Conclusions: The Kineassist is a device that allows clinicians and patients to safely perform gait and balance exercises while allowing the clinician to focus on training cues rather than fall protection. The system minimizes disturbance forces and allows patients to move relatively unimpeded during functional tasks and only interferes when loss of balance occurs. However, trajectories are slower and reduced in range with the Kineassist compared without the same tasks performed outside of the Kineassist. The Kineassist is a useful device for studying balance and gait in persons at risk for balance and may be a useful tool for clinicians who are seeking to challenge gait and balance for patients in more realistic environments. Funded by a grant from NIH NICHD/NCMRR #R42HD51240.

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FES-based training and gait evaluation of hemiplegic patients using a microsensor on their valid leg

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Introduction: Functional Electrical Stimulation (FES) allows the generation of artificial movements in patients with motor disability. FES has been shown to be a valuable method for training stroke patients in early stage of hemiplegia in order to improve the recovery of walking skills. In this framework, an accurate sequencing of muscle stimulation sequences is essential, Existing FES systems usually provide with fixed stimulation patterns tuned and programmed off-line. The triggering of stimulation sequences is often achieved manually by the clinician assisting the patient. If the patient walks faster or slower than the programmed sequence, the movements of the healthy and the paretic leg might not be well coordinated.
Methods: We designed a method that monitors on-line the ongoing movement and generates the stimulation sequences to be applied onto the muscles. Our approach relies on a unique wireless micro-sensor (embedding 3 accelerometers + 3 magnetometers) placed on the valid leg, a model of the sensor measurements being computed during walking. Since the motion is cyclical, we use a non-linear oscillator model, which can autonomously generate a cyclical output. We fit the model parameters with measurements by optimization, and build an observer of the model, which "filters" the sensor measurements. Since the observer is an oscillator itself, it is possible to reconstruct the oscillator phase, and generate the related control.
Results: For each muscle, stimulation parameters (amplitude, pulse width, frequency) are derived according to the computed phase and a pre-programmed stimulation pattern. This can be done online for patient re-education. Another important issue addressed is the performance evaluation of the patient's gait. During a given training protocol for stroke patients, it is of great interest to assess improvement of the gait. Such evaluation can be achieved through standard tests (Barthel Index, Ashworth scale, ...) performed by clinicians, or by measuring some gait variables: locomotion speed, symmetry, which however require specific equipment to be measured. Our aim is to provide with a gait analysis system which could easily give an objective criteria of gait quality. By placing an accelerometer on the healthy shank, we can measure some helpful variables, as stride frequency. We perform a spectral analysis of the accelerometer signal, and exhibit a frequency ratio that shows good correlation with gait speed and symmetry.
Conclusions: The system only requires a small and easy-to-use sensor, thus not disturbing the patients' gait. We developed a convenient analysis software that gives a quantitative result right after the test. We thus believe that such a tool could be of great help in rehabilitation centres.

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Evaluation of a lower limb exoskeleton for gait enhancement

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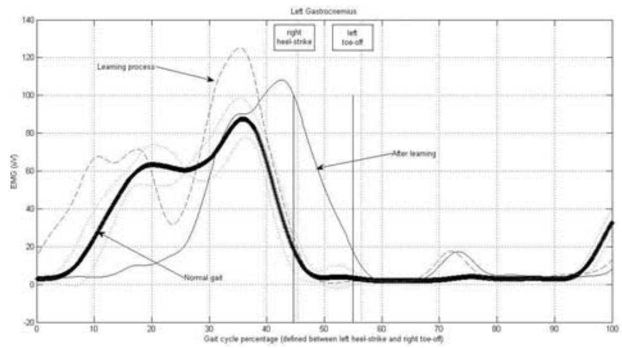
Introduction: The design and evaluation of exoskeletons to enhance human performance during gait is an emerging field of research. These exoskeletons can be seen as gait orthoses and they must account for the user's intention in order to apply the forces adequately. It is questioned if an exoskeleton designed to support patients suffering muscle weakness can enhance performance in healthy subjects. This exoskeleton was designed considering the requisites of the leg depending on the gait phase. The knee flexes during swing and extends for foot contact to support the body weight. This function was simulated by switching two springs of different stiffness, and a knee-ankle-foot-orthosis was built to compensate for leg muscle weakness. Here, the learning process in the use of this orthosis by healthy subjects is analysed.
Methods: The use of this exoskeleton was investigated experimentally. An orthosis incorporating pairs of linear springs at the knee and ankle joints was fitted to each participant. The transition between each spring (support and swing) was determined by ankle dorsiflexion at toe-off. There were 4 experimental gait conditions: 1) normal, 2) orthosis without actuation, 3) actuated orthosis without learning and 4) after learning (60 min walking and practicing). The lower limb motion, EMG data and ground reaction forces were measured. The EMG electrodes were placed bilaterally at the Gastrocnemius, Tibialis Anterior, Biceps and Rectus Femoris following the SENIAM recommendations. The EMG data was rectified and filtered to obtain the EMG gait patterns in each condition.
Results: The data indicated that subjects need to "learn" to use the orthosis. The step duration increased during the learning process. During the learning process the EMG activities were less stereotyped and the averaging of these trials resulted in large standard deviations. The bursts were also larger than normal and

