A PASSIVE HIP FLEXION DEVICE MAY IMPROVE STABILITY DURING PERTURBED WALKING

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Introduction

A major open question in exoskeleton research is how to design devices that improve stability during walking. Current approaches targeted to users with high levels of volitional control focus on providing motor-driven assistance at the hip joint (*e.g.*, [1]). However, passive devices may provide a lightweight, low-profile source of stabilizing assistance for perturbations that induce a forward pitch followed by a hip flexion response, such as forward slips or trips.

Here we present preliminary work investigating the influence of a commercial elastic hip flexion device (Moveo Exoband) on stability following rapid, transient unilateral treadmill belt accelerations designed to induce forward pitch during walking. [2] We quantified stability as the range of whole-body angular momentum (WBAM) over a stride, which is considered tightly regulated during unperturbed walking. [3] We hypothesized that increasing Exoband stiffness would improve stability during perturbations as evidenced by a decreased range of WBAM.

Methods

1 subject (M, 30 y/o, 75.8 kg, 188.5 cm tall) walked on a split-belt treadmill at 1.25 m/s in an instrumented version of the Exoband and experienced 20 transient unilateral belt accelerations (early and late stance perturbation timings, left and right legs, 5 repetitions; [2]) in each of 4 stiffness conditions. Exoband stiffness was altered using different compression springs (No spring, Low=4.9 N/mm, Medium=7.2 N/mm, High=10.9 N/mm). Exoband flexion torque (Fig B,C) was calculated using load cells in-series with the springs. The lever arm of the springs relative to the hip joint was calculated from motion capture. WBAM was calculated in OpenSim 4.0 using a full body musculoskeletal model. [4] Data were averaged across legs and repetitions and are presented for the stride before (S-1), during (S0), and after (S+1) the perturbation.

Results and Discussion

Across all stiffnesses, a forward pitch was induced by the perturbation in either early or late stance, as demonstrated by a shift to negative WBAM values on the perturbed stride (S0; Fig 1 D,E). The Exoband stiffnesses that maximized stability was different between the two perturbation timings (Fig 1 F,G) – for early stance perturbations, in agreement with our hypothesis, the high stiffness Exoband condition resulted in the smallest mean WBAM of all conditions due to a reduced backwards pitch in recovering from the perturbation. However, in contrast to our hypothesis, for late stance perturbations, the medium Exoband stiffness resulted in the smallest mean WBAM due to decreased forward pitch during the perturbation. Further, the effect of stiffness on WBAM was more muted for the late vs. early stance perturbation timings.

Overall, these preliminary findings indicate the timing of perturbations is critical for determining the mechanism and extent to which passive hip flexion assistance improves stability.

Significance

This is the first study demonstrating the potential of passive assistance to improve locomotor stability. Work is currently underway to collect a larger (N=11) data set and understand the muscle-level implications of such assistance in unstable contexts.

Acknowledgments

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References

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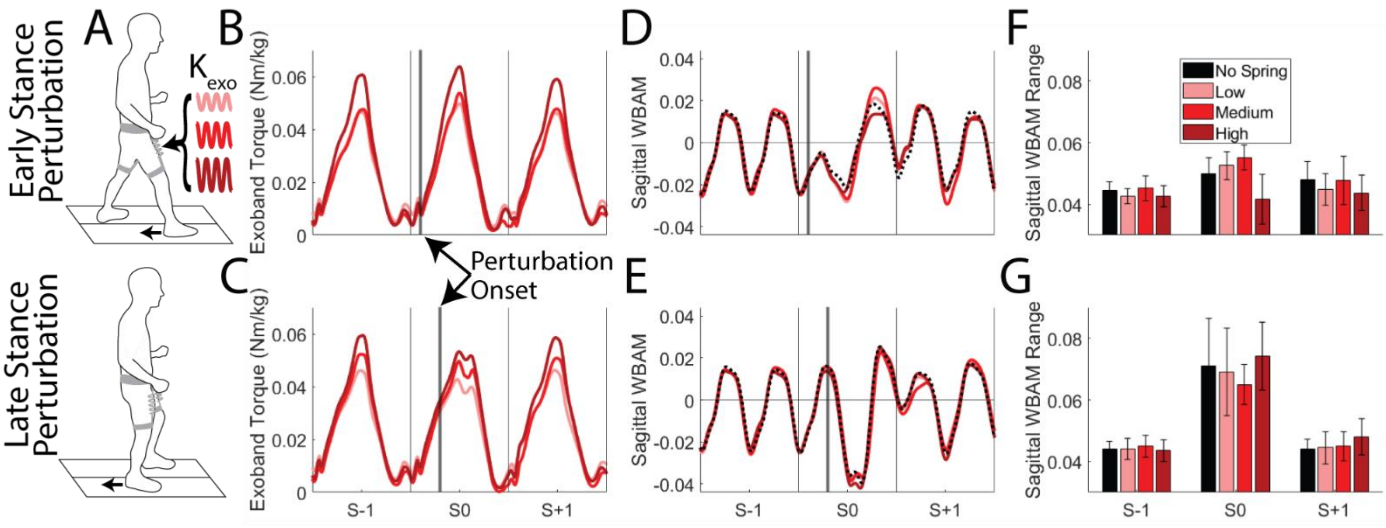

Figure 1: Top/Bottom row: Early/Late stance perturbations, respectively, for strides before (S-1), during (S0), and after (S+1) the perturbation. **A –** Methods overview. **B,C** – Flexion torque provided by Exoband. **D,E** – Sagittal whole body angular momentum normalized to height, mass, and walking speed. **F,G** – Range of normalized sagittal WBAM