Rehabilitation Robotics-Categorization

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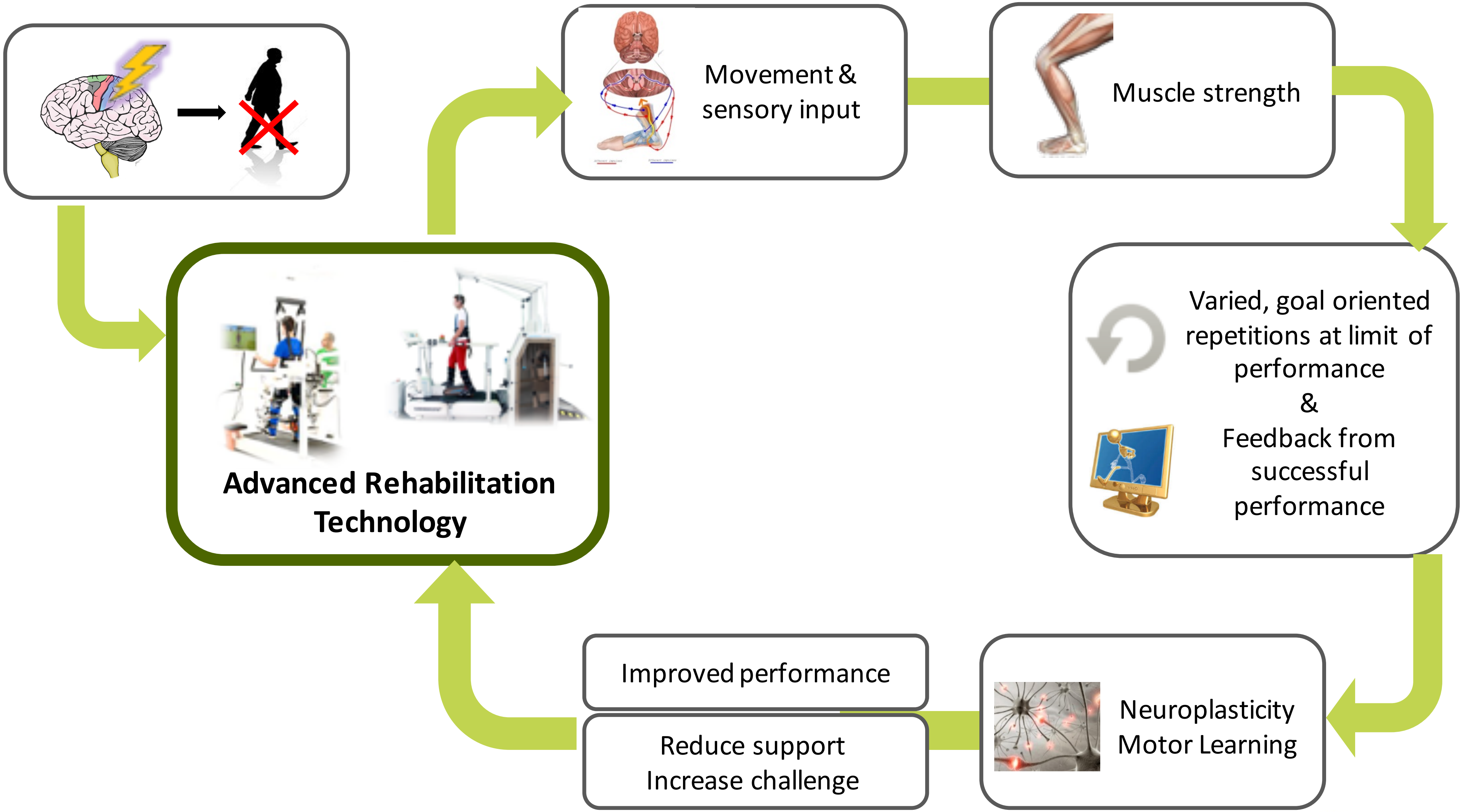
Rehabilitation Robotics- Categorization

ROBOT ASSISTED THERAPY: SCIENTIFIC EVIDENCE

Potential Influence of Rehab Robotics



Robot-Assisted Therapy: UE

Proximal Improvements

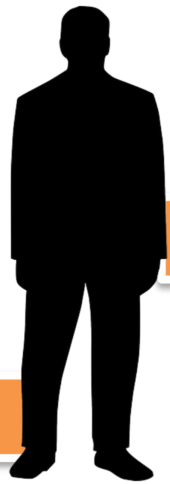
Significant effect on **motor function** of shoulder and elbow, **muscle strength** and **pain reduction**

(Veerbeek et al. 2014)

Transfer to Daily Life

Improves generic **activities of daily living** and **arm function**

(Mehrholz et al. 2012)



Distal Improvements

Elbow and wrist training **enhances motor function** and **muscle strength**

(Veerbeek et al. 2014)

Risk

No increased risk of **injury** with intensive training (Mehrholz et al. 2012)

Recovery Time

Robotic therapy **improves motor function** in a **shorter time** than physiotherapy (Sale et al. 2014)

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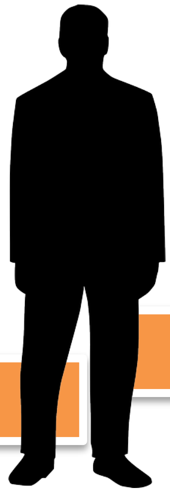
Robot-Assisted Therapy: LE

Walking improvements

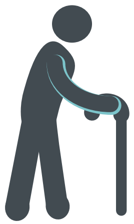
Positive effect on **gait speed**, **walking distance** and **basic activities** of daily living



Rehabilitation Time

Non-ambulatory patients in **early rehabilitation profit most** from robot-assisted therapy

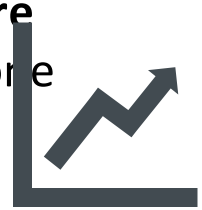
Dependency



Every **fifth dependency** in walking **could be avoided** using robotic-assisted training

Effectiveness

Robotic therapy in combination with conventional therapy is **more effective than physiotherapy** alone



(Mehrholz et al. 2013)

Rehabilitation Robotics- Categorization

ROBOT ASSISTED THERAPY: CATEGORIZATION

Robot-Assisted Therapy: Elements

Mechanical structure
- Moveable segments and joints

Actuators
- Convert energy into motion and force, e.g. motors

Sensors
- Measure physical parameters, e.g. position, force, orientation, torque

Controller
- Uses sensor data to control actuators

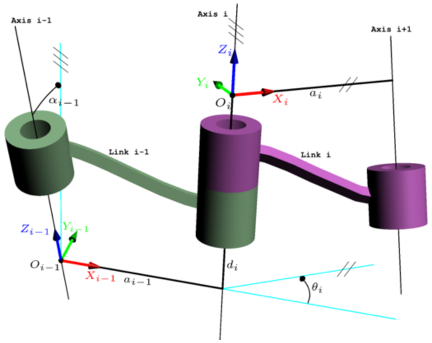
Patient interface
- Attaches to patient and transmits forces from the robot, e.g. cuffs

User interface
- Enables user to adjust controller settings

Power source
- Provides electricity to drive actuators, controller
- Pneumactic systems

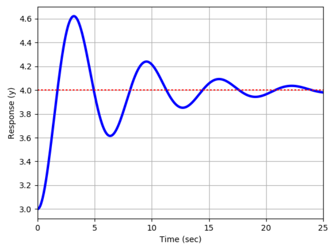
Robot-Assisted Therapy: Elements

How to categorize robot-assisted therapeutic devices?