had longer durations. This was reversed after the practice (see figure 1).

Conclusions: At the end of the learning process, the EMG pattern showed lower and shorter bursts of EMG activity. This suggests that the exoskeleton could improve aspects of gait endurance and fatigue beyond its original application to patients suffering quadriceps weakness



EMG gait patterns of the left gastrocnemius: normal (thick), with orthosis before (dashed) and after (solid) learning.

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Realism and Gait Characteritics of Walking in a Virtual Reality Mobility Simulator

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Introduction: Virtual environments (VE) are designed to simulate the real world. Presence in the VE is achieved when the user is immersed and experiences a sense of realism. We have designed a walking simulator in which the user experiences hardware driven haptic (surface) effects linked to visual stimuli in a VE. The purpose of this study was to measure subjects' perception of realism and the temporal and spatial characteristics of gait while walking in a VE mobility simulation where visual and haptic effects were manipulated.

Methods: The mobility simulator consisted of 2 Rutgers Mega-Ankle (RMA) robot platforms, each with 6 pneumatic cylinders, 6 linear potentiometers and 1 force sensor, allowing the system to change and measure positions and forces. A haptic control interface operated the RMAs and was connected to a PC. Haptic conditions (ice or mud) were rendered by the platforms, and audio and visual stimuli of a street crossing were presented as they walked. Eleven healthy subjects (20-50 years) participated. Over-ground temporal spatial gait parameters were measured using self-selected walking speed (n=3) on a GaitRite mat. Subjects stood on the platforms facing the display screen and were instrumented with markers, one on each fifth metatarsal, lateral malleolus, lateral knee, hip, and trunk. Subjects were unweighed (40% bodyweight) by a Biodex frame. They walked on the mobility simulator until they achieved a criterion gait pattern. Walking trials (n=22) of street crossing simulation were performed. Visual (on or off) and haptic (support surface of level ground, ice, or mud) stimuli conditions were randomly presented. Subjects rated realism, visual, and surface experiences using a visual analogue scale (VAS). Force data at initial swing (IS), and initial contact (IC) were extracted from the RMA platforms. Temporal spatial parameters of gait were collected with and extracted from the 6-camera Peak System.

Results: See Table 1.

Conclusions: Modest immersion was reported. Realism ratings were greatest during concurrent haptics and visual stimuli presentations. Reports of realism were more strongly influenced by the visual scene than haptic effects. Velocity decreased with the addition of haptics. Forces increased at appropriate gait events, IS to overcome mud and IC to restrain mud and ice effects. Kinematics and step length were unaffected by visual and haptic manipulations.

Mean VAS Scores, Velocity, and Forces by Condition

	Street Crossing	Visual Ice	Haptics Ice	Visual + Haptics Ice	Visual Mud	Haptics Mud	Visual + Haptics Mud
Realism (VAS)	4.1	4.0	2.8	3.9	4.4	2.7	4.7
Feel (VAS)	Not Tested	2.6	1.5	3.0	3.7	3.0	3.9
See (VAS)	Not Tested	9.5	0.2	9.8	9.6	0.7	9.5
Velocity (m/s)	0.217	0.205	0.183	0.191	0.201	0.193	0.192
Forward Force (N) @ IS	33.91	40.95	34.95	34.90	36.94	49.11	49.56
Upward Force (N) @ IS	17.42	16.50	17.67	17.71	17.38	41.20	40.20
Downward Force (N) @ IC	65.64	68.94	62.79	74.36	68.21	66.81	74.23