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„Muscle activation patterns of healthy subjects during floor walking and stair climbing on an end-effector based gait rehabilitation robot“

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Muscle activation patterns of healthy subjects during floor walking and stair climbing on an end-effector based gait rehabilitation robot

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INTRODUCTION

Gait rehabilitation primarily aims at the restoration of an independent gait and secondarily at the improvement of walking functions to meet daily requirements. Modern concepts of motor rehabilitation favor a task-specific repetitive training, i.e. who wants to relearn walking, has to walk [Hesse1994]. Accordingly a repetitive locomotor therapy on an electromechanical gait trainer in non-ambulatory stroke patients proved effective [Pohl2007].

METHODS

A total of ten healthy subjects (6 male, 4 female) without known neurological injuries or gait disorders participated in the study (mean age: 27.3 years, range: 22 - 34). All experimental procedures were approved by the research review board of the Charité University Hospital.

The goal of the study is to assess whether the muscle activation patterns while walking on the HapticWalker (see Fig. 1) [Schmidt2005] resemble those seen during free walking. The gait patterns are generated based on motion tracking data of healthy subjects. Therefore dynamic electromyograms (EMG) of healthy subjects were compared as follows: a) free walking on the floor, down- and upstairs is compared to the corresponding HapticWalker training b) with vertical CoM motion and c) with cancelled vertical CoM motion.

Fig. 1: Healthy subject on the HapticWalker

Therefore the machine was operated in position controlled mode, which proved effective in severely disabled stroke subjects on the predecessor device Gait Trainer GT I [Pohl2007]. They are the main target group for robot assisted gait retraining.

EMG signals of the healthy subjects where gathered as described above using three different given cadences that where similar in free walking and on the HapticWalker. For the assessment full wave rectified and smoothed envelopes of the raw signals are used. Smoothing is done by a moving average filter using a window size of 50 ms. For Comparison the mean signals for each muscle from all subjects as well as the corresponding standard deviation are calculated.

RESULTS

Fig. 2 shows the averaged normalized EMG values of one stride during walking on even ground (a) and climbing up a stair (b) respectively. The solid line shows muscle activity during free walking, the dotted line during HapticWalker training in normal mode and the dash-dotted line during HapticWalker training in CoM-relative mode. The displayed muscle activities were recorded at a cadence of 60 steps per minute. During floor walking and stair climbing on the HapticWalker the following facts could be observed, based on the qualitative analysis of dynamic EMGs of selected lower limb muscles:

1) Foremost the EMG activity during walking on the HapticWalker revealed a very similar phasic and rhythmic activity pattern to the one observed during free walking.

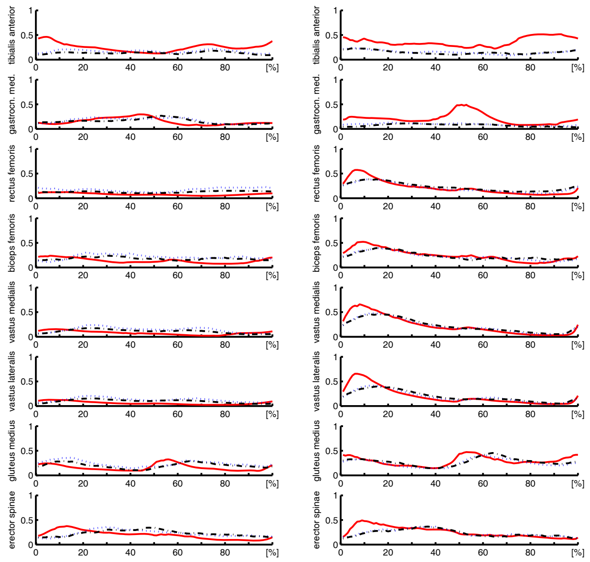
2) The activity of the tibialis anterior was slightly reduced, the co-activation with the gastrocnemicus m. was increased compared to free walking.

3) The thigh muscles' and erector spinae onset of activation was delayed, at the same time their activation was prolonged reaching into the swing phase while amplitudes were comparable in floor walking and slightly reduced in stair climbing

4) As compared to floor walking at similar cadence, stair climbing itself resulted in a facilitation of relevant

weight-bearing muscles, particularly of the thigh and pelvic girdle, in order to propel the body upwards.

5) Walking in the CoM-relative mode did not alter the pattern and amplitude of the recorded muscles significantly as compared to the non-emulated mode.



(a) floor (b) upstairs

Fig. 2: Mean EMG signals during gait cycle (N = 10, cad = 60 steps/min): free walking (solid line, red), HapticWalker standard (dotted line, blue), HapticWalker emulated CoM movement (dash-dotted line, black)

DISCUSSION

Major results of this preliminary work are as follows:

1) The facilitation of a phasic and rhythmic and thus almost physiologically correct EMG activity during walking on the HapticWalker in both gait patterns is the most relevant result for subsequent application in the rehabilitation of CNS impaired patients. This contrasts with exoskeleton and treadmill based gait rehabilitation robots like the Lokomat [Hidler2005], where tonic activation patters and severe misactivations were observed.

2) According to results obtained with the GT I, on the HapticWalker, the activity of the ankle extensors and flexors was reduced. During swing the subjects are encouraged to deload their foot; nevertheless it is still supported by the foot plate, which leads subjects to reduce their ankle dorsiflexor activity.

3) The delayed onset of thigh and erector spinae muscle activation on the HapticWalker may reflect less dynamic requirements on the machine with the forward momentum of the stationary movement missing.

4) Stair walking facilitated the activity of relevant weight-bearing muscles as compared to the floor walking. Paretic patients need to facilitate their paretic muscles in order to stabilize the pelvic girdle and knee during loading. Assisted stair climbing is well accepted for this purpose and a relieve of the strenuous effort for the therapists would be highly appreciated.

5) Emulated CoM-movement proved applicable with healthy subjects: this fact may eliminate the need for an active trunk suspension system and thereby reduce the complexity of the machine. All more advanced operation modes (e.g. dynamic body weight reduction) could then be implemented via compliance controlled footplates.

CONCLUSIONS

The preliminary results of the presented study to evaluate muscle activation in healthy subjects during free walking compared to walking on the end-effector based gait rehabilitation robot HapticWalker show that such machines have the potential to offer an advanced gait training for CNS impaired patients. Muscle activation patterns on the HapticWalker show the same rhythmic and physiological patterns as with free walking. Nevertheless all presented results cannot simply be transferred to stroke patients. Subsequent patient trials are needed to confirm them.

Differences in EMGs were observed in specific muscles (reduced amplitudes and slight delay on the HapticWalker), which can be attributed to the pure position controlled mode currently used in clinical evaluation. Therefore future work will have to include adaptive footplate control. The emulated CoM-movement might eliminate the need for an active trunk suspension system.

After very positive clinical results of the DEGAS study with the electromechanical Gait Trainer GT I [Pohl2007], positive training effects may also be expected from the HapticWalker. Studies with stroke patients have started to evaluate the additional therapeutic effects of individually adjusted gait trajectories and multiple daily life gait patterns.

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