Integration of Robotics into Clinical Practice
Teresa Wong, PT & Darrell Musick, PT

Objectives

WHAT?
- Basic definitions and terminology
- Know the various categories and groups

WHY?
- Importance of robotic technology today?
- The value of robotic technology on clinical outcomes

HOW?
- Evaluate equipment for clinical integration
- Understand how robotics technology might impact our future
- Development and Evolution of a Technology

Robotics /rōˈbātiks/ n.
Design, construction, and use of machines (robots) to perform tasks done traditionally by human beings

Modern Medicine
Deaths ↓ Disability ↑
Modern Rehabilitation
Better Outcomes
More Efficient
Less Resources

Living Well
Recover Faster and Better
“REHABILITATION”  “RECOVERY”
<table>
<thead>
<tr>
<th></th>
<th>1-2 months</th>
<th>6 months to 2+ years</th>
</tr>
</thead>
<tbody>
<tr>
<td>restore to basic</td>
<td>3rd payer control</td>
<td>restore to highest function</td>
</tr>
</tbody>
</table>
Brains are NOT the same

Albert Einstein – 35% wider area in area responsible for math and spatial perception

London taxi drivers – large hippocampus due to need to memorize all streets by heart

Blind – much larger representation of their “reading” finger

Musicians – much larger representation of their “fingering” hand

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Principles of Neuroplasticity

- Usage of body part increases brain representation
- Premotor cortex can substitute for motor cortex
- Contralateral hemisphere can take over motor control
- These mechanism can be facilitated

Rehabilitation Goal

Control this remodeling in the right direction and correct it if it’s taken a wrong turn.

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Neuroplasticity Principled Rehabilitation Model

1. Skilled/Precision Tasks
   These should be performed to facilitate neuroplastic changes, and subsequently improvements in motor behaviour. (vs. Strength Training)

2. Negative effects or Presence of Pain
   Pain alters excitability of the primary motor cortex in a rapid manner. These responses are generally protective and counterintuitive in the motor-learning process. May result in unwanted cortical neuroplastic changes.
   Negative effects are also demonstrated in the presence of low quality sleep, stress, and attention deficits. Therefore, motor skill learning should be relatively pain free.

3. Cognitive Effort
   The greater the complexity of a specific task and its corresponding intent will result in greater cortical representation and changes.

4. Quality
   Focus of each session should be on quality of performance since increasing repetition has demonstrated no difference in within-session skills learning.

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Performance Skills Training

RESULTS
- Intensity
- Consistency
- Precision
- Complexity
- Enjoyable

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Technology - WHAT does it do?
Rehabilitation Robotics

Devices that assist patient or therapists with activities that optimizes function.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>CONSIDERATIONS</th>
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</thead>
<tbody>
<tr>
<td>RESTORATIVE</td>
<td>Adjustable, Progressive, Measurable</td>
</tr>
<tr>
<td>MAINTAIN FUNCTION</td>
<td>Unobtrusive, Durable, Ease of Use</td>
</tr>
<tr>
<td>ASSIST WITH LIVING</td>
<td>Safe, Reliable, Durable</td>
</tr>
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Body Weight Support

Virtual Reality

EEG Technology

Posturography

Motion Analysis
TeleRehabilitation

Remote Delivery & Self Management

Robotic Development

HSR (Human Support Robot)

RIBA (Robot for Interactive Body Assistance)

Ubot-5 Humanoid

Wearable Robots

Exoskeleton Robotic “Extenders”
Extends strength of human beyond its natural ability but under human control

Orthotic Robots
Matches human anatomy or complements lost function or weakness

Prosthesis Robots
Substitutes for lost limb after amputation

Net power with robot to overcome human physical limits

1st Generation Wearable Robots

Equipment Considerations

- What does it do / not do?
- How big and how much space?
- Who can benefit, adaptable?
- How easy is it to operate, don/doff?
- How much time does it take?
- How comfortable for patients? Energy
- How much benefit vs other solutions?
- How much does it cost?
- Potential for take home program?
- SAFETY

Clinical Considerations

- What advantages does it offer patient or therapist?
- Quantifiable results
- Safety and proper support
- Decrease negative neuro responses
- Increase intensity of activities
- What are the barriers to clinical utilization?
- Time
- Comfort
- Ease of use
- What are the most important features for clinical implication?
- Clear value add
- Adaptibility
What does IT do? vs What do YOU want to do?