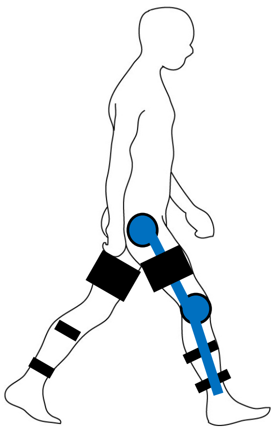
Mechanical structure

- Exoskeletons
- End-effector-based



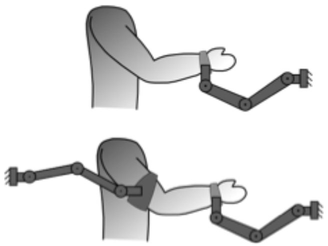
Control strategies

- Full guidance
- Patient-cooperative
- Free Space



Attachment Location

- Upper limbs
- Lower limbs

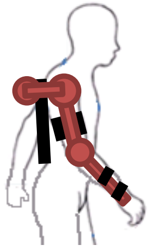


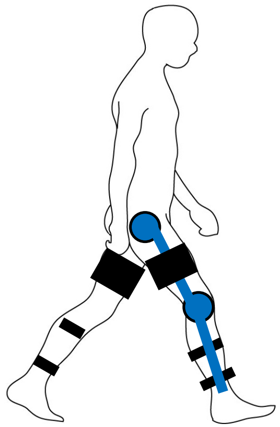
Robot-Assisted Therapy: Exoskeletons

"A wearable robot or external structural mechanism with joints and links corresponding to those of the human body."

Pons et al., 2006; History and Future of Rehabilitation Robotics, 2010

- Attached to body or body parts
- Joints transmit forces to different robotic segments
- Allows production of physiological movements
- Combination with treadmi body-weight-support, functional electrical stimulation, virtual reality





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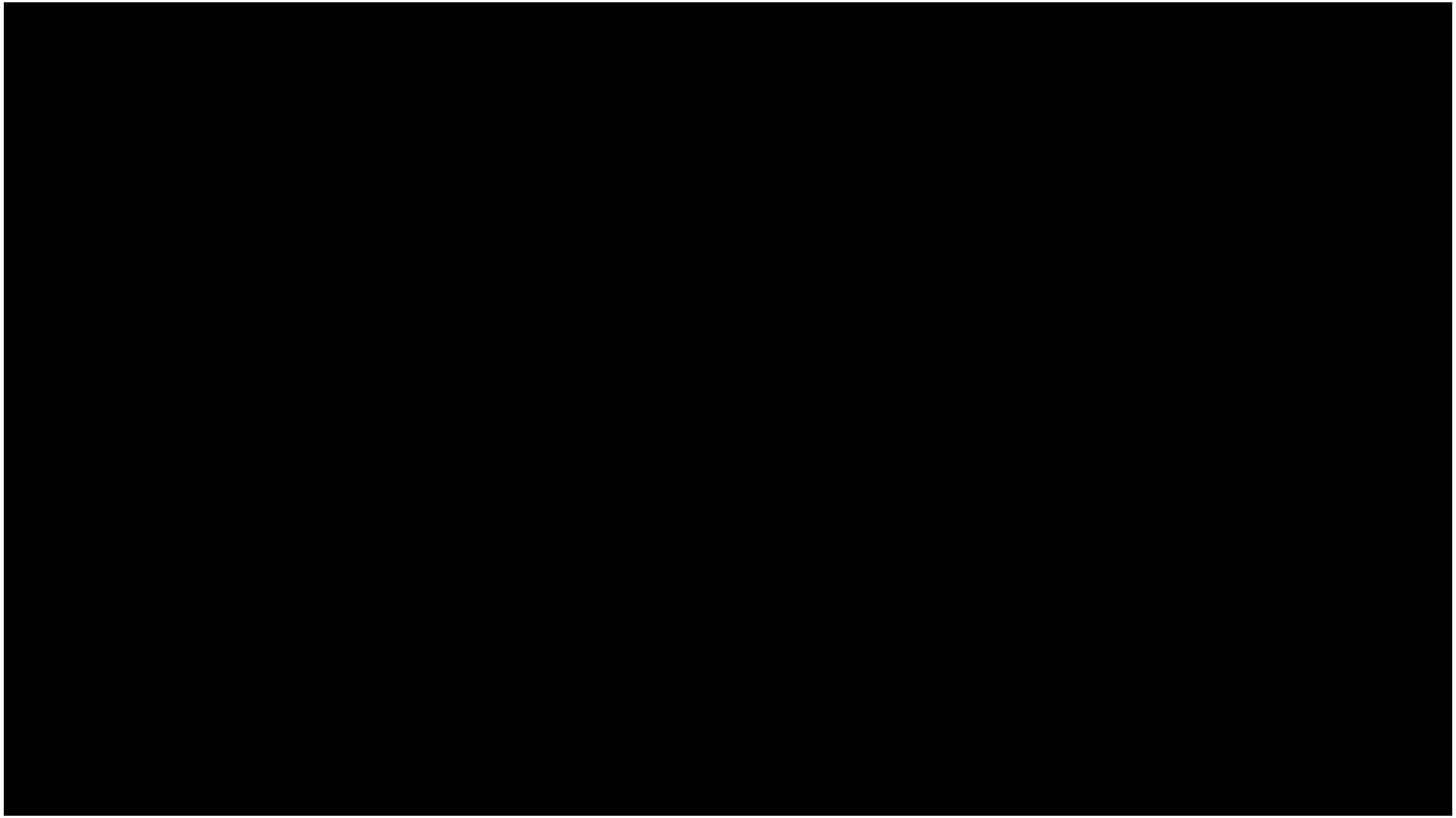
Robot-Assisted Therapy: Exoskeletons

"A wearable robot or external structural mechanism with joints and links corresponding to those of the human body."

