Robotics in Rehabilitation: Can Robots Really Enhance Function and Quality of Life?

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Introduction

According to the WHO, 15 million people worldwide suffer a stroke each year.

Of these 5 million are left with a disability.

Rehabilitation can reduce limitations and disabilities that arise from a stroke, and improve occupational performance.
Reaching Motion

Fundamental motion to many ADL

Can function as support and anchoring for other movements

Upper Limb Rehab
**Conventional Therapy**

There are limitations……

- Repetitive, labour-intensive
- Lack of quantitative measures
- Limited one-on-one therapist-patient time
- Economic pressures
- Home rehab is self-directed with little professional or quantitative feedback
- There is poor compliance at home

**A Role for Robotics**

Therapy is a great application……

- Automate interventions
- Provide accurate measures
- Minimise therapist intervention (one-therapist, many patients)
- Potential to provide home rehab solutions

Shadow Robot Hand (www.shadowrobot.com)
Increasing Popularity

- (rehabilitation OR rehab) AND (robotics OR robots) AND (upper limb)
- limited to subject areas: stroke, robotics, rehabilitation, therapy

So, where are all of the robots?
What could we buy if we had $85,000?

(HK$700,000)
InMotion (MIT Manus)

$70,000 - $80,000 (HK$560K – HK$640K)

Hacoma Armeo

$53,000 (HK$424K) $17,000 (HK$136K)
Reogo

$85,000 (HK$680K)

Occupational Therapist

$70,000 (HK$560K)
Is there evidence to support their use?

YES

and NO

Clinical Trials – Masiero et al. 2011

RCT, n=11 robot treatment, n=10 control, sub-acute stroke

Neuro-Rehabilitation-roBot (NeReBot), 3 DoF

Baseline, end treatment - 5 weeks, 3 month post

Outcomes – MRC strength, FM, mFIM, Modified Ashworth, Frenchay Arm Test, Box and Block Test, Treatment Tolerability

Most gains statistically significant pre/post, no differences between 2 groups, both groups showed functional gains
**Clinical Trials – Bovolenta et al. 2010**

n=19, chronic stroke, Pre/post test design, no control group

ReoGo, 20 sessions, 45 minutes, 2day/wk, 4 weeks

Fugl-Meyer, Ashworth Scale, FIM, MRC strength testing, pain VAS, Frenchay Arm test, Box and Block test, Timed up and Go, Euro-QoL, Treatment satisfaction VAS

From treatment start to end there was a significant increase in all scores except some strength and Ashworth spasticity for shoulder, triceps and wrist

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**Clinical Trials – Lo et al. 2010**

4-site RCT with MIT-MANUS, moderate-to-severe UL impairment

3 groups:
- n=49 intensive robot-assisted therapy
- n=50 intensive comparison therapy
- n=28 usual care

@ 12 weeks: Fugl-Meyer - intensive comparison therapy > robot therapy > usual care, but not statistically significant

@ 36 weeks: Fugl-Meyer, Wolf Motor Function Test - robot therapy > usual care, intensive comparison and robot therapy not statistically significant

Cost analysis – robot and intensive comparison therapy > usual care, robot approx. = intensive
What does this all mean?
“Although several robot systems for therapy support are already commercially available on the market, there is still little evidence for the effectiveness of the therapy concepts both in clinical and in home application”.

Robotic devices need to:

Increase opportunities for therapy and repetition

Be lower cost than therapist supervision with people

Have an impact on real-life activities

New ways of thinking are needed to develop robots that can meet these challenges.
Disruptive Technology

….when introduced, either radically transforms markets, creates wholly new markets or destroys existing markets for other technologies.

Designing a Better Robot

All of this evidence points to the need to design and build more robust and affordable robots for rehab.

New designs need to be informed by the end users, which includes therapists.

These new robots need to incorporate current therapeutic practices.

