

Effect of frequency and amplitude of FES pulses on muscle fatigue during toning of muscles

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This study presents effects of frequency and amplitude of stimulation pulses on muscle contraction. The experiments are on a complete paraplegic patient with injury level between T4 and T5. Number of contraction episode before fatigue has been more for low frequency and low voltage stimulation.

Keywords: FES, Fatigue, Frequency, Voltage

Introduction

Spinal cord injury (SCI) patients are rehabilitated by providing limb movement by applying electrical stimulation locally to the area affected. The method of enhancing and providing mobility function to SCI patient is functional electrical stimulation (FES) by producing contractions in muscles, paralyzed due to central nervous system lesions, by means of electrical stimulation¹. Muscle fatigue is decreased in force-generating ability of a muscle as a result of recent activation². Fatigue is defined as a decline in the force generating ability of skeletal muscles. Rapid fatigue may prevent generation of sufficient force and impede effective task performance during FES applications³. The study compares effect of different stimulation frequencies, stimulation period, and stimulation voltages on the number of contraction episode before fatigue of a patient and analyses the result of such programs carried on a complete paraplegic patient over a period of 6 months.

Factors Affecting Muscle Fatigue

Factors, which contribute to muscle fatigue, are failure at synaptic junction, a decrease in transmitter release, and metabolic exhaustion of contractile mechanism. In case of SCI patients, problem of fatigue is exacerbated by several physiological changes that result from

paralysis, including hypertonic and disuse atrophy. Long-term inactivity due to SCI is associated with chronic changes in muscle metabolism, blood flow, and fiber composition. The bulk of transformation in muscle fiber type (from slow- to fast-twitch) due to disuse atrophy occurs during the first 10 months after injury⁴.

The duration after which muscle cannot perform FES activity is muscle fatigue time (MFT), which is lower when stimulation is given at one stretch and increases when multiple stimulation is given to the patient. MFT can be increased by muscle training program (MTP), which is preconditioning activity before launching of FES program for a completely paraplegic patient. MTPs strengthen affected limb and prevent muscle atrophy. MFT index depends on patient's ability to gain from MTPs. Increase in muscle contraction is a measure to the MFT gain. FES exercises help SCI patient to attain required increase in muscle fatigue time⁵⁻⁷. An increase⁵ in muscle force (5 times) has been observed by using following electrical stimulation parameters: stimulation frequency, 50 Hz; pulse duration, 0.3 ms; and off duty cycle, 5s on/5s.

Materials and Methods

Experimental Setup

Experiments were carried out at Government Medical College and Hospital, Sector 32, Chandigarh. The system uses a microcontroller based 4-channel stimulator⁶, developed around an 8 bit Atmel microcontroller. High

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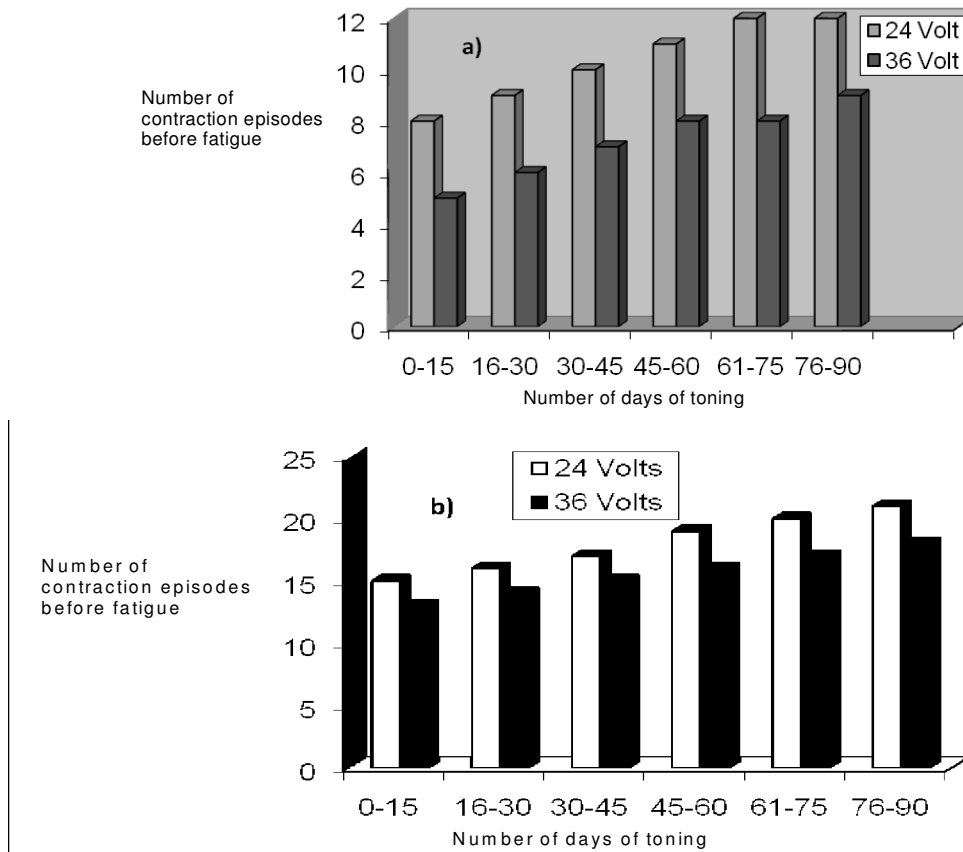


Fig. 1—Contraction episodes (amplitudes of 24 & 36 volts; stimulation period, 8 seconds):
 a) Stimulation frequency 40 Hz; b) Stimulation frequency 16 Hz

voltage requirement was provided by using stack of 12 volt batteries. The system can deliver pulses with frequencies from 16 to 40 Hz. Pulse width was set at 300 microseconds. Pulses are with output voltage levels of up to 120 volts in steps of 12 volt. The rectangular mono-phasic pulses were applied transcutaneously using carbon rubber surface electrodes⁷ (diam 6 cm, thickness 2 mm).

