An Introduction to Functional Electrical Stimulation

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3 Purpose of Neuromuscular Electrical Stimulation in Healthcare

1. To aid diagnosis.
2. As a therapeutic tool
3. To restore lost or damaged function.
What is FES?

Functional electrical stimulation (FES) is a technique that uses small electrical impulse to activate nerves leading to paralysed muscles so as to produce functional movement.
Functional Electrical Stimulation - Schematic Representation: Illustration of motor neuron stimulation - MilosRPopovic

(a) The cell nucleus is responsible for synthesizing input from dendrites and deciding whether or not to generate signals. Following a stroke or spinal cord injury, muscles are impaired because motor neurons no longer receive sufficient input from the central nervous system.

(b) A functional electrical stimulation system injects electrical current into the cell.

(c) The intact but dormant axon receives the stimulus and propagates an action potential to

(d) the neuromuscular junction.

(e) The corresponding muscle fibers contract and generate

(f) muscle force.

(g) A train of negative pulses is produced.

(h) Depolarization occurs where negative current enters the axon at the “active” electrode indicated
• FES was initially referred to as Functional Electrotherapy by Liberson in 1960 to provide muscles with electrical stimulation so that the muscle contraction has a functional purpose either in locomotion or in prehension or other muscle activity.

• In 1967, the term Functional Electrical Stimulation was coined by Moe and Post.
FES

➢ is designed to stimulate motor and sensory nerves.
➢ replicates the body’s own electrical impulse to generate a muscular response.
➢ uses low voltages to obtain deep muscle movement (9-11 Volts).
➢ provides computer-regulated signals, generated by software, for a clean & precise waveform.
➢ uses a balanced-biphasic waveform for stimulation that does not produce ion accumulation
FES – 3 classes according to the purpose

1. Restoration of sensory functions
2. Restoration of skeleto-motor functions
3. Restoration of autonomic functions
Physiological effects of stimulation on muscle tissue

- Increases circulation (Taylor 1993)
- Increases muscle bulk (Taylor 1993)
- Increases muscle strength (Milner Brown 1988)
- Increases fatigue (Dubowitz 1982, Pournezam 1988)
- Changes in muscle fibres from pale to red (fast twitch to slow twitch). In long duration of stimulation, fatigue will reduce but simultaneously strength of muscle fibre will reduce.
Effects of FES

• Suitable for producing controlled tetanic contraction of muscles which generates adequate torque to produce functional movements, in the absence of adequate voluntary contraction.
• FES may facilitate motor recovery with muscle and joint afferent feedback with repetitive movement (Daly & Ruff)
Mechanism in FES

• **Ramped current** – Sloping rise in intensity to a preset peak, within preset pulse duration followed by gradual or sudden drop to zero.

• **Gradation of stimulation** to the desired frequency and intensity is used for patient comfort.

• **Ramp time** refers to the period of time from when the stimulation is turned on until the actual onset of the desired frequency. Ramp time 1-3 secs

• (Similar in physiological characteristics to Surged faradic stimulation)
Contraindications

• Pacemakers/Defibrillators

• Pregnancy

• Carotid bodies, peripheral vascular disorders, thrombophlebitis, DVT
Who Benefits ??

- Patients with upper motor neuron lesion.
- High intensity FES of the quadriceps muscles allows patients with complete lower motor neuron lesion to increase their muscle mass, muscle fibre diameter, improve ultra structural organization of contractile material, increase of force output during electrical stimulation and perform FES assisted stand-up exercises.

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Effective use in

• Stroke
• Multiple sclerosis (MS)
• Spinal cord injury, above the level of T12 (SCI)
• Parkinson's disease
• Cerebral palsy (CP) spastic
• Head injury
• Familial or hereditary spastic para paresis
Odstock Dropped foot Stimulator

• Developed on the principle by Liberson (1961) designed and built for a patient with incomplete C6 SCI.
• Common peroneal nerve was stimulated during swing phase of walking which was controlled with a foot switch in the shoe. This enabled the patient to walk for 100 m. After redesigning five times, it has evolved from single channel - 2 channel – 4 channel – 8 channel.
• Recent ones are free hand system which enables tetraplegics to improve their arm and hand function.
Parts of an FES Single channel
FES Vs AFO

FES (Functional Electrical Stimulation)

AFO (Ankle-Foot Orthosis) [Custom-Made Plantarflexion Hinged, Solid, or Leaf Spring]
Foot drop – video
Gait Re-education with FES

- Stance: No stimulation
- Foot switch detects heel rise
- Causes stimulation to the electrodes
- Produces dorsiflexion and eversion through swing
- Produces dorsiflexion and eversion through swing
- Foot switch detects heel strike
- Stimulation ends after lowering the foot to the ground
Re-Education of gait while climbing up/down the stairs
Cycling
Ambulation
Gait training
FES functions Upper limb
Re-educating hand function
Video on improving hand function using FES
The Latest .... Neuroprosthesis
Research IN FES

➢ >40 years of FES research, principles for safe stimulation of neuromuscular tissue have been established.
➢ Methods for modulating the strength of electrically induced muscle contractions have been discovered.
➢ FES systems have been developed for restoring function in the upper extremity, lower extremity, bladder and bowel, and respiratory system.
➢ Some of these neuroprostheses have become commercialized products, and others are available in clinical research settings.
• Functional electrical stimulation of dorsiflexor muscle: effects on dorsiflexor strength, plantarflexor spasticity, and motor recovery in stroke patients by Sabut SK, Sikdar C, Kumar R, Mahadevappa M. *NeuroRehabilitation*, 29(4):393-400. (2011)


• Functional electrical stimulation for stoke rehabilitation by Krishna Bhat Subramanya, Ajithanjaya Kumar Mijar Kanakabettu, Manjunatha Mahadevappa *Medical Hypotheses* *Elsevier Inc.* (http://dx.doi.org/10.1016/j.mehy.2012.01.027), Available online (2012)


• Feasibility of Functional Electrical Stimulation-Assisted Neurorehabilitation following Stroke in India: A Case Series Bhawna Khattar,¹ Alakananda Banerjee,¹ Rajsekhar Reddi,² and Anirban Dutta³¹Department of Physiotherapy and Rehabilitation, Max Super Speciality Hospital, Saket, New Delhi, India ²Department of Neurology, Max Super Speciality Hospital, Saket, New Delhi, India ³Department of Clinical Neurophysiology, Georg-August-University, Goettingen, Germany Received 30 March 2012; Accepted 21 June 2012
• Modelling a BCI system to estimate FES stimulation intensity for individual stroke survivors in foot drop cases by M. Mahadevappa C. Shendkar P. Lenka A. Biswas R. Kumar Biomedical Engineering/Biomedizinische Technik-Berlin© 2013 ISSN-online-1862-278X/Print:0013-5585, 58 (Suppl. 1) (2013)


• An EMG-control functional electrical stimulation (FES) system for restoration of gait in foot drop patients by Sukanta Kumar Sabut, Manjunatha Mahadevappa International Journal of Biomedical Engineering and Technology, Accepted (2013)


Points to Ponder :

1. Years have gone by since FES has been introduced world wide but why is the progress so slow in India? Is it the acceptance of technology/or the cost?
2. What are the neuro-physiological effects(changes following long term use of FES?)
3. What is the carry over effect?
4. Is it cost effective?
5. Need for more clinical studies with FES in developing countries.
Thank YOU !!!