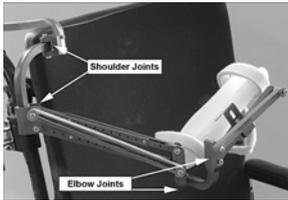


Passive exoskeletons for assisting limb movement

Tariq Rahman, PhD, et al.



We discuss state-of-the-art passive devices for enhancing upper- and lower-limb movement in people with neuromuscular disabilities. Special emphasis is placed on a passive functional upper-limb orthosis called the Wilmington Robotic Exoskeleton (WREX). It is exoskeletal, has two links and four degrees of freedom, and uses linear elastic elements to balance the effects of gravity in three dimensions. Results show that the WREX benefited a small number of children with arm weakness and allowed them to eat independently. The WREX can be used by people with cerebral palsy, spinal cord injury, multiple sclerosis, and amyotrophic lateral sclerosis (Lou Gehrig disease). WREX is also a potential low-cost therapy tool for stroke subjects.

Principle and design of a mobile arm support for people with muscular weakness

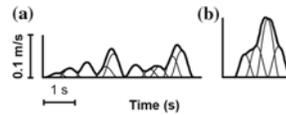
Just L. Herder, PhD, et al.



People with muscular diseases have difficulty raising their arms against gravity. We developed an arm support device in which a spring-loaded mechanism balances the arm in all configurations. Consequently, very little muscle force is needed to set the arm in motion. The spring settings can be adjusted electrically, allowing the restoration of balance in case an object is picked up or a coat is put on or off. Several users report on their experience with the device. Generally, they are positive about the functionality and aesthetics of the device, although moving their arms sideways remains difficult.

Motions or muscles? Some behavioral factors underlying robotic assistance of motor recovery

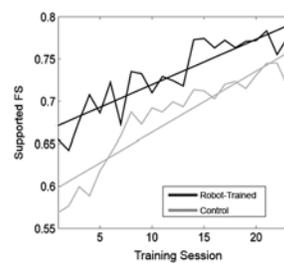
Neville Hogan, PhD, et al.



Robots provide an excellent platform from which to study recovery at the behavioral level. We reviewed some initial insights about the process of recovering upper-limb behavior that have emerged from our work. For pragmatic reasons, we primarily considered therapy focused on planar arm movements to enable clearer comparison of different forms of therapy (what worked and what did not). Our investigations indicate that, at least for the upper limb, recovery of the normal pattern of kinematic coordination is preminent. Evidence to date suggests that the form of therapy may be more important than its intensity. These results indicate that movement coordination rather than muscle activation may be the most appropriate focus for robotic therapy.

Robot-assisted movement training for the stroke-impaired arm: Does it matter what the robot does?

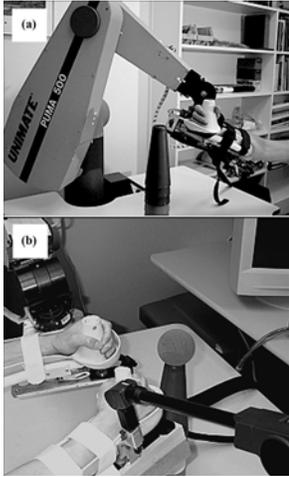
Leonard E. Kahn, PhD, et al.



A principle of motor learning is that movement practice improves motor function; the role of applying robotic forces in improving motor function is still unclear. We offer an interim analysis of our early experience with robot-assisted therapy for people with neurological injuries. A gap exists in the rationale for proceeding with widespread implementation of robotic therapy in rehabilitation clinics because this key question remains unanswered: “Could similar benefits be achieved with simpler, less-expensive, nonrobotic technology that facilitates movement practice?” By comparing results from the Assisted Rehabilitation and Measurement (ARM) Guide with those from the Mirror Image Movement Enabler (MIME) robotic trainer, we believe that robotic forces will ultimately be shown to have additional therapeutic benefits when coupled with movement practice.

MIME robotic device for upper-limb neurorehabilitation in subacute stroke subjects: A follow-up study

Peter S. Lum, PhD, et al.

