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Down-Conditioning of Soleus Reflex Activity using Mechanical Stimuli and EMG Biofeedback

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Abstract— **Spasticity is a common syndrome caused by various brain and neural injuries, which can severely impair walking ability and functional independence. To improve functional independence, conditioning protocols are available aimed at reducing spasticity by facilitating spinal neuroplasticity. This down-conditioning can be performed using different types of stimuli, electrical or mechanical, and reflex activity measures, EMG or impedance, used as biofeedback variable. Still, current results on effectiveness of these conditioning protocols are incomplete, making comparisons difficult. We aimed to show the within-session task-dependent and across-session long-term adaptation of a conditioning protocol based on mechanical stimuli and EMG biofeedback. However, in contrast to literature, preliminary results show that subjects were unable to successfully obtain task-dependent modulation of their soleus short-latency stretch reflex magnitude.**

I. INTRODUCTION

Spasticity is a common syndrome caused by various brain and neural injuries. Spasticity, clinically defined as a velocity-dependent resistance of a muscle to stretch [1], can severely impair walking ability and functional independence. It is mainly caused by an exaggerated muscle stretch reflex, i.e. muscle hyperreflexia [2]. To improve the functional independence, two types of conditioning protocols are available aimed at reducing hyperreflexia by facilitating spinal neuroplasticity. First, at muscle level EMG biofeedback of either H-reflexes elicited with electrical stimuli [3] or short-latency stretch reflexes (SSR) elicited with mechanical stimuli can be used [4]. Second, at joint level biofeedback of reflexive joint impedance together with mechanical stimuli can be used [5].

The impedance-based protocol has multiple advantages compared with the EMG-based paradigms. First, the modulation is targeted at joint level, which could help to better facilitate functional improvements [6]. Second, significant task-dependent training effects were already attained after 2, instead of 4-6, sessions. Third, compared with the H-reflex paradigm, mechanical instead of electrical stimuli are used. This could improve participant comfort and general applicability to joints across the body. Unfortunately, the long-term effect as well as the clinical implementation of the impedance-based protocol have not been investigated yet.

To evaluate the effectiveness of these conditioning protocols, it is essential to have an insight in the percentage reduction of both task-dependent and long-term reflexive activity per training session for each protocol. Currently, complete results are only available for the H-reflex protocol, thus it is unknown which of the three protocols would be best to eventually use in the clinic. Moreover, the combined results of all protocols will also give insight into the role of the type of stimulation, electrical versus mechanical, and the type of biofeedback, EMG versus impedance, during conditioning. This paper shows preliminary results for the task-dependent adaptation of a protocol based on EMG feedback of the soleus SSR elicited with mechanical stimuli.

II. MATERIAL AND METHODS

Nine healthy adults (3 female, 22.9±2.4y) participated in this study. The study was approved by the EEMCS Ethics Committee of the University of Twente and all subjects gave written informed consent. The experiment was designed in similar fashion to [3].

The protocol consisted of 5 baseline sessions followed by 18 conditioning sessions with subjects participating in 3 sessions per week. In every session, subjects were seated with their right foot attached to an actuator (Moog, Nieuw-Vennep, the Netherlands) using a rigid footplate and Velcro straps. The system applied one degree of freedom perturbations in the sagittal plane around the ankle joint to elicit the stretch reflexes. The perturbation profile had the following characteristics: an amplitude of 8.1°, a maximum velocity of $190^{\circ}/s$ and a maximum acceleration of $7000^{\circ}/s^2$.

In a baseline session, 225 control reflexes were elicited. For these control reflexes, subjects were asked to maintain a stable level of background activity set as percentage of soleus maximum voluntary contraction (MVC), measured at the start of the session. The desired level of background activity was reached by pressing on the footplate, which was kept in position by the actuator. In a conditioning session, first 25 control reflexes were elicited followed by 225 conditioned reflexes. For the conditioned reflexes, subjects were asked to decrease the SSR magnitude, while keeping a stable background activity level. Visual feedback was provided for both background activity and SSR magnitude. Reflexes were only elicited, if subjects maintained a stable background activity for a period between $2.25s$ and $4s$, picked randomly to keep perturbations unpredictable. Moreover, subjects were urged to relax the first $4s$ after every reflex to avoid fatigue.

Muscle activity of the soleus was measured at 2048 Hz using a Porti (TMSi, Oldenzaal, the Netherlands). For data analysis, the EMG signals were high-pass filtered (2nd-order Butterworth, 10 Hz), rectified and normalized with MVC.

