Robots for Ankle Rehabilitation

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UMDNJ
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Why robots in ankle rehabilitation

- The ankle is the most injured part of the body;
- Therapy after ankle injury involves regaining range of movement, strengthening, and improving control.
- Conventional therapy is repetitive, and boring.
- Robots can help by providing the repetition needed without tiring.
Human-Computer Interface Lab (now Tele-Rehabilitation Institute)

- Was first to develop an ankle rehabilitation robot, and to couple it with virtual reality games.
  - Virtual reality increases patient motivation and participation, while at the same time providing rich feedback on performance.
- Rutgers Ankle (circa 1999)
Rutgers Ankle test or chronic stroke patients

- A Stewart platform pneumatic robot developed in 2000-2002 to train adults post-stroke. Games were written in WorldToolKit. Allowed remote monitoring. Used embedded processor time-sequence piston control.
Compared training with a robot alone (control group) with an experimental group that trained with the robot and virtual reality.

![Graph showing % change in ankle moment, hip power, knee power, and ankle power between Robotic VR and Robotic conditions.]

Control study with Rutgers Ankle at Harvard University
Children with Cerebral Palsy

- Cerebral palsy (CP) is a non-progressive disorder with impaired motor function secondary to injury of the immature brain.
- The most prevalent physical disability originating in childhood.
Rutgers Ankle CP

- Redesigned robot attachment to allow easier control for children with cerebral palsy.

- Redesigned controller to increase computation parallelism by using Zbasic microcontrollers and Atom controllers which regulate the pneumatic valves.
The games

- 2 custom games written in Java 3D, Airplane (piloting plane through hoops) and Breakout3D (bouncing balls to destroy cubes)
Case Study

- 7 year old child diagnosed with mild ataxic cerebral palsy.
- He had difficulty with speech, no cognitive delays and ambulated independently.
- The participant wore bilateral shoe inserts for pronation and trips/falls were a daily occurrence.
- He received physical, occupational and speech therapy in school once weekly, which was allowed to continue during this study.
Intervention

- The child trained each ankle playing the Airplane and the Breakout 3D games, which alternated during a session, for 12 weeks, 3 times/week (36 sessions).
- Session training time was at least 40 minutes, and the difficulty of the games was progressed over the therapy.
<table>
<thead>
<tr>
<th>Assessment</th>
<th>Pre-intervention</th>
<th>Post-intervention</th>
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</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Dorsiflexion (Nm/kg)</td>
<td>0.21</td>
<td>0.50 (+238%)</td>
</tr>
<tr>
<td>Max Plantarflexion (Nm/kg)</td>
<td>2.10</td>
<td>2.37 (+13%)</td>
</tr>
<tr>
<td><strong>Motor Control</strong></td>
<td></td>
<td></td>
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<tr>
<td>In-Phase (s)</td>
<td>-0.69</td>
<td>0.10</td>
</tr>
<tr>
<td>Anti-Phase (s)</td>
<td>0.76</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Gait</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion @ initial contact (°)</td>
<td>-4</td>
<td>5</td>
</tr>
<tr>
<td>Speed (cm/s)</td>
<td>98.7</td>
<td>120.0 (+22%)</td>
</tr>
<tr>
<td>6 min walk (m)</td>
<td>508</td>
<td>556 (+9%)</td>
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<tr>
<td><strong>GMFM</strong></td>
<td></td>
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<tr>
<td>-wrj (%)</td>
<td>94.4</td>
<td>98.6</td>
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<tr>
<td><strong>Pediatric Quality Life</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child</td>
<td>85.7</td>
<td>91.4</td>
</tr>
<tr>
<td>Parent</td>
<td>79.3</td>
<td>85.0</td>
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</tbody>
</table>
Discussion

• Anti-phase lag time post- (0.42 sec) was about half of pre- value (pre- 0.76 sec), indicating the participant had improved coordination of right and left ankles.

• post-intervention gait speed was in the range of children without disability (113±18 cm/s)
Discussion

- Increase in strength of the dorsiflexors (0.29 Nm/kg) was slightly larger than those previously recorded for trained dorsiflexor muscles (0.22 Nm/kg) in children training on the Kincom dynamometer;
- The improvement in the child quality of life was clinically significant (score difference of 5.7 > 4.5 threshold of clinical significance for PedsQL);