Evaluation of Motion Controlled Arm Support

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1 OBJECTIVES

Assistive devices augmenting arm functionality in the weak upper extremity were introduced extensively after the polio epidemic in the 1940s. Many attempts have been made to help people with upper extremity limitations in daily life by means of dynamic arm supports. Current devices vary from passive supports, with low level of complexity and easy to control, providing limited support in the performance of ADL tasks to active arm supports with many functionalities, large dimensions and complex control (van der Heide, 2013). An example of a new development is the motion-controlled arm support (McArm) that aims to enhance the functional benefit of support while maintaining the user friendliness of the simple passive support systems. In addition, it aims to stimulate the use of residual muscle strength in the user (Focal Meditech BV, 2013).

The effect of support on human arm movements needs to be investigated to understand how support can be optimized. The influence of assistive devices that compensate weakened muscles on the restoration of arm functions after stroke, has been investigated by Prange et al. (Prange, 2009). They have studied the effect of gravitational pull of arm support systems with braces. They found that the activity level of shoulder and upper arm muscles during reaching movements using a forearm support system are significantly decreased. However there is still little evidence on how joint moments are changed by a support system and whether zero gravity support is the best biomechanical solution that designers should aim for. Moreover, it is still unclear how joint moments are affected in people suffering from for example neuromuscular diseases and how people perform with an arm support in a daily life situation. Information on the effects of dynamic arm supports on arm movements and use of arm supports in daily life is needed to provide insight in the limitations of current designs. That knowledge can be used in the development of new motion controlled arm support.

The aim of this study was to investigate the impact of arm support systems on the arm function and use in daily life. This was realized by studying the effect of an available support system on the arm function at various levels of the International Classification of Functioning, Disability and Health (ICF). This knowledge is integrated in the design of the new McArm.

2 METHODS

A test battery has been developed that combines questionnaires and ordinal clinical scales, with quantitative measures such as 3D motion analysis and EMG to provide a more complete picture of the compensatory movement patterns used by patients with proximal muscle weakness of the upper extremities in patients with neuromuscular disorders. Moreover, biomechanical models and inverse dynamic software were used to calculate the shoulder and elbow joint moments in three different conditions (a control set-up, a gravity compensation set-up and a simulated zero gravity environment). These measures were used to investigate movement capacities of people with various neuromuscular disorders. To evaluate the performance in daily life, a measurement protocol has been developed to measure how people use the arms and the arm support during daily activities.

The following paragraphs describe the structure of the various measures and the first results.

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2.1 Questionnaires

A web-based questionnaire containing questions on all ICF domains, was composed to evaluate overall arm function and problems people encounter in daily life. This questionnaire was distributed among various groups of people with neuromuscular diseases, namely Duchenne muscular dystrophy (DMD), fascioscapulohumeral dystrophy (FSHD), limb-girdle muscular dystrophy (LGMD) and spinal muscular atrophy (SMA).

2.2 3D Kinematics and EMG

Motion analysis and electromyography (EMG) data from various tasks (e.g. shoulder abduction/flexion, reaching and hand to mouth movement) were recorded during unsupported movement and during supported movement with a passive Sling arm support (Focal Meditech). In both cases the subject was asked to move the dominant hand from an initial position resting on a table in the sagittal plane to a target placed at a distance of a stretched arm, at shoulder height and one shoulder width on the ipsilateral side. The movements were recorded with a 3D camera Motion Capture system (Vicon). Reflective markers were attached on the subject's body following the guidelines of the Vicon Upper Limb model. These data were subsequently used in simulations with a multi-body model of the arm to calculates joint moments. EMG data were obtained from biceps brachii, deltoid, triceps brachii, trapezius, pectoralis and latissimus dorsi muscles and were normalized as percentage of the EMG during maximum voluntary contraction.

2.3 Muscle-skeletal Simulations

The coordinates of the reflective markers during the unsupported and supported ipsilateral reaching movements were used to drive the simulation model in the AnyBody Modeling System (AnyBody Technology). With the subject's anthropometric information derived from marker coordinates, the software's GaitFullBody model was scaled according to body length and mass among others. An inverse dynamic analysis was then carried out to calculate the net joint moments at the shoulder and elbow. The analysis on the unsupported movement consisted of two parts: a normal gravity situation and a simulated zero gravity situation, in which the same motion data for the unsupported movement were used but gravity was set to zero in AnyBody's model parameters. As a result the outputs of the calculation were the net joint moments in three conditions: I control, II gravity compensation with Sling and III zero gravity environment. These conditions were chosen to assess the influence of gravity compensation (I vs. II), the influence of a zero gravity environment (I vs. III) and the difference between gravity compensation induced either by a mechanism or resulting from a zero gravity environment (II vs. III)(Essers, 2013).

