A proof-of-concept study on the effects of a robotic-assisted hand rehabilitation programme after stroke on central movement control

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Background: Successful rehabilitation of highly impaired finger and hand movements after stroke is challenging and often remains unsatisfactory with conventional therapy. We therefore developed a new mechanotronic device for rehabilitation of hand function (see **inset** in **fig. 1**) which allows delivering well characterised, high frequent, repetitive movement sequences in an individualised manner. The goal of this ongoing exploratory study is to use fMRI to assess potential changes in the central control of movement of the paretic hand associated with such stimulation and to correlate these with performance gains.

Methods: To date, 11 stroke patients with a moderate to high-grade paresis of the upper limb (pinch grip force grade 2 or 3 according to MRC; spasticity according to the Ashworth Scale <3) have been included (mean age 62, range 47-78, interval to their stroke 41 to 434 days). Before and after three weeks of standardised training using a hand robot (Amadeo, www.tyromotion.com), patients were both tested behaviourally and a subgroup of 7 subjects underwent repeated fMRI using an identical paradigm at 3T. The fMRI experiment consisted of active and passive flexion and extension of the digits II-V of both hands. The Motricity Index (M.I.) before and after training and force measurements on the robot during each session were used to assess gains in functional strength.

Results: Subsequent to an average of 5000 grip movements during 15 therapy sessions on the robot additive to conventional physiotherapy, patients demonstrated significant improvements in their functional strength, both apparent clinically and by measurements of force using the device (M.I. pinch grip pre 23.3+/-6.6 vs. post 26.3+/-4.6, p=0.03; finger flexion pre 7.75+/-4.5N vs. post 11.9+/-4.8N, p=0.04; see **fig. 1**). Whereas fMRI activation patterns with movement of the healthy (not-trained right) hand vs. rest did not change after training (robust activation of contralateral primary sensorimotor cortex (SMC), supplementary and cingulate motor areas, ipsilateral cerebellum in expected somatotopy), subsequent to therapy, significant increases in brain activation in the cerebellum and basal ganglia with movement of the paretic left trained hand were noted on the group level (see **fig. 2**; contrasts not shown). Increase in the contralateral SMC (contralesional) and decrease in the ipsilateral SMC (ipsilesional) with passive movement correlated with functional gains of the affected left hand (**fig. 3**). Opposite effects were note with active movement of the affected left hand (not shown).

Conclusion: These preliminary results suggest distinct changes in SMC activity associated with robotic-assisted rehabilitation of hand function additive to conventional physiotherapy after stroke. High frequent afferent stimulation combined with increments in efferent activity might lead to a shift in the contribution of SMC activation of the unlesioned and lesioned hemisphere. However, these conclusions are limited by the small patient number, the heterogeneity of the cohort, the lack of a control group, the variance in response to therapy, and the difficulty to control for changes in movement kinematics with active movement.
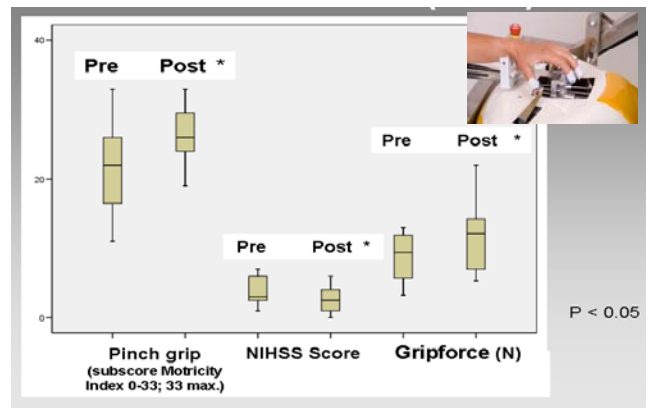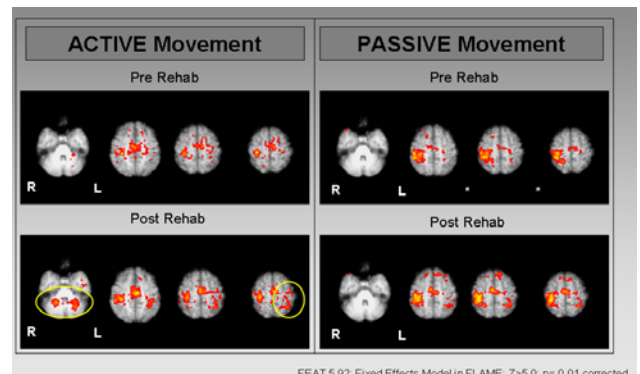

Fig. 1: Changes in clinical and behavioural data after robotic training (n=11). Signifcant increase in the pinch grip force as measured by the Motricity Index , significant decrease in the National Institute of Health Stroke Severity Score, and signficant increase in gripforce of the paretic hand. Note overlap and variability.

Fig. 2: Group mean activation maps of 7 stroke patients with active and passive movement of the left paretic hand vs. rest before and after robotic- assisted rehabilitation
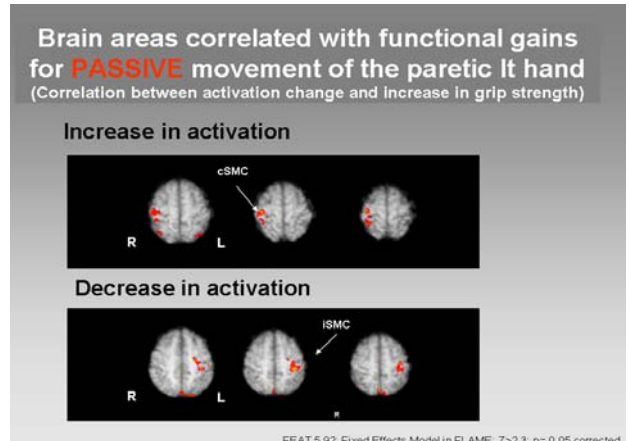
Fig. 3: Parametric variation of treatment response (change in pinch grip force) and change in fMRI activation with passive movement of the paretic left hand.

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