Modulation of Reactive Responses During the Stance Phase of Walking

Dana L. Lorenz[1,2], Antonie J. van den Bogert[2]
[1]Department of Physical Medicine and Rehabilitation, Case Western Reserve University, Cleveland, USA
[2]Department of Mechanical Engineering, Cleveland State University, Cleveland, USA
Email: dxl954@case.edu

Summary

This study investigates the modulation of reactive responses in eight lower extremity muscles when perturbations are applied at different times during the stance phase of walking. The magnitude of the EMG response in most muscles was significantly affected by perturbation time, suggesting a phase-dependent reflex gain.

Introduction

Reflexes play an important role in the control and stability of human walking. H-reflex studies, which involve electrical stimulation, have shown that reflexes are modulated through the gait cycle [1]. Mechanical perturbation with an exoskeleton showed quadriceps stretch reflex modulation between the stance and swing phase [2], but it is technically challenging and not clinically applicable. Treadmill-induced mechanical perturbations allow for reflexes to be observed in a more natural situation [3]. The aim of this study was to examine reflex responses in eight lower extremity muscles, and how these are modulated through the stance phase of gait.

Methods

Ten participants walked for six 5-minute trials on a treadmill at 1.2 m/s, while perturbed by occasional belt acceleration and deceleration at discrete time points from 10 to 80% of stance [4]. EMG envelope data were obtained from eight muscles in the right leg: Tibialis Anterior, Soleus, Lateral Gastrocnemius, Rectus Femoris, Vastus Lateralis, Vastus Medialis, Biceps Femoris, and Gluteus Maximus. Joint angles were obtained using optical motion capture. All signals were separately ensemble-averaged for the unperturbed gait cycles and the perturbed gait cycles from each type of perturbation.

Perturbation responses were calculated by subtracting the unperturbed EMG, and normalized to the peak of the unperturbed EMG. A single-factor ANOVA with repeated measures was used to determine to test for effect ($p < 0.05$) of perturbation time on peak magnitude of the reflex response.
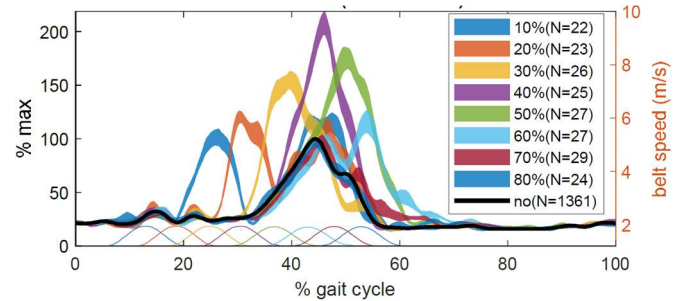

Figure 1: One participant's EMG envelope (mean ± SEM) from perturbations at 10-80% of stance, as well as unperturbed.

Results and Discussion

Substantial increases in EMG were observed after most perturbations (Figure 1). The largest responses, above 100%, were seen in the plantarflexor muscles (Table 1). Significant effects of perturbation time were found in all muscles except the Gluteus Maximus.

The variation in the amplitude of EMG responses can be attributed to modulation of the stretch reflex gain, similar to what is observed in H-reflex studies. However, some responses, such as the Soleus in late stance, were not preceded by joint angle changes and may be from cutaneous receptors. Further research is needed to identify the reflex pathways.

Conclusions

Mechanically induced reactive responses are modulated during the stance phase of walking, possibly due to reflex gain modulation.

References

[1] Zehr EP, *Prog Neurobiol* **58**: 185-205, 1999.
[2] Mrachacz-Kersting N, *Exp Brain Res* **159**: 108-122, 2004.
[3] Sloot LH, *et al*., *PLOS One* **10(12)**: e0144815, 2015.
[4] Lorenz D., van den Bogert AJ. *PeerJ* **12:**e17256, 2024.

Table 1: Peak values of reactive EMG responses during belt speed perturbations at 10-80% of the stance phase, relative to the peak of the unperturbed EMG. Mean and SD were calculated across participants. The P-value indicates significant effect of perturbation time.

	10%	20%	30%	40%	50%	60%	70%	80%	P-value
Tibialis Anterior	20.2 (16.1)	21.9 (8.9)	19.1 (7.0)	17.9 (6.2)	30.0 (12.9)	35.5 (16.8)	28.5 (12.3)	12.6 (5.0)	< 0.001
Lateral Gastrocnemius	87.4 (26.5)	88.6 (15.0)	115.2 (50.5)	119.2 (56.0)	103.8 (65.3)	65.2 (55.4)	14.5 (10.5)	9.4 (3.1)	< 0.001
Soleus	84.9 (18.6)	76.4 (14.2)	85.5 (30.4)	109.1 (34.8)	104.7 (46.7)	68.8 (36.5)	14.4 (5.9)	10.0 (4.3)	< 0.001
Rectus Femoris	26.0 (29.3)	27.2 (34.3)	55.8 (83.3)	110.1 (158.7)	107.5 (94.5)	80.8 (49.0)	34.7 (21.1)	17.7 (9.9)	0.001
Vastus Lateralis	27.0 (20.1)	18.9 (11.7)	25.0 (15.4)	39.7 (33.3)	40.2 (32.8)	26.3 (18.3)	13.2 (12.3)	9.9 (4.3)	< 0.001
Vastus Medialis	21.0 (13.5)	14.9 (6.9)	21.3 (12.1)	33.8 (15.4)	35.3 (19.8)	18.9 (9.0)	13.4 (7.0)	8.2 (3.2)	< 0.001
Biceps Femoris	50.9 (44.6)	38.4 (32.6)	30.4 (17.9)	24.4 (11.8)	12.8 (4.2)	19.0 (9.8)	19.5 (21.4)	12.3 (6.9)	< 0.001
Gluteus Maximus	21.5 (12.7)	25.7 (17.3)	21.7 (13.5)	35.5 (51.5)	17.5 (16.2)	21.8 (17.3)	20.6 (17.1)	18.9 (7.0)	0.608