2.4 Ambulatory Performance

To evaluate the effect of arm supporting devices in a daily life setting, a protocol for monitoring the arm activity outside a laboratory setting was developed. A tri-axial accelerometer (MOX, Maastricht Instruments) was placed on the upper arm just above the elbow. The acceleration signals were post-processed to obtain elevation and intensity of upper arm movements. These data give an indication on how and how often the arm support is used in daily life (Annegarn, 2012).

3 RESULTS

Preliminary results for the various studies are shown.

3.1 Questionnaires

In total of 315 boys/men with DMD, 88 with FSHD, 61 with LGMD and 73 with SMA participated. Preliminary data show that pain, stiffness and functional limitations increased with age in DMD. Data of FSHD, LGMD and SMA are being analysed.

3.2 3D Kinematics and EMG

The maximum shoulder elevation angles and the minimal and maximal elbow flexion angles were analysed in a group of 11 people with FSHD and in a group of 8 healthy controls. The data depicted in figure 1 represent the shoulder elevation angles of the healthy control group and the data of the FSHD subjects. Significant differences between the shoulder angles of the FSHD and the healthy control group were found for the shoulder elevation angle during the abduction and flexion tasks and during the two reaching tasks. Of the 11 subjects, only two were able to elevate the arm above 90 degrees. The EMG data showed higher percentages in the FSHD FSHD group compared to the control group.

3.3 Muscle-skeletal Simulations

The ipsilateral reaching task was completed by all subjects in all conditions. The FSHD subjects required more time to complete the task in the Control and the Sling condition than the healthy group (respectively 2.6 vs. 3.7s and 2.8 vs. 4.7s). Both groups required more time to complete the task in the Sling condition than in the control situation. In the control situation, the maximum value of the moment was greater by more than one order of magnitude than the moment in the Sling and the Zero gravity conditions in both groups (Figure 2). Between the two groups the signs of the average moments in the Sling condition were different, showing for the FSHD group a trend to maintain the arm more elevated and the elbow more flexed. The healthy group presented a lower mean moment in the Sling condition than the FSHD group, showing a trend to maintain the arm less elevated and the elbow more extended when using the Sling (Essers, 2013).

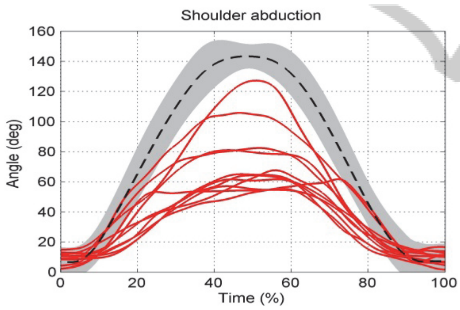

Figure 1: maximum shoulder elevation angle of shoulder abduction. The grey band represents the 95% confidence interval of the control group, the dashed lines represent the average of the control group and the continuous lines represent a group of 11 FSHD subjects.

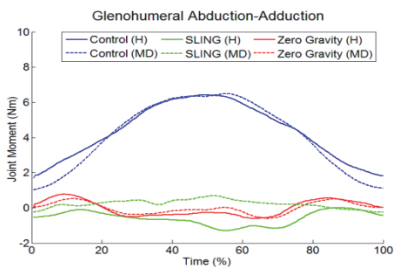

Figure 2: Joint Moments of glenohumeral abduction-adduction.

3.4 Ambulatory Performance

In a group of 12 healthy men, the activity of the arm that was performed in one day was measured. 40% of the total upper arm activity was categorized as low intensity and low elevation. Less than 2% was classified as high elevation. The average number of elevations above 90 degrees was for most subjects less than 10 times per hour.

4 DISCUSSION

The current study presents some preliminary results of initial evaluation measures. Application of these evaluation measures for the next McArm prototype is foreseen for the last stage of the project. The goals of these evaluations are multiple: to see if design goals and specifications are met, to gain first outcomes on usage and usability of the new device, and compare functionality with high- end existing devices of this class. For this purpose several existing measurement scales and instruments were combined into a specific set. The availability of such a set will be applicable for evaluation of support systems.

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