



Upper Extremity Functional Electrical Stimulation (FES)





- FES and Therapeutic Effects
- Evidence Supporting FES
- FES Technologies
- Clinical Outcomes and Use



Functional Electrical Stimulation (FES) and Therapeutic Effects



FES - A Neuro Rehabilitation Tool for Decades

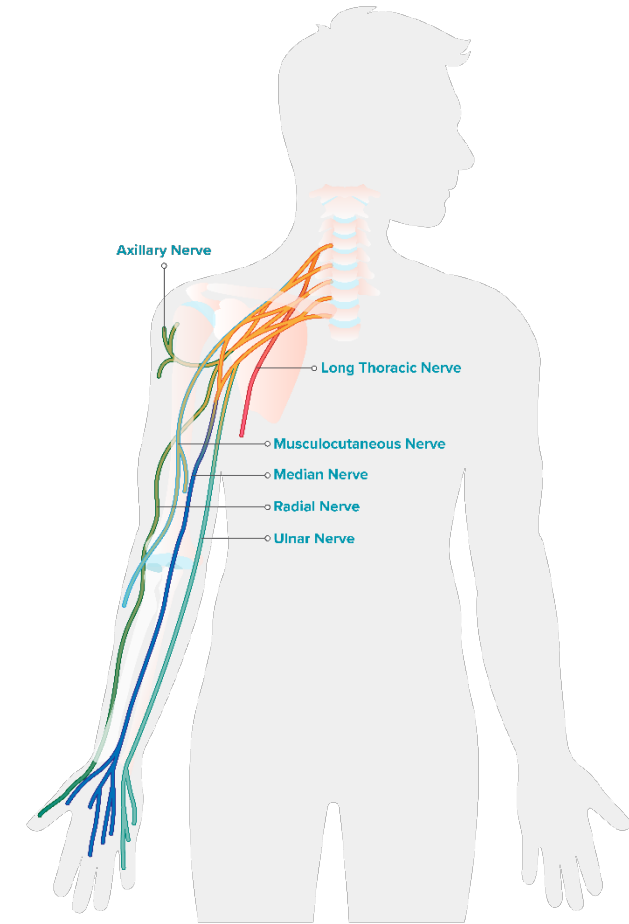
Reasons for Increased Clinical Use

- Waveforms more similar to physiologic electrical activity are more comfortable and less fatiguing.
- FES systems are more reliable with customizable programs for patients.
- Technology is efficacious, durable, safe and easy to use.
- More advanced outcomes can be achieved with FES and/or FES – orthosis hybrid treatments.
- FES systems are more affordable and more available for use outside of the rehab setting.
- Clinicians have a better understanding of how to use FES and the value of the treatment for their patients.



Definition & Function of FES

- Method of applying a low level electrical current directly to the motor nerve in order to restore function
- Motor response occurs distally; muscle function produces movement
- Sensory feedback simultaneously returns to the brain, creating a new motor plan
- Reintegration of the CNS and PNS results as the information pathway is restored
- Intact nerve-muscle pathway required



Theories Regarding Therapeutic Effects of FES

Effect of FES on Sensorimotor Function

- Stimulation of motor nerves creates feedback.
 - Proprioceptive and kinesthetic feedback from muscle spindles, GTOs and joint receptors occurs as muscle contracts.
 - This intrinsic feedback travels to the cerebellum and basal ganglia, allowing the brain to make better motor decisions and to produce better quality movement.
- Stimulation of spinal interneurons affects contractile state of muscles and antagonists.
 - Stimulation adds sensory feedback and allows for better balance of muscle effort/tone across the joint.
 - FES affects muscles grouped in synergistic patterns; as sensory info is improved, the brain remembers how to effectively group muscles in normal synergies to increase efficiency of movement.
- Practice and repetition of a proper motor plan ➡ recovery of independent function.

