Novel Robots for Gait and Arm Rehabilitation

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SMS Lab: 2 Affiliations, 2 Locations

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University Hospital Balgrist

Institute for Robotics and Intelligent Systems

Spinal Cord Injury Center
Disadvantage of Manual Training

For the Therapist
- Physically exhausting
- Ergonomically inconvenient

For the Patient
- Limited training duration
- Gait pattern not optimal

SCI Center, Balgrist University Hospital, Zurich
Challenges & Chances

What Are the Challenges in Rehabilitation?

1. Patients need intensive training to benefit from neuroplastic effects, even in the presence of pharmaceutical factors

2. Number of patients increases due to demographic shift

3. There is a shortage of personnel for rehabilitation and care

=> Chances: Application of Robotics
Robot-Aided Gait Training

Lokomat
Balgrist, Hocoma AG
Current Robotic Platforms for Neurorehabilitation
Gait Rehabilitation "Robots"

Lopes

GaitTrainer

G-EO

Autoambulator

Lokomat

Haptic Walker
Hand/Arm Rehabilitation "Robots"

MIT Manus

Bi-Manu-Track

MGA

Haptic Master, GENTLE/s

Armeo Series ARMin
ARMin History

Pilot study I (n=10)

Single case studies I, chronic stroke (n=3)

ARMin I

2005 2006

Pilot study I (n=10)

Single case studies I, chronic stroke (n=3)

ARMin II

2007 2008 2009 2010 2011 2012

Pilot study II

Single case studies II, chronic stroke (n=4)
ARMin History

2005
Pilot study I (n=10)
Single case studies I, chronic stroke (n=3)

2006
ARMin I

2007
4 Axes
ARMin II
Pilot study II
Single case studies II, chronic stroke (n=4)

2008
6 Axes
ARMin III
Pilot study III
Controlled clinical trial, chronic stroke (n=80)

2009
2010
2011
2012

Nef, Riener et al. 2006-2011
ARMin III

Exoskeletal Robot with 7 Degrees of Freedom

ETH Zurich/Balgrist, Hocoma AG
Nef, Riener et al. 2006-2011
Multicenter Randomized Clinical Trial

Hypothesis

“Patient-responsive ADL-related **robotic training** with ARMin is more effective than conventional therapy with respect to motor functional recovery of the affected arm of chronic hemiparetic **stroke** patients.”
Multicenter Randomized Clinical Trial

Study Design

• Multicenter, randomized, controlled, clinical trial
• Four medical centers
• Total of 77 patients
• Patients with moderate to severe motor impairment of an upper limb (FMA 8 to 38) after stroke
• Chronic state (at least 6 months post-stroke)
Study Outcomes

Primary Outcome

• Fugl-Meyer Assessment (FMA), impairment based, upper arm portion (max. 66 points)

Secondary Outcomes

• Wolf Motor Function Test (WMFT)
  – time
  – function

• Questionnaires
  – Stroke Impact Scale (SIS)
  – Motor Activity Log (MAL)

• Modified Ashworth-Skala (mAS)

• ROM, joint torques measured by ARMin
Time Course

-4
GAS physical exam

0
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

4
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

8
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

16
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

34
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

Tests by examiners
FMA
ROM
mAS

Tests by therapists
FMA
MAL
WMFT
SIS
ROM
mAS
ARMIn

test label
m1
0
1
2
3
4
# Therapy Session Modes

<table>
<thead>
<tr>
<th></th>
<th>Robot (ARMin)</th>
<th>Conventional (Control)</th>
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<tbody>
<tr>
<td><strong>Minimum time</strong></td>
<td>45 min</td>
<td>45 min</td>
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<tr>
<td><strong>Therapy modes</strong></td>
<td>Mobilisation (min. 10min)</td>
<td>Mobilisation</td>
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<td></td>
<td>Games (min. 10min)</td>
<td>Games</td>
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<tr>
<td></td>
<td>ADL tasks (min. 10min)</td>
<td>ADL tasks</td>
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<tr>
<td></td>
<td>«Others»</td>
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Change in FMA

73 Patients (38 ARMin, 35 Control)

![Graph showing the change in FMA over therapy and follow-up periods. The graph indicates a decline in FMA scores from therapy to follow-up.](image)

Change in FMA: Severe Cases

34 out of 73 Patients

Conclusion from Clinical Study

- Patient-responsive ADL-related robotic training with ARMin is more effective than conventional therapy with respect to functional recovery.

- Particularly patients with severe impairment benefit from robotic therapy of the arm.

