) underwent test stimulation, and 45 proceeded to permanent implantation; 27 patients exited the study (7 withdrawn consent, 7 loss of efficacy, 6 site-specific reasons, 4 withdrew other reasons, 2 lost to follow-up, 1 prior to follow-up); 18 patients (29%) attended 60-month follow-up. In 10 patients who submitted bowel diary, their improvement of symptoms was sustained: the number of defecations per week (4.1 ± 3.7 versus 8.1 ± 3.4, mean ± standard deviation, p < 0.001, baseline versus 60 months) and sensation of incomplete emptying (0.8 ± 0.3 versus 0.2 ± 0.1, p = 0.002). In 14 patients (23%) with Cleveland Clinic constipation score, improvement was sustained at 60 months [17.9 ± 4.4 (baseline) to 10.4 ± 4.1, p < 0.001]. Some 103 device-related AEs were reported in 27 (61%). The authors concluded that benefit from sacral neuromodulation in the long-term was observed in a small minority of patients with intractable constipation. The results should be interpreted with caution given the high drop-out (69%; 27 of 45) and complication rate during the follow-up period. Moreover, they stated that the role of SNM within the treatment algorithm and the clinical treatment pathway for chronic constipation in comparison with other options, as well as patient selection criteria, is unclear. Recent randomized double-blind cross-over studies have shown no difference between active and sham stimulations. In both studies, 30 to 60% of patients had a positive response during sham stimulation, suggestive of either lasting effects of sensory stimulation beyond washout period between sham and active treatment (2 to 3 weeks) or
high placebo effects of this treatment. In the light of these results from the well-designed randomized trials, it is difficult to recommend sacral neuromodulation as a treatment within a treatment algorithm of constipation.

Lu et al (2017) evaluated the long-term effectiveness of SNS in children with constipation and describe patient benefit and parent satisfaction. Using a prospective patient registry, these researchers identified patients less than 21 years old with constipation treated with SNS for more than 2 years. They compared symptoms, medical treatment, PedsQL Gastrointestinal Symptom Scale (GSS), Fecal Incontinence Quality of Life Scale (FIQL), and Fecal Incontinence Severity Index (FISI) before SNS and at follow-up. These investigators contacted parents to administer the Glasgow Children's Benefit Inventory (GCBI) and a parent satisfaction questionnaire. They included 25 children (52 % male, median age of 10 years): 16 had functional constipation, 6 anorectal malformation, 2 tethered spinal cord, and 1 Hirschsprung's disease. Defecation frequency did not change after SNS but patients reporting FI decreased from 72 % to 20 % (p < 0.01) and urinary incontinence decreased from 56 % to 28 % (p = 0.04). Patients using laxatives decreased from 64 % to 44 % (ns) and patients using antegrade enemas decreased from 48 % to 20 % (p = 0.03). GSS, most FIQL domains, and FISI were improved at follow-up; 6 (24 %) patients had complications requiring further surgery. Of the 16 parents contacted, 15 (94 %) parents indicated positive health-related benefit and all would recommend SNS to other families. The authors concluded that SNS is a promising and durable treatment for children with refractory constipation, and appeared particularly effective in decreasing FI. Although 25 % of patients experienced complications requiring additional surgery, nearly all parents reported health-related benefit. They stated that future studies to identify predictors of treatment response and complications are needed.

### CPT Codes / HCPCS Codes / ICD-10 Codes

**Functional Electrical Stimulation (FES) for spinal cord injury (e.g., Parastep I System):**

<table>
<thead>
<tr>
<th>CPT codes covered if selection criteria are met:</th>
</tr>
</thead>
<tbody>
<tr>
<td>63655</td>
</tr>
<tr>
<td>63685</td>
</tr>
<tr>
<td>64550</td>
</tr>
<tr>
<td>64555</td>
</tr>
<tr>
<td>64575</td>
</tr>
<tr>
<td>64585</td>
</tr>
<tr>
<td>64590</td>
</tr>
<tr>
<td>64595</td>
</tr>
</tbody>
</table>

