

# Quantitative Outcome Measures for Upper-Limb Motor Control

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## Abstract

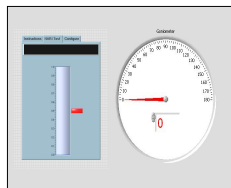
There are few tools to help guide Upper Limb (UL) therapy and encourage client compliance with objective outcome measures. To help clients with their UL therapies, we designed the Hand Arm Rehabilitation Interface (HARI), a tool that guides the arm through reaching and grasping motions while providing biofeedback and quantifying outcome.

## HARI (Hand Arm Rehab Interface)

HARI consists of a modified chair, which supports the arm against gravity, while measuring muscle activity and reaching and grasping motions, and a computer display for visual biofeedback. Muscle activity is registered with a Myokinetic Interface (MKI), consisting of a pressure sensor sleeve that is donnable by the user. HARI provides targets for the user, while producing metrics of motor control for both the elbow and hand, devised to quantify disability of joint motions and hand grasping.



Illustration of a person sitting in the modified chair, using the mast to support the arm.



On the left is a screenshot of the program used to provide grasping biofeedback. On the right is a screenshot of the program used to provide reach biofeedback.

## Reaching Disability (RD)

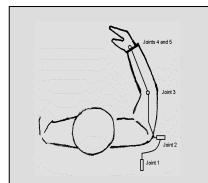
The reaching disability metric (RD) measures the subject's smoothness by calculating the root-mean-square differences between the subject's repetition and an ideal cosine wave with an amplitude equal to that of the subject's range of motion and of identical duration.

$$RD = \frac{1}{N} \sum_{i=1}^N \frac{\langle A - I_R \rangle + \langle A - I_{90} \rangle}{\langle I_R \rangle + \langle I_{90} \rangle}$$

$$\text{where } \langle A - I_R \rangle = \frac{1}{T} \sqrt{\sum_{\theta=1}^T (A_i - K \cos(\theta))^2}$$

## Methodology

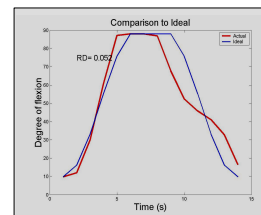
- Subjects performed elbow flexion and extension exercises two days per week for eight weeks. 3 sets of 5 elbow flexion/extensions were performed in each hour-long session,
- Elbow range of motion (ROM) tasks were not timed; subjects performed the repetitions at a self-selected pace, with rest periods in between for recovery. The RD was used to quantify the range and quality of their movements, with a lower score indicating better control.



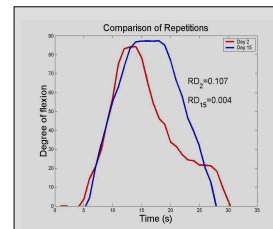
Top view of a subject performing the elbow flexion and extension exercises while seated in the mast.

## Results

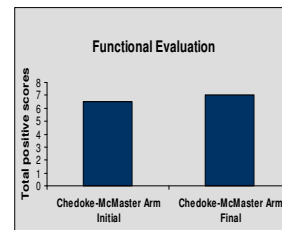
Preliminary results from 4 male and 2 female subjects (age 60-79, 4-80 months post-stroke) averaged over the first three and last three days, showed improvement in RD and functional performance as assessed by an adapted Chedoke-McMaster (CM) Arm rating scale. Since the CM scale has very little variation, the total positive scores were used to quantify functional improvement.



Typical Reach Data compared to the ideal cosine wave with similar amplitude. This figure shows the ideal cosine wave with the closes period and amplitude to the data.

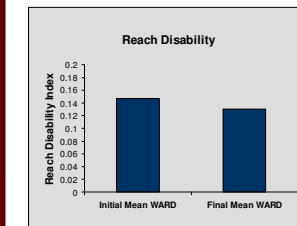


Typical Reach Before and After Data. This figure shows how both qualitatively, and quantitatively the subject's reach became smoother near the end of training.



This figure shows that on average the functional performance of the subjects increased. The initial mean score of the group was 6.5 positive scores, and the final mean score was 7.0 positive mean scores.

## Results (cont.)



Before and After of Functional Measures. The mean RD for all subjects decreased from an initial value of 0.15 to the final RD mean value of 0.13.

## Discussion

With these results, it appears that UL function can be improved, even in the chronic post-stroke phase, with a tool such as HARI that encourages active reaching through biofeedback. Additionally, we have developed quantitative measures of outcome relating to control and jerkiness of muscle that can be useful in conjunction with therapies for anti-spasticity.

## Acknowledgement

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## References

- Flint, J. A., Phillips, S. L., & Craelius, W. (2003). *Myokinetic Interface for a virtual limb*. Paper presented at the International Workshop on Virtual Rehabilitation, Piscataway, NJ USA.
- Kim, N.-H., Flint, J. A., Phillips, S. L., & Craelius, W. (2005). *Quantification of Upper Extremity Control using HARI (Hand Arm Rehabilitation Interface)*. Paper presented at the Biomedical Engineering Society, Baltimore, Maryland USA.