

# Functional Electrical Stimulation (FES)

## An Alternative Rehabilitative Option for Individuals with Spinal Cord Injuries

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Rehabilitation science is continually exploring new interventions to improve the quality of life for individuals after a spinal cord injury. The current rehabilitative options include conventional physiotherapy, occupational therapy and experimental interventions such as Functional Electrical Stimulation (FES) and Body Weight Support (BWS) treadmill training (Thrasher et al., 2005; Hicks et al., 2005).

Spinal cord injuries are usually defined as either complete or incomplete, depending on the location of the spinal cord lesion. The American Spinal Injury Association (ASIA) Impairment Scale ranks the severity of spinal cord damage on a scale from A to E. An individual in category A is considered to have a complete injury with no voluntary motor or sensory function. Individuals in categories B, C, or D have incomplete injuries where sensory function alone, partial sensory and motor preservation or useful motor functions are preserved, respectively. Patients in category E are considered normal with both sensory and motor functions intact. The ASIA Impairment Scale is currently the most widely used system for classifying spinal cord injuries (ASIA, 2001).

### WHAT IS FUNCTIONAL ELECTRICAL STIMULATION (FES)?

One of the most innovative approaches to improve the motor function in patients with spinal cord injuries is FES. This procedure involves sending electrical pulses to induce muscle contraction in a paralyzed limb after a spinal cord injury. When these pulses are applied to motor nerves, action potentials are generated which travel along the axon to the target muscle. The motor nerves of the targeted muscle must be intact in order for the action potentials to be propagated (Popovic et al., 2001).

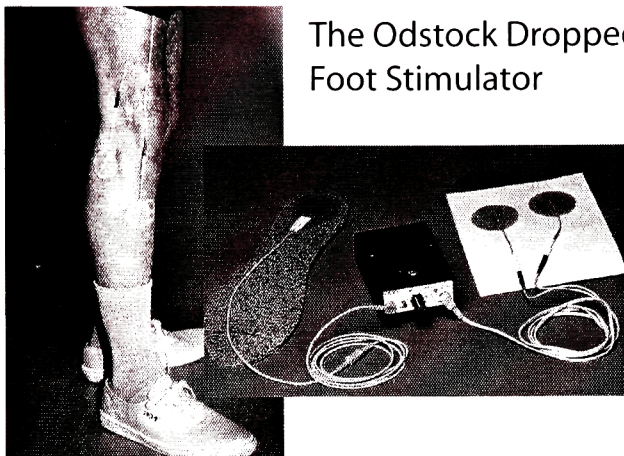
The motor nerves can be activated by surface or implanted electrodes. Surface or transcutaneous electrodes are applied directly to the skin with adhesive gel above the nerve bundles of a particular muscle. These electrodes allow for the option to implement FES into a rehabilitation program during the early stages of recovery. However, the surface electrodes require technical assistance and are most practical on a short-term basis. Conversely, implanted or percutaneous stimulation involves surgical intervention to place electrodes on the nerves or on the muscles close to nerves. These can be used for a longer period of time, but should be implanted 18-24 months after injury. Infections from the implanted electrodes are a liability and the behaviour of the activated muscles may change over time, resulting in undesired contractions (Popovic et al., 2001).

### 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.

**Figure 1:** The American Spinal Injury Association (ASIA) Impairment Scale ranking the severity of spinal cord damage (ASIA, 2001).

## The Odstock Dropped Foot Stimulator



**Figure 2:** The Odstock Dropped Foot Stimulator, an example of Functional Electrical Stimulation used to increase foot clearance during walking (Taylor, 1999).

### WHAT IS FES USED FOR? WHAT IS FES-ASSISTED WALKING?


Most FES systems today are pre-programmed to perform tasks specific to the needs of the individual. FES is currently used in various neuroprostheses such as cochlear implants, cardiac pacemakers, bladder voiding systems, grasping and reaching neuroprostheses, and FES-assisted sitting and walking prostheses (Popovic & Thrasher, 2004).

FES-assisted walking involves stimulating the relevant leg muscles in a coordinated fashion to perform the walking motion. The main nerve stimulated is the peroneal nerve and the lower-limb muscle groups activated include the hip flexors and extensors, knee flexors and extensors, and the ankle plantar flexors and dorsiflexors (Bajd et al., 1999). Walking is then performed with or without assistive devices or on a treadmill. Individuals must have a significant amount of upper body control to maintain stability and balance while walking. The schedule of application and the intensity and frequency of FES stimulation is patient-specific and needs to be monitored to prevent muscle fatigue (Popovic et al., 2001).

### WHAT ARE THE BENEFITS OF FES-ASSISTED WALKING?

FES-assisted walking is effective for individuals with incomplete spinal injuries, as it is a weight-bearing exercise that attempts to prevent the atrophy of muscles, increase the range of motion, reduce spasticity, and slow the demineralization of bones in the lower extremities (Bajd et al., 1999; CIGNA Health Care Coverage Position, 2005). Many walking neuroprostheses, such as the Odstock 2, WalkAid, and the Parastep have been developed to assist patients in foot clearance during walking (Taylor, 1999; Wieler & Stein, 1999; Graupe & Kohn, 1998). Recent studies have noted that FES-assisted walking improves walking endurance and speed, the quality of gait, and lower-extremity muscle strength (Thrasher et al., 2005; Hesse et al., 2004; Postens et al., 2004). Some individuals enrolled in a FES-assisted walking program have reported psychosocial benefits, as well as improvements in physical self-conception and a reduction in depression (Guest et al., 1997).

## THE FUTURE OF FES

Many FES systems have proven to be effective in controlled clinical environments. However, other confounding variables such as the recovery of voluntary muscle control may obscure the overall benefits of FES (CIGNA Health Care Coverage Position, 2005). The two possible applications of FES are either short-term therapeutic treatment in a clinical setting or the long-term orthotic use of a FES system (Bajd et al., 1999). However, early intervention is important in maximizing recovery after spinal cord injury and the combination of current FES treatment with standard physical therapy is the most promising approach to date (Popovic et al., 2001). 

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