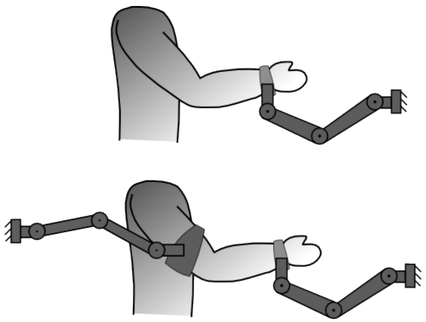
Pons et al., 2006; History and Future of Rehabilitation Robotics, 2010

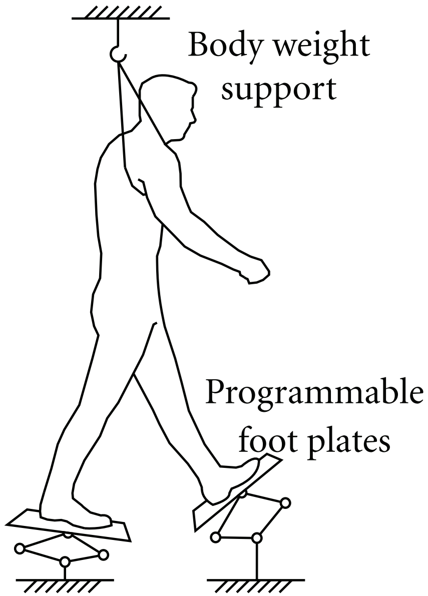


Robot-Assisted Therapy: End-Effector

"Robotic devices that provide support and forces to the patient's limb only at its most distal part (end effector) which is attached to patient's extremity."

- Maciejasz et al., 2014



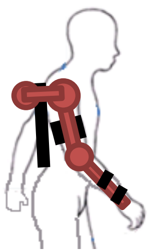


- Attached to single body segment
- Transmit force via mechanical movement chain
- Combination with treadmills, body-weight-support, functional electrical stimulation, virtual reality

Exoskeletons vs. End-Effector Devices

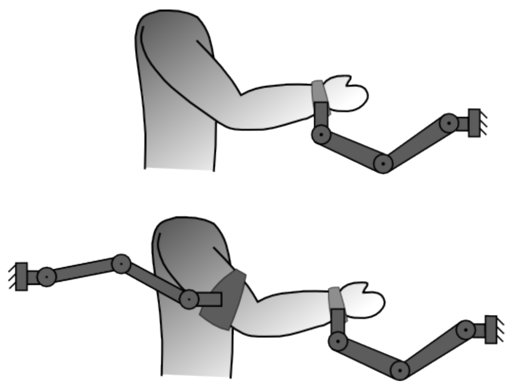
Exoskeleton

- Joint axes fully determined
- Physiological movements
- Force and position data of each joint
- Robot axes have to allign with anatomical axes
- Longer set-up times
- Challenging anatomical constraints



End-effector-based

- Simpler structure / control
- Easy to adjust to patient
- Limb posture not fully determined
- Limited force / position data
- Risk of joint injury

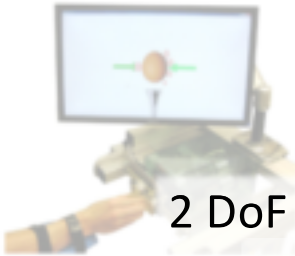


Robot-Assisted Therapy: Upper limbs

Laterality

- Parethic or unaffected arm individually
- Both arms together

Degrees of freedom



- Amount of degrees of freedom

Individual limbs

- Single limbs
- Combination of limbs

Robot-Assisted Therapy: Lower limbs

Gait training

treadmill

- Automated body-weight support training
- Exoskeleton combined with treadmill

foot-plates

- Automated body-weight support training
- End-effector based device

overground

- Body-weight support follows patient
- Allows natural walking but requires muscle activity

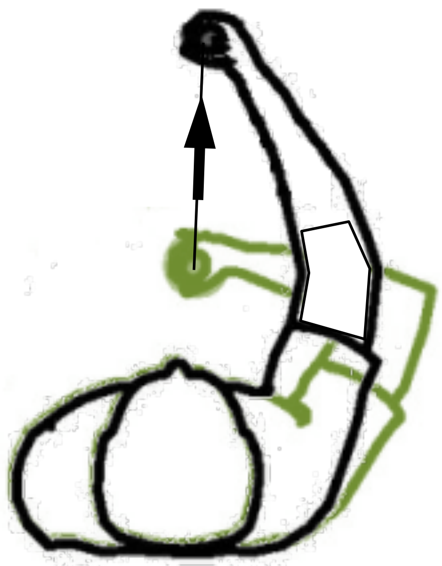
active orthoses

- Support position and motion control of leg joints
- Compensate for weakness and deformities

Robotic Therapy: Control Strategies

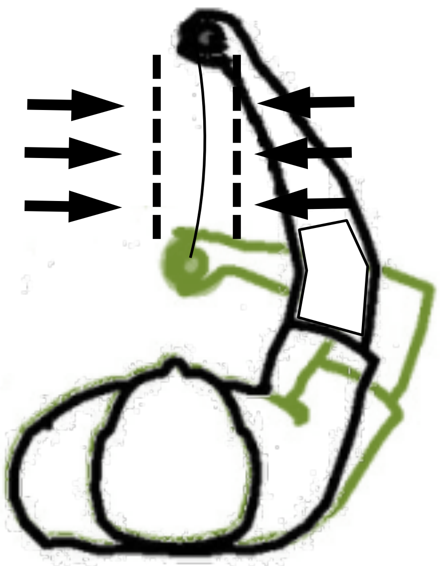
Full guidance

- Predefined motion performed by robot
- Muscle activity not required



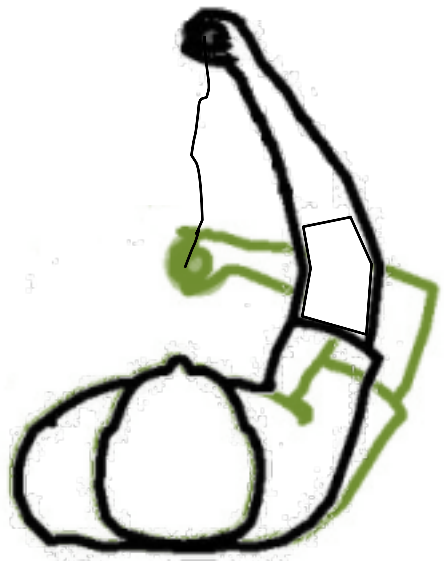
Patient-cooperative control

- Guided movements
- Partial support to initiate and perform movement
- Haptic simulation for interactive environment