Robot – Human Interaction
Actuators and structure transmits force to the human musculoskeletal system
Through Control and Flow information, power, sensors and biofeedback
Powerful and Immediate sensory Experience

Tibion BIONIC LEG
Facilitate Strength, Stability and Balance

Integrating Robotics
Example – Tibion Robotic Leg
Can Affect
STRENGTH
BALANCE
PROPRIOCEPTION

May Affect
SPASTICITY
FLACCIDITY
MOTOR CONTROL

Will Not Affect
RANGE OF MOTION
COGNITIVE TRAINING
ABNORMAL REFLEXES

Evolution

What's in our future?
Bionic Skin for a Cyborg You
Flexible electronics allow us to cover robots and humans with stretchy sensors

Development & Evolution of a Robot Technology

Ekso Development 2010-Present
2010-2012 Prototype to Compensation Device
- Device modification (Usability)
- Clinical Application(s) (Functionality)
- Clinical Training Program
- Patient and Therapist learning curves
- Inclusion/Exclusion based on success and failures

Exoskeletons in Rehabilitation 2013
- Ekso GTm
- Rex
- Indego
- ReWalk
- Honda

Initial Clinical Testing: Safety
- Kessler Institute, West Orange, NJ
- Spaulding Rehabilitation Hospital, Boston, MA
- Craig Hospital, Denver, CO
- Mt. Sinai, New York, NY
- Rehabilitation Institute of Chicago, Chicago, IL
- Rehabilitation Institute of Michigan, Detroit, MI
- TIRR, Houston, TX
- Santa Clara Valley Medical Center, San Jose, CA
- Rehabilitation Hospital of the Pacific, Honolulu, HI
- Good Shepherd Hospital, Allentown, PA
**Initial Clinical Testing: Safety**

- 63/70 qualified into trial(s)
- 7 Screen Failures:
  - unknown WB status (1); ROM deficits (5), weight (1)
- No Adverse Events
- Session 1 totals
  - 63/63 able to ambulate 81-623 feet during session 1
  - Session 1 final device: 45 Walker; 16 Crutches; 2 HMI
- Average first session: ~300 steps

**Determined Inclusion/Exclusion**

- For complete and incomplete SCI incomplete
- Enough upper extremity strength to manage assistive devices
- Medically stable and candidate for full weight bearing gait training
- Height range from 5’2”-6’2”
- Weight under 220 lbs
- “Near normal” LE ROM (-10 hips, -10 knees, neutral ankles)
- “Reasonable Spasticity”

**Kessler Foundation**

33 y/o male S/P MVA 1999
T12 AIS A Paraplegia: Compensation Device

45 y/o male  S/P MVA 2005
C5 AIS D Tetraplegia

**August 2012: Advanced Feature Upgrade: User initiation**

T12: AIS A Paraplegia
2013: Variable Assist Software Upgrade
CVA/Incomplete SCI/Other

- Key Variable Assist Features as a Rehabilitation Device

  **Type of Injury:** Bilateral vs. R/L Affected
  
  **Assistance:** Fixed swing path assistance from 0-100. Or, **Adaptive** mode for variable assistance as needed during individual swing phase for each leg

  **R/L Affected:**
  - Affected LE either Fixed/Adaptive for weakest LE
  - Stance support for Free Leg if needed
  - Swing Complete function (if fixed assistance is too low, or, patient too slow)
  - Fast, Medium, Slow
  - Allows patient time to recruit and complete step when near threshold of strength
  - New Foot Trigger (ProStep++) initiates step with sensors (Toestrap)
  - Baseline calibration (on/off as desired)