**HCPCS codes covered if selection criteria are met:**
### Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4556</td>
<td>Electrodes (e.g., apnea monitor), per pair</td>
</tr>
<tr>
<td>A4557</td>
<td>Lead wires (e.g., apnea monitor), per pair</td>
</tr>
<tr>
<td>A4558</td>
<td>Conductive gel or paste, for use with electrical device (e.g., TENS, NMES), per oz.</td>
</tr>
<tr>
<td>A4595</td>
<td>Electrical stimulator supplies, 2 lead, per month, (e.g. TENS, NMES)</td>
</tr>
<tr>
<td>E0731</td>
<td>Form-fitting conductive garment for delivery of TENS or NMES (with conductive fibers separated from the patient's skin by layers of fabric)</td>
</tr>
<tr>
<td>E0745</td>
<td>Neuromuscular stimulator, electronic shock unit</td>
</tr>
<tr>
<td>E0762</td>
<td>Transcutaneous electrical joint stimulation device system, includes all accessories</td>
</tr>
<tr>
<td>E0764</td>
<td>Functional neuromuscular stimulator, transcutaneous stimulation of muscles of ambulation with computer control, used for walking by spinal cord injured, entire system, after completion of training program</td>
</tr>
<tr>
<td>E0770</td>
<td>Functional electrical stimulator, transcutaneous stimulation of nerve and / or muscle groups, any type, complete system, not otherwise specified</td>
</tr>
<tr>
<td>L8680</td>
<td>Implantable neurostimulator electrode, each</td>
</tr>
<tr>
<td>L8681</td>
<td>Patient programmer (external) for use with implantable programmable neurostimulator pulse generator</td>
</tr>
<tr>
<td>L8682</td>
<td>Implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8683</td>
<td>Radiofrequency transmitter (external) for use with implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8685</td>
<td>Implantable neurostimulator pulse generator, single array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8686</td>
<td>Implantable neurostimulator pulse generator, single array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8687</td>
<td>Implantable neurostimulator pulse generator, dual array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8688</td>
<td>Implantable neurostimulator pulse generator, dual array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8689</td>
<td>External recharging system for battery (internal) for use with implantable neurostimulator</td>
</tr>
</tbody>
</table>

**ICD-10 codes covered if selection criteria are met:**

- S12.000+ - Fracture of vertebral column with spinal cord injury [not covered for FES of upper extremities]
**Functional Electrical Stimulation and Neuromuscular Electrical Stimulation**

<table>
<thead>
<tr>
<th>Functional options</th>
<th>Spinal cord injury, sequelae [not covered for FES of upper extremities]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S14.0xx+</td>
<td>Spinal cord injury without evidence of spinal bone injury (cervical, thoracic, lumbar) [not covered for FES of upper extremities]</td>
</tr>
<tr>
<td>S14.159+</td>
<td></td>
</tr>
<tr>
<td>S24.0xx+           -</td>
<td></td>
</tr>
<tr>
<td>S24.159+</td>
<td></td>
</tr>
<tr>
<td>S34.01x+           -</td>
<td></td>
</tr>
<tr>
<td>S34.129+</td>
<td></td>
</tr>
</tbody>
</table>

