Muscle Activation Response to Electrical Stimulation for Motor Complete SCI following a Stand Retraining and Functional Electrical Stimulation Intervention: Case Study.

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Abstract:
This case study is part of a larger study where the aim is to expand our current and ongoing research to understand muscle and bone response after four months of training (4-5 days/week) using stand retraining, body weight support (SRT) and electrical stimulation (ES) for individuals who have an incomplete SCI and who are 100% wheelchair reliant. Specifically, researchers will investigate neural, muscle and bone changes in the lower limbs in response to stand retraining using body weight support (BWS) and ES compared to standing alone and ES alone. The purpose of this paper is to present preliminary data on the neuromuscular gains following 32 sessions of SRT-ES intervention for one individual with incomplete SCI. Furthermore, we present a novel approach by utilizing EMG activities of the muscle during ES-induced contraction for evaluation of neuromuscular gain as well as muscle fatigue.

Introduction

Application of electrical stimulation (ES) has shown to improve bone mineral density, muscle hypertrophy and muscle strength in individuals with SCI. Standing retraining (SRT) is a component of locomotor training, an activity-based therapy that emphasizes the generation of muscle activity, and weight bearing in individuals who are unable to stand or walk independently. The beneficial effect of a multi modality approach using SRT-ES may have an impact on present and future interventions for recovery of neural, muscle and walking ability for individuals after SCI. Furthermore, developing EMG response curves in different postural position may provide guidelines for researchers to modify the ES application for the most efficient use during SRT-ES interventions as well as detection of muscle gain or fatigue due to ES application.

1 Method

One participant, ASIA B, 32 years old, 3.5 years post injury, 100% wheelchair reliant participated in this study after signing a consent form approved by KMRREC’s IRB. The participant completed 32 training sessions of an SRT-ES intervention, and completed pre intervention testing in a supine position and post intervention testing in a supine and standing position.

Intervention:
ES was applied during standing on a treadmill using BWS for 60 minutes 4-5 times per week for 32 sessions. ES was delivered over a duty cycle of 11 seconds on, 60 seconds off, with overlap during each contraction between the upper and lower leg. Therefore, gastrocnemius (GC), and tibialis anterior (TA) muscles were contracted first for 4 seconds. The biceps femoris (BF) and rectus femoris (RF) were contracted next for 7 seconds, while the other musculature were still being stimulated (11 second total). This was followed by 60 seconds of rest (no stimulation). The timing and phasing of contractions were selected to promote the muscle groups to contract and relax alternately in an overlapping fashion. Since maximum ES inducible contraction is required for the venous pump to be effective, the participant was acclimated to the ES prior to training to find the maximum tolerable level of stimulation for each muscle and apply that during the training. Stimulation started at the threshold level for minimal contraction and advanced incrementally to the maximum contraction. Blood pressure and heart rate were...
monitored throughout training at every 10 minutes. A standardized stand retraining protocol was implemented with the ES for the 60 minutes on treadmill using BWS. 

**Testing: Pre and Post intervention:**
Surface EMG (pre-amplified electrodes, MA-300, Motion Lab Systems, Inc., LA.) data were collected for the right rectus femoris (RRF) while in supine and standing positions. Baseline electrical stimulation intensity was 6mA and increased 2mA every 10 sec until knee extended 180 degrees. During supine position left knee was extended and the right knee was flexed, with the shank 30 degrees from the right horizontal. For the standing test on a treadmill using a harness at 0% BWS, the hip was extended at 180 degrees, the right knee and shank were orientated in a similar position as in supine. During testing the ES electrodes were placed over the motor points of the RRF. Two surface EMG electrodes were used to collect RRF muscle activation. One EMG electrode was mid point between 2 ES electrodes and one EMG electrode was at mid point, 1-2cm lateral to ES pads.

To analyze the EMG data for all testing conditions we established an EMG Response Curve (Figure 1). EMG data were low-pass filtered sequentially at 35Hz and 7 Hz using a fourth-order zero-lag digital Butterworth filter to remove stimulation artifact. For every 10 second interval, the one second of filtered data with the lowest standard deviation was selected and averaged. EMG activity was plotted against stimulation amplitude to generate the muscle activation response curve.

2 Results

We evaluated the EMG profiles pre and post supine and post standing under two testing conditions: 1) EMG electrodes placed lateral to ES electrodes and 2) EMG electrodes placed between ES electrodes (Figure 1). For all testing conditions there were increases in the EMG response following the intervention compared to pre-supine condition. Pre and post data on supine position indicated that muscle recruitment increased following SRT-ES intervention. The highest EMG activation were recorded during post-supine data collection. Pre intervention, during the supine position, EMG activation plateau at 45 mA. Post intervention, the EMG activation continuously increased up to 65 mA. For all conditions better response curves were recorded, when EMG electrodes were positioned in between ES electrodes.

3 Discussion

An EMG response curve to different stimulation intensities before and after intervention was established. For the supine position, there was a greater muscle response/recruitment after intervention for the same ES intensity. This could be an indication of muscle gain following intervention. At post intervention, these EMG responses were also greater when compared to standing fully weight bearing. Given that the same muscles are activated during post intervention (supine and standing), one would expect the same response rate. Possible explanations are that 1) it is likely that during supine the ES directly activates the RF and therefore the neuromuscular gains were more obvious, 2) during standing due to positional changes, the direct activation of the RF muscle is more challenging and harder to achieve, and 3) during standing multiple muscles contribute to compensation strategies to initiate and maintain knee extension, and ES activation of the RF may be reduced due to these mechanisms. Finally, before training the amplitude reached a plateau as ES increased, possibly indicating fatigue. This was not seen after the intervention possibeley due to an improved training. We are recruiting more partipants into our ongoing research project and our future research may further support the results presented in this case study.

4 Conclusions

An EMG/muscle dose response curve to incremental changes in ES can be developed for individuals with motor complete SCI. The results indicate that ES in standing with BWS may allow individuals with SCI to tolerate standing for longer period of time due to improved muscle firing. It may also postulate that improvements in blood return may occur due to activation of the lower limb physiological muscle pump. Further study on the effect of ES on different muscle groups during standing and supine is warranted to evaluate the effectiveness of this intervention.

5 Literature


