DOES DIVERSITY IN MUSCULOSKELETAL MODELS MATTER?

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Introduction

Currently, musculoskeletal (MSK) models can be personalized by processing medical imaging data, like magnetic resonance imaging (MRI) or computerized tomography (CT), which is time-consuming and costly. In the absence of medical imaging, it is common to linearly scale (no deformations) a generic MSK model with male bone geometries to resemble an individual [1,2]. The aim of our project is to develop a pipeline to enable the creation of personalized musculoskeletal models from optical 3D body surface scans. This abstract shows preliminary data emphasizing the differences in anatomical bony landmarks, joint centres and muscle moment arms between a MSK model with personalized geometries and two linearly scaled generic models.

Methods

A healthy female participant (age 29) underwent a full-body MRI scan from which the skeleton was segmented. Additionally, we acquired an optical 3D body scan (Vitronic) of the participant wearing reflective markers for motion capture. We performed non-linear deformations to warp a generic MSK model [1] onto the segmented geometries by manually selecting bony landmark pairs between the meshes (software: OpenSim Creator). The fit was assessed through Hausdorff distance. The hip joint centre (HJC) of the warped model was defined at the centre of the femur head. The gluteus maximus muscle (GMAX1, GMAX2, GMAX3) was warped using bony landmarks at its attachment points as defined by the generic model. Additionally, we scaled the generic model using the general pipeline for (linear) scaling based on the HJC defined by: 1) a regression equation using pelvic bone landmarks [3] (scaled model 1), 2) MRI-based HJC (scaled model 2). For these models, the muscles were linearly scaled with the segment geometries. We compared the differences in geometry, HJC position, and muscle moment arms of GMAX1-3.

Results

The warped pelvis attained a good fit to the segmented MRI shape (mean Hausdorff distance = 0.13cm, max. distance = 0.95 cm) (Fig. 1A). The Euclidean distance between the HJC of the warped vs the scaled model 1 and 2 was 2.28 cm and 1.61 cm respectively. The warped model shows larger muscle moment arms for GMAX in hip flexion up to ~16%, and smaller in hip extension compared to the linearly scaled models (Fig. 1B).

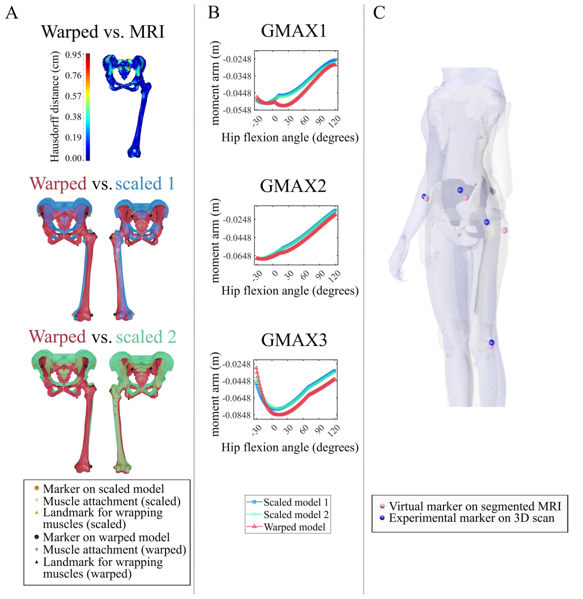

Figure 1:A: Hausdorff distance heatmap and visual comparison of the warped model and the scaled models. B: GMAX muscle moment arms. C: Overlay of the MRI segmentation with a 3D body scan.

Discussion

Comparison of linearly scaled vs. non-linearly warped MSK models underscores significant differences (over 15% moment arms and 2 cm landmark offsets), emphasizing the importance of personalized geometries for accurate simulations. Differences in muscle moment arms and HJC can be attributed to characteristic male and female differences in pelvic shape, with females generally having a larger and rounder pelvic cavity, a more posteriorly projected sacrum, a wider subpubic angle, and a larger distance between acetabula [4]. Additionally, differences in the surface body shape of individuals can introduce similar deviations into the modelling pipeline through errors in landmark palpation and marker registration onto the MSK model skeleton (Fig. 1C). These inaccuracies are subjective to differences in body shape due to gender and fat percentage. Our results draw attention to the importance of increasing the diversity of the sample populations used to generate MSK models and the relevance of non-linearly personalizing the models through an optimized pipeline.

References

1. Rajagopal et al, IEEE Trans. Biomed. Eng., 63:2068-2079, 2016.
2. Delp et al, IEEE Trans. Biomed. Eng., 37:757-767,1990.
3. Reed et al, SAE Tech. Pap., 01-0959, 1999.

Fischer et al, Anat. Rec., 300:698-705, 2017.