Bern University
of Applied Sciences

Research Group
IRPT – Rehabilitation Engineering
Robotics-Assisted Technology for Cardiopulmonary Rehabilitations

Abstract
Maintenance of fitness is vital for health and well-being, but how can patients with severe disability participate in exercise? The Institute for Rehabilitation and Performance Technology (IRPT), together with clinical partner Reha Rheinfelden, has developed robotic systems for exercise testing and training.

Fig. 1: G-EO System end-effector rehabilitation robot

Aim
This research programme focus is developing techniques and protocols for cardiopulmonary rehabilitation using robotics-assisted technology. The methods are clinically applied for patients following stroke and spinal cord injury to obtain crucial data on fitness and to allow the informed prescription of an exercise training programme.

Background
Because patients with serious impairments cannot use a conventional system like a treadmill or a cycle ergometer, the IRPT has focused its research programme on the development of robotic rehabilitation systems which facilitate exercise testing and training, and on the translation of assessment protocols from high-performance sports to this new and very challenging context.

The key is to adapt robotic systems so that the patient is able to perform an increasing amount of work over a short time by volitional activation of their available muscles. To do this, we provide patients with a biofeedback system which shows them a target level of exercise intensity together with a visualization of their own performance: the target intensity increases steadily over about 10 minutes while the patient is instructed to exert themselves more and more to keep following the target. The test stops when it is clear that the patient has reached his limit.

Results
We have used this principle to adapt several systems: the G-EO-System, an end-effector robotic device for walking and stair climbing (Fig. 1) [1]; the Lokomat, an exoskeleton-based system for treadmill walking (Fig. 2) [2-4]; and the Erigo-System, a robotics-assisted tilt table (Figs. 3-4) [5,6]. For the most severely disabled patients, the Erigo allows the exercise intervention and assessments to start at the earliest possible stage of rehabilitation.

Fig. 2: Lokomat exoskeleton rehabilitation robot.

In collaboration with our clinical partners at the Reha Rheinfelden, we recently completed a breakthrough clinical study where a group of severely disabled stroke patients trained for four weeks using the augmented Lokomat system. Overall fitness was assessed using cardiopulmonary exercise testing implemented on the Lokomat [3]. We found that cardiovascular fitness, i.e. the maximal oxygen uptake (V›O2-max), increased on average by 20% even though the four-week training period was relatively short and the training intensity was moderate [2,3]: this is a rapid and substantial improvement in cardiopulmonary fitness early after stroke.

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Fig. 3: Erigo robotic tilt table for early rehabilitation.

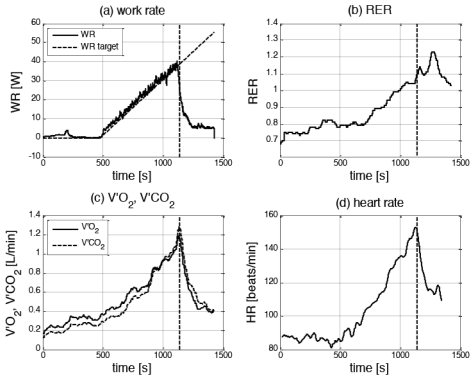

Fig. 4: Typical cardiopulmonary responses from a stroke patient – maximal exercise test on the Erigo.

Clinical potential

These very promising new results represent the successful translation of methods and protocols from the field of high-performance sports to the context of neurological rehabilitation. These are important and necessary steps towards the clinical implementation of effective cardiopulmonary exercise training and accurate assessments in patients with severe impairments.

Selected Publications

[1] O. Stoller, M. Schindelholz, L. Bichsel, and K. J. Hunt, Cardiopulmonary responses to robotic end-effector-based walking and stair climbing, Med Eng Phys, 2014.
[2] O. Stoller, E. D. de Bruin, M. Schindelholz, C. Schuster-Amft, R. A. de Bie, and K. J. Hunt, Efficacy of feedback-controlled robotics-assisted treadmill exercise to improve cardiovascular fitness early after stroke: a randomised controlled pilot trial, J Neurol Phys Ther, 2015.
[3] O. Stoller, E. D. de Bruin, M. Schindelholz, C. Schuster-Amft, R. A. de Bie, and K. J. Hunt, Cardiopulmonary exercise testing early after stroke using feedback-controlled robotics-assisted treadmill exercise: test-retest reliability and repeatability, J Neuroeng Rehabil, 2014.
[4] M. Schindelholz and K. J. Hunt, Feedback control of oxygen uptake profiles during robotics-assisted treadmill exercise, IET Control Theory & Applications, 2015.
[5] J. Saengsuwan, T. Nef, M. Laubacher, and K. J. Hunt, Comparison of peak cardiopulmonary performance parameters on a robotics-assisted tilt table, a cycle and a treadmill, PloS ONE, 2015.
[6] M. Laubacher, C. Perret, and K. J. Hunt, Work-rate-guided exercise testing in patients with incomplete spinal cord injury using a robotics-assisted tilt-table, Disabil Rehabil: Assistive Technology, 2014.

Project Partner

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