Rehabilitation and assessment of reaching disability using an active biofeedback device

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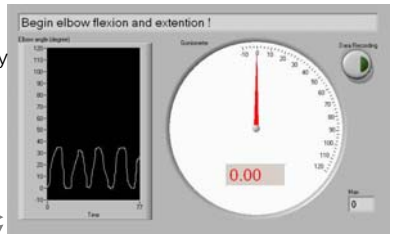
Abstract

Restoration of function to the upper limb (UL) following stroke requires an active exercise protocol and assessment of functional and motor abilities. The Hand-Arm Rehabilitation Interface (HARI) supports the UL while the user actively retrains his reaching motion, and provides quantitative measures for biofeedback and assessment. Herein we describe HARI and the reaching disability index (RDI). The RDI is a new metric for motor control based on the smoothness and range of motion of elbow flexion and extension. Results showed a good correlation between RDI and muscle tone, evaluated by a clinical therapist.

HARI: Hand-Arm Rehabilitation Interface

HARI supports the arm against gravity and constrains elbow motion to the transverse plane 1.

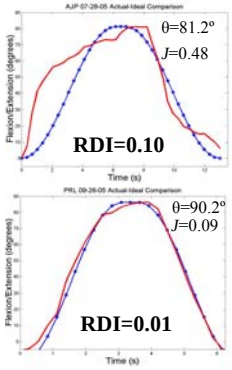
- Provides active upper-limb therapy
- Supports arm against gravity
- Allows smooth flexion & extension about the elbow
- Records elbow motion via digital goniometer
- Patient movement displayed on computer screen through LabVIEW GUI



HARI screenshot. Real-time biofeedback display of elbow flexion trajectory and instantaneous position indicating degree of flexion/extension.

Reaching Disability Index (RDI)

- Compares patient's elbow flexion/extension motion to ideal cosine.
- 1→complete paralysis; 0→no disability
- Ideal cosine chosen by amplitude-matched *wavelet transform* convolution
- Jerkiness (J)= point-wise root mean difference comparison to ideal repetition



RDI calculation: comparison of actual repetition (red) to matched ideal cosine (blue)

$$\mathbf{RDI}= \underbrace{e^{-k\theta^2}}_{\text{Range of motion}} \sqrt{\frac{\sum_t^N \left(A_t-\theta\cos(\omega\cdot t)\right)^2}{\sum_t^N \theta\cos^2(\omega\cdot t)}}$$

$$k \equiv -\frac{\ln(\frac{1}{2})}{45^{-2}} \qquad \omega=\pi/4$$

A= Actual Repetition
θ=ROM

- Range of motion (ROM, θ)= Sigmoidal (Boltzmann) weighting factor, constant determined empirically: 0°→1, 45°→0.5, 90°→0.

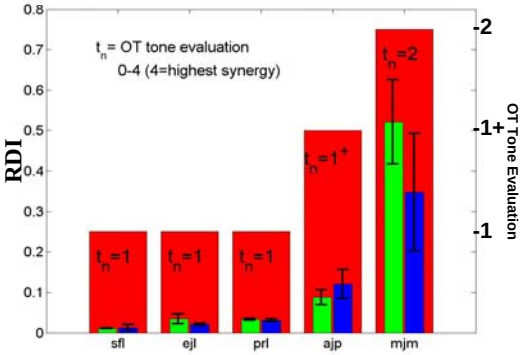
Protocol

- 5 subjects: 4Male/1Female; (72.9±8.7 yrs old)
  - Chronic stroke patients (2.2±1.9 yrs post-stroke)
- 16 sessions: 2x/week, 8 weeks total
- 3 sets of 5 flexions & extensions about the elbow
- Flexion/extension to maximum ability • Self-selected pace

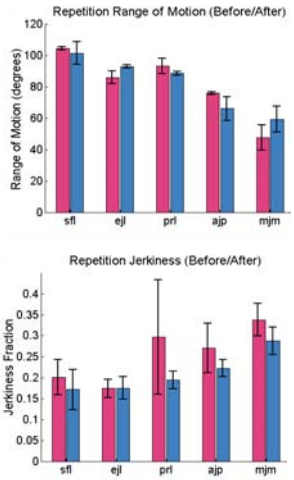
Results

- RDI compares favorably to occupational therapist (OT) tone evaluation

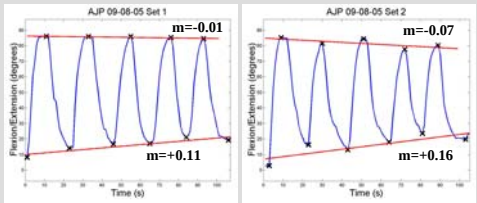
Comparison of RDI to OT evaluation



RDI averaged over the first 3 sessions *(green)* and last 3 sessions *(blue)* of total 16 sessions.OT tone evaluations, scored 0 (no tone)→4 (maximum synergy) *(red bars)*.



Subject performance. Subject range of motion *(top)* and jerkiness *(bottom)* averaged over first 3 *sessions (red)* and last 3 sessions *(blue)*.



Profile of elbow flexion/extensions. Slope (*m*, red line) indicates fatigue over the course of the set.

Set-to-set Performance

- Track variables over the session
- Patient Performance
  - Spasticity
  - Fatigue
- Line connecting maximum flexions and extensions show accumulating fatigue

Acknowledgements

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References

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