Free space

- Negligible interaction with robot



Rehabilitation Robotics- UPPER EXTRIMITIES DEVICES

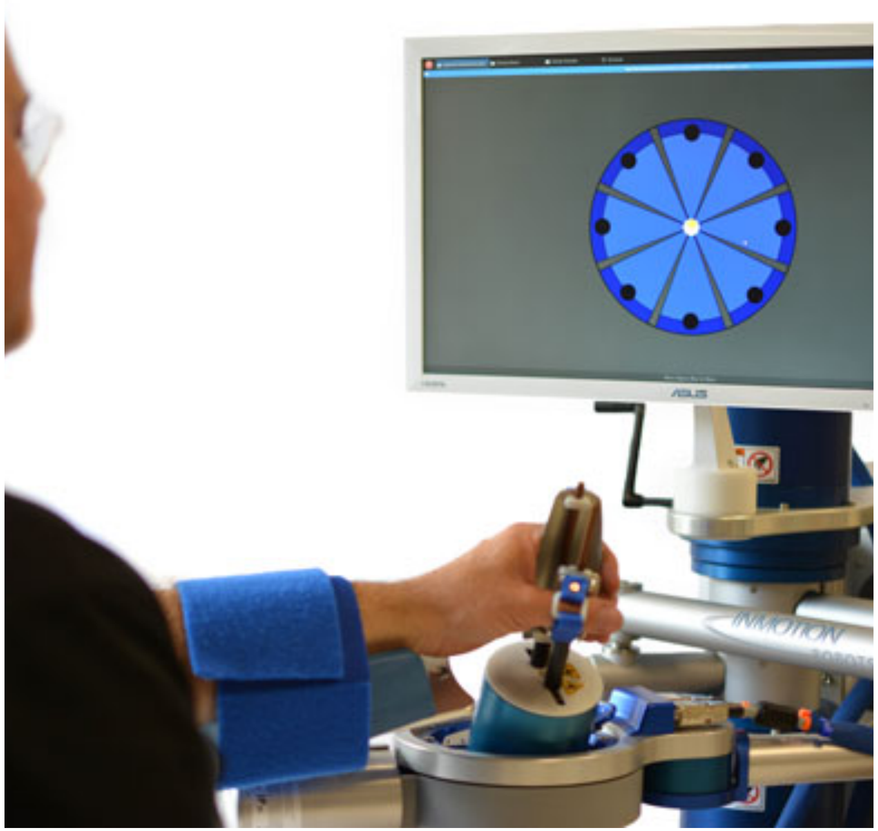
ROBOT ASSISTED THERAPY: UPPER EXTREMITIES DEVICES

INMOTIONARM

Bionik

Key Points

- From MIT-manus: 1000+ patients
- Add-on InMotion HAND
- Assist-as-needed
- InMotion EVAL
  - Quantifies upper extremity motor control and movement recovery
  - Correlated with traditional assessment scales: Fugl-meyer, Motor-Power and NIH stroke scale performance



Many published researcha using MIT MANUS and the commercial version (INMOTIONARM)

INMOTIONARM® (Bionik)

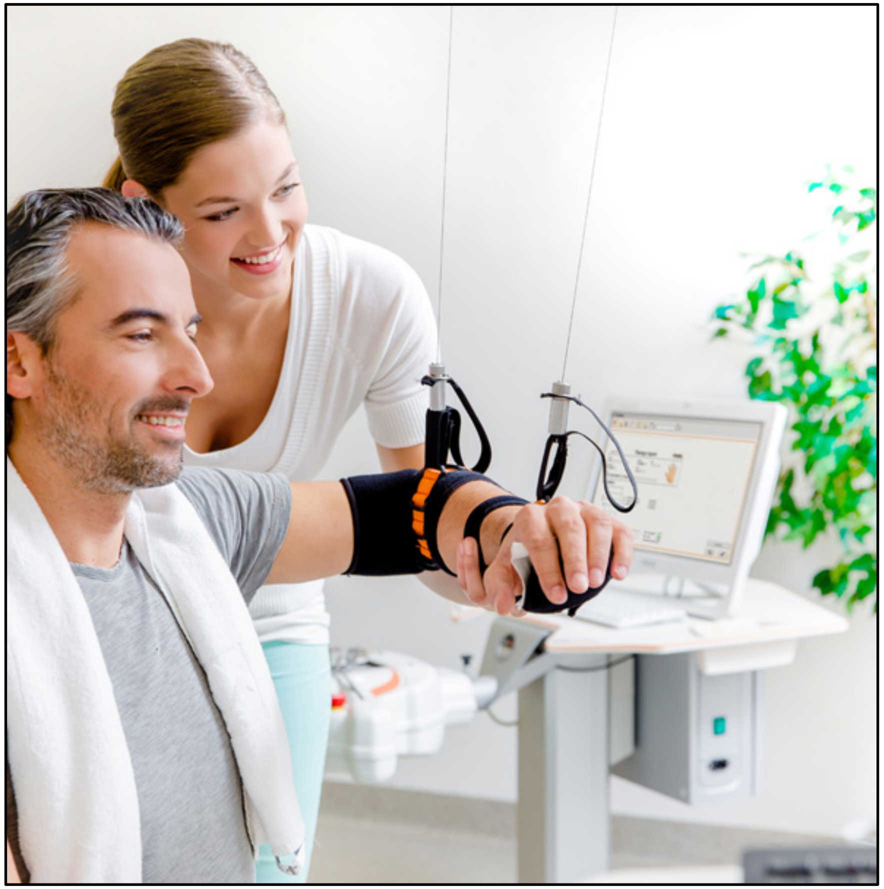
INMOTIONARM

Diego

Tyromotion

Key Points

- Robot-assisted arm and shoulder therapy system
- Intelligent gravity compensation (IGC) to assist-as needed for functional reaching training
- Bilateral, unilateral and symmetric arm training
- 3D bio-feedback
- Individual applications for children and adults
- Task-oriented training with real objects



Diego® (Tyromotion)

Mehrholz et al., *Electromechanical and robot-assisted arm training for improving generic activities of daily living, arm function, and arm muscle strenght afters troke (Review)*, The Cochrane Library (2012)