**FES of upper and lower extremities:**

**ICD-10 codes not covered for indications listed in the CPB:**

<table>
<thead>
<tr>
<th>Code Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C00.0 - C95.92</td>
<td>Malignant neoplasms</td>
</tr>
<tr>
<td>G12.20 - G12.9</td>
<td>Motor neuron disease</td>
</tr>
<tr>
<td>G20 - G21.9</td>
<td>Parkinson's disease</td>
</tr>
<tr>
<td>G35</td>
<td>Multiple sclerosis</td>
</tr>
<tr>
<td>G45.0 - G45.2</td>
<td>Occlusion and stenosis of precerebral arteries, occlusion of cerebral arteries, transient cerebral ischemia, and acute, but ill-defined cerebrovascular disease</td>
</tr>
<tr>
<td>G45.8 - G46.2</td>
<td></td>
</tr>
<tr>
<td>I63.00 - I66.9</td>
<td></td>
</tr>
<tr>
<td>I67.89</td>
<td></td>
</tr>
<tr>
<td>G47.31</td>
<td>Primary central sleep apnea</td>
</tr>
<tr>
<td>G51.0</td>
<td>Bell's palsy (facial palsy) [also not covered for FES of lower extremities]</td>
</tr>
<tr>
<td>G56.00 - G56.92</td>
<td>Mononeuropathies of upper limb and other mononeuropathies</td>
</tr>
<tr>
<td>G58.0 - G58.7</td>
<td></td>
</tr>
<tr>
<td>G71.0 - G72.9</td>
<td>Muscular dystrophies and other myopathies</td>
</tr>
<tr>
<td>G73.7</td>
<td></td>
</tr>
<tr>
<td>G80.0 - G80.9</td>
<td>Cerebral palsy [also not covered for FES of lower extremities]</td>
</tr>
<tr>
<td>I50.1, I50.22, I50.32, I50.42, I50.9</td>
<td>Chronic heart failure</td>
</tr>
<tr>
<td>I69.031 - I69.069</td>
<td>Sequelae of cerebrovascular disease, hemiplegia/hemiparesis, monoplegia, or other paralytic syndrome</td>
</tr>
<tr>
<td>J40 - J47.9</td>
<td>Chronic lower respiratory diseases</td>
</tr>
<tr>
<td>M17.0 - M17.9</td>
<td>Osteoarthritis of knee</td>
</tr>
<tr>
<td>P11.3</td>
<td>Birth injury to facial nerve [Facial nerve palsy]</td>
</tr>
<tr>
<td>S04.011s - S04.899s</td>
<td>Injury to cranial nerve [traumatic brain injury], sequelae</td>
</tr>
<tr>
<td>S06.0x0+ - S06.9x9+</td>
<td>Intracranial injury [traumatic brain injury]</td>
</tr>
<tr>
<td>S06.0x0s - S06.9x9s</td>
<td>Intracranial injury without mention of skull fracture [traumatic brain injury], sequelae</td>
</tr>
</tbody>
</table>
## Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

### Neuromuscular Electrical Stimulators (NMES):

<table>
<thead>
<tr>
<th>CPT codes covered if selection criteria are met:</th>
</tr>
</thead>
<tbody>
<tr>
<td>64550 Application of surface (transcutaneous) neurostimulator</td>
</tr>
<tr>
<td>64565 Percutaneous implantation of neurostimulator electrodes; neuromuscular</td>
</tr>
<tr>
<td>64580 Incision for implantation of neurostimulator electrodes; neuromuscular</td>
</tr>
<tr>
<td>97014 Application of a modality to one or more areas; electrical stimulation (unattended)</td>
</tr>
<tr>
<td>97024 Application of a modality to one or more areas; diathermy (eg, microwave)</td>
</tr>
<tr>
<td>97032 Application of a modality to one or more areas; electrical stimulation (manual), each 15 minutes</td>
</tr>
</tbody>
</table>

### Other CPT codes related to the CPB:

<table>
<thead>
<tr>
<th>Other CPT codes related to the CPB:</th>
</tr>
</thead>
<tbody>
<tr>
<td>63190 Laminectomy with rhizotomy; more than two segments</td>
</tr>
</tbody>
</table>

### HCPCS codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>HCPCS codes covered if selection criteria are met:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4556 Electrodes (e.g., apnea monitor), per pair</td>
</tr>
<tr>
<td>A4557 Lead wires (e.g., apnea monitor), per pair</td>
</tr>
<tr>
<td>A4558 Conductive gel or paste, for use with electrical device (e.g., TENS, NMES), per oz.</td>
</tr>
<tr>
<td>A4595 Electrical stimulator supplies, 2 lead, per month, (e.g. TENS, NMES)</td>
</tr>
<tr>
<td>E0745 Neuromuscular stimulator, electronic shock unit</td>
</tr>
<tr>
<td>L8680 Implantable neurostimulator electrode, each</td>
</tr>
<tr>
<td>L8681 Patient programmer (external) for use with implantable programmable neurostimulator pulse generator</td>
</tr>
<tr>
<td>L8682 Implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8683 Radiofrequency transmitter (external) for use with implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8685 Implantable neurostimulator pulse generator, single array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8686 Implantable neurostimulator pulse generator, single array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8687 Implantable neurostimulator pulse generator, dual array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8688 Implantable neurostimulator pulse generator, dual array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8689 External recharging system for battery (internal) for use with implantable neurostimulator</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met:
Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

