Experimental correction of drop foot by neural network learning FES

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Abstract – The purpose of this study was to evaluate whether neural network learning FES by using the signals of a tri-axial accelerometer and a gyroscope could detect the gait cycle of hemiplegic patients and improve the drop foot gait. Six hemiplegic patients in chronic stages participated in this study. The walking speeds were 0.54 ± 0.08 m/s (mean ± SD) of the non-FES assisted gait and 0.58 ± 0.10 m/s of the neural network learning FES assisted gait, respectively. The step cadences were 23.6 ± 0.9 steps of the non-FES assisted gait and 22.0 ± 1.0 steps of the neural network learning FES assisted gait. The neural network learning FES produced statistically significant improvement in the correction of the drop foot (p < 0.05).

Keywords: functional electrical stimulation (FES), neural network learning, drop foot, hemiplegia

Introduction

From the report of Liberson in the 1960s [1], functional electrical stimulation (FES) has been used for the correction of drop foot after the occurrence of an upper motor neuron disease, such as a stroke [2,3,4]. For the correction of drop foot, the common peroneal nerve was electrically stimulated during swing phase of the gait.

There are some gait cycle detection systems for the correction of drop foot by FES. We carried out neural network learning FES by using the signals of a tri-axial accelerometer and a gyroscope. The purpose of this study is to evaluate whether this system can detect the gait cycle of hemiplegic patients and correct the drop foot gait.

Subjects and Methods

A tri-axial accelerometer (Hitachi Metals H48D, 4.8×4.8×1.5 mm) and a gyroscope (Murata ENC-03R, 4.0x8.0x2.0 mm) were fixed on one base (2.0×1.4 cm) and were fixed on the tibial tubercle of the affected knee (Fig.). A heel sensor was placed on the affected sole as a control signal (Click BP, Tokyo Sensor Co., 35×17×4 mm). The collected signals during walking were sent to a data logger (Hioki 8430 Memory Hilogger), and the recorded signals were transferred to PC for processing using Neural Network Learning (MATLAB Neural Network Toolbox). The use of Neural Network Learning (NNL) enables detection of gait cycle by using only a tri-axial accelerometer and a gyroscope by means of converting their signals into signals showing swing and stance phases, like the signals of a heel sensor.

Six hemiplegic patients in chronic stages participated in this study. For walking with neural network learning FES, the sensors were placed on the tibial tubercle of the affected knee and the tibialis anterior muscles and peroneal nerve were stimulated using surface electrode stimulation device (Pulsecure Pro, OG-Giken). For the assessment, the walking speeds and the step cadences of the neural network learning FES assisted gait using a 10m course were measured and compared with the non-FES assisted gait.

Fig.: A tri-axial accelerometer and a gyroscope sensor circuit (A) and the mounted position (B).
Results

All patients successfully could walk with neural network learning FES. Patients with FES from signals of only the tri-axial accelerometer and gyroscope had faster walking speed and fewer steps than patients without FES. The walking speeds were $0.54 \pm 0.08$ m/s (mean $\pm$ SD) of the non-FES assisted gait and $0.58 \pm 0.10$ m/s of the FES assisted gait, respectively. The walking speed was significantly greater with the AHSS assisted gait ($p < 0.05$; Wilcoxon signed ranks test). The step cadences were $23.6 \pm 0.9$ steps of the non-FES assisted gait and $22.0 \pm 1.0$ steps of the FES assisted gait. The step cadence was significantly smaller with the AHSS assisted gait ($p < 0.05$; Wilcoxon signed ranks test).

Discussion

The neural network learning FES produced statistically significant improvement in the correction of the drop foot in hemiplegic patients. All patients were able to walk faster with neural network learning FES assisted gait than with the non-FES assisted gait. Kostov et al. reported that sensor signals were recorded using a pressure sensor installed in the insoles of a subject’s shoes and a goniometer attached across the joints of the affected leg in a subject with spinal cord injured. The machine-learning techniques used were adaptive logic network and inductive learning algorithm\[5\]. Although gait analysis using a tri-axial accelerometer has been carried out, clinical validity of using a tri-axial accelerometer and neural network learning for hemiplegic patients has not been reported. In this study, by using neural network learning FES from the signals of an accelerometer and a gyroscope, the gait ability of hemiplegic patients was improved.

Conclusions

The results demonstrate that neural network learning FES produced statistically significant improvement in the correction of the drop foot.

References


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