Diego

ReoGo

Motorika

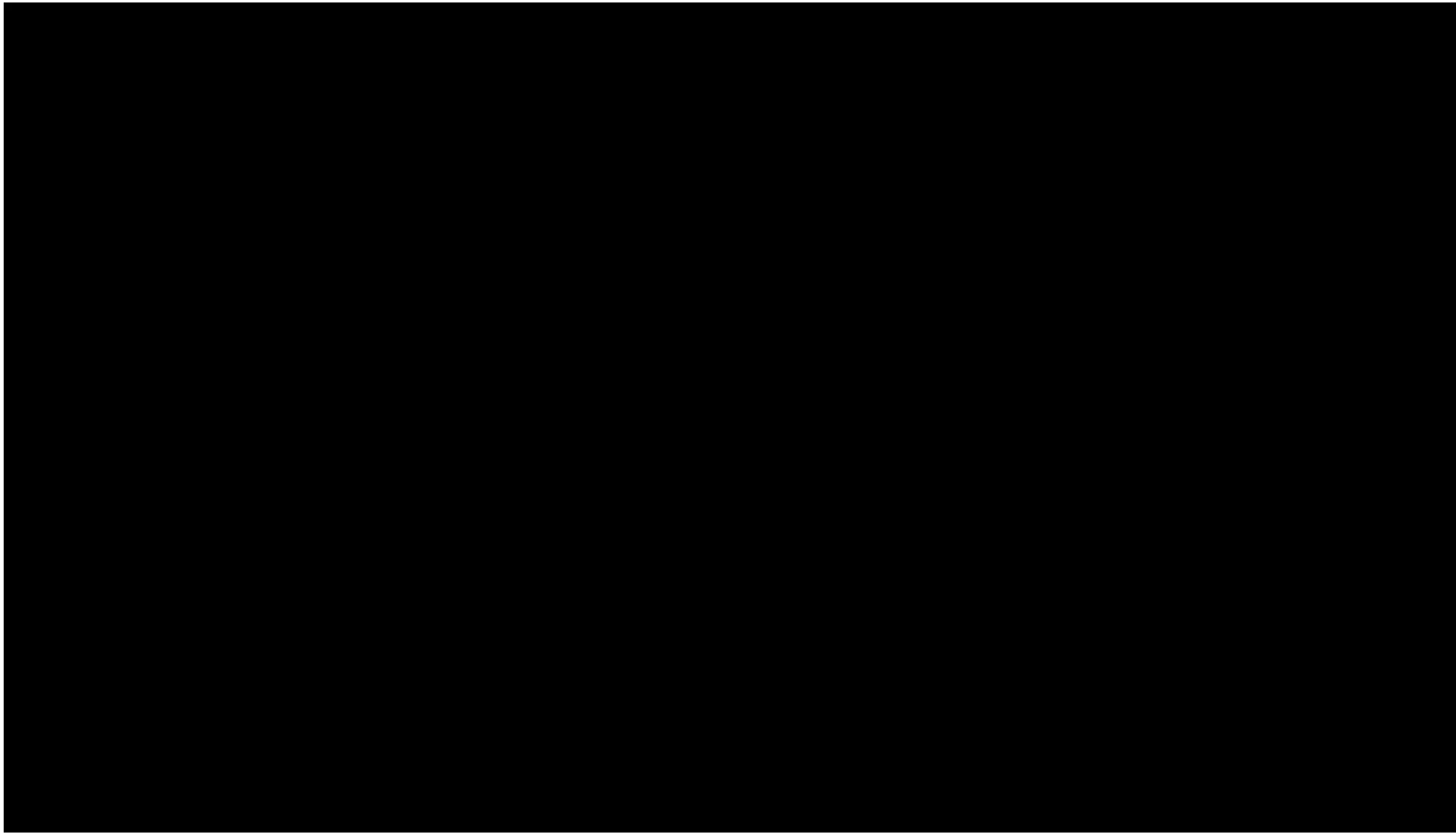
Key Points

- Clinical evaluations of therapy using the **ReoGo™** have been conducted in the US, Japan, Italy, Germany and Israel with a combined total of over 350 sub-acute and chronic stroke patients
- Features five operating modes (Guided, Initiated, Step Initiated, Follow Assist and Free) that gradually increase load and movement complexity, which enables treatment of all rehabilitation stages from completely passive to active patients

ReoGo® Motorika)

Bovolenta F, Sale P, Dall'Armi V, Clerici P, Franceschini M. Robot-aided therapy for upper limbs in patients with stroke-related lesions. Brief report of a clinical experience. *Journal of NeuroEngineering and Rehabilitation*. 2011;8:18. doi:10.1186/1743-0003-8-18.

ReoGo



Armeo Power

Hocoma

Key Points

- Early rehabilitation training for severely affected patients
- Extensive 3D workspace (6 actuated dof)
- Assist-As-Needed support automatically adapts to patient's capabilities
- Augmented Performance Feedback increases motivation and trains activities of daily living
- Assessment Tools for objective analysis of patient's progress

Klamroth-Marganska et al., *Three-Dimensional, Task-Specific Robot Therapy Of The Arm After Stroke: A Multicentre, Parallel-Group Randomised Trial*, Lancet Neurol. (2014)

ArmeoPower® (Hocoma)

Armeo Power

ALEx

Wearable Robotics srl

Key Points

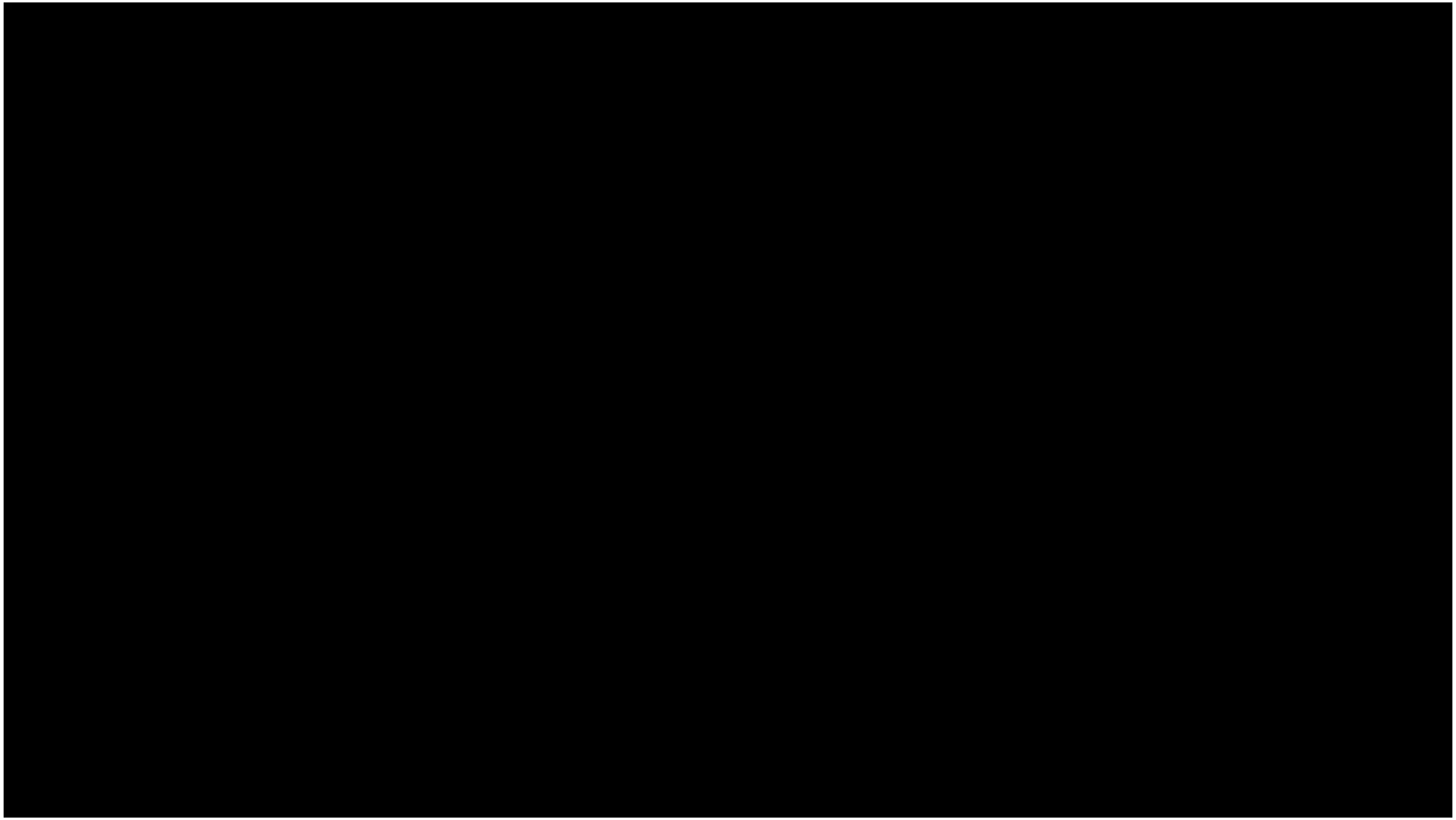
- ALEx is a six DoFs mechanically compliant exoskeleton for the human upper limb.
  - two sensorized and passive joints (the forearm prono-supination, FO-Pro-Sup, and the wrist flexion-extension, WR-Flx-Ext).
- Assistance as Needed