Theories Regarding Therapeutic Effects of FES

Effect of FES on CNS Tone Management

- Restoration of reciprocal inhibition is key. Contraction of wrist and digit extensors leads to inhibition of spastic flexors.
- A normal balance of muscle effort facilitates normal synergistic grouping of muscles.
- Improved sensory input leads to improved quality of motor output and improved motor planning.
- Functionally, tone will decrease as movement improves.

improved movement → decreased effort → decreased tone

- CNS after injury has all the tools necessary to restore function, but no plans on how to do it.
- Plans have to be supplied.
 - They may be provided through:
 - Functional training
 - Tone management
 - Facilitation of proper movement synergies
- Plans have to be correct.
 - Training must be:
 - Functional
 - Task specific
 - Providing appropriate proprioceptive and kinesthetic cues
 - Passive support, PROM and mass activation of muscles with NMES are not sufficient.

Therapeutic Effects of FES

- Improve joint stability
- Increase functional mobility
- Increase strength and endurance
- Reduce/delay/reverse muscle atrophy
- Increase circulation
- Decrease hypertonicity
- Maintain/increase ROM
- Maintain/increase bone density
- Improve sensory awareness
- Promote muscle re-education & facilitation
- Treat entire neuro-musculoskeletal system



FES May be Appropriate for These Conditions

- Diseases, injuries or disorders affecting the Central Nervous System (CNS), for example:
 - Stroke
 - Multiple Sclerosis
 - Incomplete Spinal Cord Injury
 - Cerebral Palsy
 - Traumatic Brain Injury
 - Hereditary Spastic Paraparesis
 - Etc.



Contraindications and Considerations

Contraindications

- LMN lesions (i.e. peripheral nerve damage from injury, disease or surgery)
- Pacemakers*
- Seizures*
- Pregnancy*
- Malignant tumors in the area of stimulation
- Blood clot in the area of stimulation

**Insufficient evidence exists to confirm or deny that FES is contraindicated in these circumstances. Medical clearance from a physician is necessary for considering use of FES with these conditions.*

Considerations

- Presence of other electrically controlled devices (i.e. Baclofen pumps, deep brain stimulators or indwelling pain control devices)
- Morbid obesity
- Severe sensory deficit
- Chronic infectious disease
- Neurogenic pain syndromes
- Patient safety (i.e. ability to follow instructions, manage technology, compliance)
- Inappropriate response to stimulation
- Chronic skin conditions or poor skin integrity in the area of stimulation

Evidence Supporting FES



FDA Stated Potential Benefits of FES

- Relaxation of muscle spasms
- Prevention or retardation of disuse atrophy
- Increasing local blood circulation
- Muscle re-education
- Maintaining or increasing ROM



Outcomes Noted in the Literature

- Decrease in abnormal tone
 - Physiologic measures of spasticity (EMG, H Reflex and M Wave Ratio)
 - Clinical measures (MAS, Fugel Myer Score)
- Neuroplastic changes
 - Motor evoked potentials
 - Cortical activation
 - Transcranial magnetic stimulation has documented cortical changes, specifically re-activation of areas lost post brain insult.
 - Spinal reflex activity
 - Multiple studies have shown normalization of spinal reflexes after FES; most notably, restored reciprocal inhibition.
- Changes in other systems
 - Cardiovascular function
 - Bone density
 - Muscular atrophy

Functional Electrical Stimulation Enhancement of Upper Extremity Functional Recovery During Stroke Rehabilitation: A Pilot Study

The interactive training program that included FES enabled patients to reach, grasp, move, place and release objects and resulted in better functional recovery of the UE in ischemic stroke survivors than task related exercise training alone.

Alon, 2007

Persons with C5 or C6 Tetraplegia Achieve Selected Functional Gains Using a Neuroprosthesis

Five weeks of daily home training with a task-specific stimulation program improved selected hand functions and upper limb impairments associated with chronic post-stroke paresis.

- Decreased simulated feeding time
- Decreased spasticity
- Decreased pain

Alon, 2003

The Use of Functional Electrical Stimulation on the Upper Limb and Interscapular Muscles of Patients with Stroke for the Improvement of Reaching Movements: A Feasibility Study

The application of FES to upper limb and interscapular muscles of stroke patients with motor impairment of the upper limb improved reaching movements.

