Relating Improvements in Step Trajectory to Ankle Flexor Activity During Training

Patricia Sanchez, Parisa Kamgar, Monalisa Sarhadi, TeKang Chao, Ankit Agarwal, and Deborah S. Won, *Member, IEEE*

A neuromuscular electrical stimulation (NMES) therapy combined with robotic treadmill training (RTT) was recently developed for a rodent model of spinal cord injury (SCI). In this NMES+RTT therapy NMES of the ankle flexor muscle (*tibialis anterior*, or TA) is timed to the beginning portion of the swing phase in each gait cycle. The timing is coordinated by a robotically controlled treadmill device, which optically senses the actual position of the hindlimb. We hypothesized that NMES+RTT would be more effective than RTT alone in rehabilitating stepping after SCI because the external stimulation may reinforce appropriate afferent activity during the step cycle, which has been shown to drive spinal plasticity.

Tests were conducted at baseline, 3 weeks after spinal contusion, and then the day after two weeks of either RTT or NMES+RTT training were completed (n=7). As is typical in the evaluation of rehabilitation therapies, improvements after some fixed amount of training were measured. Comparisons between changes after RTT vs. those after NMES+RTT revealed mostly non-significant differences, although many of these measures approached significance (p<.10). However, such analyses neglect the possibility that differences in training could occur across animals even in the same group which were nominally receiving the same type of training.

In order to test our hypothesis more accurately, EMG burst activity and its coordination with stepping patterns during training were analyzed and compared with the changes in step trajectory from baseline to final testing (during which neither NMES nor robotic assistance were provided).

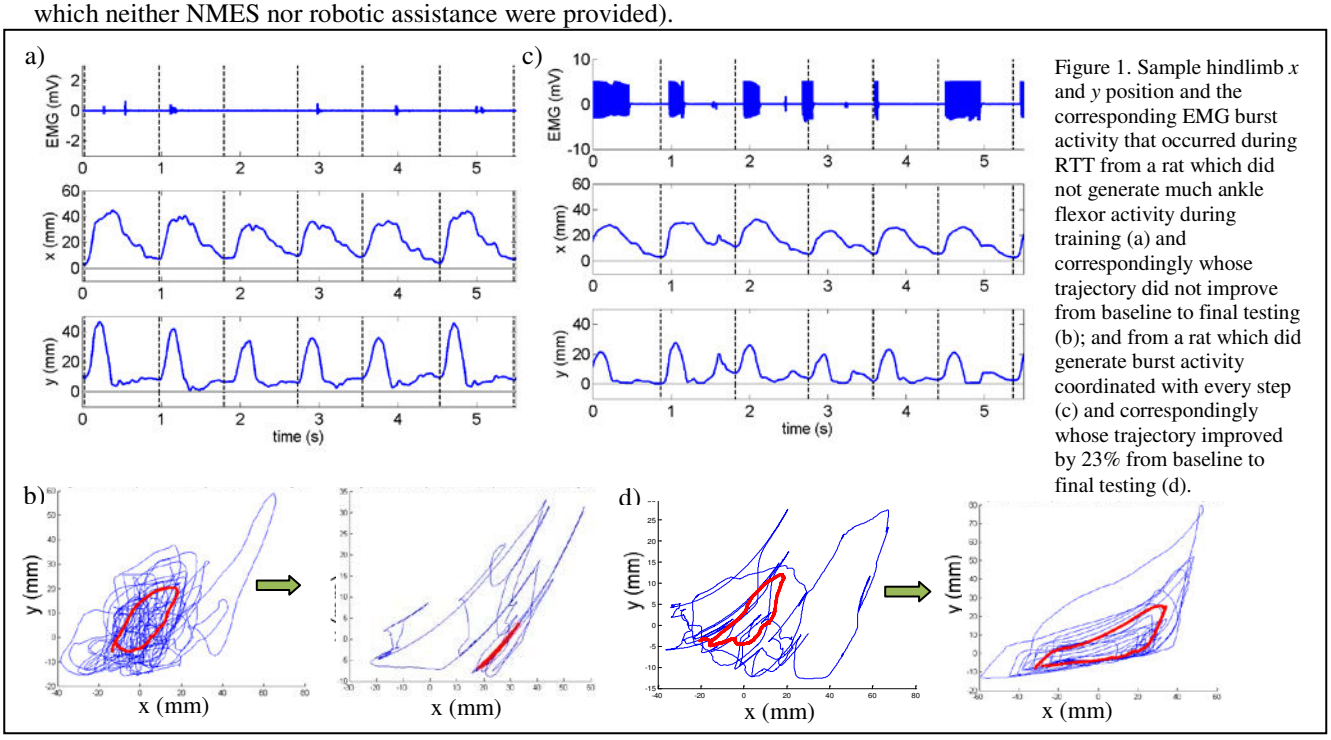

Figure 1. Sample hindlimb x and y position and the corresponding EMG burst activity that occurred during RTT from a rat which did not generate much ankle flexor activity during training (a) and correspondingly whose trajectory did not improve from baseline to final testing (b); and from a rat which did generate burst activity coordinated with every step (c) and correspondingly whose trajectory improved by 23% from baseline to final testing (d).

A robot guides the hindlimb in a pre-programmed trajectory but allows the rat freedom to deviate from the trajectory within a 10mm window. One example is shown for a rat which showed a 32% decrease in step performance (Fig. 1b) according to a trajectory deviation measure and correspondingly exhibited very little burst activity, but what burst activity was produced occurred at random times with respect to the onset of the step (Fig. 1a, indicated by the dashed vertical black lines). Another example was for a rat which exhibited 23% improvement in step trajectory (Fig. 1d) and correspondingly exhibited strong burst activity which overlapped with the portion of the gait cycle in which the rat lifts the hindlimb from the treadmill (Fig. 1c).

This work was supported in part by the National Institutes of Health under Grant # 1SC2NS075743.

P. Sanchez is with the Electrical and Engineering Department, California State University, Los Angeles, CA 90032 USA.

D. S. Won is with the Electrical and Engineering Department, California State University, Los Angeles, CA 90032 USA (phone: 323-343-5908. Fax: 323-343-4547. e-mail: dwon@calstatela.edu).