Comparing different length-based scaling approaches using MRI: a Pilot Study

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Summary

Different methods have been proposed to scale musculoskeletal models based on gait or standing data, but so far, these have not been validated. Here, we compared two length-scaling approaches, the manual scaling approach in OpenSim [1] and the automatic scaling approach of AddBiomechanics [2], against a model scaled using magnetic resonance imaging (MRI) data. We found that both models showed similar results to the MRI-based scale model.

Introduction

Musculoskeletal (MSK) models can be used to estimate different biomechanical variables, such as joint angles, joint moments, and muscle forces, among others. The accuracy of these estimations depends on how well the MSK model represents the study participant. Image-based personalization, for example using MRI, is most accurate [3,4], but obtaining the images is expensive and time-consuming and cannot be applied to large populations.

Instead, MSK model lengths are normally personalized by scaling a generic model based on a reference pose or gait data and its inertial properties using the individual's body weight and the segment lengths. Scaling in OpenSim is based on a reference pose and predefined local marker positions [1]. However, an incorrect static pose, interdependency between scaling and marker registration, and user expertise make scaling time-consuming and its output operator-dependent. Instead, AddBiomechanics provides an automatic scaling approach based on gait data, which is independent of user expertise and faster [2]. However, neither method has been validated against an image-based personalization. Therefore, we compared a model scaled with OpenSim and one scaled with AddBiomechanics against a model scaled with MRI.

Methods

We conducted a pilot study with one participant. First, we recorded marker positions of 41 markers and ground reaction forces in a T-pose and while walking on a treadmill at three speed settings. We also created an MRI scan of both legs, in which the marker positions of 16 leg markers were recorded.

We generated three musculoskeletal models. To define our MRI-based model, we first segmented the MRI data using 3D Slicer to identify the bone tissue. Then, we identified the origin of the ankle, knee and hip coordinate system [5]. Using the coordinate systems, we defined the femur and tibia length as the Euclidean distance between the knee and hip coordinate system and the ankle and knee coordinate system, respectively, and the marker positions were adjusted accordingly. To define our OpenSim model, we scaled the generic Rajagopal model [6] in OpenSim using the T-pose. We also scaled the model in AddBiomechanics using the walking data to create the AddBio model.

To evaluate the models, we performed inverse kinematics on the walking trial at 1.2 m/s using each model. We compared the models using the root mean square error (RMSE) between the measured and virtual markers of the inverse kinematics. We compared the RMSE for the 16 leg markers separately and for all markers that were applied to the model for the OpenSim and AddBio model.

Table 1: Inverse Kinematics RMSE for the leg markers captured in the MRI and for all markers.

	AddBio	OpenSim	MRI-based
Leg markers	1.79 cm	1.59 cm	1.69 cm
All markers	1.80 cm	1.62 cm	-

Results and Discussion

When comparing the RMSE for the leg markers, we found that the RMSEs of both the AddBio model and the OpenSim model are similar to the RMSE of the MRI-based model (Table 1). Furthermore, the RMSE for all markers is also similar between the AddBio model and the OpenSim model. The remaining error that is found in the MRI-based model can be attributed to measurement error in the marker position. The similarity between the RMSE of all three models indicates that both OpenSim and AddBiomechanics are effectively able to reduce the modelling errors through model scaling.

Conclusions

We conclude that scaling with both AddBiomechanics and OpenSim effectively reduces the modelling error in inverse kinematics, as the resulting RMSEs are similar to that of the MRI-based model. We aim to extend our investigation by including more participants. Moreover, we are interested in extending our validation to include inverse dynamics and muscle force estimations as well.

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