Cuesta-Gomez, 2017

Functional Electrical Stimulation for Grasping and Walking: Indications and Limitations

FES treatment combined with conventional occupational and physical therapy still remains the most promising approach in rehabilitation of SCI patients.

Popovic, 2001

Neuromuscular Electrical Stimulation Improves Severe Hand Dysfunction for Individuals With Chronic Stroke: A Pilot Study.

Severe hand impairment was reduced after a short duration of NMES therapy in a pilot data set for individuals with chronic stroke. NMES-assisted grasping trended towards greater functional benefit than traditional NMES activation of wrist flexors/extensors.

Santos, 2006

Effects of Functional Electrical Stimulation with and Without a Wrist Hand Orthosis on Hand Opening in Individuals with Chronic Hemiparetic Stroke: Pilot Study

FES applied to the finger extensors resulted in a trend of larger opening distance, but was associated with a significant reduction in wrist extension angle. Overall, mixed results of varying significance regarding finger/thumb extensors and wrist positioning were noted. Results suggest that combined FES and WHO should be considered when designing interventions or devices to enhance hand opening in individuals with stroke.

van Klink, 2013

Effectiveness of Upper Limb Functional Electrical Stimulation After Stroke for the Improvement of Activities of Daily Living and Motor Function: A Systematic Review and Meta-Analysis

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 primary outcomes of ADL. Firm conclusions could not be drawn about the effectiveness of FES or its optimum therapeutic window. Hence, there is a need for high quality large-scale randomized controlled trials of upper limb FES after stroke.

Eraifej, 2017

FES Technologies



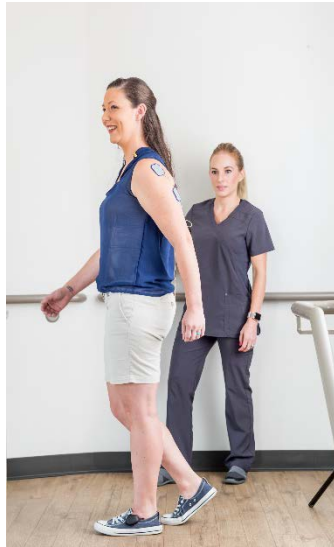
FES Technologies

OmniHi5™



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ODFS[®] PACE XL



Bioness H200



ReGrasp



Clinical Outcomes and Use



Clinical Outcomes



- The best outcomes occur when FES is an adjunct to a complete therapy plan of care.
- Although it would be ideal for an individual to use FES at home in addition to treatment while in therapy, FES is a valuable tool for use in rehab alone when combined with other treatments.
- Using FES at home in addition to participation in physical/occupational therapy, allows the individual to continue treatment beyond the walls of the rehab facility.
- Use of FES at home can help prepare an individual for higher levels of function, for example, by addressing spasticity, tone or ROM limitations.
- Consistent and repeated performance of skilled activities using appropriate movement patterns facilitates motor learning and recovery.

Treatment Ideas

- Use NMES to decrease finger flexor tone by stimulating the finger extensors.
- Use NMES for ROM and/or strength training for finger, wrist, elbow and/or shoulder extensors.
- Use NMES to promote scapular and/or glenohumeral stabilization; inhibit shoulder subluxation and reduce related pain.
- Incorporate FES during functional activities, such as:
 - Reaching to take hold of an item
 - Stabilizing the involved UE with hand on a counter top while reaching into a cabinet with the other hand
 - Extending the shoulder and elbow to hand a ball back to the therapist then reaching forward for another
- Take advantage of technologies offering gaming/VR to engage patients for increased repetitions and increased participation in therapeutic exercises.
- Assign patients home exercise programs, with or without FES, to further progress their recovery.

