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**„HapticWalker - A Novel Gait Rehabilitation Robot for  
Arbitrary Foot Trajectories“**

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## HapticWalker - A Novel Gait Rehabilitation Robot for Arbitrary Foot Trajectories

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### INTRODUCTION

The restoration of gait for patients with impairments of the central nervous system (CNS), like e.g. stroke, spinal cord injury (SCI) and traumatic brain injury (TBI), is an integral part of rehabilitation and often influences whether a patient can return home or to work. Particularly stroke is the leading cause for disability in all industrialized countries. Modern concepts of motor learning favor a task specific training, i.e. to relearn walking, the patient should ideally train all walking movements needed in daily life, repetitively in a physically correct manner. Manually guided treadmill training or free walking training, proved to be effective. But this type of training is very labor intensive because it requires the assistance of at least two therapists per patient and is very exhausting for them. Assisted gait movements other than walking on plane floor, are almost impossible to train, due to the overstrain of the therapists. Assistive training devices may offer a solution to these shortcomings.

### GAIT REHABILITATION MACHINE CONCEPTS

The development of gait rehabilitation devices started with machines for training of walking on even ground, beginning with the electromechanical 'Gait Trainer GT I' developed by our group [Hesse2000] and the 'Lokomat', an exoskeleton type robot in combination with a treadmill, developed by a group from ETH Zurich and Balgrist University Hospital, Zurich [Colombo2000]. The machines allow more effective training sessions for the patients and relieve the physiotherapists, who can now concentrate on training supervision. In both machines the patients trunk is secured by a harness for body weight support.

The machine types apply two different approaches to gait rehabilitation: exoskeleton type machines in combination with a treadmill require the patient to be fixed to the robot kinematics from the pelvis on downward along the legs. This results in a bilateral and proximal guidance. The patients body weight is carried by the treadmill. Due to the complete fixture of the

patient to the machine, the device is not designed for physical access of the therapist to the patient during the training session, but rather for fully automated training.

In contrast, the Gait Trainer GT I applies the principle of movable footplates, which was also the basic design idea for our robotic walking simulator 'HapticWalker'. There each of the patients feet is positioned and strapped on a separate footplate, which leads to a bilateral and distal training. The patients legs are not fixed, in order to allow therapist access for physical contact with the patient [Carr1998] and also let him do corrections of the knee motion if needed. Another important reason for this design approach is that the patient should not feel restrained by the device.

Several clinical studies with both machine types have been done so far. The largest clinical study worldwide for gait rehabilitation devices was the recently finished DEGAS (DEutsche GAntrainer Studie) study [Werner2004]. It was a multi-center RCT study with more than 150 stroke patients at four different German rehabilitation hospitals. It compared GT I supported and conventional gait training (4 weeks of training at 5 sessions/week), showing significant improvements in the GT I group at all relevant scores, compared to the control group (see Figure 1 for FAC index scores).

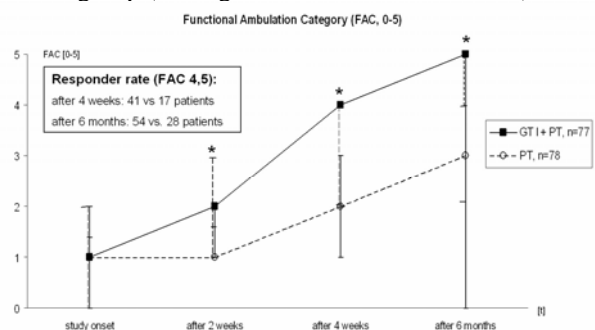


Fig. 1: FAC results of the clinical multi-centre RCT study DEGAS

The results of previous GT I studies by our group and independent clinical studies with the machine by other groups in Europe and Asia are in line with the DEGAS results. In all studies the GT I was run in

position controlled mode. To the best of our knowledge, no other gait rehabilitation device could show similar results so far.

## HAPTICWALKER

After these clinical proofs of concept, we decided to extend the movable footplate concept to a more flexible design. Thus the HapticWalker (see Fig. 2) became a generic robotic walking simulator, based on freely programmable footplates, which are mounted at the end effectors of two separate robot arms.



Fig. 2: HapticWalker with SCI patient and therapist

The HapticWalker accomplishes the paradigm for optimal gait training, because it is the first rehabilitation device, which is not restricted to training of walking on even ground. In contrast to all treadmill-bound machines, it enables the patient to train arbitrary and individually adjusted gait trajectories needed in daily life, like, for instance, walking on even ground, stepping staircases up/down. The machine comprises a translatory and rotatory footplate workspace designed for guidance of arbitrary walking trajectories during all phases of gait, because a permanent foot attachment to the footplate is essential for gait rehabilitation machines. Furthermore, the hybrid parallel-serial robot kinematics, driven by linear direct drive motors, comprises high footplate dynamics. Thus it can perform the realistic simulation of arbitrary walking trajectories at speeds of up to 5 km/h and cadences of 120 steps/min. The most widely practiced gait rehabilitation training starts with walking speeds of less than 1 km/h and gradually increases the speed to normal walking velocities of up to 4-5 km/h, depending on the patients learning success [Carr1998]. In contrast, some clinical groups in the USA favor the application of normal walking speeds of 4-5 km/h right from the beginning of therapy [Behrman2000]. The high footplate dynamics also enable the realistic simulation of perturbations like stumbling, sliding and other asynchronous walking events, which we also implemented in the control software. Regarding usability, the HapticWalker is

designed to allow therapist access to the patient for physical contact during training from all sides, as well as facilities for easy patient transfer into the machine, since they are usually bound to the wheelchair. Technical Details of the machine design, robot kinematics, control system, algorithms for motion generation, haptic features, therapist user interface and safety aspects can be found in [Schmidt2005] and the referring references cited in there.

## RESULTS

A full working prototype of the HapticWalker has been successfully developed and built, and is currently being clinically tested after receiving full approvals by the German Technical Committee for Medical Devices (TÜV) and the Charité ethics board. An in depth clinical study with focus on staircase walking in addition to even ground was started in order to evaluate the machine. First trials with stroke and SCI patients are very promising and give reason to anticipate even better results than the ones seen in the DEGAS study.

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