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Background activity was calculated using a 100ms window before perturbation onset. SSR magnitude was calculated as the area under the curve in the reflex interval, a 20ms window with a subject specific start after perturbation onset (typically 43ms), minus the background activity.

III. RESULTS

The preliminary results of the executed experiment focus on the within-session, task-dependent adaptation of the SSR magnitude using the differences between the conditioned and control reflexes. Based on the results of H-reflex experiments [7], task-dependent adaptation should be visible after 4-6 conditioning sessions. The baseline sessions, which were executed without subject instruction to reduce SSR magnitude, are used as reference as no within-session adaptation should occur.

Unfortunately, on average subjects show no task-dependent adaptation of the SSR magnitude during the conditioning sessions, see Fig. 1. To confirm, the task-dependent adaptation of the 5 baseline sessions and the last 5 conditioning sessions also show no statistical difference ($p = 0.45$, unpaired t-test). Individually, only 1 subject shows a significant effect between these groups of sessions ($p < 0.05$, unpaired t-test) with an average task-dependent reference of +8.6% during baseline and change of -3.3% during the last 5 sessions of conditioning. However, this is still about 5 times smaller than the -15% of task-dependent conditioning obtained with the H-Reflex protocol [7]. The group change in background activity accompanying the task-dependent reflex adaptation was significantly different between start and end of the experiment ($p < 0.05$, unpaired t-test), see Fig. 1. On average, background activity slightly increased during baseline sessions, 0.04% MVC, while it slightly decreased during the last 5 conditioning sessions, -0.44% MVC.

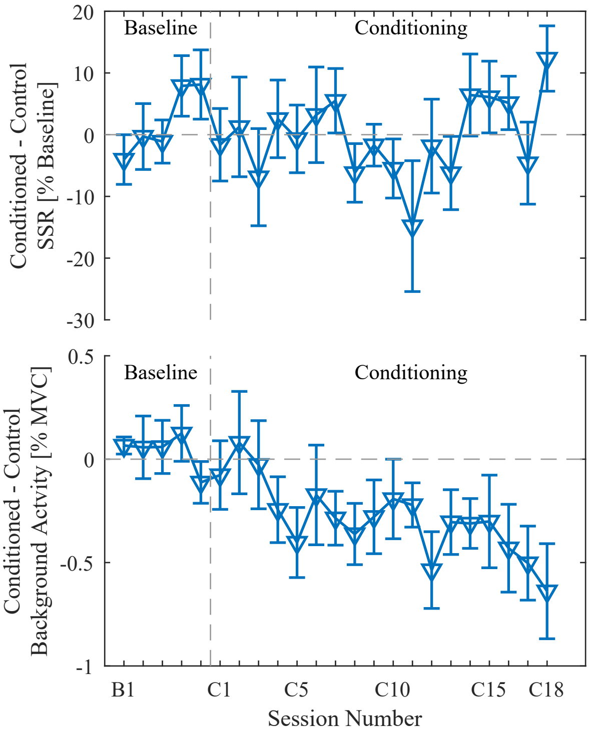

Fig. 1. *(Top)* Group average (± SE) conditioned SSR size minus control SSR size, i.e. task-dependent adaptation *(Bottom)* Group average (± SE) change in background activity conditioned minus control block accompanying task-dependent adaptation of reflexes

IV. DISCUSSION AND CONCLUSIONS

The goal of our experiment was to show the effectiveness of a SSR conditioning protocol based on EMG feedback and mechanical stimuli. In contrast to our expectations, subjects were unable to show within-session, task-dependent down-conditioning of the SSR magnitude. These results are not in line with literature, as previous research with the combination of mechanical stimuli and EMG feedback was successful in showing an overall conditioning effect [4] and long-term effect specifically [8].

Two aspects of the experiment could potentially cause a difference between our study and literature. First, on average a slight within-session decrease in background activity was observed during conditioning. However, a decreased background activity should help obtain a task-dependent reduction in SSR magnitude as motoneuron excitability is reduced. Second, task instructions were slightly different compared to the experiment of [4]. In our study, subjects were instructed to press on the footplate, which was kept in position by the actuator. Contrarily, in [4] subjects were requested to hold a steady position while an actuator delivered a constant bias torque to their joint. The potential effect of the difference in task instruction on task-dependent adaptation will be subject for further research. Moreover, once task-dependent adaptation is achieved, also the across-session long-term effects can be evaluated.

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