

THERAPEUTIC EFFECT OF FUNCTIONAL ELECTRICAL STIMULATION ON GAIT MOTOR RECOVERY AND MOTOR CORTEX IN STROKE REHABILITATION

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ABSTRACT: Stroke causes walking and grasping difficulties. As per WHO, globally 16 million new strokes case are reported every year, out of which 1.64 million cases occurs in India alone. These numbers reflecting the disease burden points toward challenges of making post-stroke rehabilitation accessible to every affected individual. Recent evidence related to stroke rehabilitation therapies shows that task-specific repetitive exercise remodels the brain via synaptogenesis. The most commonly used stroke rehabilitation methods are physiotherapy, constraint-induced motor therapy, use of robotic devices, functional electrical stimulation (FES), and transcranial magnetic stimulation. Work described in this thesis investigates the use of FES in stroke rehabilitation.

FES therapy is a rehabilitation method facilitating regain of lost functional movements. FES device applies an electrical impulse to nerves-muscles to assist limb movements. A literature review reveals two major needs: development of efficacious FES devices and clinical studies on effectiveness of FES. A new FES device architecture is needed, designed to produce near ideal stimulation waveform for more efficacious FES therapy. Also, there are challenges to reduce the muscle fatigue produced by prolonged duration of electrical stimulation. Researchers are also exploring the use of physiological signals such as sEMG and EEG as command signals to FES devices to make them suitable for personalized therapy. So far clinical trials of FES have concentrated on studying the orthotic effect of FES and does not attempts to explain the underlying mechanisms for FES caused functional improvements. Hence, this thesis studies the therapeutic effect of FES by analyzing motor changes and changes in motor cortex of the brain.

This thesis has four research objectives. First, to design an ultra-low power, portable, FES device that could produce charge balanced biphasic stimulation waveform. Second, to find out methods of controlling stimulus strength using electrophysiological signals from patients such as sEMG and scalp EEG. Third, objective was to evaluate the therapeutic effect of FES in stroke patients having 'foot drop'. Fourth, to evaluate the therapeutic effect of FES in stroke patients having 'hand grasping' difficulties. To achieve these objectives a new FES devices (InStim) was developed and its efficacy was tested on stroke patients in a clinical setting. Also, the effect of FES on gait, motor condition, and motor cortex was investigated by studying the post-FES changes in 48 stroke subjects by analyzing their gait, sEMGs and EEG signals.

The experimental results shows that FES device generating biphasic charge-balanced pulses could be realized using an architecture that constituted DC-DC booster and Op-Amp based driver stage in design. The developed FES device (InStim) is effective in producing appropriate dorsiflexion and produces less muscle fatigue. Further, the sEMG and EEG based model for estimation of stimulus strength is also presented. The clinical trial evaluating effect of FES on foot drop and hand grasp reveals that FES not only produced an orthotic effect but also has a therapeutic effect. These findings were elucidated after evaluating the post-FES improvements in gait, muscle force, sEMG and EEG signals of the patients. To conclude, FES not only improves the functional abilities of stroke patients but also improves gait, muscle force, motor recovery and produce cortical changes in the motor cortex area of the brain.

Keywords: Functional electrical stimulation (FES); Stroke rehabilitation; Gait; sEMG; EEG.