Biography (100 words)

Thu Nguyen is a PhD candidate in the Biomechatronics Laboratory at Stanford University. She is interested in improving walking ability in individuals with chronic stroke, with an emphasis on developing active assistance exoskeletons.

Primary topic: Adult neurological disorders

Alternate topic: robotics and other devices? Or musculoskeletal disorders?

Title: Human-in-the-loop optimization of active plantarflexion exoskeleton assistance for one individual with chronic stroke

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The maximum abstract length is 450 words without references

Introduction

Individuals with chronic stroke often have higher metabolic energy consumption during walking than able-bodied individuals [1]. A soft assistive ankle device, or exosuit, reduced metabolic cost by 10% compared to walking with the device applying no assistance in individuals with chronic stroke [2]. The device applied predefined active plantarflexion and dorsiflexion assistance on the paretic side.

A different unilateral ankle plantarflexion device, or exoskeleton, has been shown to decrease metabolic energy consumption by about 24% compared to walking with the device applying no assistance in able-bodied individuals with human-in-the-loop optimization [3], [4]. Human-in-the-loop optimization identifies user specific assistance strategies in real time based on biological measurements of the user.

Research Question

Does customized assistance significantly reduce the metabolic cost of walking in one participant with chronic stroke using our active plantarflexion exoskeleton with added passive dorsiflexion assistance?

Methods

One individual with hemiparesis (male, age 74, 38 months post-stroke) walked on a treadmill at a self-selected speed wearing an ankle exoskeleton on the paretic leg while the optimizer worked to find a customized assistance strategy. The optimizer relied on a genetic algorithm where the best assistance strategies from one generation inform the next generation of strategies to be sampled.

Device assistance was optimized over four days of walking. The participant completed four generations during the first two days. The participant was then further trained to more effectively use the device. Optimization was restarted, and three generations and a validation test were conducted over the last two days. Metabolic cost and ankle angle were collected. Ankle angle was approximated using an encoder located coaxially with the ankle joint.

Results

The participant showed a 5% metabolic energy reduction while walking with the customized controller compared to walking with the device applying no assistance (Figure 1A). The participant’s peak dorsiflexion angle in late stance was significantly reduced by about 6° when walking with customized assistance ($p<0.001$, two-sample t-test) (Figure 1C&D).