ICD-10 codes not covered for indications listed in the CPB (for FES or NMES):

- G71.8, M62.50 - M62.59, M62.84, M79.7
- Muscular wasting and disuse atrophy, not elsewhere classified [see criteria]

ICD-10 codes not covered for indications listed in the CPB (for FES or NMES):

- C00.0 - C95.92 Malignant neoplasms
- G35 Multiple sclerosis
- G47.31 Primary central sleep apnea
- G51.0 Bell's palsy (facial palsy)
- G80.0 - G80.9 Cerebral palsy [also not covered for FES of lower extremities]
- I50.1, I50.22, I50.32, I50.42, I50.9 Chronic heart failure
- J40 - J47.9 Chronic lower respiratory diseases
- J44.0 - J44.9 Chronic obstructive pulmonary disease
- P11.3 Birth injury to facial nerve [Facial nerve palsy]

Form-fitting Conductive Garment:

HCPCS codes covered if selection criteria are met:

- E0731 Form-fitting conductive garment for delivery of TENS or NMES (with conductive fibers separated from the patient's skin by layers of fabric)

ICD-10 codes covered if selection criteria are met:

- G71.8 M62.50 - M62.59 Muscular wasting and disuse atrophy, not elsewhere classified
- M79.7
- Z51.89 Encounter for other specified aftercare

Diaphragmatic/phrenic Pacing:

CPT codes covered if selection criteria are met:

- 0424T Insertion or replacement of neurostimulator system for treatment of central sleep apnea; complete system (transvenous placement of right or left stimulation lead, sensing lead, implantable pulse generator)
- 0425T Insertion or replacement of neurostimulator system for treatment of central sleep apnea; sensing lead only
- 0426T Insertion or replacement of neurostimulator system for treatment of central sleep apnea; stimulation lead only
- 0427T Insertion or replacement of neurostimulator system for treatment of central sleep apnea; pulse generator only
- 64580 Incision for implantation of neurostimulator electrodes; neuromuscular
### Other CPT codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>94660</td>
<td>Continuous positive airway pressure ventilation (CPAP), initiation and management</td>
</tr>
</tbody>
</table>

### HCPCS codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0745</td>
<td>Neuromuscular stimulator, electronic shock unit</td>
</tr>
<tr>
<td>L8680</td>
<td>Implantable neurostimulator electrode, each</td>
</tr>
<tr>
<td>L8681</td>
<td>Patient programmer (external) for use with implantable programmable neurostimulator pulse generator</td>
</tr>
<tr>
<td>L8682</td>
<td>Implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8683</td>
<td>Radiofrequency transmitter (external) for use with implantable neurostimulator radiofrequency receiver</td>
</tr>
<tr>
<td>L8685</td>
<td>Implantable neurostimulator pulse generator, single array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8686</td>
<td>Implantable neurostimulator pulse generator, single array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8687</td>
<td>Implantable neurostimulator pulse generator, dual array, rechargeable, includes extension</td>
</tr>
<tr>
<td>L8688</td>
<td>Implantable neurostimulator pulse generator, dual array, non-rechargeable, includes extension</td>
</tr>
<tr>
<td>L8689</td>
<td>External recharging system for battery (internal) for use with implantable neurostimulator</td>
</tr>
<tr>
<td>L8696</td>
<td>Antenna (external) for use with implantable diaphragmatic/phrenic nerve stimulation device, replacement, each</td>
</tr>
</tbody>
</table>

### Other HCPCS codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1120</td>
<td>Injection, acetazolamide sodium, up to 500 mg</td>
</tr>
<tr>
<td>J2810</td>
<td>Injection, theophylline, per 40 mg</td>
</tr>
</tbody>
</table>

