The Challenge of Balancing Predictive and Personalized Simulations of Upright Standing

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Summary

Most forward dynamic simulations are based on generic models. In this paper, we investigate the influence of person-specific scaling as well as motion tracking on forward dynamic simulations of postural control. We detected comparable group characteristics between simulations and experimental data, however, individual biomechanical parameters were not always in exact accordance to corresponding experimental data. In the next steps, ideal input data must be investigated to create person-specific forward dynamic simulations while preserving a predictive nature.

Introduction

Forward dynamic simulations using neuromusculoskeletal human models can give insights into internal processes and help to deepen the understanding of specific movement tasks. Often, due to predictive nature of such simulations, the long-term goal is an application in rehabilitation settings to estimate influences of specific interventions. So far, most predictive simulations are based on generic models. However, to recommend interventions based on predictive simulations, it is essential to use person-specific simulations that can yield realistic and person-related simulation outcomes. Therefore, we aim to determine how forward dynamic simulations can be tailored to the movement behavior of individual persons. In this paper, we investigate the influence of person-specific scaling as well as additional motion tracking (MT) on forward dynamic simulation outcomes of postural control. We evaluate these simulations in the context of unperturbed upright standing tasks.

Methods

To simulate upright standing, we used a previously published neuromusculoskeletal model [1] and forward-dynamic simulations within the software SCONE [2] and Hyfydy [3]. We conducted simulations using scaled models based on motion capture data of 8 participants and an OpenSim-based person-specific scaling approach [4]. Additionally, MT was achieved by incorporating a tracking term into the model's cost function which was subsequently minimized.

$$J_{cost} = J_{prev} + \frac{1}{n}\sum_{i=1}^{n}\left(\theta_{sim,i} - \theta_{exp,i}\right)^2$$

J_{prev} represents the initial cost function based on [1], mainly optimizing muscular effort, supplemented by a mean squared error term for hip, knee, and ankle joint angles of simulation and experimental outcomes with fixed objective weightings.

We compared simulation results with motion capture data of the corresponding 8 healthy participants for evaluation.

Results and Discussion

We found that forward dynamic simulations using person-specific models still resulted in significant group differences in pelvis tilt and knee angles between simulations and experimental data. Simulations with additional MT showed comparable group characteristics, with no significant differences in all joint angle ranges of motion (ROMs) (Figure 1). However, person-specific simulations did not necessarily yield outcomes more comparable to the corresponding person's experimental data. Further investigation is needed to identify ideal input information for person-specific forward dynamic simulations of postural control.

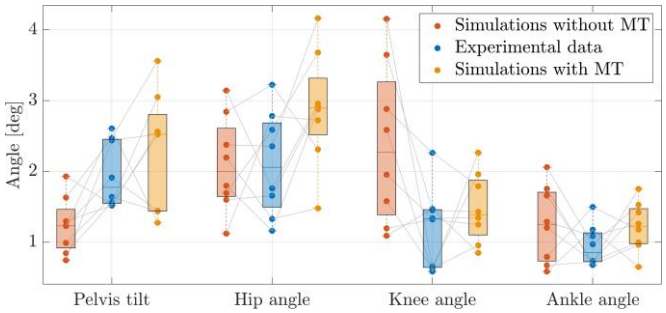

Figure 1: Comparison of experimental data and simulations with and without motion tracking (MT) for joint angles' ROMs.

Conclusions

We created simulation results comparable to experimental data. However, these results are applicable on a group rather than an individual basis. By fitting simulations to measurement data, person-specific internal parameters can be determined and considered for pre-post-comparisons. Next, it will be necessary to investigate the information required to ensure comparable forward dynamic simulations on an individual basis, including the effects of different weightings of the MT objective. Furthermore, the minimal input required to preserve the predictive nature of forward dynamic simulations needs to be determined.

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