

# Chapter 44

## Electromyography–Based Functional Electrical Stimulation (FES) in Rehabilitation

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### ABSTRACT

*Loss or impairment in the ability of muscle movement or sensation is called Paralysis which is caused by disruption of communication of nerve impulses along the pathway from the brain to the muscles. One of the principal reasons causing paralysis is Spinal Cord Injury (SCI) and Neurological rehabilitation by using neuro-prostheses, based on Functional Electrical Stimulation (FES) is extensively used for its treatment. Impaired muscles are activated by applying small amplitude electrical current. Electromyography (EMG), the recording of biosignals generated by muscle activity during the application of FES can be used as the control signal for FES based rehabilitative devices. This method is predominantly used for restoring upper extremity functioning (wrist, hand, elbow, etc.), standing, walking (speed, pattern) in stroke patients. FES, collaborated with conventional methods, has the potential to be utilized as a useful tool for rehabilitation and restoration of muscle strength, metabolic responses etc. in paralyzed patients.*

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## INTRODUCTION

The EMG signal is produced by active contraction of the muscles. So, since electromyogram shows some function of muscle states it has been long harnessed for being used as a feedback signal for functional electrical stimulation or FES. Although there had been innumerable works on EMG for normal muscle conditions, less is known about electrically stimulated muscle EMG. (N Chesler et al, 1997)

Functional electrical stimulation can be controlled by signals obtained from surface EMG of activated voluntary muscles. EMG does not only signals muscular FES but also neuromuscular FES (Baldi, J. C. et al., 1998). It is so done that the recording electrodes are placed properly in position with respect to the stimulation electrodes. After that required processing is done on those recorded signals so as to minimize the artifacts and non-voluntary M-wave contribution. (B Daruishi et al, 1998) It poses added difficulties on detecting EMG signals in the presence of FES as the FES electrode signals are of much higher magnitude as compared to the muscle generated signals and hence can result in saturating the biopotential amplifiers for a significant amount of time (Durfee, 1995). Hence many researchers earlier had considered removal of stimulation artifacts. But with newer researches this theory is abandoned and instead control scheme for FES is developed. Thus many studies have been carried out on optimal compromise between voluntary muscle activity detection and artifact removal. (C Robinson et al, 1997)

The desired characteristics of the EMG electrodes are low noise, high impedance, high common mode rejection ratio preamplifier having typically a gain around 100 and a frequency range of 10 to 10,000 Hz. The preamplifier signal is then usually fed to a high pass filter, full wave rectifier and a blanking device that is used to reject the aforesaid stimulation artifacts. The signal now obtained is thus used as a trigger signal for initiating or stopping stimulation (A Demosthenous et al, 2008)

Artificial neural network can be also an good option for eliminating adaptive interference effectively. Since the last two decades there had been studies over EMG controlled FES using ANN (artificial neural network) for pattern recognition and discrimination of EMG signals which in turn is used to control the FES. (Z Li et al, 2012) Prior to nineties there had been various studies on ANN implementation on EMG but all those were related to artificial limbs but not functional electrical stimulation. Controlling FES with the same idea was a difficult challenge as FES involved the controlling of peripheral nerves. Back propagation theory of Artificial neural network was used initially to answer this problem which was then modified with time. (H Yamaguchi et al, 2000)

In FES applications EMG are particularly used in those situations where an indication for muscle fatigue is needed. (Durfee 1995) Hence it can massively help in detecting muscle collapse in cases where FES is applied to treat hemi or paraplegic patients (Graupe et al, 1982) or those having ambulation aids or patient suffering from stroke (I Jerman et al, 2009) or spinal cord injury, (Hamzaid et al, 2009) there are quite a few methods to track fatigues but the most common fatigue tracking performance indicators are derived from the root mean square of electromyogram signal amplitude and from the MF i.e. the median frequency of EMG power spectral content. It has been found that such results indicated that for practical FES application it is pretty difficult to obtain proper fatigue tracking indicators. (J Winslow et al, 2003) Thus it is very evident that EMG controlled FES has a very promising field of application and has multiple usages for varied kind of human diseases.

Apart from EMG signals, plenty of other signals get generated due the different activities going on continuously in the human body, known as Biosignals (Kaniusas, E. et al., 2012). These signals are basically used as the control signals needed to drive the FES devices. In case of feedback systems, these feedback signals are also extracted from these biosignals. The biosignals available with the human body

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