### ICD-10 codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G12.21</td>
<td>Amyotrophic lateral sclerosis</td>
</tr>
<tr>
<td>G47.31</td>
<td>Primary central sleep apnea</td>
</tr>
<tr>
<td>G47.34</td>
<td>Idiopathic sleep related nonobstructive alveolar hypoventilation</td>
</tr>
<tr>
<td>G47.35</td>
<td>Congenital central alveolar hypoventilation syndrome</td>
</tr>
<tr>
<td>G82.51 - G82.52</td>
<td>Quadriplegia C1-C4 complete/incomplete</td>
</tr>
<tr>
<td>S12.000+ - S12.391+</td>
<td>Fracture of vertebral column with spinal cord injury (cervical, C1-C4)</td>
</tr>
<tr>
<td>S14.101+ - S14.111+</td>
<td>Spinal cord injury without evidence of spinal bone injury (cervical, C1-C4)</td>
</tr>
</tbody>
</table>
S14.114+  
S14.121+  
S14.124+  
S14.131+  
S14.134+  
S14.141+  
S14.144+  
S14.151+  
S14.154+  

Numerous options  Spinal cord injury, sequelae [not covered for FES of upper extremities]

**Electrical Stimulation of Sacral Anterior Roots:**

**CPT codes covered if selection criteria are met:**

63185  Laminectomy with rhizotomy; one or two segments  
63190  more than two segments  
63655  Laminectomy for implantation of neurostimulator electrodes, plate/paddle, epidural  
64561  Percutaneous implantation of neurostimulator electrode array; sacral nerve (transforaminal placement) including image guidance, if performed  
64581  Incision for implantation of neurostimulator electrode array; sacral nerve (transforaminal placement)

**HCPCS codes covered if selection criteria are met:**

A4290  Sacral nerve stimulation test lead, each  
E0745  Neuromuscular stimulator, electronic shock unit  
L8680  Implantable neurostimulator electrode, each  
L8681  Patient programmer (external) for use with implantable programmable neurostimulator pulse generator  
L8682  Implantable neurostimulator radiofrequency receiver  
L8684  Radiofrequency transmitter (external) for use with implantable sacral root neurostimulator receiver for bowel and bladder management, replacement  
L8685  Implantable neurostimulator pulse generator, single array, rechargeable, includes extension  
L8686  Implantable neurostimulator pulse generator, single array, non-rechargeable, includes extension  
L8687  Implantable neurostimulator pulse generator, dual array, rechargeable, includes extension  
L8688  Implantable neurostimulator pulse generator, dual array, non-rechargeable, includes extension  
L8689  External recharging system for battery (internal) for use with implantable neurostimulator
<table>
<thead>
<tr>
<th>ICD-10 codes covered if selection criteria are met:</th>
</tr>
</thead>
<tbody>
<tr>
<td>N31.9 Neuromuscular dysfunction of bladder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICD-10 codes not covered for indications listed in the CPB (not all-inclusive):</th>
</tr>
</thead>
<tbody>
<tr>
<td>K59.00 - K59.09 Constipation [chronic]</td>
</tr>
</tbody>
</table>

**Transurethral electrical stimulation:**

No specific code

<table>
<thead>
<tr>
<th>ICD-10 codes not covered for indications listed in the CPB (not all-inclusive):</th>
</tr>
</thead>
<tbody>
<tr>
<td>G83.4 Cauda equina syndrome</td>
</tr>
<tr>
<td>N31.9 Neuromuscular dysfunction of bladder, unspecified</td>
</tr>
</tbody>
</table>

**Peroneal Nerve Stimulators:**

No specific code

<table>
<thead>
<tr>
<th>HCPCS codes not covered for indications listed in the CPB:</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0770 Functional electrical stimulator, transcutaneous stimulation of nerve and / or muscle groups, any type, complete system, not otherwise specified</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICD-10 codes not covered for indications listed in the CPB (not all-inclusive):</th>
</tr>
</thead>
<tbody>
<tr>
<td>M21.071 - Other acquired deformities of ankle and foot</td>
</tr>
<tr>
<td>M21.079</td>
</tr>
<tr>
<td>M21.371 -</td>
</tr>
<tr>
<td>M21.379</td>
</tr>
<tr>
<td>M21.6x1- M21.6x9</td>
</tr>
</tbody>
</table>

