Priority Statement Title: Development of Powered Orthoses and Robotic Exoskeletons for Human Locomotion

Priority Statement Code: LF2A

Domains: Limb and Whole Body, Functional Outcomes

Priority Statement

Background and Relevance

In the United States, over 5 million people use orthoses to combat paralysis, deformity or orthopedic impairments, and over 10 million people have mobility impairments due to spinal cord injury, stroke, traumatic brain injury, or cerebral palsy. Recent technological advances have enabled companies and research labs to develop powered orthoses and robotic exoskeletons for the lower limbs (e.g. LOKOMAT, HAL, BLEEX, HULC, XOS, ReWALK, Stride Management Assist, and the Bodyweight Support Assist). The devices are intended as assistive technology for individuals with mobility impairments, therapeutic training devices for individuals with neurological disabilities, and performance augmentation for individuals without impairments. However, physiological measurements on individuals using the devices have indicated the devices do not perform ideally, and in some cases are not even beneficial. This is largely a result of **a fundamental lack of knowledge on how the neuromusculoskeletal system responds acutely and chronically to mechanical assistance of the lower limbs**. Most of the device development is done by engineers with commercial interests precluding open scientific publication. There needs to be an increase in interdisciplinary collaborations along with more published empirical data for developing theoretical frameworks. A large number of motor adaptation studies have been done on upper limb movements with robotic mechanical devices, but there is a paucity of data on lower limb motor adaptation to mechanical gait assistance. If the principles governing motor adaptation during human locomotion are not known, it is not possible to optimize control algorithms for exoskeletons used for neurological rehabilitation. Increased metabolic energy expenditure during walking is a major factor limiting mobility in patient populations and promotes a sedentary lifestyle. In order to design robotic exoskeletons to counteract increased metabolic energy expenditure, there needs to be clear theoretical frameworks explaining how the metabolic cost of walking is affected by different types of robotic assistance. One reason prosthetic development has traditionally been a slow moving field has been that it is primarily manufacturer-driven and eschews open scientific publication. Rather than waiting for independent companies to hit on effective powered orthosis and robotic exoskeleton designs by trial and error, federal agencies can facilitate development of successful devices. Acceleration of device development in the field will be enhanced by promoting interdisciplinary collaborations, increasing basic scientific understanding of physiological and biomechanical effects of mechanical gait assistance, and encouraging open scientific publication.

Objectives

1. Identification of relationships between gait biomechanical parameters and metabolics when using mechanical assistance of the lower limbs.
2. Identification of principles governing motor adaptation to mechanical assistance of the lower limbs.
3. Increase the number of scientific studies published in the literature on the biomechanical and physiological effects of mechanical gait assistance.
4. Development of powered orthoses and robotic exoskeletons for the ankle, knee, hip, and whole limb that can reduce muscle activation, reduce metabolic energy expenditure, or promote gait rehabilitation.

Recommended Actions

1. Promote collaboration between biomechanists, physiologists, and engineers in the development of powered orthoses and robotic exoskeletons.
2. Provide initiatives for increasing academic or open source research into powered orthoses and robotic exoskeletons (e.g. focused research center or “Open Prosthetics Project”-like resource).
3. Promote more basic biomechanical and physiological research on neuromechanical adaptations to mechanical gait assistance.
4. Facilitate collaborations between industry and academics in device development.