Joint Contact Forces Divide Generic and Personalized Morphologies

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Summary

Using a semi-automatic, segmentation-free pipeline, we create scaled generic and MRI-personalized models for eight participants. Our results show that generic models differ substantially from personalized models in morphology, which is also incidentally correlated with lower joint contact forces.

Introduction

Musculoskeletal simulation, mostly based on generic models, are increasingly used in medical and research applications. However, generic models fail to capture individual anatomical differences, e.g. differences in bony shape and consequently muscle lines-of-action. [1]. Recent approaches to model personalization have estimated muscle-tendon unit pathways using segmented muscle surfaces from 3D medical images [2] or optimization algorithms [3]. In this study, we propose a semi-automatic alternative that uses a Thin-Plate Spline (TPS) function and an MRI-based workflow, eliminating the need for bone or muscle segmentation.

Methods

We collected 3D motion capture data (marker trajectories and ground reaction forces) and MRI scans from eight healthy volunteers. A generic gait model [4] was scaled to each participant using OpenSim API. A reference set of 43 bone markers was placed on the pelvis, femur, and tibia in both the generic model and MRI scans. A bone-based TPS function was then used to map the muscle origin and via points into the MRI space. The estimated muscle locations were validated against MRIs and used for segment-wise rotation and translation to a standardized child coordinate system.

For each participant, both generic and personalized models were generated and analyzed using OpenSim API in Python. Joint angles, muscle forces and joint contact forces were estimated using inverse kinematics, static optimization, and joint reaction analysis, respectively. Peak joint contact forces at the right hip, knee, and ankle joint were used for further analysis

Results and Discussion

Generic models differ from personalised in their skeletal and muscle morphology so that the two groups do not overlap despite modelling same individuals (Fig.1A). The main differences between the groups are in the relatively wider ischiopubic arches, longer femora and relatively shorter tibia among the personalised models (Fig.2). The generic morphology strongly associates with lower joint reaction forces in the hip and knee joints (Fig.1B). Personalised models produce a larger variety of force with peak values for some individuals exceeding generalised versions by up to two body weights.

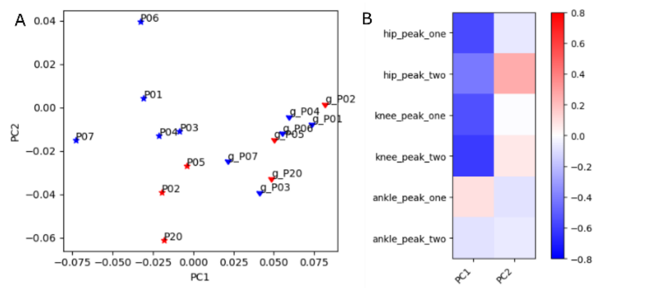

Figure 1. Analysis of morphology and joint forces. A. Principal component analysis of generic (triangle) and personalized (star) models. Males are in red; females are in blue. B. Correlation of the first two components with peak joint forces.

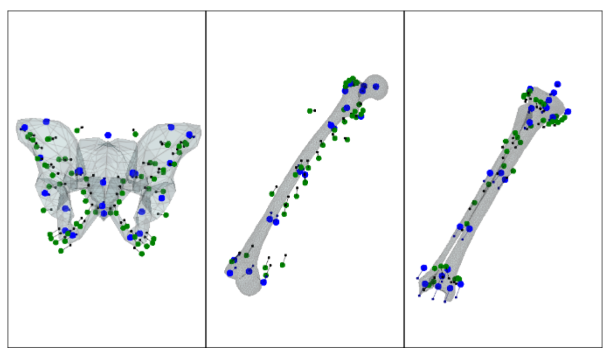

Figure 2. Bone and muscle morphology as captured by the first principal component. Grey shows generic scaled values. Colors show personalized values: muscle paths are in green, bone markers are in blue.

Conclusions

Medical image-based personalization should be used wherever possible to avoid potential inaccuracies in assessment.

Acknowledgments

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References

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