Mechanical Engineering Doctoral Defense

On the Effect of Walking Surface Stiffness on Inter-leg Coordination during Human Walking: a Unique Perspective to Robot-assisted Gait Rehabilitation

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abstract

Millions of individuals suffer from gait impairments due to stroke or other neurological disorders. A primary goal of patients is to walk independently, but most patients only achieve a poor functional outcome five years after injury. Despite the growing interest in using robotic devices for rehabilitation of sensorimotor function, state-of-the-art robotic interventions in gait therapy have not resulted in improved outcomes when compared to traditional treadmill-based therapy. Because bipedal walking requires neural coupling and dynamic interactions between the legs, a fundamental understanding of the sensorimotor mechanisms of inter-leg coordination during walking is needed to inform robotic interventions in gait therapy. This dissertation presents a systematic exploration of sensorimotor mechanisms of inter-leg coordination by studying the effect of unilateral perturbations of the walking surface stiffness on contralateral muscle activation in healthy populations. An analysis of the contribution of several sensory modalities to the muscle activation of the opposite leg provides new insight into the sensorimotor control mechanisms utilized in human walking, including the role of supra-spinal neural circuits in inter-leg coordination. Based on these insights, a model is created which relates the unilateral deflection of the walking surface to the resulting neuromuscular activation in the opposite leg. Additionally, case studies with hemiplegic walkers indicate the existence of the observed mechanism in neurologically impaired walkers. The results of this dissertation suggest a novel approach to gait therapy for hemiplegic patients in which desired muscle activity is evoked in the impaired leg by only interacting with the healthy leg. One of the most significant advantages of this approach over current rehabilitation protocols is the safety of the patient since there is no direct manipulation of the impaired leg. Therefore, the methods and results presented in this dissertation represent a potential paradigm shift in robot-assisted gait therapy.

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