ALEx (Wearable Robotics)

Evaluation of a New Exoskeleton for Upper Limb Post-stroke Neuro-rehabilitation: Preliminary Results

Replace, Repair, Restore, Relieve – Bridging Clinical and Engineering Solutions in Neurorehabilitation, Biosystems & Biorobotics Volume 7, 2014, pp 637-645

ALEx

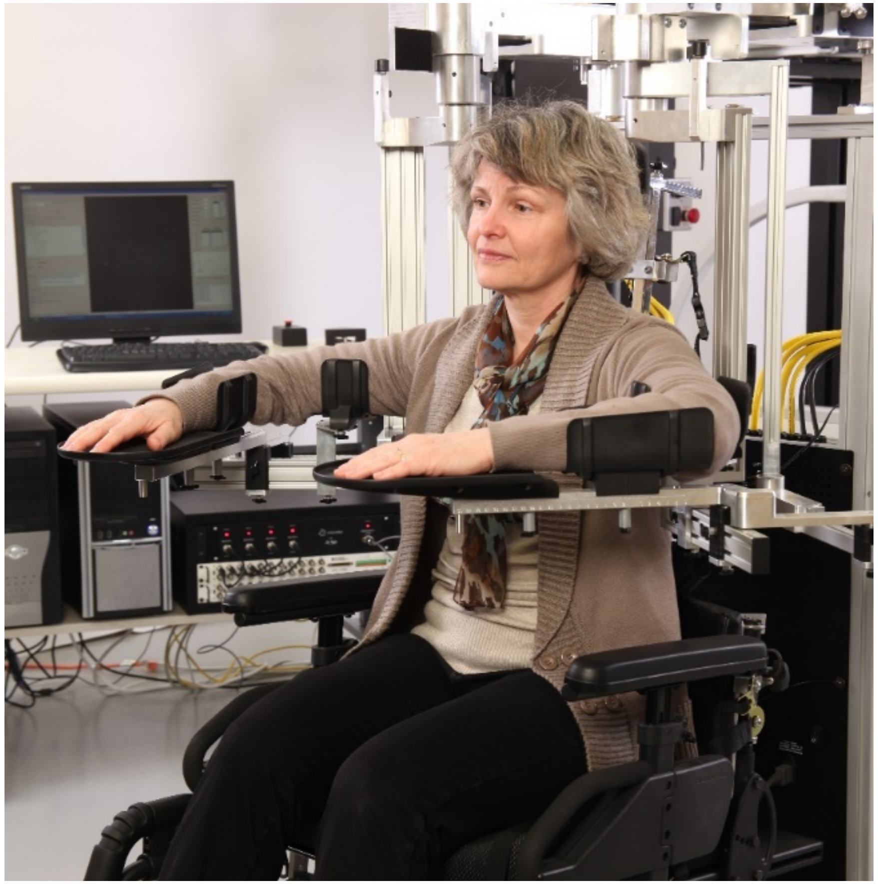


KINARM Exoskeleton Lab

BKIN Technologies Ltd

Key Points

- Assessment of range of neurological impairments associated with stroke, spinal cord injury, CP, Parkinson's
- Quantitative and objective measures of brain function and dysfunction through precise measurement of human behaviour
- Supports clinical researchers in the development of novel therapies for improved outcomes



KINARM Exoskeleton Lab (BKIN Technologies Ltd., Canada)

Semrau, J.A. et al. *Robotic identification of kinesthetic deficits after stroke.* Stroke. 44:3414-3421 (2013)