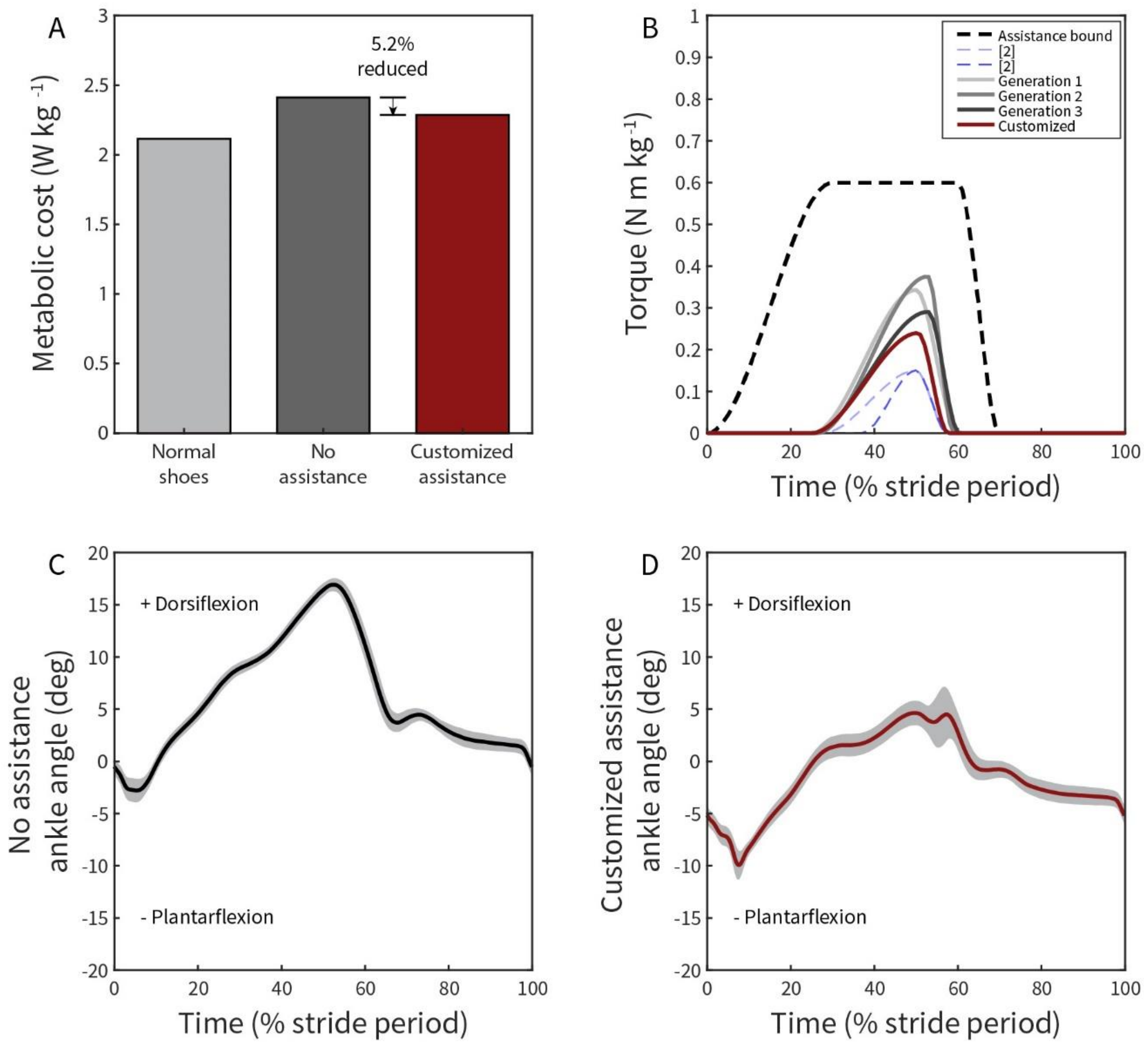

Figure 1. Experimental Results. (A) Metabolic energy cost of walking in normal shoes, the device applying no assistance, and the device applying customized assistance during validation. Customized assistance reduced the metabolic cost by 5.2% compared to walking with the device applying no assistance. The increase in metabolic cost between normal shoes and no assistance is likely due to the added mass of the device. **(B)** Average assistance profiles for each generation during optimization. The participant-specific assistance bound placed limits on the possible assistance profiles to ensure safety during optimization. The average assistance strategies from [2] is shown for comparison. **(C)** Ankle angle measured using the device encoder with the device applying no assistance during validation. **(D)** Ankle angle measured using the device encoder with the device applying the customized assistance profile during validation. Angle magnitudes recorded were dependent on device placement, but the ranges were consistent throughout trials.

Discussion

Although the peak torque of the customized assistance was higher than that of the exosuit presented by [2] (Figure 1B), the participant's energy reduction was lower than the average reduction in [2]. Individuals post-stroke often experience drop-foot due to dorsiflexor muscle weakness, so active dorsiflexion could have contributed to additional energy reductions. The participant did not have voluntary control over knee flexion, which is normally coupled with plantarflexion during ankle push-off. Due to this, applying greater plantarflexion torques could have led to higher energy compensatory strategies, such as hip hiking and reduced change in ankle angle at push-off. While dorsiflexion and knee flexion could both help foot clearance in early swing, knee flexion assistance could allow for additional plantarflexion at push-off. We are therefore building a knee-ankle exoskeleton.

References

[1] M. M. Platts, D. Rafferty, and L. Paul, “Metabolic cost of overground gait in younger stroke patients and healthy controls,” *Med. Sci. Sports Exerc.*, vol. 38, no. 6, pp. 1041–1046, 2006.

[2] L. N. Awad *et al.*, “A soft robotic exosuit improves walking in patients after stroke,” *Sci. Transl. Med.*, vol. 9, no. 400, 2017.

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[4] K. A. Witte, J. Zhang, R. W. Jackson, and S. H. Collins, “Design of two lightweight, high-bandwidth torque-controlled ankle exoskeletons,” *Proc. - IEEE Int. Conf. Robot. Autom.*, vol. 2015–June, no. June, pp. 1223–1228, 2015.