The choice of low-pass filter cutoff frequency affects the interpretation of joint moments in gait

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Summary

The original goal of this study was to estimate antigravity muscle efforts in walking by relating peak joint moments from gait to maximum values obtained from the same muscle group during an isometric reference test. The seemingly high effort ratios – especially in the hip joint – led us to investigate how the choice of filtering frequency might affect the interpretation of joint kinetics in gait analysis. We analyzed gait trials low-pass filtered with 10 Hz and 15 Hz cutoff frequencies, as well as with no filter at all. There were statistically significant differences between the filtering conditions for the hip and knee joints, but not for the ankle.

Introduction

There have been studies describing the effects of different digital filtering frequencies on joint moments in movements such as jumping [1], cutting [2] and running [3]. Adjusting the low-pass cutoff frequency has been reported to affect the more proximal joints in particular [2,3]. However, previous literature focuses heavily on movements characterized by high impact forces, whereas research on filtering conditions in walking seems very sparse.

Methods

Seven healthy participants (29.4±5.0 y.o.; 2 F) volunteered for the measurements. Each participant performed several gait trials at a self-selected speed. Five clean force plate contacts per dominant foot were averaged for analysis.

Kinematic data was gathered via a 16-camera 3D motion capture system (Vicon Motion Systems, Oxford, UK). Kinetic data was acquired via four force platforms (AMTI, Watertown, MA) embedded in the laboratory floor. Sampling frequencies of 300 Hz and 1500 Hz were used for motion capture and force data, respectively.

The data was processed in Nexus v2.16 (16-marker plug-in-gait lower body model, Vicon Motion Systems, Oxford, UK). To estimate the effects of filter choice on joint moment peaks, a low-pass 4th order Butterworth filter was applied at two cutoff frequencies: 10 Hz and 15 Hz [1]. For the third condition, no filter was used at all ("raw"). In each case the filtering condition was the same for both motion and force data as this has been shown to reduce impact artefacts [1,2,3].

Statistical analyses and plotting were performed with IBM SPSS Statistics v.28 (Chicago IL, USA) and R Statistical Software (v4.4.1, R Core Team 2021). Repeated measures ANOVA with a Greenhouse-Geisser correction was used for hypothesis testing at an alpha level of 0.05. The Holm-Bonferroni method was utilized for post hoc pairwise comparisons.

Results and Discussion

There were statistically significant differences between filtering conditions for the knee and hip joints, whereas the ankle joint was unaffected (Fig. 1). Introducing a low-pass filter significantly decreased the peak joint moments of the knee and hip, and lowering the cutoff from 15 Hz to 10 Hz augmented this effect.

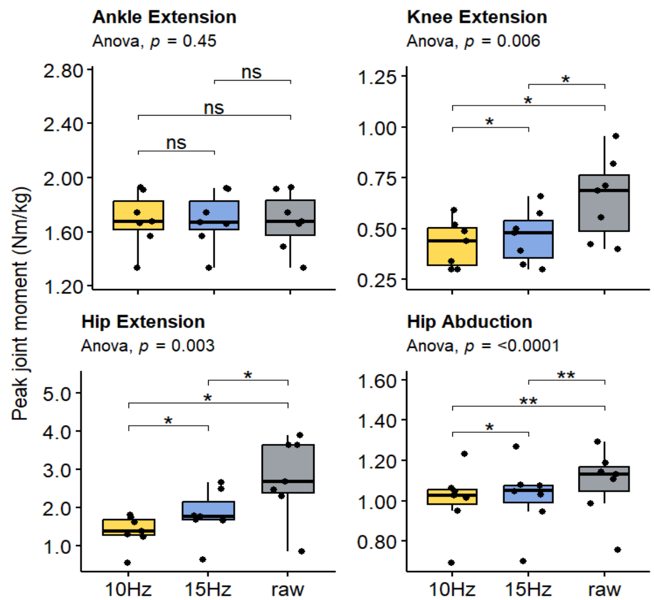

Figure 1: Peak joint moments in different filtering conditions.

These results are in accordance with existing literature, which has almost exclusively considered activities with higher impact forces [1,2,3]. Our findings thus suggest that the effects of altering the cutoff frequency apply similarly to even moderate forms of movement, such as walking. It is important for researchers to acknowledge that the choice of filter parameters can directly affect the way their gait data is later interpreted.

Conclusions

The current results indicate that the joint moments in more proximal joints are highly sensitive to impact artefacts, even during less dynamic activities like walking. Future studies are necessary to determine the filtering frequencies that provide physiologically relevant joint moments, especially at the hip joint.

References

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