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Investigation of Different Stimulation Patterns to Reduce Muscle Fatigue during Functional Electrical Stimulation

Authors : R. Ruslee, H. Gollee

Abstract : Functional electrical stimulation (FES) is a commonly used technique in rehabilitation and often associated with rapid muscle fatigue which becomes the limiting factor in its applications. The objective of this study is to investigate the effects on the onset of fatigue of conventional synchronous stimulation, as well as asynchronous stimulation that mimic voluntary muscle activation targeting different motor units which are activated sequentially or randomly via multiple pairs of stimulation electrodes. We investigate three different approaches with various electrode configurations, as well as different patterns of stimulation applied to the gastrocnemius muscle: Conventional Synchronous Stimulation (CSS), Asynchronous Sequential Stimulation (ASS) and Asynchronous Random Stimulation (ARS). Stimulation was applied repeatedly for 300 ms followed by 700 ms of no-stimulation with 40 Hz effective frequency for all protocols. Ten able-bodied volunteers (28±3 years old) participated in this study. As fatigue indicators, we focused on the analysis of Normalized Fatigue Index (NFI), Fatigue Time Interval (FTI) and pre-post Twitch-Tetanus Ratio (ΔTTR). The results demonstrated that ASS and ARS give higher NFI and longer FTI confirming less fatigue for asynchronous stimulation. In addition, ASS and ARS resulted in higher ΔTTR than conventional CSS. In this study, we proposed a randomly distributed stimulation method for the application of FES and investigated its suitability for reducing muscle fatigue compared to previously applied methods. The results validated that asynchronous stimulation reduces fatigue, and indicates that random stimulation may improve fatigue resistance in some conditions.

Keywords : asynchronous stimulation, electrode configuration, functional electrical stimulation (FES), muscle fatigue, pattern stimulation, random stimulation, sequential stimulation, synchronous stimulation
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