

A KNEE-ANKLE-FOOT ORTHOSIS (KAFO) POWERED BY ARTIFICIAL PNEUMATIC MUSCLES

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INTRODUCTION

After stroke or spinal cord injury, treadmill stepping with manual assistance can facilitate re-learning how to walk (Harkema 2001). However, manual assistance is labor intensive and highly variable from therapist to therapist. A lightweight powered lower limb orthosis could decrease labor requirements and provide more consistent therapy during gait rehabilitation. In addition, a powered orthosis would also provide a way to design controlled motor adaptation studies during locomotion. With these goals in mind, we constructed a pneumatically powered, myoelectrically controlled, knee-ankle-foot orthosis (KAFO) for human walking.

METHODS

Figure 1 (right). A healthy male subject was fitted with a custom-made carbon fiber KAFO for his left lower limb. The KAFO permitted free motion at the ankle and knee joints, and had a mass of 4 kg (4% of body mass). We attached six pneumatic muscles: a plantarflexor (moment arm = 9 cm), a dorsiflexor (moment arm = 9 cm), two knee flexors (moment arms = 3.5 cm and 3 cm), and two knee extensors (moment arms = 3 cm and 3.5 cm). Real-time control software modulated artificial muscle forces proportional to rectified, lowpass filtered EMG ($f_c = 10$ Hz) (soleus \rightarrow plantarflexor, tibialis anterior \rightarrow dorsiflexor, medial hamstrings \rightarrow knee flexors, and vastus lateralis \rightarrow knee extensors). We recorded artificial muscle forces with load cells, lower body kinematics with electrogoniometers, and EMG signals from eight muscles of the left leg. The subject walked on a treadmill at 1.25 m/s while wearing the KAFO. The subject first walked for six minutes while wearing the KAFO with the artificial muscles



unpowered (Passive). Then the subject walked while wearing the KAFO powered for thirty minutes (Active). Finally, the subject walked for fifteen more minutes with the KAFO unpowered again. We recorded gait data every three minutes for ten second intervals.

RESULTS AND DISCUSSION

When the artificial muscles were initially powered on, the subject walked with a great deal of co-activation in the artificial muscles about both the ankle and knee joints (Fig. 2). After thirty minutes on the treadmill, the force produced by the artificial knee extensors and artificial knee flexors had decreased by about half. This resulted in a substantial reduction in co-activation about the knee joint. However, there was virtually no change in artificial muscle force for the plantarflexor or the dorsiflexor muscle. This suggests that knee muscle activation patterns may be much more adaptable than ankle muscle activation patterns during human locomotion.

SUMMARY

We built a pneumatically powered knee-ankle-foot orthosis (KAFO) to assist gait rehabilitation and study human locomotor adaptation. Preliminary data using proportional myoelectrical control to activate the KAFO on a healthy subject indicate that the human nervous system can quickly modify some muscle activation patterns when walking with the powered orthoses. Future work in our laboratory will examine alternative control strategies for the KAFO and extend the concept to a bilateral hip-knee-ankle-foot orthosis (HKAFO) for full lower body assistance.

REFERENCE

Harkema S.J. (2001). *Neuroscientist* 7, 455-468.

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Figure2.

Mean Plantarflexor Load, Mean Dorsiflexor Load, Mean Total Hamstrings Load and Mean Total Quadriceps Load for walking at 1.25 m/s with KAFO. Graphs display average artificial muscle load over the course of the gait cycle beginning and ending with left heel strike. We low pass filtered raw load cell force data at 10 Hz.

