Back to TOC

Reduction of Trunk Extensor Muscle Activation using a Cable-Driven Asymmetric Back Exosuit

Jared M. Li[1], Dean D. Molinaro[1,2], Andrew S. King[1], Anirban Mazumdar[1,2], Aaron J. Young[1,2]
[1]Woodruff School of Mechanical Engineering at Georgia Institute of Technology, Atlanta, GA, USA
[2]Institute of Robotics and Intelligent Machines, Georgia Institute of Technology, Atlanta, GA, USA
Email: jli649@gatech.edu

Introduction

Musculoskeletal disorders of the back are extremely prevalent in the workforce and are often cited as the top workplace health concern in the United States. These injuries are caused by compression of the lumbosacral joint (L5/S1) due to repetitive lifting, especially asymmetric movements[1]. In response to this, wearable exoskeleton devices have been developed to reduce the risk of back injury, often reporting decreased muscle activation as indication of reduced lumbar loading[2,3]. While effective in mainly symmetric lifting, most of these systems lack controllability or are restrictive of asymmetric motions. We designed the Asymmetric Back Exosuit (ABX) to fill this gap with novel active cable-driven actuation. We hypothesized that this would allow ABX to reduce trunk extensor muscle activation during asymmetry.

Methods

ABX was designed in order to achieve the functionality of active muscle activation reduction while allowing the user full freedom of movement. Assistive force is applied to the user through the nylon cables that run from actuators on the thighs up to opposite shoulders on a support vest, creating a crossing pattern along the wearer's back. Active assistance is achieved through pulley-gearbox actuators which are regulated by a microcontroller. An inertial measurement unit (IMU) is used to sense trunk orientation and angular velocity relative to the ground. This allows the exosuit to autonomously apply assistance to the user at lift onset and otherwise slack the cables to allow unimpeded motion.

To examine the exosuit's assistance method, a single-subject experiment was conducted to measure the change in activation of trunk muscle groups when lifting a 23 kg weight from the ground onto a table at waist level with a right-to-left 180° twist for five repetitions. Trials consisted of a sweep of assistive force from 5% to 20% of the subject's bodyweight in 2.5% increments as well as a NO EXO condition in which the subject completed the tasks without wearing the exosuit. Delsys Trigno EMG sensors were used to measure the left and right erector spinae, latissimus dorsi, external obliques, and rectus abdominis muscle groups. RMS of each EMG channel was averaged across repetitions and normalized to max activation per muscle group.

Results and Discussion

As seen in Figure 1, muscle activation reductions of up to 30% and 28% were observed in the left and right erector spinae respectively, as well as 53% for both left and right latissimus dorsi muscles. The trunk flexor muscles (left and right external obliques and rectus abdominis) experienced either a decrease or no increase in activation for most assistance magnitudes. Reduction in activation of erector spinae muscles likely indicates reduced muscular force applied to the L5/S1 joint. This is likely related to decreased joint reaction loads in the lumbar spine.

Because of the cross pattern formed by the actuator cables, assistance that is symmetric in magnitude was supplied to the user asymmetrically, demonstrated by the agonistic muscles (left side) experiencing generally greater activation reduction than the antagonistic (right side). Further studies will examine the biomechanical effects (joint reaction loads, lumbar moments) and investigate the results' sensitivity to changing assistance profiles.

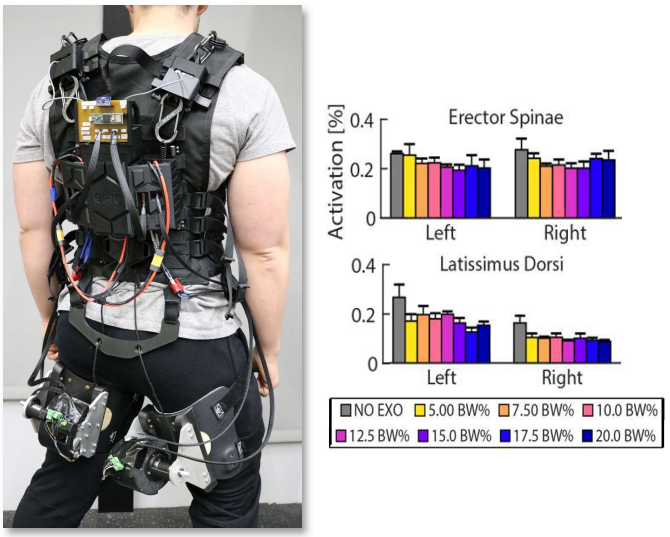

Figure 1: The Asymmetric Back Exoskeleton (left) uses thigh mounted actuators to drive cables attached to opposite shoulders to assist during lifting tasks. RMS electromyography measurements of the erector spinae and latissimus dorsi muscle groups during the asymmetric lift are shown on the right. The results are presented as a function of exosuit assistance by body weight percentage (BW%). The NO EXO condition represents muscle activations without wearing the exosuit. In general, exosuit assistance reduced muscle activation for observed muscle groups.

Significance

Our study presents a novel method of providing active assistance during asymmetric lifting. Asymmetric application of assistance characteristic to this exosuit design allows the cables to naturally follow the twist of the lumbar spine. This method has shown to reduce EMG of the measured trunk extensor muscles, with a larger reduction on the leading side. Because of the prevalence of asymmetric lifting in manual materials handling occupations, this assistance method has the potential to greatly reduce risk factors for back injury during natural lifting movements.

Acknowledgments

The authors would like to acknowledge the NSF Research Traineeship: ARMS Award #1545287 and the NSF NRI Award #1830215.

References

[1]Kelsey et al. (1984). *J. Orthop. Res.*, vol. 2, no. 1, pp.61–66. [2]Toxiri et al. (2018). *Front. Robot. AI*, vol. 5, 2018. [3]Alemi et al. (2019) *J. Electromyogr. Kinesiol.*,vol. 47, pp.25–34.