PERSONALISED GEOMETRIES IMPROVE KNEE JOINT CONTACT PREDICTIONS IN MUSCULOSKELETAL MODELS

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Summary

The effect of using personalised, rather than generic, musculoskeletal model (MSM) geometries on tibiofemoral (TF) joint contact pressure estimates was assessed with gold standard Biplane Video Radiography (BVR) outputs. Four healthy volunteers performed level gait whilst marker-based motion capture, force plate data, and BVR were captured. A personalised model was created by replacing contact geometries from a generic model with 3D geometries segmented from MRI scans. Contact pressures were estimated for both MSMs using OpenSim-JAM, with equivalent BVR contact maps generated using BVR-derived kinematics. Sørensen–Dice coefficients quantified the similarity between MSM and BVR contact maps. Results showed that personalised MSMs had higher mean Dice coefficients compared to generic MSMs, suggesting improved contact prediction.

Introduction

MSM estimates of contact pressure are highly dependent on articular contact geometry. Therefore, personalised geometry of contact surfaces is predicted to improve MSM estimations of contact pressure distribution. BVR is the gold standard for measuring accurate in-vivo kinematics [1] and can be used to investigate the accuracy of MSM pipelines [2].

Methods

Ethical approval was obtained (Wales Research and Ethics Committee), and 4 healthy volunteers (2M/2F, mean age 53 years, mean BMI 22.5 kg/m^2) provided written informed consent. Marker-based motion capture and force plate data were recorded with simultaneous BVR (60 FPS, 1.25 ms pulse width) during stance phase of level gait. Marker trajectories were tracked (Qualysis Track Manager), and a static trial used to scale a generic MSM [3]. Personalised models were created by replacing generic knee joint bone and cartilage geometries with segmented 3D geometries (Simpleware, ScanIP) from MRI (Magnetom 3T Prisma, Siemens), then muscle and ligament attachment points, paths, and tissue properties were optimised accordingly [4].

Opensim-JAM (https://github.com/clnsmith/opensim-jam) was used to calculate TF contact pressures for both MSMs (Figure 1a, b). Equivalent BVR contact maps were generated using elastic foundation theory [5] with BVR-derived kinematics and MRI cartilage geometries (Figure 1c).

Tibial plateau contact maps were projected into 2D binary images (defining pixels in contact), centred on the tibial origin. Sørensen–Dice coefficients, calculated as twice the shared ‘contact’ pixels divided by the total, quantified similarity between each MSM and BVR map (0 = no similarity, 1 = identical) across all frames for each participant.

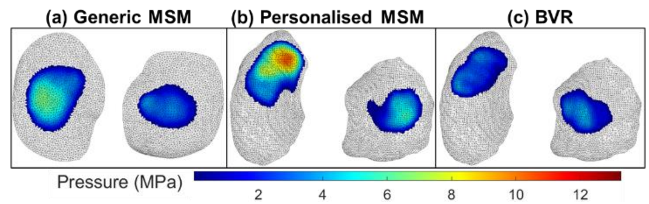

Figure 1: Example contact pressure maps from a single frame.

Results and Discussion

The mean Sørensen–Dice coefficient was higher for the personalised MSM than the generic MSM when compared to BVR images for all participants (Table 1), suggesting improved contact estimates with personalised TF geometries. Some participants had low Dice scores for both models, likely due to smaller contact regions in their BVR maps, which account for meniscus contact, whereas the MSMs do not.

Conclusions

Incorporating personalised geometries into the MSM increased similarity between MSM contact pressure maps, and those derived from BVR motion.

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References

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Table 1: Mean Sørensen–Dice coefficients for each healthy volunteer (HV) between MSMs and BVR contact maps.

	HV1		HV2		HV3		HV4	
	Generic	Personalised	Generic	Personalised	Generic	Personalised	Generic	Personalised
Mean Dice Coefficient	0.541	0.547	0.334	0.377	0.507	0.754	0.336	0.427