ANKLE AND HIP MUSCLE ACTIVATION IN RESPONSE TO GROUND SLIDE PERTURBATIONS

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Introduction: Humans are excellent at maintaining balance during steady state walking and in response to perturbations. When someone is perturbed, there are two main strategies to deal with the perturbation: (1) an ankle strategy, which involves modulating the center of pressure underneath the foot and (2) a hip strategy, which involves changing where the foot is placed during walking. It has been shown that in healthy young adults, as perturbation magnitude increases, step placement changes are more often used to correct for instability. The role of these two strategies and how different muscles contribute in response to varying magnitude and direction perturbations in both the stance and swing leg has not been extensively investigated [1,2]. We hypothesized that as perturbation magnitude increases, increases in hip muscle activity will be more pronounced than ankle muscles as individuals switch from ankle strategy to hip strategy.

Methods: Eleven healthy participants walked at 1.25 m/s on a 6 degree-of-freedom instrumented treadmill while being exposed to translational perturbations of varying directions magnitudes and timings (Figure 1). Surface electromyography (sEMG) was collected at 2000 Hz on the Tibialis Anterior (TA), Medial Gastrocnemius (MG), Rectus Femoris (RF), and Biceps Femoris (BF). The full experimental protocol has been previously described by Leestma et al. [3]. This analysis will focus on anterior and posterior perturbations at 50% double support (Fig 1). We will compare hip and ankle response in the sagittal plane using muscle activation patterns from the above-mentioned muscles. sEMG signals were processed using a 4th order Butterworth filtered between 10 and 450 Hz and smoothed with a 100ms root mean square (RMS). The integrated signal was computed over one stride.

Results & Discussion: As hypothesized, we observed there were larger increases in hip muscle activation vs. ankle muscle activation for the larger magnitude perturbations (Fig. 2). This is expected for two reasons. First, larger perturbations are more destabilizing and thus necessitate alterations in step placement to produce the external moments needed to restore baseline fluctuations in angular momentum. Second, smaller perturbations (5cm) remain within the foot's lever arm, allowing for center of pressure adjustments without the need for hip involvement. We observed that as perturbation magnitude increased, *all* muscles - both agonists and antagonists with respect to the perturbation direction - had higher activation. This suggests a limb-wide co-activation strategy as part of the repertoire used to restore balance, especially at the higher perturbation magnitudes, Presence of co-activation also suggests the ankle strategy remains essential for balance recovery during larger perturbations, perhaps because the step placement is not precise for achieving immediate stability, requiring continued ankle adjustments to compensate for any residual instability after the step.

Significance: Young- healthy adults shift muscle coordination to rely more on proximal vs. distal muscles for large pitch-perturbations in the sagittal plane – indicating that hip driven step placement is critical to recover from perturbations large enough to elicit falls. This finding could help improve our understanding of balance deficits in clinical populations, such as older adults or individuals' post-stroke that suffer localized (asymmetric) muscle weakness. In addition – focusing therapies and assistive technologies to strengthen proximal rather than distal joints may be a key to preventing falls in scenarios where altering foot placement restores balance.

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References: [1] Rankin et al. (2014) J. neurophysiology; [2] Stimpson et al. (2018) J. Biomechanics; [3]Leestma et al. (2023), J. Exp Biol.

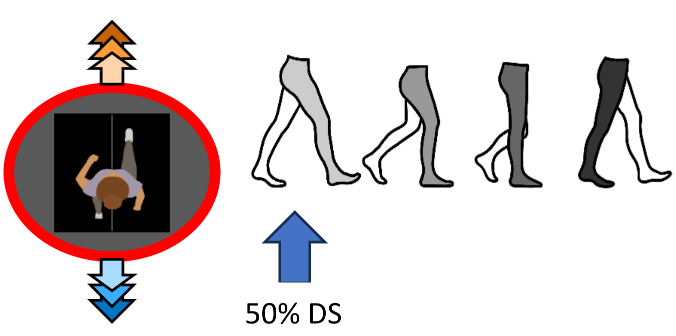

Figure 1: Perturbation conditions with varying magnitudes (hue) following DS perturbations

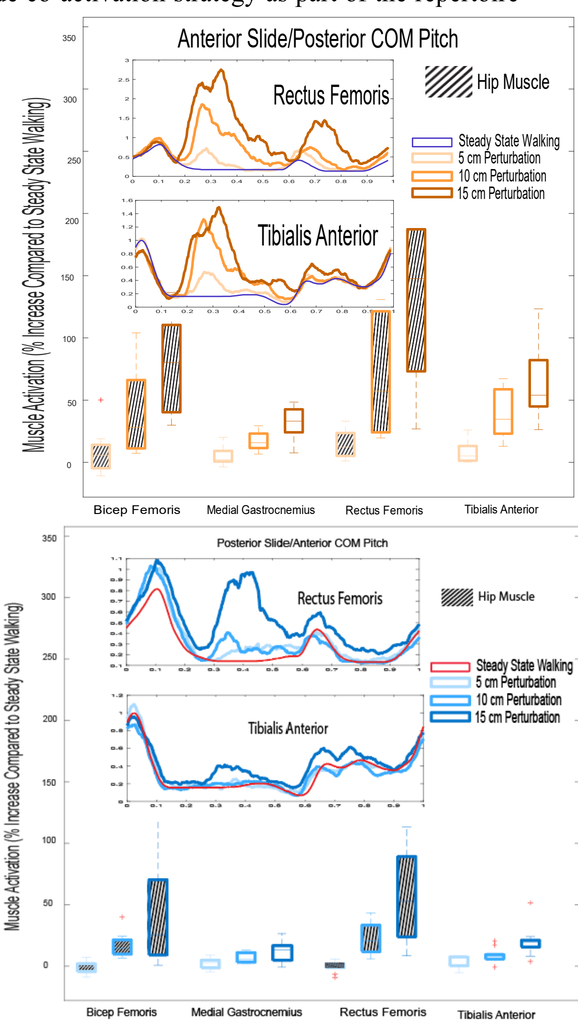

Figure 2: Averaged sEMG curve over a gait cycle for steady state and perturbation conditions. Increase in muscle activation compared to steady state walking for Anterior (top) and Posterior (bottom) ground slide Perturbation Condtitions