KINARM Exoskeleton Lab

Rehabilitation Robotics- LOWER EXTRIMITIES DEVICES

ROBOT ASSISTED THERAPY: LOWER EXTREMITIES DEVICES

ZeroG® Gait and Balance System

Aretech

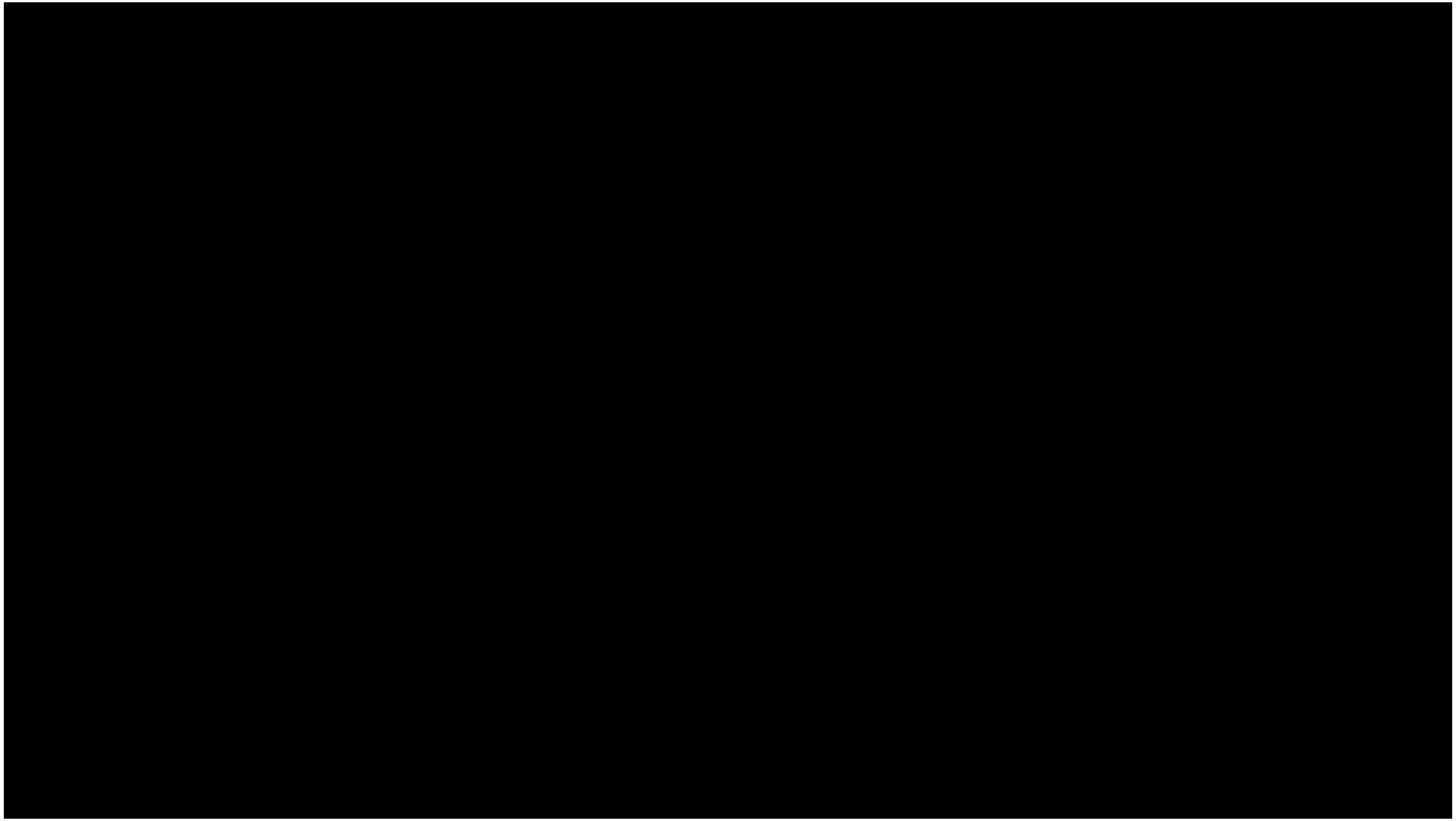
Key Points

- Dynamic body-weight support compensates for weakness & poor coordination
- Robot tracks movements along a ceiling track
- Interactive games and balance training with biofeedback
- Lowers the risk of injury to patient & therapist
- Practice functional activities safely
- Monitor & track functional progress

Hidler, et al. *J Rehabil Res Dev.* (2011) 48(4):287-98.

ZeroG (Aretech, Ashburn, VA USA)

ZeroG® Gait and Balance System



System 4 Pro

Biodex Medical Systems

Key Points

- Over 5,600 Peer Reviewed Citations in Support
- Objective Data
- Documented Progress, Need and Outcomes
- Research, Rehabilitation, Testing and Training
- 5 Modes of Operation, Passive, Isometric, Isokinetic, Isotonic and Reactive Eccentrics
- Capable of delivering concentric and eccentric contractions in 4 modes

System 4 Pro (Biodex Medical Systems, Shirley, New York, USA)

Lokomat® Pro

Hocoma

Key Points

- Adjustable exoskeleton for a physiologic gait pattern
- Assist-As-Needed support for optimal training challenge
- Augmented Performance Feedback for increased patient participation
- FreeD Module for balance activation and weight shift

Lokomat® Pro (Hocoma, Zurich)

Mehrholz et al., *Electromechanical-assisted training for walking after stroke*, Cochrane Database (2013)

Lokomat® Pro

Erigo® Pro

Hocoma

Key Points

- Early and safe mobilization of severely impaired patients even in acute care
- Progressive verticalization up to 90°
- Cyclic leg movements 8-80 steps/min
- Cyclic leg loading (up to 50 kg) allows enhanced cardiovascular output
- Improved orthostatic tolerance through Functional Electrical Stimulation (FES)
- Sensorimotor stimulation improves patient awareness

Yoshida et al., *Cardiovascular response of individuals with spinal cord injury to dynamic functional electrical stimulation under orthostatic stress*, IEEE Trans Neural Syst Rehabil Eng (2013)

Erigo® Pro (CHUV, Lausanne)

Erigo® Pro

Rehabilitation Robotics- UPPER EXTRIMITIES DEVICES

ROBOT ASSISTED THERAPY: HAND REHABILITATION

Amadeo

tyromotion

Key Points

- Robot-assisted finger and hand therapy system
- Rehabilitation training for all levels of hand impairment
- Simulation of grasping and individual finger movements
- Force and ROM assessments
- Wide range of therapy applications, e.g. passive (CPM), assistive, active, spasticity and proprioceptive therapy
- Easily adjustable for children and adults

Amadeo® (tyromotion, Graz)

Sale et al., *Recovery of hand function with robot-assisted therapy in acute stroke patients: a randomized-controlled trial.* Int J Rehabilitation Research (2014).

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Amadeo

Hand of Hope

Rehab-Robotics Company

Key Points

- 1st EMG-driven hand exoskeleton
- Active and Assistive device
- Hand and arm training
- Adjustable length for each finger
- Light, compact and portable
- Interactive games
- Easy-to-use interface
- Automatic report availability

Hand of Hope (Rehab-Robotics Company, Hong Kong)

The effects of post-stroke upper-limb training with an electromyography (EMG)-driven hand robot
X.L. Hu, K.Y. Tong X.J. Wei, W. Rong, E.A. Susanto, S.K. Ho Journal of Electromyography and Kinesiology 23 (2013) 1065–1074

Hand of Hope

Rehabilitation Robotics- Categorization

ROBOT ASSISTED THERAPY: VIRTUAL REALITY

CAREN

Motekforce Link

Key Points

- Computer Assisted Rehabilitation Environment
- Multi-sensory input for advanced rehabilitation protocols
- Interactive and dynamic Virtual Reality providing applied games for rehabilitation of movement discorders
- D-Flow application development software offering options to create custom research and clinical applications

CAREN (Motekforce Link, Amsterdam)

Geijtenbeek et al. (2011). "D-Flow: immersive virtual reality and real-time feedback for rehabilitation“. Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry (VRCAI '11). ACM, New York, NY, USA, pp. 201-208.