The new system needs to be easy and intuitive to use by everyone.
User-Centred Design

A design process in which the needs, wants, and limitations of end users of a product are given extensive attention at each stage of the design process.

Why use UCD?

To obtain a system which:

• is easier to understand and use, thus reducing training costs
• improves the quality of life of users by reducing stress and improving satisfaction
• significantly improves the productivity and operational efficiency of individual users and consequently the organisation
Artificial Intelligence

Techniques that can be used to design a system that acts like a human when performing cognitive functions (e.g. decision making)

Haptics
Applying these Principles

We used an evidence-based approach in the design of the new robotic system.

Through several information sessions and surveys with both OTs & PTs we learned about the types of features that would be desirable in this type of technology.

We have also applied artificial intelligence to allow the system to learn and adapt.

What do therapists want?

Objectives:
- To understand current rehabilitation methods and aims
- Features that would be desirable in an upper limb rehabilitation robot

Methods:
- Online questionnaire with 85 questions distributed to professional therapist organizations & listservs
- Analysis based on descriptive statistics
Survey Results

Data analyzed for 233 respondents:
- Mainly from Australia, Canada, USA
- Mainly physiotherapists (72%) and occupational therapists (27%)

Main approaches to upper limb rehabilitation:
- Repetitive task training (88%)
- Motor relearning (76%)
- Neurodevelopmental/Bobath (65%)
- Use of robot assisted (6%)


Desired Robot Features

- Facilitate many arm movements
- Be usable in a seated position
- Give biofeedback to the user
- Have virtual ADL activities
- Useful for clients to use at home
- Adjust resistance based on client performance
- Modular
- Maintain proper joint alignment
New Robot

Key Characteristics

Our new prototype is:

- Haptic, 2DOF
- Lightweight and portable (10 kg)
- Cost effective (~10X less than current systems)
- Self-contained unit
- Adaptive to user states and goals
- Collects key data for therapists
Therapist Interface

Provides simple and intuitive controls to create constant resistive force, damping force, and assistive force on the end-effector.

Provides a calibration process to define the workspace of the robot.

Shows instantaneous performance analysis and a comparison of performance of the previous sessions.

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Therapist Interface

Provides three modes of operation:

1) **Interactive mode**: The therapist can set different combinations of resistive/assistive forces for a target position to be reached by the patient.

2) **Waypoint mode**: The therapist defines a set of waypoints with specific force setting.

3) **Autonomous**: The therapist only defines a set of target points and the intelligent system repeats the target positions with different force setting until the patient becomes fatigued.
Therapist Interface

User’s Virtual Environment
AI Controller

Developed a controller that can automatically modify the exercise parameters to account for the specific needs and abilities of each user.

Controller based on a probabilistic model that can use input from the robot and sensors to characterize the state of the person and robot.

AI Model - Parameters

The basis of the model was developed from what was observed during conventional therapy:

- First increase target distance and then resistance;
- If patient is showing signs of fatigue, rest;
- Signs of fatigue: ↑ in compensatory movements, ↓ in control, ↑ in time to target
Estimating Fatigue

Posture Detection
“There is no treadmill for the arm”

Implications for Practice

Robotics can complete repetitive tasks effectively and efficiently, which is important in the rehabilitation process.

Opportunity for extended practice of motor skills is limited in the clinic, intelligent robotics can extend time and influence plastic change.

Intelligent robotics can adjust to the state of the person, minimizing risks and chances of injury.
Implications for Practice

Novelty of the technology is engaging for clients (and therapists).

Potential versatility of the device to adjust speed, resistance, direction, and plane will allow people with minimal level of recovery to engage in an exercise program that will be “just the right challenge”.

Potential for more objective measurement of abilities and progress.

Is there a future for rehab robotics?
Hopefully, YES!
Robots need to be cheaper

New delivery models are needed

Robots need to be smarter

Therapists need to be more engaged

Rehab Robot Clinics

(Intelligent Assistive Technology and Systems Lab)
Into the home

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