Title: Autonomous soft exosuit with hip extension assistance for overground walking and jogging

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Background & Purpose: Wearable soft exosuits have been developed to as a way to provide gait assistance. Previously, our lab has created a multi-joint exosuit that powered both the ankle and hip joint to provide walking assistance [1]. In order to create a smaller and lighter system, we proposed a exosuit that provides assistive torque to only the hip joint. Furthermore, we recently showed that it is possible to reduce net metabolic expenditure during not only walking but also jogging by assisting hip extension with an off-board system [2]. The objective of this study was to develop a robust and portable hip-only system capable of providing consistent external assistance to the hip joint for both overground walking and jogging.

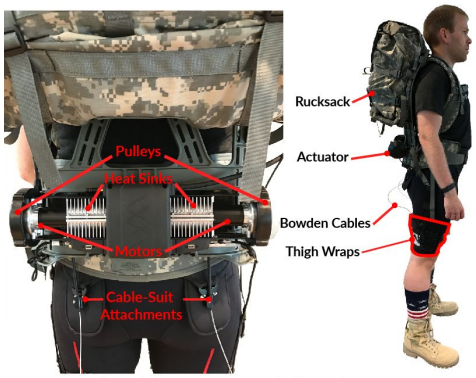

Figure 1: System actuator and soft exosuit components

Subjects:3 healthy subjects (male, age 32.7±9.8 years; height 183.7±3.2 cm; mass 85.0±5.6 kg)

Methods: Overground tests consisting of 3 [km] jogging and 3[km] walking were conducted to evaluate the robustness and consistency of the provided system assistance. Subjects wore the system and were allowed to travel at a self-selected speed and freely transition between walking and running. Inertial measurement units (IMUs) mounted on the stomach and thighs were used to determine appropriate timing to provide assistance, as well as to detect transitions between walking and running in order to determine the appropriate assistance force timing profile to apply to the wearer. The assistance force profiles for walking and running are based on our previous studies [2, 3]. A peak force value of 300 [N], approximately 45 [Nm] hip assistance, was selected for both running and walking assistance profiles.

Results: The average peak force assistance provided on the system was 296.8 ± 20.4 [N] for walking, at 28.3 ± 3.9 % gait cycle (GC), where 0% of the gait cycle corresponds to maximum hip flexion. For running, the average peak force was 301.1 ± 24.3 [N] at 35.9 ± 0.9 % GC.This demonstrates that the system is capable of robustly delivering the specified peak forces to the wearer for both walking and jogging assistive profiles.

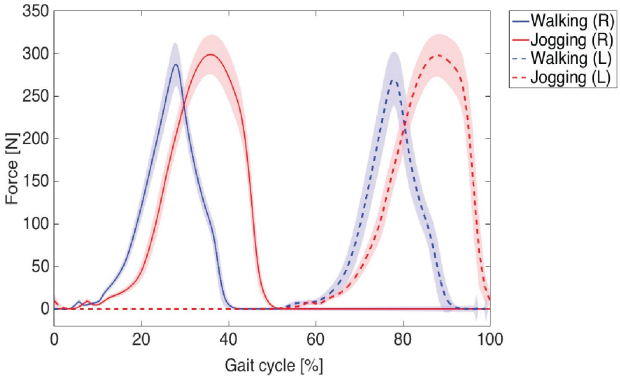

Figure 2: Assistive Force [N] vs Gait Cycle [%] (both legs) for walking and jogging for a representative subject

Conclusions: Our system is capable of robustly delivering 300N of assistance at the specific gait cycle during overground locomotion regardless of jogging and walking gait patterns.

Clinical Relevance: The presented findings will inform the design of future protocols utilizing this system to investigate the metabolic benefits provided by the proposed exosuit.

References

[1] A. T. Asbeck, K. Schmidt, I. Galiana, D. Wagner, and C. Walsh, "Multi-joint Soft Exosuit for Gait Assistance," IEEE International Conference on Robotics and Automation (ICRA), May 2015.
[2] G. Lee, J. Kim, F. A. Panizzolo, Y. M. Zhou, L. M. Baker, P. Malcolm, C. J. Walsh, Reducing the metabolic cost of running with a tethered soft exosuit. *Sci. Robot.* **2**, eaan6708 (2017).
[3] Y. Ding, F. A. Panizzolo, C. Siviy, P. Malcolm, I. Galiana, K. G. Holt, C. J. Walsh, Effect of timing of hip extension assistance during loaded walking with a soft exosuit. *J. Neuroeng. Rehabil.* **13**, 87 (2016).