Verification of estimated secondary ankle joint kinematics using biplanar videoradiography

Barbara Postolka[1,2], Bryce A. Killen[1], David E. Williams[3], Ilse Jonkers[1]
[1]Human Movement Biomechanics Research Group, Dep. Movement Sciences, KU Leuven, Leuven, Belgium
[2]Functional Biomechanics Research Group, Dep. Biomedical Engineering, University of Basel, Basel, Switzerland
[3]Musculoskeletal Biomechanics Research Facility, School of Engineering, Cardiff University, Cardiff, United Kingdom
Email: barbara.postolka@kuleuven.be

Summary

Combining *in silico* musculoskeletal and articular contact models provides a unique opportunity to assess articular joint loading during motion. To verify a novel foot-ankle modelling workflow, estimated secondary ankle joint kinematics were compared against biplanar videoradiography beads-based kinematics. For one walking trial of one subject, plantar/dorsiflexion and eversion/inversion showed relatively good agreement, especially with respect to the rotational pattern. Despite smaller absolute differences, internal/external rotation, showed lower levels of agreement. Further work is needed to realign coordinate systems and verify joint loading.

Introduction

Knowledge of *in vivo* articular joint loading can provide information about joint contact stress and as such inform about onset and/or progression of pathological conditions such as osteoarthritis. However, articular joint loading can currently not be measured non-invasively *in vivo*. To overcome this, *in silico* musculoskeletal models combined with articular contact models can be used to simultaneous estimate joint kinematics, articular joint mechanics, and muscle/ligament forces during dynamic activities. Such workflows have been validated for the knee joint [1], but similar approaches are missing for the foot-ankle complex. Therefore, the aim of this work was to verify estimated secondary ankle joint kinematics against *in vivo* biplanar videoradiography (BVR) data.

Methods

A level walking trial was performed by one healthy male subject with tantalum bead implants (five in the distal tibia, four in the talus). Synchronised lower limb skin-marker trajectories (125 Hz), ground reaction forces (2000 Hz), and BVR (125 Hz, 1.25 ms pulse width, 80 kV, 160 mA) were recorded [2]. Location and orientation of the tibia and talus was reconstructed using gold standard bead-based 2D/3D registration. Ankle joint kinematics were calculated using anatomical coordinate system and Euler angles [3]. An extended foot-ankle model [4] was supplemented with a cartilage contact model between the tibia and talus [1,5]. The model was scaled to the dimensions of the participant and the Concurrent Optimization of Muscle Activations and Kinematics (COMAK) algorithm [1] was used to simultaneously estimate ankle joint kinematics (inversion/eversion, internal/external rotation), muscle forces as well as articular joint mechanics [1]. Absolute differences between estimated and measured ankle joint kinematics were calculated and wave forms compared for verification purposes.

Results and Discussion

Model-based ankle kinematics were estimated over full stance, beads-based kinematics covered ~87% of stance due to a smaller BVR field of view. Despite high absolute differences between frames, model and beads-based rotational patterns were relatively well aligned for plantar/dorsiflexion and eversion/inversion. Internal/external rotation showed smaller absolute differences but larger variation in rotational patterns, especially at the beginning of stance (Figure 1). Definition of anatomical coordinate systems varies between the two approaches, therefore differences in estimated and measured rotations are to be expected.

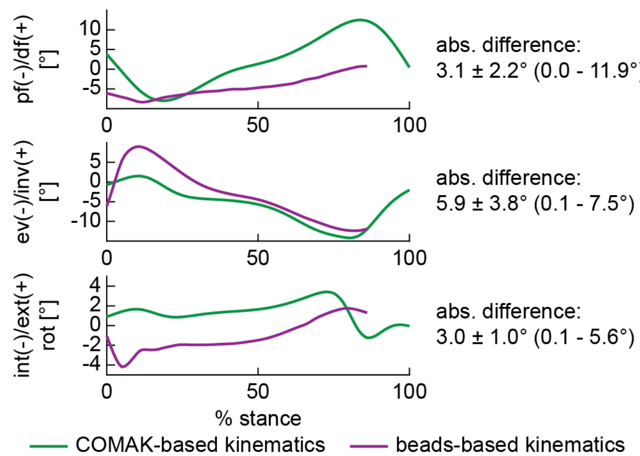

Figure 1: Ankle plantar/dorsiflexion (pf/df), eversion/inversion (ev/inv), and internal/external rotation (int/ext rot) during stance. Mean ± standard deviations as well as ranges of absolute differences are mentioned beside each figure.

Conclusions

The analysis provides an initial verification of our musculoskeletal modelling workflow. Further work is needed to refine anatomical coordinate system alignment and verify articular joint mechanics using *in vitro* data.

Acknowledgments

This work was supported by the Swiss National Science Foundation and the EPSRC Impact Accelerator Account.

References

[1] Smith CR et al. (2018). *CMBBE Imaging Vis*, **6**:491-498.
[2] Reddiough R et al. (2024). 30th ESB Congress.
[3] Peterson AC et al. (2023). *Front Bioeng Biotechnol*, **11**:1255464.
[4] Malaquias TM et al. (2017). *CMBBE*, **20**(2):153-159.
[5] Postolka B et al. (2024). *Gait Posture*; **112**:8-15.