Design of a powered exoskeleton orthotic system for children with lower limb paralysis

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Background & Significance: Spinal cord injury (SCI) in pediatric patients before the age of 15 accounts for approximately 4% (~480 cases/yr) of the total annual incidence in the US. The average lifetime costs for an individual with lower limb paralysis can reach $3M. Additionally, decreased mobility in SCI patients is directly associated with shorter life expectancy, social stigma, and increased rates of depression. SCI during youth may also lead to many secondary complications and deformities; thus, early intervention is important for greater chances of successful rehabilitation. In the last decade, a number of assistive exoskeletons have been developed for adults; however, despite having greater potential for long-term functional gains and improved quality of life, few have been developed for the pediatric population, and none are for over-ground walking.

Approach: This project is a fully faceted collaborative effort to develop and validate a pediatric powered robotic lower-limb exoskeleton augmented with non-invasive systems that interpret user's intent. This device will assist young children ages 4-8 years old with functional upper extremities and paraplegia to walk independently by enabling standing and sitting, walking, turning, and ascending and descending stairs/curbs. The patient-centered approach will ensure simplicity of use, safety through emergency backup systems in the event of failure, and a practical range of use. The first generation personalized wearable robot, P-LEGS (Pediatric Lower-Extremity Gait System), is designed to be light, form-fitting, highly modular, and have 8 degrees of freedom: 6 powered (one for each joint at the hip, knee and ankle for both legs) and 1 passive (hip abduction/adduction). The frame will be adjustable for heights between 3'0"-4'6" (90-135cm) and a maximum weight of 77 lbs (35 kg), encompassing the 5th percentile of 4 year-olds to the 95th percentile of 8 year-olds. The system will include custom-fitting carbon fiber orthotic leg supports, low-resilience polyurethane foam lining, variable tension elastic strapping systems, and 3D-printed motor mounts/adjustment mechanisms. Active sensing will be used to monitor pressure, interaction and shear forces, movement and muscle activity (electromyography, EMG) during use. A unique quick release system will allow for rapid donning and removal of joints, leg straps, and the waistband, for ease of wear and removal. Shared control strategies, including user's intent estimated from a noninvasive neural interface, will be used to command the exoskeleton. Here, we provide an update on the rapid prototyping and design work.

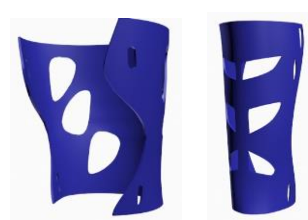
a. b.

Figure 1: 3D models of (a) hip and (b) leg brace based on geometry of 7 year old child.

Conclusions: We are currently near the completion of the design, prototyping and fabrication of the exoskeleton. We have developed a mechanical framework, including rapid prototyped components and 3D computer aided drawing (CAD) component models (Fig. 1). All electromechanical, actuation and sensor systems have been specified and control algorithms are currently under development.

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