An electromechanical device for distal upper limb training: preliminary results

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Introduction

Functional improvement in the paretic upper limb after stroke continues to be a challenge in neurorehabilitation. Task specific and repetitive robot-assisted training has been shown to be useful in relearning physiological motor patterns in the lower and upper limbs. The electromechanical finger robot (AMADEO) has been developed in order to apply these principles to improve hand function and fine motor skills. The AMADEO system consists of a finger/hand orthosis, a vertically adjustable PC desk, a sensor system for isometric force measurements and integrated software containing several therapy modules. The software provides patterns for moving the fingers and thumb; either consecutively or simultaneously, flexion and extension movements can be programmed in a preset range of motion to imitate grasp.

Methods

36 stroke patients (27 ischemic, 9 hemorrhagic) were randomized into three treatment groups (A = add-on active Amadeo training, B = add-on passive Amadeo training, C = Jacobsen progressive muscle relaxation technique). The patients were evaluated over ten weeks (two weeks baseline, four weeks intervention, follow-up at week ten). The AMADEO tested resistance at four speeds (2, 20, 40, and 200 mm per second) and strength in flexion and extension against preset resistance (R=40N per finger). Range of motion (ROM) was measured passively. The Action Research Arm Test (ARAT) served as a functional outcome measurement, and the Chedoke-McMaster stroke assessment evaluated clinical recovery.

Results

Differences between groups were evaluated by means of ANOVA for continuous data and the Mann-Whitney U test in the case of counted data. Within-group multiple comparisons of treatment effects were conducted with the Student's t-test using the Bonferoni method of p-value correction and the Wilcoxon test, respectively.

Muscle strength in finger flexion improved significantly in group A (p=0.048), but did not in group B (p=0.058) and group C (p=0.269) from beginning to end of study. Muscle strength in finger extension did not improve in any group (group A: p=0.284; group B: p=0.298; group C: p=.859) (Fig. 1). Resistance measurements were found to be greater at lower than at higher speeds. Resistance measured in 2 mm per second revealed significant improvement from beginning to end of study (p=0.024) and during the AMADEO training phase (p=0.040) in group B. No significant differences were found for the rest of the three other movement velocities (20, 40, and 200 mm per second) (Fig. 2). ROM remained unchanged in each finger. ARAT revealed significant improvement of finger function in the AMADEO training groups (group A: p=0.043; group B: p=0.028), but no improvement on a significant level in group C (p=0.080) from beginning to end of study. The Chedoke-McMaster stroke assessment (part 1: arm) exhibits significant improvement in group C (p=0.047) during the training phase and in part 2 (hand) significant improvement in group B (p=0.046) over the entire study period.

Figure 1. AMADEO system in action with a stroke patient

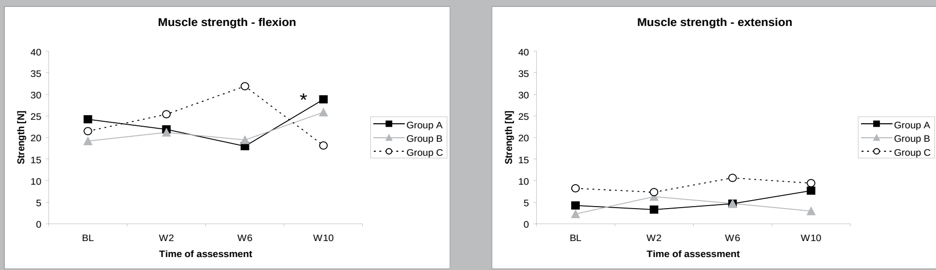

Figure 2. Development of muscle strength in all three groups. Significant improvement was measured in group A from beginning to end of study (p=0.048), but not in the other two groups. No significant improvement was seen in muscle strenth during finger extension in all three training groups.

Figure 3. Development of finger resistance of the hemiplegic hand: black boxes show the resistance of fingers moved at 2 mm per second, dark grey the resistance of fingers moved at 20 mm per seconds, light grey the resistance of fingers moved by 40 mm per second, and white at 200 mm per second. Measurement found to be greater at lower speeds than at higher speeds. Significant improvements were seen in group B at 2 mm per second from beginning to end of study (p=0.024) and during the AMADEO training phase (p=0.040).

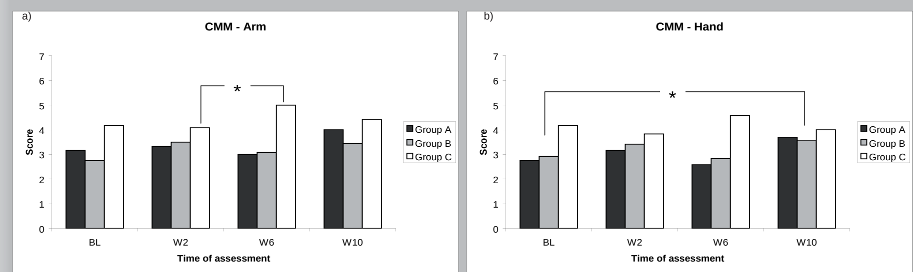

Figure 4. Development of arm (a) and hand (b) function measured by means of the Chedoke-McMaster stroke assessment. Black boxes depict group A, grey group B, and white group C. Group C exhibit significant improvements in arm function during the training phase (a) and group B significant improvement in hand function from beginning to end of study (b; asteriks above the columns).

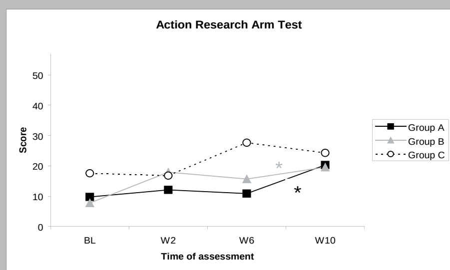

Figure 3. Development of finger function (Action Research Arm Test) in all three groups: significant improvement of function in both AMADEO groups (group A: p=0.043; group B: p=9.028)

Discussion

Active finger training with the AMADEO system seems to be effective in improving strength of finger flexion in stroke patients. Higher scores of strength in flexion are probably due to higher muscle tone in the flexors and the increased activity of the entire upper limb during strength testing. No improvement of muscle strength was measured for finger extension in any group, which would be an important feature in improving good finger function in stroke. Resistance measurements were greater at lower than at higher speeds, contradicting the definition of clincal testing by Lance. The explanation could be changes in soft tissue (tendons, ligaments, and joints), resulting in increased stiffness. Resistance increased significantly with low movement speeds in group B. Stroke patients in this group conducted the training without concentrating on their finger movement and without any visual feedback. These factors, however, may be important to relearning new movement patterns and to controlling pathological hypertonus, especially in finalized movements of the upper limb. Although no significant improvement of upper limb function was measured by means of the ARAT during the AMADEO training phase, stroke patients improved singificantly in arm/hand function from beginning to end of the study. Therefore, AMADEO training may help to promote hand function in later stages in the rehabilitation process.The AMADEO system is a novel electromechanical device which allows for objectification of kinematic parameters of active and passive movements of individual fingers, repetitive training, and assessment of the therapeutic intervention.