A Robotic Exosuit Improves Ankle Joint Biomechanics and Energetic Cost During Walking in Children with Unilateral Cerebral Palsy

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Background

Walking is a fundamental method of mobility, community participation, and independence in humans. During healthy walking, effective ankle joint function is essential to enable foot clearance during swing phase, produce forward propulsive power, and facilitate energetic efficiency through storage and release of elastic energy. For those with Cerebral Palsy (CP), a neuromotor pathology caused by injury or maldevelopment of the brain before or shortly after birth, ankle joint function is often impaired, however, which can have devastating effects on these patients' walking ability. Deficits in selective motor control and muscle weakness can lead to deviant walking patterns at the ankle joint, such as toe walking or foot drop. Exoskeletons and exosuits have been developed for patients with neuromotor dysfunction to enhance patient mobility by providing robotic assistance to one or more joints and supplementing for lost function, but little is known about the effects of these devices in patients with CP. In this study, we investigated the effects of a unilateral soft exosuit (ReWalk ReStore) on the ankle joint mechanics and metabolic cost of walking in a small cohort of children with unilateral CP.

Methods

In this single-session cross-sectional study, seven individuals with unilateral CP (12-16 years old; GMFCS I) performed two walking trials: one exosuit walking trial and one unassisted walking trial without the device. The exosuit utilized in this study assists plantarflexion and dorsiflexion movements of the patients' affected ankle joint via contraction of Bowden cables at the front and rear of the foot. To investigate the isolated effects of the robotic assistance on the mechanics and energetics of walking, the weight of the exosuit motor was offloaded from the participants during the exosuit-assisted walking trial. For the measurements, participants walked on a force-sensing treadmill and joint biomechanics were evaluated using a marker-based 3D motion-capture system. Additionally, oxygen consumption was measured and used to calculate the metabolic cost of walking for each of the trials.

Results

The assistance provided by the exosuit at the front of the foot increased the degree of dorsiflexion during swing as well as at ground contact by 5.5° ($p=0.043$) and 9.2° ($p=0.001$), respectively, compared to normal walking. Further, the posterior exosuit cable delivered an average of 0.072 Nm/kg of assistive plantarflexion torque, which lead to a 10.2% ($p=0.027$) increase in the peak plantarflexor moment produced at push-off. These mechanical changes at the ankle aided in generating a more efficient walking pattern with the exosuit, as the metabolic cost of walking was reduced by 14.7% using the device, although this reduction was not statistically significant ($p=0.175$).

Conclusions

The results from this study indicate that powered ankle assistance delivered by a lightweight robotic exosuit can augment ankle joint biomechanics during walking and has the potential to reduce the energetic cost of walking in patients with unilateral CP. These findings support the continued investigation into the use of robotic assistive technology for improving gait therapy and general mobility in patients with neuromotor dysfunction.

Applicability

Exoskeletons and exosuits are exciting assistive devices because they have the potential to enhance gait therapy in the clinical setting as well as improve mobility at home and in the community. The reduction in the energetic cost of walking presented here points to the potential of this exosuit device to make walking easier and more efficient in everyday settings. Further, the ability of the exosuit to augment joint biomechanics, as shown in this study, indicates this device can enhance gait therapy by training a more normal walking pattern. The results from this preliminary pilot study support our future research investigating exosuit-assisted gait training compared to traditional therapy and should help to inform the use of these technologies for patients with CP moving forward.