Central modulation of spinal reflexes during locomotor adaptation in healthy adults

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Summary

H-reflexes have previously been studied during standing and walking to investigate spinal reflex pathways in locomotion, but not in the context of locomotor adaptation. Here, we show that adaptive neuromuscular control of split-belt walking involves phase-specific modulation of spinal reflex pathways.

Introduction

Walking is a complex process in which spinal and supraspinal control are integrated to progress forward. The role of spinal reflexes in locomotion has been investigated using the Hoffmann-reflex (H-reflex) [1], showing phase-dependent H-reflex modulation in the gait cycle [2]. Recently, it was shown that the H-reflex at mid-stance is dynamically modified during adaptation to split-belt walking [3]. However, it remains unknown if and how the phase-dependent modulation of the H-reflex changes over the course of adaptation. Here, we assess how the m. soleus H-reflex is modulated over different phases of the gait cycle during adaptation to split-belt walking in healthy young adults.

Methods

Twenty healthy young adults walked on a split-belt treadmill while we recorded m. soleus H-reflex amplitudes. First, the recruitment curve and maximal M-wave amplitude were measured during standing. Then, participants walked 5 minutes fast (1.5 m s^{-1}) and 5 minutes slow (0.5 m s^{-1}) baseline, 10 minutes split-belt adaptation (left: 1.5 m s^{-1}, right: 0.5 m s^{-1}), and 5 minutes slow tied-belt washout (0.5 m s^{-1}). Surface-electromyography (EMG) was measured from the m. soleus and ankle kinematics were measured with the Vicon Plug-in Gait model. Stimulations were delivered in the popliteal fossa on the right leg (slow belt), at eight discrete timepoints throughout the gait cycle. H-reflex amplitudes were extracted from m. Soleus EMG, normalized to maximum M-wave amplitude, and compared between experimental conditions (condition) and stimulation timepoints (timepoint) with a linear mixed effects model ($\alpha = 0.05$).

Results and Discussion

H-reflex amplitudes were successfully determined in 65.6 % of all stimulations (Fig. 1). The linear mixed effects model showed a significant main effect of condition ($F(5,627)=4.09$, $p=0.001$) and a significant condition*timepoint interaction ($F(35,627)=4.15$, $p<0.001$). Post-hoc analyses of early adaptation compared to baseline revealed a suppressed H-reflex at mid-stance ($p=0.024$) and enhanced H-reflex at mid-swing ($p<0.001$). Furthermore, post-hoc analyses of early washout compared to baseline showed an increased H-reflex at initial stance ($p=0.002$) and terminal swing ($p=0.002$), and decreased H-reflex at pre-swing ($p=0.010$). Ankle kinematics (Fig. 2) indicate that increased H-reflex amplitudes during early adaptation and early washout coincide with increased dorsiflexion in swing, and decreased H-reflex amplitudes with decreased dorsiflexion in mid- and late-stance. Our results align with previous research [2,3] and show that adaptive neuromuscular control of split-belt walking involves phase-specific modulation of spinal reflex pathways.

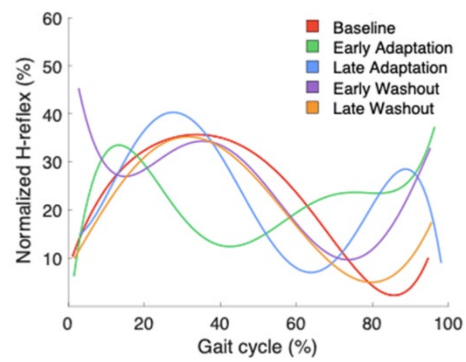

Figure 1: Fifth-order polynomial fits of all H-reflex amplitudes.

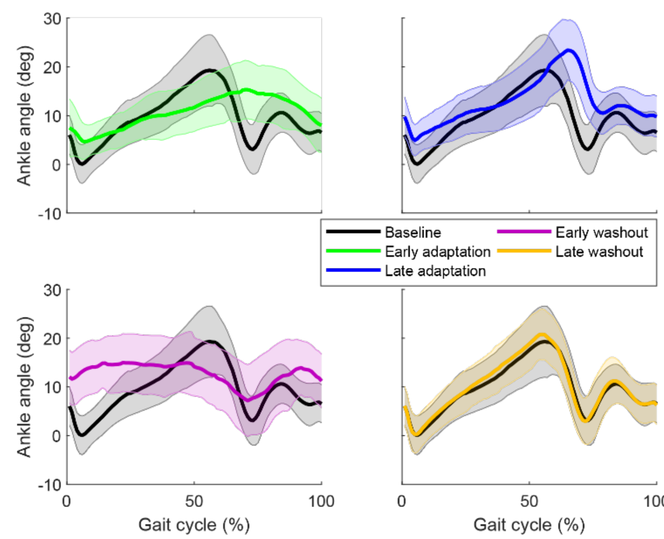

Figure 2: Anke dorsiflexion kinematics.

Conclusions

Spinal reflexes are modulated throughout the gait cycle during adaptation to split-belt walking to facilitate ankle kinematics. This shows that central modulation of spinal reflexes may play a key role in human locomotor stability and adaptation.

References

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