Favorable soleus muscle contractile conditions and activation for body energy regulation in drop-like gait perturbations

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Summary

Nineteen adults received an unpredictable (no experience) and adapted (based on experience) drop-like walking perturbation. Despite lengthening of the soleus muscle-tendon unit (MTU) after touchdown, muscle fascicles operated with small length changes, low velocity and close to optimal length, thus at high force-length-velocity potentials in both perturbations. Electromyographic (EMG) activity was high in this phase, yet lower in the adapted perturbation. During MTU shortening, the EMG activity again increased and fascicles shortened, indicating energy production. The results show favorable contractile conditions regulated by activation to manage the center of mass (CoM) energy absorption and production after drop-like perturbations, which improved with experience.

Introduction

Daily locomotion involves irregularities and perturbations. During unpredictable perturbations, reactive neuromotor responses allow for fast compensations [1] while prior experience triggers predictive adjustments [2]. Here we investigated the neuromuscular control of the soleus for the management of the total CoM energy after unpredictable and adapted drop-like walking perturbations. We expected favorable contractile conditions regulated by activation that facilitate the recovery and adapt with further experience.

Methods

Nineteen adults (10♀) were perturbed during walking by a hidden drop plate (15 cm drop). Unperturbed walking, an unpredictable perturbation and an adapted perturbation were investigated by motion analysis, EMG and ultrasound. Soleus muscle intrinsic properties were assessed and operating length and velocity were mapped onto the force-length and force-velocity curve to assess the force-length-velocity potential.

Results and Discussion

Total CoM energy was constant in unperturbed walking, while it fluctuated in the unpredictable (-1.36 and +0.62 J/kg) and adapted (-0.82 ($p<0.05$) and +0.52 J/kg) drop-like perturbation, indicating energy absorption and production by the musculoskeletal system. The soleus MTU lengthened after touchdown in the hole in both perturbations while the EMG activity showed a peak in this phase, yet lower in the adapted perturbation ($p<0.05$, Figure 1). Despite MTU lengthening, the soleus fascicles operated with small length changes and close to optimal length (Figure 1). Fascicle velocity was not different to zero ($p>0.05$) in the unpredictable perturbation during MTU lengthening, accompanied by high EMG activity (Figures 1&2). The short interval of a significantly different velocity to zero in the adapted perturbation (9-21 %stance) coincidence with a decrease in EMG activity. Accordingly, the force-length-velocity potential in the unpredictable and adapted perturbation was high (0.89, 0.98). During MTU shortening later in stance, fascicles shortened continuously at increasing EMG activity (Figures 1&2), indicating energy production, similar in both perturbations.

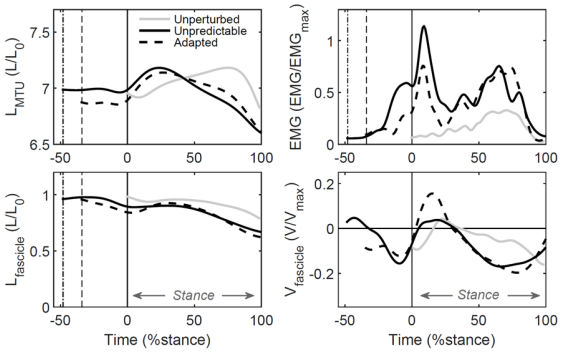

Figure 1: Soleus MTU length (L), EMG activity and fascicle length and velocity (V) during unperturbed walking, the unpredictable and adapted perturbation. Lines indicate plate and hole touchdown.

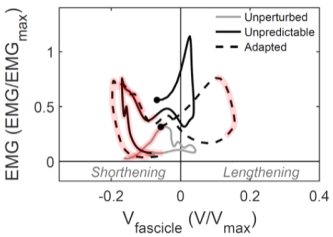

Figure 2: Soleus EMG activity-fascicle velocity relationship in the different tasks. Dots indicate touchdown. Intervals with significant velocity difference to zero are underlaid in red (SPM{t}, $p<0.05$).

Conclusions

Favorable soleus contractile conditions regulated by muscle activation contribute to the management of the CoM energy during drop-like perturbations. The lengthening of the soleus fascicles by a reduction of the EMG activity in the adapted perturbation, indicates the involvement of higher control centers for the energy absorption with further experience.

Acknowledgments

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References

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