

Estimating Voluntary Muscle Activity During Constant and Time-Varying Electrical Stimulation

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Abstract— We evaluated the Gram Schmidt (GS) filter’s ability to remove the stimulation response, M-wave, from electromyogram (EMG) signals generated by stimulation. We compared estimated resting EMG in able-bodied participants at the height of a stimulation ramp, during constant stimulation, and during no stimulation. In the absence of a simultaneous voluntary contraction, the filtered EMG estimates during no stimulation were lower than during ramping stimulation, but not during constant stimulation. Results show this approach deserves further study as a way to measure effort during therapeutic interventions.

I. INTRODUCTION

Conventional neuromuscular electrical stimulation for stroke rehabilitation cannot prevent slacking (minimization of volitional effort) and allowing stimulation to passively move a paretic limb, which is not beneficial for motor relearning. Slack detection requires accurate estimation of volitional EMG during stimulation. Prior studies demonstrated the feasibility of separating M-waves from volitional effort but did not rigorously evaluate filter effectiveness [1]. This study examines the Gram-Schmidt filter’s ability to separate volitional and stimulation-induced EMG components during ramping and steady state stimulation. We hypothesized that filtered EMG during rest will be independent of the application of stimulation and stimulation dynamics.

II. METHODS

Four able-bodied participants performed volitional and stimulated isometric index finger abduction. Surface stimulation and recording electrodes targeted first dorsal interosseous while recording finger abduction force. We recorded maximum voluntary contractions, ramped voluntary contractions, and ramped stimulated contractions with 20 Hz stimulation. Pulse width ramped linearly over 1s and was sustained for 1s as participants remained relaxed.

The Gram-Schmidt filter was applied to EMG during stimulation ramping, constant stimulation, and when no stimulation was applied while the participant was relaxed. EMG between subsequent stimulus pulses was defined as a frame. The preceding six frames worth of data were incorporated into the filter to predict and extract the M-wave during the current frame. At least four trials were completed

per participant. Estimated resting EMG during stimulation was calculated for the last frame of the ramp and for a single frame with all preceding frames having constant stimulation. Mean absolute value (MAV) was calculated for a single frame and compared between conditions. An ANOVA compared the differences between estimated resting EMG during no stimulation, ramping stimulation, and constant stimulation. Factors were participants and stimulation type (none, ramping, or constant).

III. PRELIMINARY RESULTS AND DISCUSSION

Statistically significant differences were found between mean MAV of ramping stimulation and no stimulation, and between ramping stimulation and constant stimulation. An example trial in Fig. 1 (left) shows an MAV before and after filtering for each frame of EMG. Ramping stimulation occurred up to 2s and became constant afterward. Fig. 1 (right) shows mean filtered MAV for all participants under no stimulation, ramping stimulation, and constant stimulation.

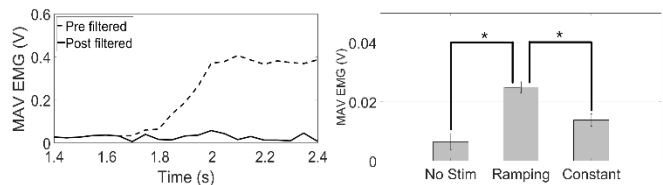


Figure 1: Left - EMG MAV with respect to time both with and without filtering (ramping stimulation becomes constant at 2s); Right - Mean EMG MAV and standard deviation bars of all participants in each condition (* indicates statistically significantly difference).

The mean MAV for the no-stimulation condition was significantly lower than the ramping condition, and the ramping condition was significantly higher than the constant condition. Force relative to maximum voluntary contraction for the mean MAV during ramping stimulation was 7% and for constant stimulation was 3.9%. Though the volitional resting EMG was overestimated, the associated forces were < 10% of maximum voluntary contraction. Therefore, this approach deserves further investigation as a method to link assistive stimulation to estimated volitional effort during therapeutic interventions to prevent passive movement.

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REFERENCES

- [1] H. Yeom, Y.H. Chang, “Autogenic EMG-controlled functional electrical stimulation for ankle dorsiflexion control,” *J Neurosci Methods*, vol. 193, pp. 118–125, Oct 2010.