The effect of exoskeleton footwear on joint angular motion during walking in patients with peripheral artery disease

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Abstract:

Introduction: Peripheral artery disease (PAD) manifests from atherosclerotic blockage of arteries in the legs. Patients with PAD have consistently demonstrated weak calf muscles and reduced ability to generate ankle torque and power comparable to older individuals without PAD. We have developed a lightweight exoskeleton to support ankle muscles during push-off in patients with PAD. This study investigated different levels of exoskeleton footwear (EF) assistance on joint angle motion in patients with PAD. **Methods**: Joint kinematics were collected during four overground walking conditions (control shoe, EF without spring, EF with 5.6 kN/m spring, and EF with 7.9 kN/m spring) from seven patients (Age (72.57±6.48 years), height (172.46±8.29 cm). The condition with the maximum walking distance was determined as the optimal EF spring condition. Peak joint angle values between the control shoe and optimal EF conditions were compared using paired sample t-tests. **Results:** Due to the small sample size, statistical models were not sufficiently powered to detect significant changes. However, walking with optimal exoskeleton significantly reduced knee peak flexion angle during early stance ($p=0.03$). While not significant, the peak knee extension value was reduced during optimal EF compared to the control ($p=0.5$). The peak hip flexion and extension angle values were greater when walking with optimal EF versus the control shoe ($p=0.71$ and $p=0.92$, respectively). The peak ankle dorsiflexion angle was decreased with optimal EF versus the control condition ($p=0.10$), while peak plantar flexion was increased compared to the control condition ($p=0.19$). **Discussion:** Patients with PAD have been shown to have reduced hip range of motion compared to healthy controls. The optimal EF condition increased the hip range of motion, which is an improvement in patients with PAD, making their walking patterns more like healthy controls. Previous studies reported assistive devices could restrict ankle movement, this was the case for peak dorsiflexion, but maximal plantarflexion angle was increased to offset the overall range of motion at the ankle. Overall, the EF with the optimal assistance allowed the spring and clutch system to store energy in early stance and release it during push-off. This allowed patients to walk for longer distances. Future work will determine whether the EF assists patients by decreasing ankle work or through other mechanisms.