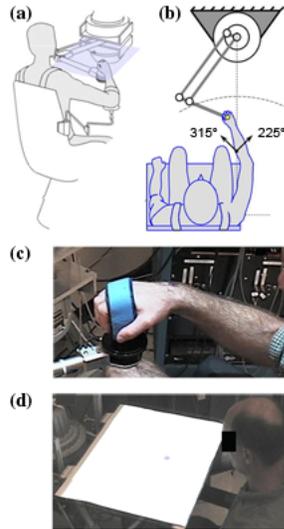


We reviewed our work with the Mirror Image Movement Enabler (MIME) robotic device to identify the essential therapeutic features. We compared robot-assisted therapy with conventional therapy and present trial results for shoulder and elbow neurorehabilitation in subacute stroke patients. We randomly assigned poststroke subjects to robot-unilateral, -bilateral, or -combined unilateral and bilateral training or to conventional therapy for the

same duration and dosage of treatment. Compared with conventional therapy, robot-combined unilateral and bilateral training had advantages that produced larger improvements on a motor impairment scale and a measure of abnormal synergies. Gains in all treatment groups were equivalent at the 6-month follow-up; however, robot group gains exceeded those expected from spontaneous recovery. Until a major breakthrough occurs in the treatment of stroke, robot-assisted therapy appears to have an appropriate role in rehabilitation.

Custom-designed haptic training for restoring reaching ability to individuals with poststroke hemiparesis

James L. Patton, PhD, et al.



We present a new technique for retraining reaching skills of hemiparetic stroke survivors in which errors are magnified to encourage learning and compensation. First, we sought to determine whether adaptation can be exploited for restoring movement ability. Second, we sought to determine whether the benefit persists for the duration of the experiment. Patients held a horizontal plane robot arm that could exert a variety of forces while recording patients' movements. All patients showed

immediate benefit from the training, although 3 of the 10 patients did not retain these benefits for the remainder of the experiment. We believe that the error-amplification approach presented here provides a new pathway for augmenting motor relearning in individuals with brain injury.

Tools for understanding and optimizing robotic gait training

David J. Reinkensmeyer, PhD, et al.



We reviewed tools developed by our research groups to improve understanding of the mechanisms of locomotor adaptation during gait training following spinal cord injury, with a view toward implementing locomotor training with robotic devices. Studies with these tools are helping guide development of a robotic device and appropriate control algorithms for human

gait training. Using an instrumented orthosis to measure the forces and motion applied by human trainers, we aimed to identify the impedance control and timing features associated with eliciting better stepping. We will also refine our computational models to provide theoretical guidance for

developing training algorithms and to make our assumptions and hypotheses mathematically concrete. Our results suggest that an optimal gait-training robot will minimize disruptive sensory input, facilitate appropriate sensory input and gait mechanics, and intelligently grade and time its assistance.

Machines to support motor rehabilitation after stroke: 10 years of experience in Berlin

Stefan Hesse, MD, et al.



The Klinik Berlin/Charité University Hospital, Berlin, Germany, designs intelligent machines to intensify motor rehabilitation without overstressing therapists. We designed a gait trainer to intensify patient gait training and relieve the strenuous effort of

therapists when assisting movement of the paretic limbs. We then developed the HapticWalker, a robotic walking simulator with freely programmable foot plates. For the upper limb, the computerized arm trainer Bi-Manu-Track enabled the bilateral practice of forearm and wrist movement. The Nudelholz, our most recent development, is a purely mechanical device intended for home therapy to train the shoulder, elbow, and wrist joints. In the studies presented here, machines are a supplementary tool assisting the therapist and enabling more intensive practice, thereby improving treatment. While no machine can ever substitute for the “human touch” of an experienced therapist, we look forward to the future development of this exciting new field of rehabilitation.

Human-centered robotics applied to gait training and assessment

Robert Riener, Dr-Ing, et al.



We reviewed human-centered strategies that enable robots to behave in a patient-cooperative way and support motor-function assessment. We then applied those principles to treadmill gait training, for example, through the use of motion controllers, biofeedback, and automated assessment functions. Rehabilitation robots that behave in a

human-centered way can maximize patients’ therapeutic outcomes. Promising methods from the literature and our research show that rehabilitation robots can (1) account for patients’ intentions, efforts, and musculoskeletal properties and (2) automatically assess the patients’ motor performance. Human-centered rehabilitation robots can make future gait therapy easier, more comfortable, and more efficient.

Telerehabilitation robotics: Bright lights, big future?

Craig R. Carignan, ScD; Herman I. Krebs, PhD



Using robotics for remote treatment over the Internet is now a reality. As care moves from the inpatient setting to the home, mining potential technologies such as telerehabilitation becomes critical to extend effective treat-

ment outside the acute care hospital. We focused on the integration of two technologies, telemedicine and rehabilitation robotics, to the upper limbs poststroke, the primary area of application thus far. Many in the health industry rank these two tools high among the technology well-suited to answering the needs of a growing aging population, because robotic-assisted telerehabilitation offers innovative, interactive, and precisely reproducible therapies that can be performed for an extended duration with consistent implementation from site to site. However, the technical challenges still include developing complex multidimensional robots capable of simulating more task-oriented home therapy.

