Activation patterns and joint energy transfer potential of the biarticular gastrocnemii muscles during drop-like gait perturbations in humans

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Summary

The energy transfer potential between the ankle and knee joint via the biarticular gastrocnemii muscles during unpredictable without experience and predictable with experience drop-like gait perturbations in early and late stance was investigated using kinematic parameters of the ankle and knee joints in combination with muscle activation. We found an increased activation of the gastrocnemii muscles and an increase in the knee-to-angle joint energy transfer potential via the gastrocnemii muscles in the push-off phase in the perturbed and recovery steps, indicating an important contribution of biarticularity to the required increase in total centre of mass (CoM) energy. Furthermore, the higher activation of the gastrocnemii during the ankle-to-knee joint energy transfer phase in the first part of stance shows a relevant contribution of biarticular mechanisms to the absorption of total CoM energy in the perturbed conditions.

Introduction

Due to their biarticularity, the gastrocnemii muscles are able to transfer energy between the ankle and knee joints [1]. In-phase fluctuations between the ankle and knee angles lead to an energy transfer between the two joints, while anti-phase fluctuations indicate simultaneous energy absorption or production at the two joints [2]. The purpose of this study was to investigate the energy transfer potentials between the ankle and knee joint via the gastrocnemii muscles and their activation during drop-like gait perturbations. We hypothesized an increase in the energy transfer potentials between the two joints with a simultaneous increase in the activation of the gastrocnemii during both the perturbed and recovery steps, indicating an important involvement of biarticularity in the management of total CoM energy.

Methods

A hidden drop-plate was used to introduce unpredictable without experience and predictable with experience drop-like gait perturbations (15 cm drop) in early (18 participants, 10F/8M) and late (19 participants, 10F/9M) stance. Whole body kinematics were measured using a motion capture system (Vicon Motion Systems, 250 Hz), and electromyographic (EMG) activity of gastrocnemius medialis (GM) and lateralis (GL) muscles were measured bilaterally at 1000 Hz. Using vector coding, the coupling angles of the ankle and knee joints were calculated to quantify in-phase fluctuations. The energy transfer potential between the two joints was determined as the fraction of the contact time when the ankle and knee angles are in-phase. The first-order differential equation proposed by Zajac [3] was used to calculate muscle activations. The data for the pre-perturbation, perturbation and recovery steps were analyzed separately using linear mixed models.

Results and Discussion

The peak-to-peak range of total CoM energy during the stance phase increased ($p<0.05$) in the early and late perturbed conditions compared to unperturbed walking in all steps. We also found an increase ($p<0.05$) in the energy transfer potential between the two joints via the gastrocnemii muscles in the early and late perturbed conditions in both the perturbed and recovery steps (Figure 1). The increased energy transfer potential between the two joints was mainly due to the increase ($p<0.05$) in the energy transfer potential from the knee to the ankle joint during the push-off phase. In all perturbed conditions, the activation of the gastrocnemii muscles in the ankle-to-knee and knee-to-ankle joint energy transfer phases increased ($p<0.05$) compared to unperturbed walking.

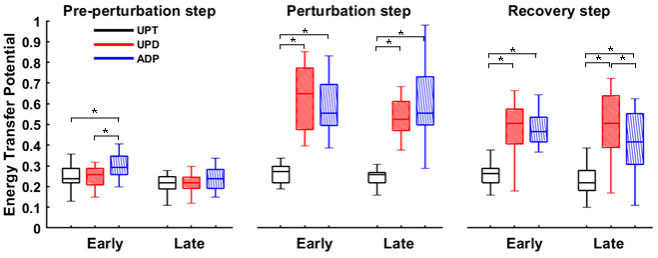

Figure 1. Energy transfer potentials via the biarticular gastrocnemii muscles during the pre-perturbation, perturbation and recovery steps for the unperturbed walking (UPT), unpredictable (UPD) and adapted (ADP) perturbations in early and late stance phase.

Conclusions

The increased energy transfer potential combined with the increased activation of the gastrocnemii muscles during the ankle-to-knee and knee-to-ankle joint energy transfer phases indicates a relevant involvement of biarticular mechanisms in maintaining body stability and managing total CoM energy after drop-like gait perturbations. The results also show that the increased involvement of biarticular mechanisms in the management of total CoM energy continues into the recovery step.

References

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