**Threshold electrical stimulation:**

<table>
<thead>
<tr>
<th>HCPCS codes not covered for indications listed in the CPB:</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0745 Neuromuscular stimulator, electronic shock unit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICD-10 codes not covered for indications listed in the CPB (not all-inclusive):</th>
</tr>
</thead>
<tbody>
<tr>
<td>A52.11 Tabes dorsalis</td>
</tr>
<tr>
<td>F51.8 Other sleep disorders not due to a substance or known physiological condition</td>
</tr>
<tr>
<td>F95.0 - F95.9 Tic disorder</td>
</tr>
<tr>
<td>F98.4 Stereotyped movement disorders</td>
</tr>
<tr>
<td>G11.0 - G11.9 Hereditary ataxia</td>
</tr>
<tr>
<td>G20 - G21.9 Parkinson's disease</td>
</tr>
<tr>
<td>G23.0 - G26 Extrapyramidal movement disorders</td>
</tr>
<tr>
<td>G47.61 - G47.69 Sleep related movement disorders</td>
</tr>
<tr>
<td>G52.7 Disorders of multiple cranial nerves</td>
</tr>
<tr>
<td>G80.0 - G80.9 Cerebral palsy</td>
</tr>
</tbody>
</table>
Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M17.0 - M17.9</td>
<td>Osteoarthritits of knee</td>
</tr>
<tr>
<td>M62.40 - M62.49</td>
<td>Contracture of muscle</td>
</tr>
<tr>
<td>R25.0 - R25.9</td>
<td>Abnormal involuntary movements</td>
</tr>
<tr>
<td>R26.0 - R26.9</td>
<td>Abnormalities of gait and mobility</td>
</tr>
<tr>
<td>R27.0 - R27.9</td>
<td>Other lack of coordination</td>
</tr>
</tbody>
</table>

The above policy is based on the following references:

Functional Electrical Stimulation for Walking:


**Functional Electrical Stimulation of the Upper Extremities:**


Functional Electrical Stimulation and Neuromuscular Electrical Stimulation


Neuromuscular Electrical Stimulation for Disuse Atrophy:


Functional Electrical Stimulation/Neuromuscular Electrical Stimulation for Stroke:


Functional Electrical Stimulation and Neuromuscular Electrical Stimulation


Neuromuscular Electrical Stimulation for Spinal Cord Injury:


Diaphragmatic/Phrenic Pacing:

Functional Electrical Stimulation and Neuromuscular Electrical Stimulation


Sacral Nerve Stimulation With Dorsal Rhizotomy (Vocare Bladder System):


Functional Electrical Stimulation and Neuromuscular Electrical Stimulation


Transurethral Electrical Bladder Stimulation:


Electrical Stimulation for Cerebral Palsy:


Electrical Stimulation for Bell's Palsy:


Foot Drop (e.g., Walkaide Device):

Neuromuscular Electrical Stimulation for Ambulatory Function in Patients with Multiple Sclerosis:


Neuromuscular Electrical Stimulation for Knee Osteoarthritis:


Threshold Electrical Stimulation:


Improve of Ambulatory Function/Muscle Weakness in Individuals with Progressive Diseases:


Neuromuscular Electrical Stimulation/Phrenic Nerve Stimulation for Central Sleep Apnea/Ventilator-Dependent Respiratory Failure:


Functional Electrical Stimulation/Neuromuscular Electrical Stimulation for Chronic Obstructive Pulmonary Disease:


Sacral Nerve Stimulation for the Treatment of Chronic Constipation:

Amendment to
Aetna Clinical Policy Bulletin Number: 0677 Functional Electrical Stimulation and Neuromuscular Electrical Stimulation

For the Pennsylvania Medical Assistance Plan, requests for nerve stimulator devices submitted as a procedure code E0770 will be reviewed for medical necessity as a program exception on a case by case basis.