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EFFECT OF SOLEUS STRETCH REFLEX CONDITIONING ON LOWER LEG CONTROL DURING PERTURBED ONE LEG STANDING

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SUMMARY
It has recently been demonstrated that stretch reflexes can be altered by operant conditioning even though they are commonly referred to as involuntary muscle responses. Conditioning might be a useful tool for treating musculo skeletal dysfunctions. This study verifies the effect of up-conditioning on the excitability of the soleus muscle and lower leg control on a perturbed one leg standing (POLS) task. Seven healthy subjects were submitted to pre evaluations of balance and soleus muscle excitability during POLS. Subjects then took part in a soleus stretch reflex up conditioning paradigm and were retested hereafter. Five subjects were successfully up-conditioned (SC) and two subjects were non-successfully conditioned (NC). Peak to peak Hmax in relation to Mmax (H:M ratio) and tibial displacement (TD) were obtained during perturbations. In four of the five SC subjects, the H:M ratio assessed during the backward perturbation was increased, while NC subjects presented either a decrease or a slight increase in the H:M ratio. TD angular velocity had a tendency to decrease for all SC subjects For the NC subjects this increased.Operant up-conditioning has promoted an increase of soleus excitability in four SC subjects These results indicate that neuroplasticity is induced by up-conditioning. The changes in excitability were expressed in balance tasks which may lead to better control by decreasing TD in healthy subjects. These findings have yet to be correlated to other kinematic outcomes in order to verify its implications on performance for healthy or dysfunctional subjects.

INTRODUCTION
We have recently developed a protocol based on Thompson et al. [1] to operantly condition the soleus stretch reflex in normal subjects. Our preliminary unpublished data shows that human subjects are able to change the soleus stretch reflex size in the direction of conditioning after 24 to 30 up-conditioning sessions, indicating that human subjects can learn to change the soleus stretch reflex size in response to operant conditioning.

However, there is lack of information regarding functional consequences of this training in terms of how much of the conditioning can be transferred to more dynamic stability tasks. In spinal cord injured subjects, conditioning of the soleus H-reflex led to a more symmetrical gait pattern, indicating that functionally relevant changes are possible [2] In individuals presenting with ankle sprains such conditioning may lead to improved balance control as has been shown when other types of training are implemented. These include sensory motor training and bracing that both lead to alterations in reflex activity [3]. As such the possibility is raised if an altered motor control such as that induced due to our conditioning paradigm can be used for the purposes of prevention or rehabilitation of sports injuries.

The present study aimed at verifying how afferent contribution to ankle joint stiffness and soleus excitability are affected by operant up-conditioning of the soleus muscle in healthy subjects.

METHODS
Seven healthy (4 male and 3 female, 28.8±3.8 years old) subjects with no history of musculoskeletal or neurological dysfunctions were selected to take part in this study. After signing an informed consent approved by the local ethical committee (N-20120044) subjects were submitted to pre and post conditioning perturbed one leg standing (POLS).
POLS consisted of perturbed one leg standing tasks performed on a movable platform (AMTI, OR6-5, Watertown, MA) constructed over a hydraulic system [4] that will randomly slide backwards (5 cm at $66.6 cm.s^{-1}$) or remain stationary, such that the subject did not know which condition followed while attempting to keep standing as still as possible and recovering balance from perturbation as fast as they could. A total of 12 trials were performed with six perturbed trials being considered for analysis. An electrical stimulator (Noxitest IES 230) was used to generate single square-wave pulses of one millisecond duration to elicit soleus H-reflex with the cathode (custom built silver ball with 20 mm diameter) placed over the tibial nerve and anode (PALs platinum rectangular electrode, 75 × 100 mm, Axelgaard Manpositioned) just above the patella. Electrical stimulation strength was varied randomly to obtain the w M-wave and H-reflex recruitment curves [5]. These intensities at which the maximal H-reflex and maximal M-wave were elicited were subsequently used for the POLS test.

Retroreflective spherical markers were placed on the dominant leg of the subject on the skin overlying the following landmarks: calcaneus, first and fifth metatarso-phalangeal joint, lateral malleolus, lateral femoral condyle. Extra markers were placed on the shank serving as tracking markers to define the 3D motion. Marker positions were tracked with a motion analysis system with eight infrared digital video cameras (Oqus 300 series, Qualisys, Gothenburg, Sweden). Kinematic data were recorded with a sampling frequency of 256 Hz. The body of the subjects was modeled as an interconnected chain of rigid body segments: foot and shank as described before [6]. Joint angles were calculated as the three rotations of the shank segment with respect to ground and angular velocity of tibia displacement (TD) was calculated.

