Quadriceps mechanomyography reflects muscle fatigue during electrical stimulus-sustained standing in adults with spinal cord injury – a proof of concept

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Abstract

This study investigates whether mechanomyography (MMG) produced from contracting muscles as a measure of their performance could be a proxy of muscle fatigue during a sustained functional electrical stimulation (FES)-supported standing-to-failure task. Bilateral FES-evoked contractions of quadriceps and glutei muscles of four adults with motor-complete spinal cord injury (SCI), were used to maintain upright stance using two different FES frequencies: high frequency (HF – 35 Hz) and low frequency (LF – 20 Hz). The time at 30° knee angle reduction was taken as the point of critical ‘fatigue failure’, while the generated MMG characteristics were used to track the pattern of force development during stance. Quadriceps fatigue, which was primarily responsible for the knee buckle, was characterized using MMG-root mean square (RMS) amplitude. A double exponential decay model fitted the MMG fatigue data with good accuracy ($R^2 = 0.85–0.99$; root mean square error (RMSE) = 2.12–8.10) implying changes in the mechanical activity performance of the muscle’s motor units. Although the standing duration was generally longer for the LF strategy (31–246 s), except in one participant, when compared to the HF strategy, such differences were not significant ($p > 0.05$) but suggested a faster muscle fatigue onset during HF stimulation. As MMG could discriminate between different stimulation frequencies, we speculate that this signal can quantify muscle fatigue characteristics during prolonged FES applications.

Keywords: FES-supported standing; functional electrical stimulation; mechanomyography; muscle fatigue, spinal cord injury

References