Chapter 9
A Feedback Controlled FES in Rehabilitation

Yu-Luen Chen
National Taipei University of Education, Taiwan

Te-Son Kuo
National Taiwan University, Taiwan

ABSTRACT

A feedback control functional electrical stimulation (FES) system was proposed to prevent quadriceps weakness and drop-foot of the hemiplegia during gait training. The FES system is triggered by a foot-switch on the heel of the affected foot to stimulate the tibialis anterior muscle for dorsi-flexion and to turn-off the knee locker in the swing phase through the main controller. The footswitch on the heel of the affected-side can be used to stimulate the quadriceps and turn-on the knee locker for quadriceps weakness in the stance phase. It was revealed that the mean velocity, cadence, stride length, active ankle motion range and functional ambulation category (FAC) were significantly improved. A paired t-test indicated that the differences in the electromyography (EMG) of the tibialis anterior and the quadriceps muscles between patient's affected foot and unaffected foot were not significant (p>0.05) after 16 weeks of training. The proposed knee locker device with closed-loop FES system is capable of providing a hemiplegic patient with regular walking restoration after appropriate gait training.

INTRODUCTION

In this chapter, targeted commonly seen problems in stroke patients, carrying out a discussion on knee joint weakness and drop-foot. The goal was to design a more convenient knee lock device combined with closed loop control FES. On one hand, it was hoped to improve the weak knee joint support problem in stroke victims using a knee locker. On the other hand, it was hoped to rectify the drop-foot problem in stroke victims using sensors(footswitch, position sensor)closed loop control. After system construction was completed, before and after gait analysis documentation of stoke victims using this system in walking train-

ing, the system's actual benefit to stroke victims in walking was evaluated.

BACKGROUND

The development of functional electrical stimulation (FES) has a history of more than 40 years. Along with improvements in hardware technology and software control, FES now occupies an important role in rehabilitation medicine. In 1961, to rectify the drop-foot problem in hemiplegics, Liberson and Holmquest used FES to stimulate the peromeal nerve of the hemiplegics paralyzed side and discovered that this method was able to effectively correct drop-foot on the patient's paralyzed side. In those days, the method was simply called functional electrotherapy. It was not until 1962 that Liberson and Holmquest named this kind of therapy functional electrical stimulation (Liberson et al. 1961). From this time on, FES provided another favorable option for rehabilitation medicine and numerous correlated FES studies were subsequently undertaken.

In 1988, Andrews used sensory feedback combined with closed loop control. A standing state control study was carried out in which FES was administered to the lower limbs of two spinal cord injured (SCI) patients. The results of the study were then compared to results from conventional rehabilitative aids. Aids combined with FES were able to allow spinal cord injured patients to stand for relatively long periods of time (Andrews et al. 1988). In 1996, Rongching Dai (Rongching et al. 1996) used tilt sensors to replace conventional footswitches to detect angular variations in the movement of the lower limbs of stroke and SCI patients. These angular variations were used to control the current of the electric stimulus, thereby enabling the patient's walking movements to approach a more normal state. The gait analysis experiment results also proved that this method was superior to conventional ankle support orthosis combined with a footswitch control.

Apart from using tilt sensors and sensory feedback control as a means of control, other methods such as machine learning, fuzzy control, EMG myoelectrical signal control and neural network control were combined with FES to stimulate patient functional movement generation, all producing favorable results (Vodovnilc et al. 1984; Peckham et al. 1992; Chen et al. 2001).

Of the various aids commonly seen on the market, more than half rely on movement from the patient's own residual motor function, which is then corrected using aids. The rectifying ability of these kinds of passive correctional aids is limited. However, in the majority of studies, FES has already been acknowledged in rehabilitation medicine as having reasonably good effects in dealing with increased muscle force shrinkage, promoting muscle activation and the reestablishment of auxiliary motor function. FES is therefore often used in rehabilitation treatment (Kostov et al. 1995; Chen et al. 2004; Miyamoto et al. 1999; Abbas et al. 1995). In the rehabilitation of stroke, the most commonly seen problem during standing and walking movement training is inadequate knee joint support strength (knee back) and drop-foot. When the knee joint support strength is inadequate in walking, patients are prone to fall due to unstable support when standing on the hemiplegic side. The patient's fear of falling results in different step lengths for the left and right feet when walking. Drop-foot can affect patient abilities when walking. Apart from the toes coming into contact with the ground first and resulting in patient tripping, it also has affects the step length when walking and influences the esthetic appearance of the patient's walk.

FEEDBACK CONTROL FES

Instrumentation

The configuration of the proposed a feedback control FES system is shown in Figure 1. This

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