Subjects then took part in 30 sessions of soleus stretch reflex operant up-conditioning (UC) as outlined in [7]. After 30 sessions, subjects completed a post UC evaluation as described above. In order to verify whether UC was successful or not, Student *t*- test was used to compare the average of the stretch reflex size of six BL and the last six UC sessions.

Peak to peak maximum H-reflex size in relation to M-max size (H:M ratio) as well as angular velocity of TD during POLS for UC and NC were compared. Paired Student *t* test was performed to verify differences in SC (significance level: $p<0.05$).

RESULTS AND DISCUSSION

Five subjects were successfully up conditioned (SC), increasing the size of the reflex by 51.1±7.51%. Two subjects were non-successfully conditioned (NC).

In four of the five SC subjects, the H:M ratio assessed during the backward perturbation was increased by 20.1±17.8%. NC subjects presented either a decrease or a slight increase in the H:M ratio (Figure 1).

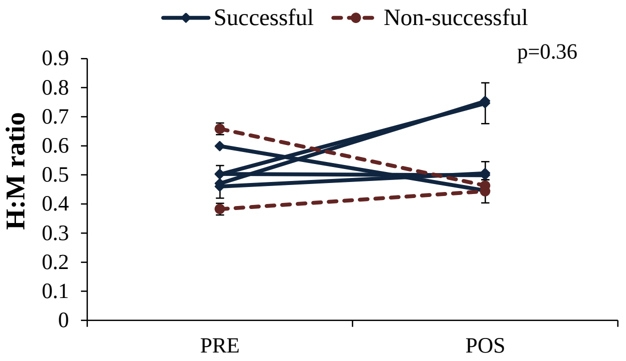

Figure 1: Mean (SD) H:M ratio of soleus muscle during one leg standing backward perturbation for each SC (continuous lines n=5) and NC (dotted lines (n=2) conditioned subjects.

TD angular velocity had a tendency to decrease for all SC subjects ($p=0.32$) varying from almost no change to a 40% decrease. For the NC subjects this increased by 9±30% (Figure 2).

Preliminary data for this ongoing study indicates that indeed an increased stretch reflex size, caused by operant up-conditioning, is transferred to functional tasks such as POLS. Previous studies exposing rats to up conditioning revealed larger H-reflexes during dynamic tasks [8]. This carry over effect onto other tasks has recently been demonstrated in SCI patients where a down conditioning of the soleus H-reflex led to a more symmetrical gait pattern.

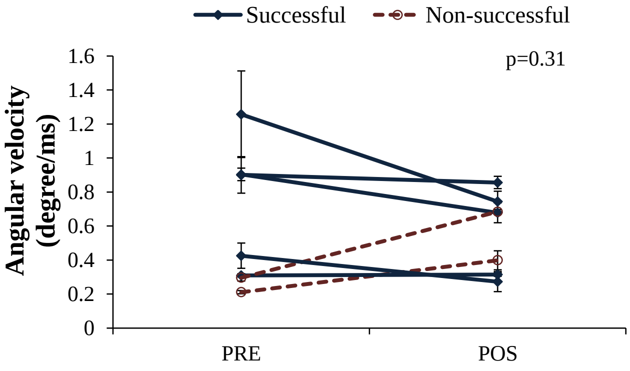

Figure 2: Mean (SD) velocity of TD during one leg standing backward perturbation for each SC (continuous lines n=5) and NS (dotted lines n=2) conditioned subjects.

Taken together with the previous studies, data presented here indicates that up-conditioning induced changes in reflex function may be expressed in a functionally meaningful way.

The tendency to decrease TD angular velocity may reflect a higher soleus control during POLS. Afferent feedback contributes to joint stability, accounting for up to 50% of the total joint stiffness at high isometric force levels [9]. Furthermore, it has been shown that afferent feedback can contribute up to 50% to the normal ongoing activation of the soleus muscle during human walking. [10]. It is possible that the increased excitability of the soleus muscle induced through the successful conditioning sessions transferred to POLS. This may have led to an improved TD control by decreasing the angular velocity.

In conclusion, operant up-conditioning has promoted an increase of soleus excitability in four SC subjects, which was also expressed in the balance tasks through an enhanced control of TD at the ankle in healthy subjects. This finding may offer a direction to improve prevention programs and treatment for populations with altered soleus excitability.

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