- Differences are clinically questionable.

- Were patients “too chronic”? Were robots stimulating too little and supporting too much?

- Future question: Where are the responders?
ARMin History

**ARMin I**
- 2005
- Pilot study I (n=10)
- Single case studies I, chronic stroke (n=3)

**ARMin II**
- 2006
- Pilot study II
- Single case studies II, chronic stroke (n=4)

**ARMin III**
- 2007
- Pilot study III
- Controlled clinical trial, chronic stroke (n=80)

**ARMin IV**
- 2008
- 2009
- 2010
- 2011
- Pilot study IV
- Novel assessment methods

2012
- Technology Transfer
  - Armeo®Power

Nef, Riener et al. 2006-2011
ARMin History

2008
Pilot study III

2009
Controlled clinical trial, chronic stroke (n=80)

2010
ARMin II

2011
ARMin III

2012
ARMin IV

2013
Pilot study IV, novel assessment methods

2014 ...
ChARMin

Technology Transfer
Armeo®Power

MR-compatible robotics
ChARMin Setup

U. Keller, R. Riener & KiSpi Zurich
Human-Robot Interaction
Human-Robot Cooperation

Human

Interaction, Cooperation

Machine
Human-Robot Cooperation

Key Features

- Intensive
Human-Robot Cooperation

Key Features
- Intensive
- Guided?
Human-Robot Cooperation

Key Features

- Intensive
- Cooperative
- Transparent
Mechanical Interaction

Path Control

- Robot behaves assistive, corrective or transparent, when needed
- Free timing for patient
- Support patient, but do not restrict patient

Duschau-Wicke, Vally, Riener, et al.
Path Control Increases Participation

**Heart Rate**

- Relative increase of heart rate
- Pos. contr. vs. Path contr.

**Muscle Activity**

- Normalized muscle activity (BF)
- Position control vs. Path control
- 11 incomplete SCI subjects
Path Control Enhances Variability

“Repetition without Repetition” (Bernstein)
Motivation During Gait Training

Conventional Training

Can be monotonous and boring
Gait Training & Virtual Reality
Engagement Increases Neuroplasticity

Physical activity

Neuroplastic effects
Engagement Increases Neuroplasticity

Engagement

Physical activity

Mental activity

Increased neuroplastic effects
Human-Robot Cooperation

Key Features
- Intensive
- Cooperative
- Transparent
- Engaging
- Rewarding
Human-Robot Cooperation

Key Features
- Intensive
- Cooperative
- Transparent
- Engaging
- Rewarding
- Task-specific
Activities of Daily Living Training

Chronic Stroke Patient (FMA=26)

Guidali, Riener et al., MBEC 2011
Activities of Daily Living Training

Guidali, Riener et al., MBEC 2011
Social Reward: Tele-Rehabilitation

Player RED
Uniklinik Balgrist

Player BLUE
ETH Zurich
Social Reward: Collaborative Gaming
Outlook & Vision
Problem: Averaging

FMA ARMin Group

Responder

Non-responder

FMA Control Group
Challenge: Find the Responders

Human Subjects

- Subject A
- Subject B
- Subject C
- Subject D
- Subject E
- Subject F
- Subject G
- Subject H
- Subject J
- Subject K

Technical Features

- Visual feedback
  2D/3D, VR
- Dose (intensity)
- Auditory feedback
- Game, control
- Task difficulty
- Further displays
- Distal/proximal
- ROM
- Axis 4

Human Subjects: Subject A, Subject B, Subject C, Subject D, Subject E, Subject F, Subject G, Subject H, Subject J, Subject K

Technical Features: Visual feedback, Dose (intensity), Auditory feedback, Game, control, Task difficulty, Further displays, Distal/proximal, ROM, Axis 4
Conclusion
Conclusion

Robots should Cooperate and Motivate

• Current robotic approaches often ignore patient activity
• Therapeutic outcome can be increased, when patient is active
• Therefore, future robots should be “patient-cooperative” enhancing patient activity and engagement/reward

Outlook

• Implement novel technical features (e.g. provide high intensity treatment, reward-driven therapy)
• Adjust the technology and therapy to find the responders
• Prove effectiveness in clinical studies
CYBATHLON

CHAMPIONSHIP FOR
ROBOT-ASSISTED PARATHLETES
Six Different Disciplines

General Criteria
• Challenge requires actuated devices
• Course contains tasks of daily life
Objectives of the Cybathlon

The Cybathlon will promote the development of assistive systems for people with disabilities to be suitable for daily use. This should remove barriers between general public, the users and the developers.