



Mechanomyography responses characterize altered muscle function during electrical stimulation-evoked cycling in individuals with spinal cord injury

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ABSTRACT

Background: Investigation of muscle fatigue during functional electrical stimulation (FES)-evoked exercise in individuals with spinal cord injury using dynamometry has limited capability to characterize the fatigue state of individual muscles. Mechanomyography has the potential to represent the state of muscle function at the muscle level. This study sought to investigate surface mechanomyographic responses evoked from quadriceps muscles during FES-cycling, and to quantify its changes between pre- and post-fatiguing conditions in individuals with spinal cord injury.

Methods: Six individuals with chronic motor-complete spinal cord injury performed 30-min of sustained FES-leg cycling exercise on two days to induce muscle fatigue. Each participant performed maximum FES-evoked isometric knee extensions before and after the 30-min cycling to determine pre- and post- extension peak torque concomitant with mechanomyography changes.

Findings: Similar to extension peak torque, normalized root mean squared (RMS) and mean power frequency (MPF) of the mechanomyography signal significantly differed in muscle activities between pre- and post-FES-cycling for each quadriceps muscle (extension peak torque up to 69%; RMS up to 80%, and MPF up to 19%). Mechanomyographic-RMS showed significant reduction during cycling with acceptable between-days consistency (intra-class correlation coefficients, ICC = 0.51–0.91). The normalized MPF showed a weak association with FES-cycling duration (ICC = 0.08–0.23). During FES-cycling, the mechanomyographic-RMS revealed greater fatigue rate for rectus femoris and greater fatigue resistance for vastus medialis in spinal cord injured individuals.

Interpretation: Mechanomyographic-RMS may be a useful tool for examining real time muscle function of specific muscles during FES-evoked cycling in individuals with spinal cord injury.

1. Introduction

Functional electrical stimulation (FES)-evoked cycling, has reportedly improved muscle fibre histochemical adaptations and increased muscle strength (Ferrante et al., 2008; Mayson and Harris, 2014; Sabut et al., 2011). FES cycle training, when purposely embedded into rehabilitation interventions, led to improved fatigue resistance of human muscles (Decker et al., 2010; Haapala et al., 2008; Thrasher et al., 2013). However, rapid onset of muscle fatigue during FES exercise often limits its clinical benefits, because neuromuscular fatigue occurs earlier and more rapidly during FES-evoked contractions in paralyzed or paretic muscles compared to normally-innervated tissues

(Binder-Macleod et al., 1995). In clinical practice, muscle fatigue can be assessed during FES-cycling as a reduction of power output over time, often counteracted by user real-time modulation of current amplitude or other neuromuscular stimulation parameters to minimize negative fatigue effects (Pincivero et al., 2001). The development of physical sensors and signal quantification software to monitor real-time fatigue at the muscle level would improve the deployment of FES systems for practical use by allowing the patient to regulate neuromuscular stimulus parameters and maintain the quality of a physical activity by reducing fatigue-related negative sequelae (Haapala et al., 2008). This would be useful both for “closed-loop” medical devices requiring real-time feedback, as well as “open-loop” systems requiring muscle status

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