The subject was completely paraplegic patient (26 years old). Injury level was between T4 and T5⁸. Patient had SCI injury two months before trials started. MTP was planned in consultation with ortho surgeon and physiotherapist at GMCH. Exercise was planned as ½ h daily, 5 days a week. Surface electrodes were applied on quadriceps and calf muscles. Welcrow straps were used to tie electrodes with patient’s body. Voltage level used was 24 volts in morning sessions and 36 volts in evening sessions. Stimulation period was 8s ON and 8s OFF⁹. For first 3 months, stimulation frequency was 40Hz and for next 3 months frequency was 16 Hz.

Stimulation was given by pressing a single On/Off switch. Isometric contraction was observed after stimulation was applied¹⁰. The number of time leg responds to applied stimulation is the number of contraction episodes. The height for rise in level of leg is marked and when it touches the height after stimulation was applied the event is taken as contraction episodes¹¹.

Results and Discussion

The number of contraction episodes before fatigue is more at low voltage and low frequency (Fig. 1). At higher frequency and higher amplitude level, muscle will fatigue early and results in less FES activity. MTP carried at low voltage and low frequency is more promising in terms of increase in fatigue time. Increase in the number of contraction episodes before fatigue is more as compared to 40 Hz stimulation frequency (Fig. 1b). With respect to time with multiple stimulation, there is increase in the number of contraction episodes (Fig. 2). This increase is less for stimulation at 36V, 16 Hz whereas increase in the number of contraction episodes is more at 24 V, 16

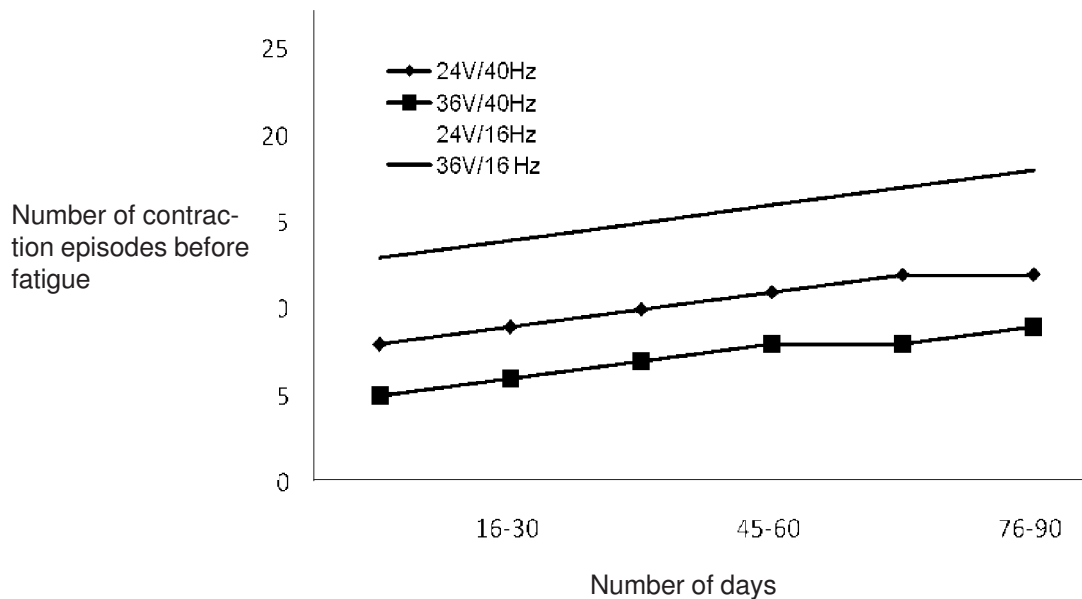


Fig. 2—Effect of frequency and voltage on muscle fatigue as a function of toning

Hz, indicating better muscle toning at lower voltage and low frequencies.

Conclusions

Electrical stimulation given on low voltage and low frequency improves muscle fatigue time. This can be rephrased, as at low voltage and low frequency muscle will do more FES activity. Before taking any FES activity on SCI patient, MTP are required to enhance muscle fatigue time. With proper and regular stimulation exercise given to a completely paraplegic patient, there is a gradual increase in the number of contraction episodes before fatigue. The experiments prove that as time increases contraction level increases. By optimizing frequency, increase in number of contraction is higher in comparison to optimization in terms of amplitude. This also implies that carefully designed and planned training program may increase muscle fatigue time and produce better improvements. The result may vary according to patient's level of SCI injury and muscle residual capability.

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