  **Feedback Tools to enhance Variable Assist**

  - **Feedback on Walk Screen:**
    - Displays 5 step average of Min Forward Assistance needed to complete a step
    - LIFT, EXT, or L&E Swing notifications

  - **Detailed Feedback Screen:** 5 step average
    - **Forward Assistance:** Average Ekso assistance provided in the forward direction
    - **Minimum Assistance:** Min Forward Ekso Assistance needed to complete a step
    - **Path Assistance:** Amount of assistance provided to the pilot to keep them on the “path” or gait trajectory

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**Case Study 1**

33 y/o female S/P MVA 1/2012
L1 AIS C Paraplegia

**Case Study 2**

33 y/o female S/P AVM
Ataxia; Dysarthria; Bilateral involvement

**Case Study 3**

19 y/o S/P AVM repair
Flaccid Left Hemiplegia
Ambulatory with LBQC and Min (A) x 30’
Case Study 3: 19 y/o S/P AVM repair

First steps: Bilateral Adaptive
Pre Ekso walk

Left Affected; Adaptive assist

Left Affected, Fixed; swing complete

Pre Ekso Post Ekso

Case Study 4: Dr. K

- 66 y/o s/p R CVA w/ L hemiparesis
- Date of onset: 9/5/10
- Rehab/outpatient standard
- Continues w/ 2-3 hours of PT/day (Private PT)
- 4 Ekso sessions: Steps between 243 and 706 in 45’ sessions
Preliminary Research with Variable Assist software w/ post CVA patients

- L CVA/R Hemi
- Ambulatory with R AFO and Hemi-walker
- 4 sessions in Bilateral/Adaptive

<table>
<thead>
<tr>
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<th>Pre 5/29/13</th>
<th>Post 6/14/13</th>
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<tbody>
<tr>
<td>10 MWT</td>
<td>Unable</td>
<td>Unable</td>
</tr>
<tr>
<td>6 MWT</td>
<td>Unable</td>
<td>Unable</td>
</tr>
<tr>
<td>RPE</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>BBS</td>
<td>21/56</td>
<td>28/56</td>
</tr>
<tr>
<td>5x STS</td>
<td>31.03'</td>
<td>37.0' (Post 422 steps)</td>
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Subject One: CVA Preliminary Data

- 66 y/o L CVA/R Hemi April 2013
- Non Ambulatory (Lives in SNF)
- 3 sessions in Bilateral/Adaptive

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<td>10 MWT</td>
<td>Unable</td>
<td>Unable</td>
</tr>
<tr>
<td>6 MWT</td>
<td>Unable</td>
<td>12' in Parallel bars with A x2 breaks</td>
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<tr>
<td>RPE</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>BBS</td>
<td>83</td>
<td>28</td>
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<tr>
<td>5x STS</td>
<td>Unable</td>
<td>Unable</td>
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Subject Two: CVA Preliminary Data

- L CVA/R Hemi Non-Ambulatory in PT (Never walked due to "pushing Syndrome")
- 4 sessions in Bilateral/Adaptive

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<tr>
<td>10 MWT</td>
<td>Unable</td>
<td>P Amb 9.4' in 3m 56s</td>
</tr>
<tr>
<td>6 MWT</td>
<td>Unable</td>
<td>18.4' with x2 seated rest breaks</td>
</tr>
<tr>
<td>RPE</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>BBS</td>
<td>43</td>
<td>N/A</td>
</tr>
<tr>
<td>5x STS</td>
<td>N/A</td>
<td>N/A</td>
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Subject Three: CVA Preliminary Data

- L CVA/R Hemi
- Non-Ambulatory in PT (non-ambulatory due to "pushing syndrome")
- 4 sessions in Bilateral/Adaptive

