EMG BASED TRIGGERING AND MODULATION OF STIMULATION PATTERNS FOR FES-ASSISTED AMBULATION – A CONCEPTUAL STUDY

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INTRODUCTION

The surface electromyogram (sEMG) from the rectus-femoris is a good indicator of the gait-speed in able-bodied subjects [1], and may be used to temporally scale functional electrical stimulation (FES) patterns to change the speed of assisted gait [2]. The purpose of this study was to investigate the potential of utilizing the sEMG as both a proportional and discrete control source for FES-assisted ambulation after incomplete spinal cord injury (ISCI). The ability to modulate volitional sEMG was measured in two subjects with ISCI and four able-bodied volunteers to determine its suitability as a proportional command input for FES to paralyzed synergists. The muscle activations during over-ground walking of the able-bodied subjects were further analyzed to determine whether the sEMG can provide a consistent trigger that could replace of the mechanical switches currently employed during FES-assisted ambulation.

METHODS

Two subjects with incomplete spinal cord injury (age 22 and 36 yrs, C7 ASIA C and T4 ASIA D respectively) and four able-bodied volunteers (ages 25 to 54 years) participated in the study. Subjects were positioned on a Biodex System3 dynamometer (Biodex Medical Systems, USA) with the knee fixed isometrically at 30 degrees of flexion while surface recording electrodes were positioned over the rectus-femoris. The sEMG was pre-amplified by a CED 1902 preamplifier (Cambridge Electronic Design, England) and low-pass (1000 Hz) filtered before sampling at 2200 Hz by AT-MIO-64F-5 data-acquisition card (National Instruments, USA). The rectified sEMG was normalized by the average value during maximum voluntary contraction (MVC) before modulating the vertical position of a tracking signal displayed to the subjects on a computer monitor. Subjects were instructed to track a rectified 0.01 Hz sinusoidal target signal of amplitude 0.7. A set of five, 100-second trials were taken for each subject and the results were ensemble averaged. Mean square tracking error (MSE) between the target and sEMG modulated pursuit signals were computed separately for the ascending and descending phases of each trial. Able-bodied subjects then participated in walking trials in which linear envelopes of the sEMGs were derived bilaterally from the tibialis, quadriceps, hamstrings, triceps surae and gluteal groups with the VICON motion analysis system (Oxford Metrics Ltd., Oxford, UK). Principal component analysis was performed to reduce the order of the data [3]. Analysis was then performed in the eigen-space of the sEMGs for pattern identification.

RESULTS AND DISCUSSION

The MSE for the ISCI subjects were 6.72 % MVC during phases of increasing muscle activity, and 9.69 % MVC for the relaxation phases. The MSE for the able-bodied subjects were 6.39 and 5.59% MVC for the increasing and relaxation phases, respectively.

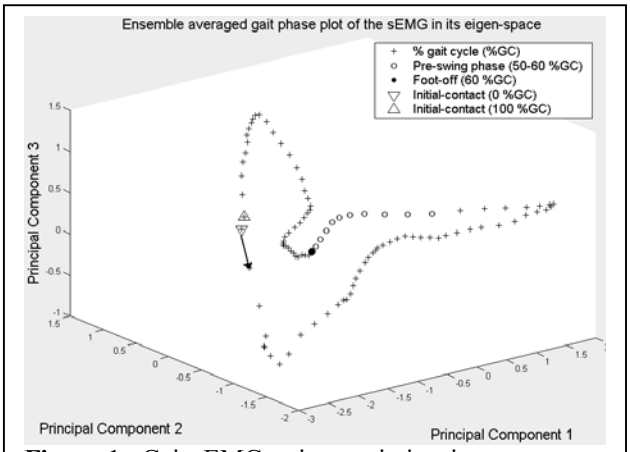

Figure 1: Gait sEMG trajectory in its eigen-space

The first four principal components (PC) of the sEMG during able-bodied gait accounted for about 98% of the variance (%VAF) in the data. **Figure 1** shows the sEMG in its eigen-space defined by the first three PCs (90.67 %VAF). The data-points representing the pre-swing phase of the gait cycle were clustered together in a pattern and may be appropriate for use as a gait event detector. The presence of such a pattern of volitional muscle activations remains to be confirmed in a set of partially paralyzed muscles in individuals with ISCI.

CONCLUSIONS

ISCI subjects performed as well as the able-bodied subjects during increasing muscle activity, while their performance degraded during relaxation of the muscle, implying that the sEMG may potentially be a proportional control source. Furthermore, a consistent pattern of muscle activation exists during the pre-swing phase in the able-bodied subjects. If such a pattern of volitional muscle activation exists during the switch activated FES assisted gait in ISCI subjects, then it might be used to replace the manual mechanical triggers and better integrate and coordinate stimulation with their intact voluntary function. This is the topic of current investigation.

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