CAREN

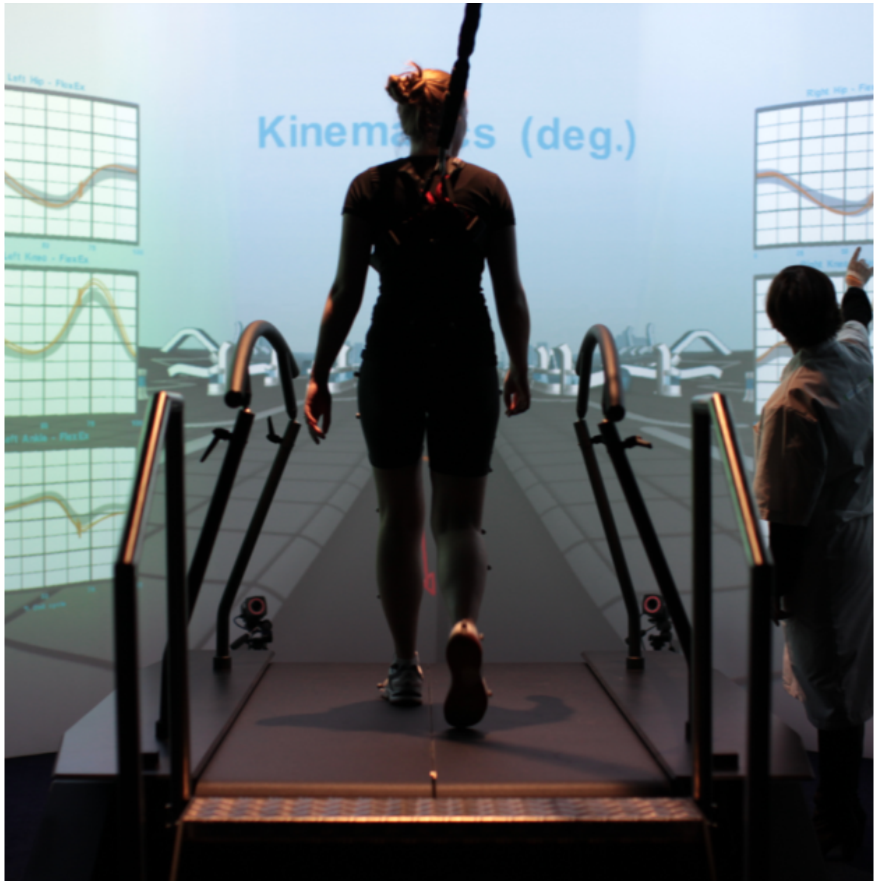
GRAIL

Motekforce Link

Key Points

- Full 3D gait analysis of multiple cycles within 30 minutes
- All gait parameters available in real-time for monitoring and intervention
- Self-paced mode enables patient to walk at a self selected pace
- Visual, mechanical or cognitive dual tasks for 'functional gait analysis' and gait training

Van der Krogt et al. *Overground versus self-paced treadmill walking in a virtual environment in children with cerebral palsy*, Gait & Posture (2014).



CAREN (Motekforce Link, Amsterdam)

GRAIL

C-Mill

Motekforce Link

Key Points

- Instrumented treadmill with projection
- Projection of cues relative to gait pattern
- Obstacle avoidance
- Train gait and gait adaptability
- Gait analysis with CueFors software

C-Mill (Motekforce Link, Amsterdam)

Roerdink et al., *Online gait event detection using a large force platform embedded in a treadmill* (2008).

C-Mill

VirtualRehab

Virtualware Group

Key Points

- CE certified and clinically validated cloud-based physiotherapy videogame platform
- Incorporates motion capture technology
- Variety of engaging 3D styled games exercising different motor functions
- OnPremises version for clinical use and SaaS version for in-home TeleRehabilitation
- Used to treat Neurodegenerative diseases, Neuromuscular and Neurovascular disorders and to help improve mobility for the elderly

Murie Fernandez et al., *VirtualReality Games combined with normal rehabilitation are an effective alternative in Multiple Sclerosis patients* (2014)

VirtualRehab (Virtualware Group, Bilbao, Spain)

VirtualRehab

Rehabilitation Robotics- Categorization

ROBOT ASSISTED THERAPY: NON-ACTUATOR DEVICES

Non-Actuator Devices

Non-actuator devices emerged from improvement ideas for robotic therapy

- Decrease device complexity and cost
- Increase safety for patients
- Improve training of functional movements and activities of daily living

therapeutic robot

-

actuators/motors

=

non-actuator devices

Non-Actuator Devices: Elements

Weight support
- Static balancing mechanisms using links, springs or wires

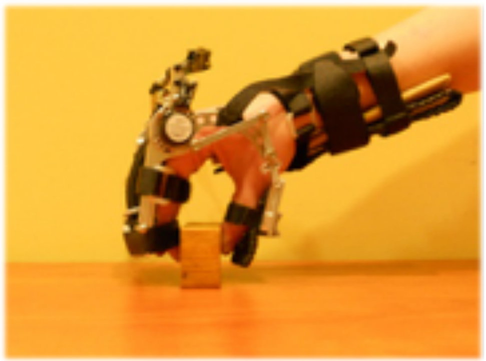
Sensors
- Measure physical parameters, e.g. position, force, orientation, torque

Patient interface
- Attaches to patient and transmits forces from the device, e.g. cuffs

User interface
- Enables user to adjust controller settings

Non-Actuator Devices: Upper/Lower Limbs

Upper limbs



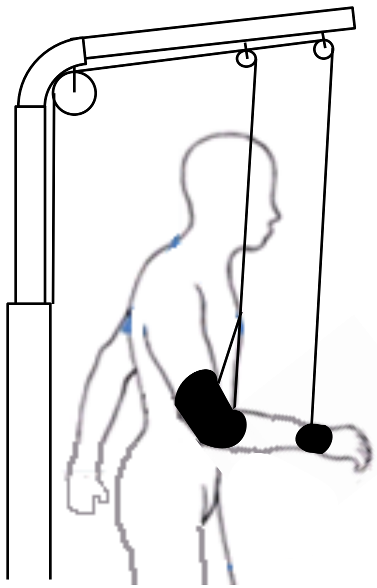
- Arm weight support against gravity
- Ellbow, finger or wrist joint support

Lower limbs

- Static body weight support against gravity
- Hip, knee or ankle joint support

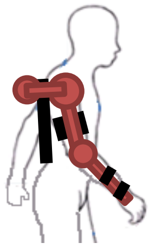
Non-Actuator vs. Robotic Devices

Non-actuator devices

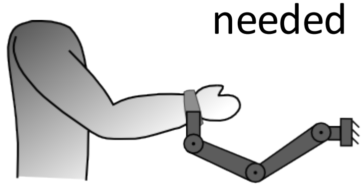


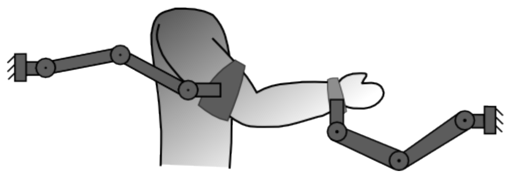
- Significant lower costs
- Less weight
- Easier to use and intrinsically safe
- No power source needed
- No support other than against gravity
- No movement correction
- Limited resistance

Robotic devices



- Movement guidance for optimal trajectory
- Full movement support even for severely impaired patients
- Adjustable resistance
- Expensive and heavy
- More complex to use
- More safety precautions needed





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Non-Actuator + Robotic Devices