

Development of a passive exoskeleton for swing phase gait assistance

Jesse C. Dean
Medical University of South Carolina
email: deaje@musc.edu

SUMMARY

A simple exoskeleton was built to test if passive bi-articular springs can assist leg swing during walking. In three healthy subjects, swing phase hamstring activity decreased but quadriceps activity increased or remained the same. Future exoskeleton modifications will attempt to address the cause of this increased muscle activity.

INTRODUCTION

The principles of passive dynamic walking have driven the development of relatively simple robots able to generate human-like gaits [1]. This success implies that similarly simple devices could be created for gait rehabilitation. During treadmill training for patients who have suffered a spinal cord injury or stroke, leg swing is powered either by therapists [2] or complex robotic devices [3]. However, passive dynamic simulations have demonstrated that passive bi-articular springs are sufficient to drive leg swing at a rate that allows typical walking speeds [4]. The purpose of this project is to test whether a passive device based on these simulations can assist leg swing during gait.

METHODS

We built a simple exoskeleton (mass = 5.5 kg) consisting of a padded waist belt and adjustable length aluminum thigh and shank segments. An aluminum brace connected the legs above the hips so large forces were not transmitted to the user's torso. A bi-articular spring system was created by placing extension springs in series with wires running along grooved circular plastic sheaves and attaching to the exoskeleton above the hip (moment arm = 22 cm) and below the knee (moment arm = 9 cm) (Fig. 1). The exoskeleton hinges were aligned with the subject's hip and knee joints, and the segments were attached to the subject's legs with Velcro straps.

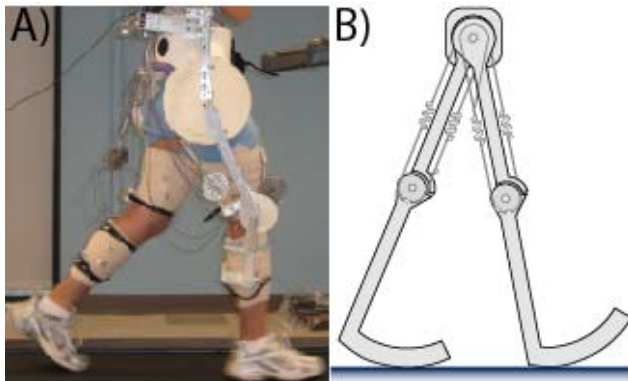


Figure 1. An exoskeleton with bi-articular springs crossing the hip and knee joints was designed (A), based on mathematical simulations of a passive dynamic walker (B).

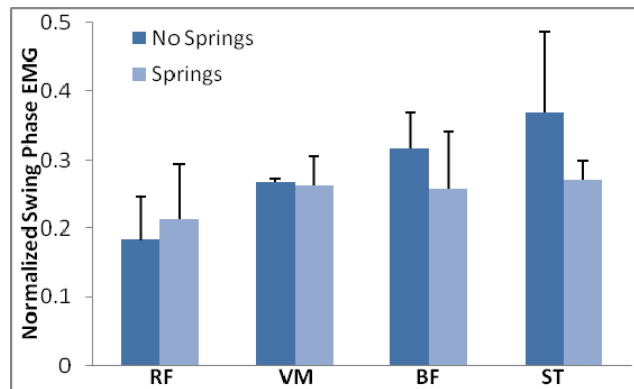


Figure 2. During the swing phase, the addition of springs was associated with increased RF activity and decreased BF and ST activity.

Three young, healthy subjects walked on a treadmill at 1.25 m/s while wearing the exoskeleton without any springs and with springs of varying stiffness (38, 62, 86 N/cm). After walking for one minute, data was collected for 15 seconds from pressure sensors under each foot and EMG electrodes placed over the rectus femoris (RF), vastus medialis (VM), biceps femoris (BF), and semitendinosus (ST) on each leg. For each muscle, the average filtered EMG activity during the swing phase was normalized by the peak EMG activity across trials. Because of the small number of subjects, data from all spring stiffness levels were combined for comparison with the data with no springs.

RESULTS AND DISCUSSION

During the swing phase, there was a trend of decreased BF and ST activity (hip extensors/knee flexors) and increased RF activity (hip flexor/knee extensor) (Fig. 2). No statistics were performed due to the low subject number.

These preliminary results motivate further investigation of the passive exoskeleton. While the addition of springs appears to assist the hamstrings, it may cause greater hip flexion muscle activity. The bi-articular spring system may not be optimally designed, as prior simulations indicated that only a narrow range of knee-to-hip moment arm ratios produced human-like gaits [4]. It is also possible that one minute is not sufficient time for subjects to adapt to the assistance generated by the exoskeleton. Future experiments will test the effect of varying the moment arm ratio and increasing the walking time.

REFERENCES

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