Upper Extremity Robot Therapy for Individuals with Spinal Cord Injury

Bui KT, Sprigle S, Backus D
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Background: Spinal Cord Injury (SCI)

- SCI annual incidence in the U.S.
  - 11,000 new cases per year
- SCI prevalence in the U.S. 2006
  - 253,000 people
- Statistics
  - Average age at injury: 28 yrs
  - Gender: 77.8% males
  - Etiology: 46.9% from motor vehicle accident
- Impairment or loss of motor/sensory function
  - Tetraplegia – impaired function of arms, trunk, legs, pelvic organs
  - Paraplegia – impaired function of trunk, legs, pelvic organs

http://www.fscip.org/facts.htm
Background: Recovery After SCI

- Functional recovery of some muscles can occur for several years after incomplete SCI
  - Recovery depends on the reorganization of preserved nerve connections and formation of new connections [Beekhuizen 2005]

- Cortical reorganization
  - Reorganization is associated with activity [Beekhuizen 2005, Fasioli 2003, Raintenteau 2001]
  - Cortical reorganization occurs after SCI as it does after stroke [Beekhuizen 2005]

- SCI recovery mechanism is similar to that in stroke subjects
  - Interventions used after stroke have demonstrated potential to improve strength after SCI [Beekhuizen 2005]
Background: Robotic therapy

- Current use: rehabilitation for motor impairment and limb weakness after stroke [Fasioli 2003]

- Therapy modes: passive & active-assisted, active-resisted [Stein 2004]

- Results
  - improved motor coordination and strength in early stroke subjects
  - reduced motor impairment in moderate to chronic stroke subjects [Fasioli 2003]


- Disadvantages: generic treatment protocols, unable to identify specific benefits of each therapy modality [Stein 2004]
Robotic Device: Muscle Tech

- **Background**
  - Designed by Muscle Tech company in Israel

- **Functions**
  - Elbow flexion/extension
  - Forearm pronation/supination

- **Setup**
  - Device stands independently to side of wheelchair
  - Controlled through computer program
Objectives

- **Phase 1**
  - **Assess usability**: safety, comfort, ease of use, fit and exercise protocol in order to optimize the device

- **Phase 2**
  - Investigate effectiveness of robotic exercises for **strengthening** after SCI
Inclusion Criteria

**Phase 1**
- SCI level C5, C6, or C7
- ASIA impairment B, C, or D
- Male or female
- 18 - 59 years old
- Tolerate sitting upright at 90 degrees for at least one hour
- Demonstrate at least 50% of normal range of motion (ROM) for each joint involved in this therapy
- Palpable contraction (grade 1-3) in the biceps and triceps
- Chronic impairment
Study Protocol

- **Phase 1**: 3 hr session
  - Pre-treatment
    - Clinical Assessment
    - Robotic Evaluation
  - Treatment
    - 1 hr robot exercises
  - Post-study Questionnaire

- **Subjects**

- **Phase 2**: 4 weeks
  - Pre- and Post-treatment
    - Clinical Assessment
    - Robotic Evaluation
    - Treatment
      - 1 hr robot exercises
      - 3 days/wk, 4 wks
  - Post-study Questionnaire

- **Robotic Exercises**
  - Modalities
    - Passive-assisted movement
    - Isometric contraction
  - Therapeutic exercises
    - Strengthening
      - 3 days/wk, 4 wks
    - Subjects
    - Clinicians
    - Muscle strength: kgF

- **Pre-treatment Clinical Assessment**
  - Range of motion: active, passive
  - Manual muscle test: Kendall

- **Post-study Questionnaire**
  - Design optimization
  - Safety
    - Comfort
    - Ease of use
    - Fit
  - Therapeutic usefulness
Results – Phase 1: Pre-treatment

- **Subjects**
  - 3 males, 2 females
  - Ages: 19 – 46 yrs
  - Injury year: 1980-2006

- **IRB approval**
  - Georgia Institute of Technology
  - Shepherd Center
  - Emory University

- **PROM average**

<table>
<thead>
<tr>
<th>Treatment Arm</th>
<th>Clinical</th>
<th>Robot</th>
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</thead>
<tbody>
<tr>
<td>Elbow Flexion</td>
<td>135°</td>
<td>110°</td>
</tr>
<tr>
<td>Elbow Extension</td>
<td>4°</td>
<td>27°</td>
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- **Device limitations**
  - Flexion limit: 110 degrees
  - Extension: subject selected end point
Results – Phase 1: Treatment

- Subject #3
  - Passive-assisted
  - Isometric contraction
  - Active-resisted
Results – Phase 1: Questionnaire

- Safety (9/10)
  - “felt safe with padding and splint”
  - “didn’t feel it squeeze”
  - “ROM limits were good”

- Comfort (8.6/10)
  - “snug fit”
  - “exercising is uncomfortable, not the machine b/c is was padded well”
  - “arm cuff not wide enough for larger arm”
  - “pressure at wrist but with breaks between exercises it was not an issue”

- Design ideas
  - Flexible plastic arm section to expand and conform
  - Modify splint to redistribute pressure at wrist
Results – Phase 1: Questionnaire

- Ease of Use
  - Don (4.2/10)
    - “tetraplegics need assistance or initial set up”
    - “rings on velcro straps”
  - Use (7.6/10)
    - “need instructions for exercises”
  - Doff (6.4/10)
    - “rings on velcro straps”
    - “no buttons”

- Fit
  - Of arm in device (8.4/10)
    - “straps and pads helped the fit”
    - “one-size arm section was tight on larger arm”
  - Security during exercise (9.2/10)

- Design ideas
  - Rings on velcro straps
Results – Phase 1: Questionnaire

- **Therapy**
  - **Challenging (8.4/10)**
    - "triceps exercises were challenging but not biceps"
    - "colored graphs made me try harder on the next set"
  - **Motivating (7.6/10)**
    - "how many more repetitions?"
    - "signals for stop/go not always clear"
  - **Strengthening (7.6/10)**
    - "enough exercise but not exhausting"
    - "may be good for recently injured person"

- **Design ideas**
  - "maintaining strength is more important than building up"
  - "don’t know how much I can build up the muscles I still use"
  - color code all graphs, repetition counter, stop/go signal on computer screen
  - greater range of resistance
Discussion

Future Design Considerations

- Robot exercises vs. hand weights
  - Safety – risk of stretching muscle
  - Independence
  - Measures of improvement
  - Interest in technology

- Home device vs. therapist tool
  - Level of assistance to set-up and operate
  - Portable or permanently fixed
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