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</tr>
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<td>RPE</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>BBS</td>
<td>43</td>
<td>N/A</td>
</tr>
<tr>
<td>5x STS</td>
<td>N/A</td>
<td>N/A</td>
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Exoskeleton Research Review

- Soft signs during device testing
  - Improved endurance
  - Increased confidence
  - Improved balance (sitting/standing) and weight shifting
  - Increased alertness
  - Improved overground walking following Ekso session

Ekso GTm: Fall 2013

- Designed for Neuro Gait Training for SCI, CVA, TBI and other neuro diagnosis
  - Improved stability at ankle and foot for more confident stance and faster gait
  - Ability to free hip rotation and abduction for high level patients
  - Ability to free ankle plantarflexion/dorsiflexion if strength permits
  - Quicker hip/thigh adjustments for fast patient turnaround
  - Weightshift assist at footplate
Exoskeleton Research Review

Stephanie A. Kolakowsky-Hayner PhD, CBIST, Director of Rehabilitation Research Rehabilitation Research Center Santa Clara Valley Medical Center

On August 28, 2012, SCVMC reported the results of their first study on Ekso related to the safety of the device. The results were presented at the Paralyzed Veterans of America conference and at the annual scientific meeting of the International Spinal Cord Society in London. Among the findings were:

- 8 patients were included in the research (all within 2 years of injury).
- Bionic exoskeletons can enhance mobility in those without voluntary lower extremity function.
- The Ekso™ suit is safe for those with a thoracic SCI.
- Use of an overhead tether should be considered (3 falls where tether came into play).
- There appears to be a training effect with the device.
- No major skin effects and no pain reports.
- No adverse events were reported.

Miami Project
Mark Nash, PhD
Professor, Neurological Surgery, Rehabilitation Medicine, and Kinesiology & Sport Science

Miami Project is assessing over ground bionic ambulation (OBA) condition effects on cardiorespiratory endurance and the energy demands of steady state OBA. They are also assessing the OBA condition effects on biomarkers of SCI-specific cardioendocrine risk, assisting the functional utility and kinematic responses to OBA and determining if changes in activation are associated with conditioning improvements for walking function, mobility, balance and fitness enhancements, and assessing OBA conditioning enhancements on life satisfaction, psychological well-being.

- 50 week project with various milestones and complicated outcome measures.
- Pilot Study (Q1 2013) with preliminary results examining a range of benefits while walking in the Ekso bionic exoskeleton.

Most obvious for us in conducting the research was the limited amount of energy needed by individuals with chronic SCI to walk in the brace, making the device a serious candidate for use as a mobility device. In this respect, the prosthesis is the first to allow functional ambulation without rapid exhaustion by the user. Moreover, individuals with SCI who walked in the brace self-reported reduction in their habitual musculoskeletal pain, and a lessening of lower extremity muscle spasms. We are currently submitting these findings to a peer-review journal, and are in the midst of planning the second generation of our studies.
Indego: Goldfarb, Hartigan et, al

- Preliminary results favorable

So, where are we going?
More research in all areas

<table>
<thead>
<tr>
<th>Rehabilitation</th>
<th>Personal</th>
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<tbody>
<tr>
<td>Stairs/Ramps/Curbs</td>
<td>Lighter</td>
</tr>
<tr>
<td>Improved turning and stability</td>
<td>More functional</td>
</tr>
<tr>
<td>Increased degrees of freedom at hip</td>
<td>Better battery life</td>
</tr>
<tr>
<td>Variable assist in stance and with sit to stands</td>
<td>Stable and safe outdoors on varied terrain</td>
</tr>
<tr>
<td></td>
<td>PT spotter not required</td>
</tr>
<tr>
<td></td>
<td>Affordable</td>
</tr>
<tr>
<td></td>
<td>Ability to carry items? Fit in WC or drive in suit</td>
</tr>
</tbody>
</table>

Conclusion

- Exoskeletons are gaining momentum
- Technology is advancing quickly
- Research is underway and initially favorable
- Rehab clinicians should be aware of the technology and as patients will be asking questions