Effect of Pelvis Bone Geometry Personalization on Hip Kinematics and Moment Arms during Walking

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I. Introduction

Personalized models can represent musculoskeletal systems more accurately than generic models based on cadaver data in simulating gait movement [1]. We seek model personalization of pelvis as a potential way to address the research need of designing better treatment for pelvic sarcoma patients. Joint kinematics is an important aspect of movement and muscle length and moment arms are each the key component in force and joint moment generation respectively. Therefore, this study investigates the effect of personalizing a pelvis model on estimation of joint kinematics and muscle geometry.

II. Methodology

We collected motion capture (Vicon Corp., Oxford, UK), and ground reaction (Bertec Corp., Columbus, OH) data of a subject (male, mass 70 kg, age 48 years) walking on a instrumented split-belt treadmill at a self-selected speed of 1.2 m/s for more than 50 gait cycles.

We used a generic OpenSim musculoskeletal model [2, 3] as the base model to create two separate models to represent the subject. The first model was created using the OpenSim scaling tool. We named the first model as the scaled generic model. Additionally, we segmented the CT images of the subject in the pelvic region using software ITK-SNAP [4]. We then replaced the pelvis in the scaled generic model with the segmented pelvis. We updated the muscle attachment locations on the pelvis by registering published data of attachment locations onto the subject-specific pelvic model using affine transformation function of software NMSBuilder [1]. The two hip joint centers were also updated as the center of the two spheres that best fit the contour of the acetabular cups. We named this model as the personalized model.

We used OpenSim inverse kinematics tool to estimate the joint kinematics from experimental marker data. We used the OpenSim muscle analysis tool to obtain muscle geometric data such as muscle-tendon length (l_{MT}) and moment arms about joints for the estimated joint kinematics during gait. We performed the aforementioned analyses on both scaled generic and personalized model of the subject and compared the results to see the effect of geometric model personalization.

III. Results

Generic scaled model on average underestimated hip flexion, adduction, and external rotation angle by 4º, 1º, and 3º respectively compared to personalized model (Fig. 1A). The personalized model predicted lower l_{MT} for adductor and hamstring muscles. Moment arms about HipFE revealed large inconsistency between two models. Adductor magnus gained 8 mm while other adductor and hamstring muscles lost approximately 10 mm in moment arms (Fig. 1B).

IV. Conclusion

The discrepancy in estimated joint angles estimation and inconsistency in muscle moment arm prediction between the two models substantiated the need for personalization of musculoskeletal models. Future work would compare the dynamics between the two models and seek more ways to improve model personalization of the model. One way would be using statistical shape modeling to generate more accurate bone models than the scaled ones when medical image is absent.

Acknowledgment

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Reference

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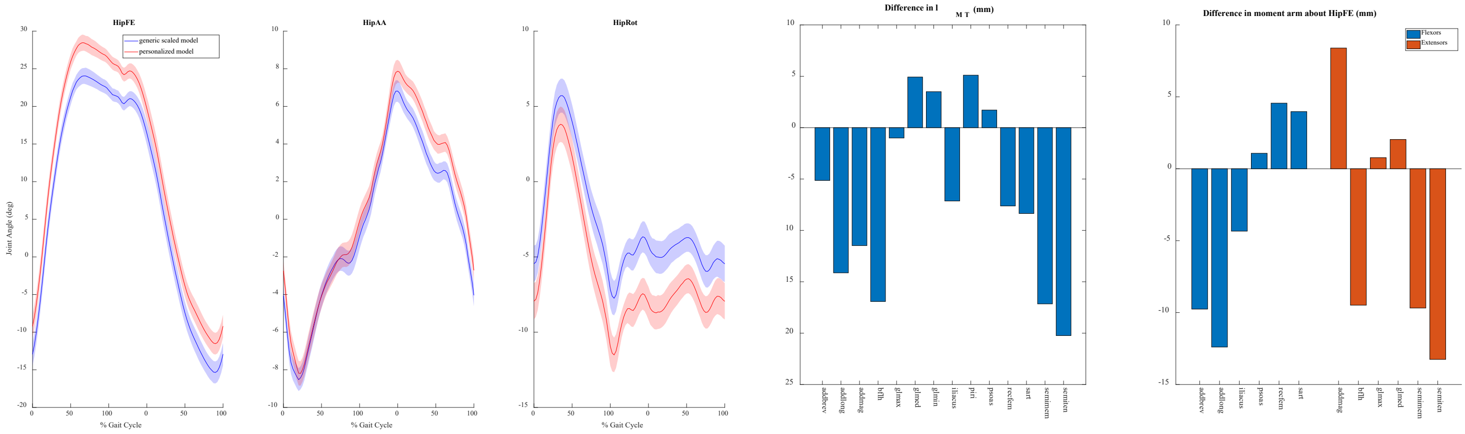

Fig. 1A: Hip joint angles estimated from two models; 1B: difference in muscle-tendon length and moment arms about HipFE for hip muscles, difference = results from personalized model – results from scaled generic model.