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SVR modelling of mechanomyographic signals predicts neuromuscular stimulation-evoked knee torque in paralyzed quadriceps muscles undergoing knee extension exercise

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ABSTRACT

Background and objective: Using traditional regression modelling, we have previously demonstrated a positive and strong relationship between paralyzed knee extensors' mechanomyographic (MMG) signals and neuromuscular electrical stimulation (NMES)-assisted knee torque in persons with spinal cord injuries. In the present study, a method of estimating NMES-evoked knee torque from the knee extensors' MMG signals using support vector regression (SVR) modelling is introduced and performed in eight persons with chronic and motor complete spinal lesions.

Methods: The model was developed to estimate knee torque from experimentally derived MMG signals and other parameters related to torque production, including the knee angle and stimulation intensity, during NMES-assisted knee extension.

Results: When the relationship between the actual and predicted torques was quantified using the coefficient of determination (R^2), with a Gaussian support vector kernel, the R^2 value indicated an estimation accuracy of 95% for the training subset and 94% for the testing subset while the polynomial support vector kernel indicated an accuracy of 92% for the training subset and 91% for the testing subset. For the Gaussian kernel, the root mean square error of the model was 6.28 for the training set and 8.19 for testing set, while the polynomial kernels for the training and testing sets were 7.99 and 9.82, respectively.

Conclusions: These results showed good predictive accuracy for SVR modelling, which can be generalized, and suggested that the MMG signals from paralyzed knee extensors are a suitable proxy for the NMES-assisted torque produced during repeated bouts of isometric knee extension tasks. This finding has potential implications for using MMG signals as torque sensors in NMES closed-loop systems and provides valuable information for implementing this method in research and clinical settings.

1. Introduction

Spinal cord injury (SCI) results from trauma to the nervous system and may lead to a long-term permanent neurological impairment [1] especially when the primary motor cortex is severely affected and unable to send motor commands [2]. SCI significantly limits individuals' abilities to perform activities of daily living because it causes central nervous system deficits (i.e., voluntary motor control and sensory

function impairments) below the injury level [3]. One viable treatment for this population is neuromuscular electrical stimulation (NMES) for involuntary muscle contractions [3,4]. Most commonly, this technology is manually administered through an open-loop paradigm [5]. While this approach is preferred by individuals with SCI due to its operational simplicity, its clinical effectiveness is limited [6]. As a better alternative, closed-loop NMES systems have been recommended [5]. With this approach, the electrical stimulation parameters can be modulated by the

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