Stimulus Settings

- Stimulus – a series of pulses
- Pulse Width – the duration of each pulse within a stimulus; an increase or decrease affects power and functional response
- Intensity – the amplitude of the stimulus; has a direct correlation with pulse width that affects the net amount of energy sent from the device to the patient
 - If the intensity is high with a small motor response, increase the pulse width
 - If the intensity is low and the patient cannot tolerate the stimulation, decrease the pulse width
- Frequency – the speed at which the pulses occur; an increase enhances comfort, controls functional response and increase the net energy delivered

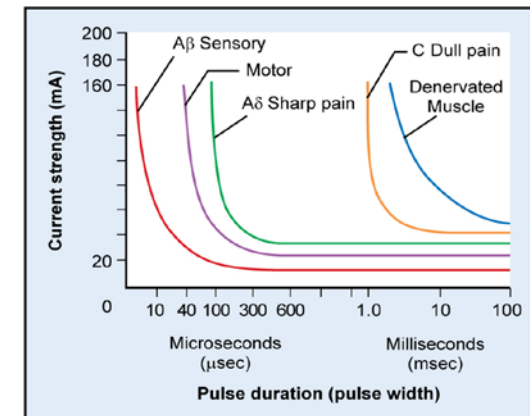


Fig. 8-3. Strength-duration curve.

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Sample Wearing Schedule for Home Use



This wearing schedule includes treatment and time the device is not providing stimulation but is still being worn on the arm.

Day	On Time
1	1.0 hr
2	1.5 hrs
3	2.0 hrs
4	2.5 hrs
5	3.0 hrs
6	3.5 hrs
7	4.0 hrs
8	4.5 hrs
9	5.0 hrs
10	5.5 hrs
11	6.0 hrs
12	6.5 hrs
13	7.0 hrs
14	7.5 hrs
15	8.0 hrs
16	unlimited

Skin Irritation Risk, Prevention and Treatment

- Prevention
 - The patient should follow a prescribed wearing schedule, gradually increasing FES use.
 - Remove the electrodes and device from the arm every 2-3 hours for 15 minutes.
 - Use the lowest intensity necessary to facilitate the desired response.
 - Wet electrodes prior to each use.
- If skin irritation occurs, STOP using FES until the skin is completely healthy. Review and/or revise the wearing schedule, hygiene, etc.
- If the patient follows all instructions for hygiene, wearing schedule, electrode management, intensity, etc. and they still have skin irritation, try alternate electrodes.
- A patient with a true allergy to the stainless steel or gel electrodes will have a reaction if the electrodes are placed anywhere on their skin (i.e. leg) even without electrical stimulation. Try alternate electrodes when the skin is completely healthy.

Skin Care and Hygiene

- Use natural soap without lotion, deodorant or antibacterial agents that can leave a film on the skin which inhibits stimulation from passing efficiently through it.
- Do not use lotion in the area of the electrodes unless the skin is extremely dry, and then use a light lotion at night followed by natural soap to clean the area before applying the electrodes.
- Drink plenty of water (8 glasses or more daily) to keep the skin and tissues hydrated so that the stimulation is efficiently conducted and skin integrity preserved.



Electrodes and Stimulation Parameters

- Cover the gel electrodes with the plastic backing when not in use.
- Assess the integrity of the electrodes with each use and replace about every 2 weeks.
 - This promotes efficient and safe stimulation.
 - More efficient stimulation requires less net charge to produce a response, thereby preserving the skin, muscle and nerve integrity.
- Using the lowest net charge possible is ideal.

Decreasing pulse width may require an increase in intensity to produce the desired response. It's a balancing act. These settings affect comfort and functional output. The other items listed above and on previous slides are more likely to reduce the risk of skin irritation.

Summary



- FES is a clinically proven tool that may help promote optimal functional outcomes for individuals with upper motor neuron lesions.
- Technologies today offer therapists efficient set-up and means for calculating objective measures, all while expediting patient recovery.
- Although patients benefit from using FES in therapy, today's technologies make it possible for many patients to continue their treatment outside the rehab setting as well.



THANK YOU!

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