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ELECTRICAL STIMULATION PARAMETERS INFLUENCE IN MUSCLE ACTIVITY INHIBITION: EXPERIMENTAL STUDY

Ana Campos [1], João Gouveia[1], Rui Coelho[1] and Jorge Martins[1]

[1] IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal

a.rita.campos@tecnico.ulisboa.pt; joao.g.gouveia@tecnico.ulisboa.pt; rui.coelho@tecnico.ulisboa.pt; jorgemartins@tecnico.ulisboa.pt

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1 INTRODUCTION

According to the World Stroke Organization, stroke is ranked as the second-leading cause of mortality and the third-leading cause of both mortality and disability combined in 2022. In the same year, the global population of stroke survivors numbered 101 million individuals; they may experience long-term disabilities, with up to one-third remaining physically dependent and facing cognitive and motor impairments impacting their gait. These impairments increase the risk of falls and, in severe cases, mortality. Data from 1990 to 2019 showed a 70% increase in stroke incidence, with projections suggesting a continued upward trend [1, 2].

Hence, gait rehabilitation is essential for stroke survivors' recovery, promoting independence in daily activities. Functional electrical stimulation-based orthoses have been proven effective in restoring movement disorders. However, these existing solutions do not account for the potential presence of spasticity or other debilitating spastic paresis disorders in patients. These devices exhibit limiting performance when used by such individuals, as they must be capable of counteracting muscle overactivity, which may pose risks to the user. Spasticity affects 4-42% of survivors, and in 2022, 12 million people worldwide suffered from this condition, including stroke survivors, individuals with cerebral palsy, spinal cord injuries, and multiple sclerosis [3, 4].

To reduce muscle activity in spastic muscles, electrical stimulation (ES) has been used to enhance inhibitory reflexes, although there is controversy regarding the stimulation parameters due to their high variability. Additionally, variations in outcome measures make it challenging to establish the most effective parameters for inhibiting unwanted muscle activity. This study aims to develop an experimental protocol to investigate the influence of ES parameters on the ability to inhibit ankle muscle activity through arc reflexes, particularly through reciprocal inhibition. This work analyses the connection between the agonist muscle tibialis anterior (TA), which will be subjected to ES, and the antagonist muscle soleus (SOL), where the inhibition will be evaluated.

2 EXPERIMENTAL STUDY

Eight healthy people (4 males and 4 females) between the ages of 23-56 years old participated in this study. ES was applied on the common peroneal nerve (CPN) with a custom-made stimulator and with self-adhesive electrodes (axion GmbH). The tested stimulation parameters can be categorized into three sets, each characterized by distinct pulse widths. Within these sets, four amplitude values are examined. The pulse amplitudes under consideration are: 50% of the sensory threshold, the sensory threshold itself, the motor threshold, and the maximum amplitude that can

be applied without causing discomfort to the participant. These pulse amplitudes are evaluated against pulse widths of 0.01ms, 0.2ms, and 0.3ms. To monitor muscle activity, electromyography (EMG) electrodes were placed on the tibialis anterior (TA) and soleus (SOL) muscles.

The experimental procedure starts with a familiarization with ES, aiming to minimize any potential impact on the collected data by ensuring participants remain calm throughout the trial. This involves locating the optimal electrode placement and gradually adjusting the experimental ES parameters to ensure a smooth and comfortable transition. Special attention is required to avoid activating the peroneal muscles, as they are not SOL's antagonist and could affect the study if activated. Afterwards, the SOL's maximal voluntary isometric contraction (MVIC) is determined by instructing the participant to execute a maximal voluntary isometric plantarflexion while seated with their foot restrained for a duration of 5 seconds for three consecutive trials. Throughout the contraction, the participant is provided with EMG feedback to enhance performance, and the SOL's MVIC is derived from the average of the three trials.

Lastly, the participant is instructed to execute a 20% MVIC of the SOL muscle while maintaining the same positioning as during the collection of the SOL's MVIC. Visual feedback is provided to enable the participant to monitor their own SOL contraction. During the isometric plantarflexion, the participant receives five ES pulses with varying frequencies to prevent bias. The mean and standard deviation (SD) of the SOL's EMG are calculated before each pulse to analyse excitations and inhibitions. Excitations and inhibitions are considered only if the signal exceeds the mean ±1 SD for at least 2ms, using trapezoidal numerical integration to compute its magnitude. Furthermore, the reflex responses resulting from ES are expected to occur between 31-65ms, corresponding to the time it takes for the stimulus to provoke a response in SOL and the arrival of a supraspinal signal to the SOL as a consequence of the CPN ES.

In conclusion, this study can offer evidence that the reciprocal inhibition reflex can be modulated, providing insight into the most effective ES parameters for eliciting the required inhibition. This can mark an initial step towards accounting for spastic paresis in orthoses, with the next step being the validation of this study's findings in individuals with spastic paresis disorders.

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