Exploring the effect of varying transtibial prosthetic alignment on knee moment estimations in musculoskeletal models

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SUMMARY

Prosthetic alignment is an important step in prosthetic fitting, yet it is rarely varied in musculoskeletal models. This study aims to explore the effect of varying transtibial prosthetic alignment when customising musculoskeletal simulation models and its effect on knee moment estimations. Kinematic and kinetic data of overground running was captured for 7 unilateral transtibial prostheses users and used to scale two OpenSim model variations: (1) prosthetic alignment constrained; (2) prosthetic alignment unconstrained. The effect of allowing prosthetic alignment to vary on scaling and inverse kinematics accuracy was small (scaling: 1.3 mm; inverse kinematics: 0.17 mm). No significant differences were found between normalised knee joint moments time histories or peak knee moments. Individual variations coinciding with the largest offsets in alignment were observed, however, suggesting that prosthetic alignment should be considered when developing musculoskeletal models to simulate movement and understand individualised cause and effect.

INTRODUCTION

Previous research has investigated the biomechanics of transtibial prostheses users through 3D inverse musculoskeletal simulations [1]. However, prosthetic alignment has rarely been considered. In the clinical prosthetic fitting process, alignment is crucial and influences foot ground contact and movement patterns, such as knee adduction or abduction during the stance phase. The aim of this study is therefore to explore the effect of varying prosthetic alignment during the scaling process when customising musculoskeletal simulation models and to evaluate its effect on estimated knee joint moments.

METHODS

Kinematic and kinetic data of overground running was collected from 7 transtibial prostheses users [2]. A full-body OpenSim model [3] incorporating a 9-segment prosthetic foot was scaled to each participant for two model variations: (1) prosthetic alignment was constrained (unable to translate or rotate relative to the socket); (2) prosthetic alignment was unconstrained (free to translate and rotate relative to the socket), similar to how a prosthesis can be aligned in practice. Inverse kinematics (IK) and inverse dynamics were then performed within OpenSim, and the results were truncated to the stance phase. Variation differences in marker errors (scaling and IK processes) and normalised (to body mass) knee joint moment time histories were assessed using a paired t-test in SPM (spm1d.org). Peak knee moment differences were also compared via Bland-Altman plots [4].

RESULTS AND DISCUSSION

The effect of allowing prosthetic alignment to vary on the scaling and IK marker tracking error was on average 1.3 (±0.5) mm and 0.16 (±0.17) mm, respectively. These were considered too low for prosthetic alignment to be considered to influence the scaling or IK processes. No significant differences were observed in the normalized knee joint moment time histories (Figure 1) or peak knee moments. Individual variation, however, was observed between participants, ranging from very similar time histories to constant offsets. Interestingly, the largest deviations between time histories coincided with the largest offsets in alignment. This may suggest on average the effect is small, however, the effect for an individual user could be significant. Therefore, prosthetic alignment should be considered when developing individualised musculoskeletal models to simulate movement to understand cause and effect.

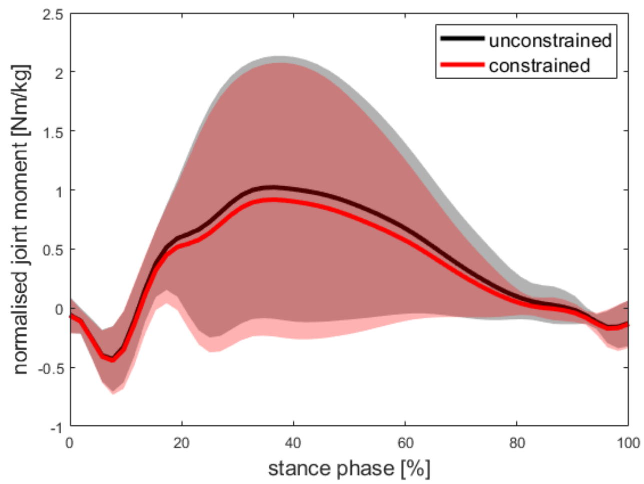

Figure 1: External knee flexion moment means and standard deviations for both model variations.

CONCLUSION

On average, the effect of prosthetic alignment on the scaling and IK processes, as well as knee joint moment estimations is small. However, the individual variations observed suggest incorporating prosthetic alignment should be considered when developing musculoskeletal models to simulate movement and understand individualised cause and effect.

REFERENCES

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