# GRAVITY COMPENSATION BY STROKE REHABILITATION ROBOTICS

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## Introduction

A stroke is a sudden loss of consciousness resulting when the rupture or occlusion of a blood vessel leads to oxygen lack in the brain, and is the leading cause of disabilities in Western civilizations. Compared to healthy people, hemiplegic stroke patients have lower muscle strength and decreased smoothness, speed, range and accuracy of motion of the upper extremities.

The treatment of stroke patients is labour intensive and strongly dependent on the best-practice opinion of the rehabilitation centre or the individual therapist. The most popular rehabilitation therapies focus on functional recovery by functional training, but strengthening and motor control training is in use too.

In the last two decades, several therapeutic devices have been developed by research groups from around the world [1], which have both made the therapy less labour intensive and have provided the therapists and scientific community with more objectively gathered measurements. However, the resulting robotic therapies have not been proven more effective than regular therapy. Our goal is to develop and validate new robotic rehabilitation theories, principles and techniques.

Movement execution might improve when the gravitational pull on the arm is counter balanced. The reduced need for tonic muscle activation enables the patient to focus purely on the control of movements. Secondly, lowering the average muscle activation may reduce the effective feedback gains of overexcited reflexes, preventing spasms and allowing for better control. But as gravity is incorporated in the human motor programs, overcompensation might become a problem.

Therefore, the objective of this study is to determine the upper extremity muscle activation and movement patterns of hemiplegic stroke patients during three dimensional exercises with scaled gravity compensation. The results are compared to those of the patient's unaffected side and of healthy subjects.

*Figure 1: FreeBal (not fully extended)*

*Figure 2: elbow and wrist supports, EMG pads and Vicon markers*

## Methods

A gravity compensating device called the FreeBal (see Figures 1 and 2) has been developed. The FreeBal has two independent ideal spring mechanisms connected to both the elbow and the wrist of the patient. Complete freedom of movement of the arm was possible inside a cube of $1.0m^3$, in which the gravity compensation was roughly constant. The amount of gravity compensation for wrist and elbow was scaled (independently) to account for inter-patient differences or force higher degrees of participation.

The movements of the limbs were recorded by a optical motion capture system (Vicon, sampled at 50Hz; accuracy 1-2mm) and a Xsens inertia sensor (max. sample frequency 512Hz, accuracy 1° RMS) and translated to smoothness, speed, range and accuracy of motion of the hand. The Vicon markers were positioned in accordance with the recommendations of the International Society of Biomechanics [2] allowing for the full description of the motions of the Thorax, Clavicle, Scapula, Humerus and Forearm.

Muscle activation changes were determined by EMG recordings (sampled at 1000Hz) on the Pectoralis Major, Deltoideus Anterior, Deltoideus Medialis, Deltoideus Posterior, Biceps, Triceps and Trapesius. A dedicated software program then matched the EMG bursts to segment angles, resulting in a measure for the coordination and control of movements.

The recommended marker positions made it possible to use the position data as input for the inverse dynamics Delft Shoulder and Elbow Model (DSEM), which predicted theoretical optimal muscle activations. It should be possible to alter the optimisation criteria and/or introduce further restrictions and fit the models output to the recorded hemiplegic EMG data. Because the movement results are reported to be velocity dependent [3], subjects executed the experiments on voluntary chosen and maximum velocities. In the latter case, muscle synergies should have a profound influence on the performance of the patients.

## Results

Initial results for the EMG recordings during an exercise, with and without gravity compensation are shown in Figure 3.

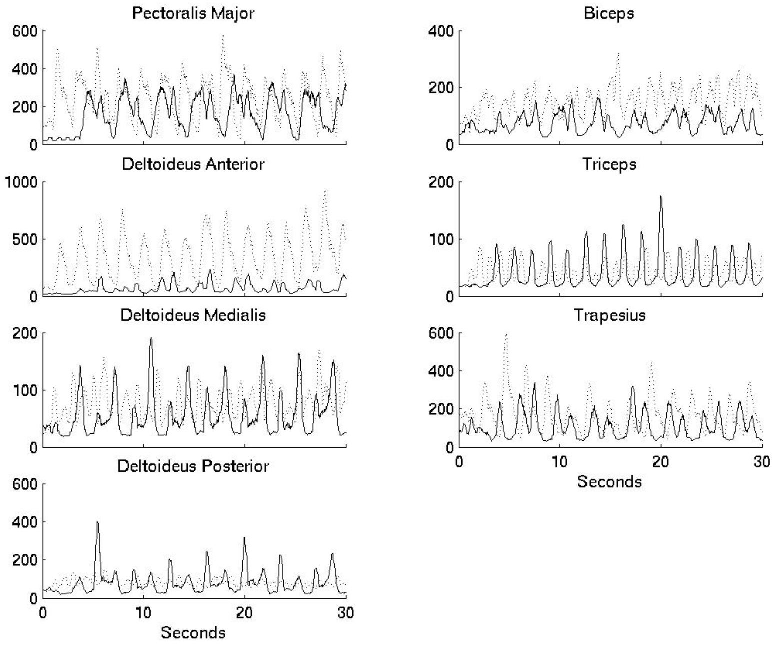

*Figure 3: EMG recordings during an exercise, with and without gravity compensation (resp. the solid and the dotted line), and with the absolute values of the recording moving averaged over 420 ms. The healthy subject was sitting behind a table, initially without any shoulder flexion or abduction, and with the elbow at a 90 degrees angle. She was then requested to repeatedly move her right hand on a normal table from a dot in front of her right elbow to a dot roughly 25 cm away in the left-forwards direction. The effects of gravity compensation are clearly seen in the plots for the Biceps and Deltoideus Anterior, as these are the gravitational load bearing muscles.*

## Conclusions

The FreeBal could provide us with the required data to determine whether gravity compensation on its own can be beneficial for the patient, and whether we should explicitly include it in our future designs.

## Acknowledgements

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