Neuromuscular adaptation during and after Asymmetry Surface Stiffness Walking

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Summary

Asymmetric surface stiffness walking increases peak muscle excitations at the ankle at push-off during early post-adaptation. The gastrocnemius and soleus had an increased ratio of muscle excitation asymmetry in early adaptation, favoring the soft side. Asymmetric surface stiffness walking can potentially promote neurological adaptation for post-stroke rehabilitation at critical gait cycle phases, improving walking performance.

Introduction

Previous studies of split-belt treadmill walking have reported improvements in step length asymmetry in individuals post-stroke [1]. However, it does not address other gait impairments [2]. A recent study using a unilateral variable stiffness treadmill has reported increased gastrocnemius muscle excitations at push-off in both legs [3]. However, there are no reports of neuromuscular control adaptation during weight acceptance, which can be associated with weight bearing adaptation, improving weight bearing asymmetries. We quantified changes in neuromuscular control during weight acceptance and push-off gait events after asymmetric surface stiffness walking. We hypothesized an increased muscle excitation of the triceps surae at push-off on the perturbed side and an increased muscle excitation on the body-supporting muscles on the perturbed side during early post-adaptation. These increased muscle excitations can be a mechanism that triggers a shift in weight bearing.

Methods

Ten healthy individuals (20 $\pm$ 0.648 years, 73.4 $\pm$ 9.97 kg) with no musculoskeletal or neurological injuries participated in this study. Participants completed three walking trials in a single session. All trials were performed at a constant speed of 1.25 m/s. Baseline and post-adaptation conditions were performed on an instrumented dual-belt treadmill (Bertec, Columbus, OH, USA) for 5 minutes. The adaptation condition was performed on the AdjuSST [4] for 12 minutes; the first 2 minutes were used for acclimatization with belts set at 300 kN/m. Immediately after, the left belt was adjusted to 15 kN/m, in a single step. We measured muscle excitations of 5 muscles bilaterally (10 total) using a Delsys Trigno system (Delsys Inc., Natick, MA): soleus, lateral gastrocnemius, tibialis anterior, biceps femoris (short head), and vastus lateralis. We assessed changes in peak muscle excitations between sides by calculating the symmetry ratio $SR = \frac{M_p - M_u}{M_p + M_u} * 100$. We averaged 20 strides at the end of baseline, early post-adaptation, and late post-adaptation. We assessed the gastrocnemius and soleus at push-off, tibialis anterior during mid-swing, vastus lateralis during weight acceptance, and biceps femoris during late swing. We performed repeated measures ANOVA and used Bonferroni corrected paired t-tests between baseline and early post-adaptation, as well as between baseline and late post-adaptation, to determine any significant change in muscle excitation symmetry ratio.

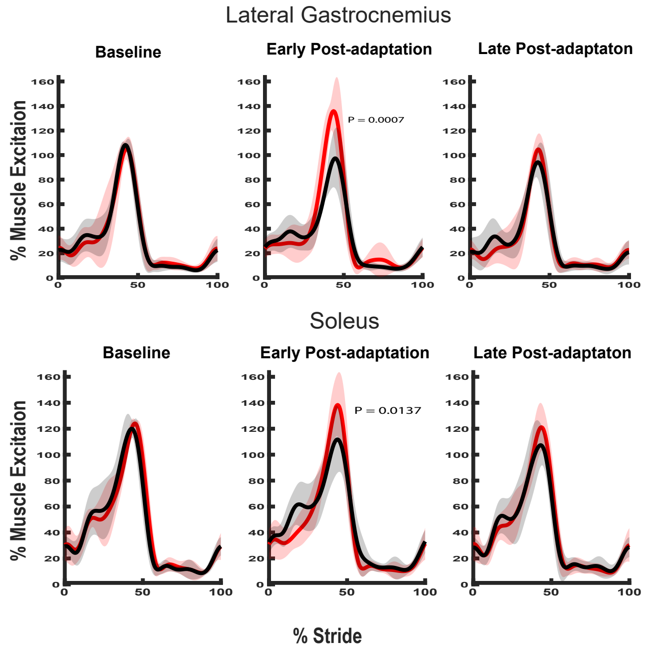

Figure 1: The red line is the perturbed side (low stiffness); the black line represents the unperturbed side (high stiffness)

Results and Discussion

We found significant differences between the baseline (B) and early post-post (EP) adaptation conditions for the lateral gastrocnemius ($SR_B = 0; SR_{EP} = 18.28$) and the soleus ($SR_B = 0; SR_{EP} = 12.15$) (Figure 1), partially confirming our hypothesis. We did not find a statistical significance for the vastus lateralis muscle excitation between baseline and early post-adaptation ($SR_B = -0.30\, SR_{EP} = 3.81$; p = 0.4704). Our results indicate that walking on an asymmetrical surface stiffness treadmill can create a neuromuscular adaptation that engages the triceps surae. This can potentially help individuals post-stroke engage their tricep surae muscles on their paretic side through continuous exposure to asymmetric surface stiffness walking.

Conclusions

Asymmetric surface stiffness walking has the potential to induce walking adaptations that promote the engagement of the tricep surae to improve walking performance. Further studies with individuals post-stroke should explore this.

References

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