Smartphone-based musculoskeletal model personalization – A proof of concept MRI validation study

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Summary

We present a method to personalize human musculoskeletal models based on smartphone images. A body hull is reconstructed from smartphone pictures taken from all directions. We then use existing models to estimate the location of bone, muscle, and fat tissue and estimate inertial parameters using their respective densities. We validated the parameter estimations using magnetic resonance imaging (MRI). Our inertial parameter estimations better match parameters estimated from MRI scan than state-of-the-art model personalization methods based on static or gait data.

Introduction

Correct body segment inertial parameters (BSIPs) are essential to estimate kinetic variables, such as joint moments and muscle forces, from movement data. Commonly, BSIPs are personalized using body height and segment lengths, based on parameters from cadaveric studies with limited diversity and vastly different values [1, 2]. Here, we propose a low-cost and accessible method to personalize BSIPs using a body hull created from smartphone images. We compared these body hull BSIPs to common personalization methods based on static or gait data, using MRI as a ground truth.

Methods

We recruited a single participant (F, 27 y, 167 cm, 64 kg). We recorded gait with an optical motion capture system and an instrumented treadmill. Additionally, we took pictures from all angles using a smartphone camera while the participant stood in a T-pose. Finally, a full-body MRI scan without arms was undertaken to provide ground-truth BSIPs.

Table 1: Mean absolute error (MAE) compared to MRI-based model of BSIPs derived from scaled musculoskeletal models ("scaled"), addBiomechanics ("addB") and the body hull ("phone").

	Segment Mass (rel. MAE [%])	Center of Mass (rel. MAE [%])	Moment of Inertia (rel. MAE [%])
scaled	33.2	33.7	35.0*
addB	33.6	33.5	35.7*
phone	**10.7**	**14.1**	**20.4**

*only first principal axis, the MAE around other axes was much higher

From the gait data, we created two state-of-the-art musculoskeletal models - one using OpenSim [3] scaling and one using addBiomechanics [4]. We reconstructed the body hull with estimated muscle and fat layers from the smartphone pictures using [5, 6] and subsequently segmented it using vertex correspondences from the SMPL [7] model. Then, we estimated mass, center of mass and moment of inertia for each foot, shank, and thigh, and the pelvis and torso combined.

We first annotated tissue density to each voxel in the MRI scan and then decompressed the body shape (see Fig. 1) [8]. Finally, we segmented the resulting volume and calculated BSIPs for each segment.

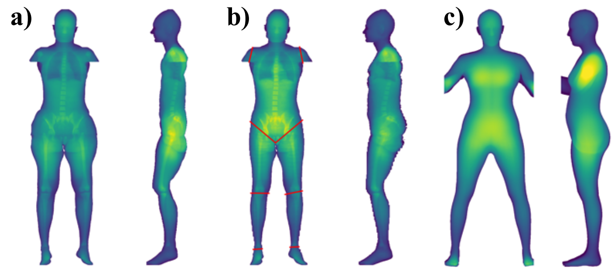

Figure 1: Frontal- and sagittal plane mass projections of a) the MRI scan, b) the decompressed MRI scan and c) the smartphone-based body hull. Yellow corresponds to higher mass, while blue corresponds to lower mass. Segmentations are annotated in b) (red).

Results and Discussion

The smartphone-derived body hull resembles the decompressed body hull (Fig. 1). For our study participant, the BSIPs estimated from this body hull are closer to the MRI ground truth than those estimated from gait data (Table 1). Taking the smartphone pictures took about 3 minutes and subsequent processing was completed in less than 40 minutes.

Conclusions and Outlook

We showed a promising new method for accessible BSIP personalization using body hulls estimated from smartphone pictures. The method is low-cost and easily applicable. We plan to validate the method on a larger cohort and additionally evaluate the influence of the estimated BSIPs on joint moments estimated using inverse dynamics or simulation.

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