Investigating the Composition and Tissue Deformation During Simulated Prosthetic Loading of Intact and Trans-Tibial Residual Limbs

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BACKGROUND

Post-amputation, reconstructed tissues are not conditioned to tolerate loading experienced during activities of daily living, which can cause recurring damage[1]. Studies have examined the relationships between tissue damage and internal tissue strains, indicating that high strains can lead to muscle damage within 10 minutes[2]. To date there is limited understanding of how loading affects vulnerable residuum tissues during early prosthetic rehabilitation. MRI has demonstrated potential to observe morphology[3,4] and the response to simulated static prosthetic loading in participants without amputation[5].

AIM

This study aims to compare the morphology and biomechanical response of residual and contralateral limb tissues during representative prosthetic loading in people with trans-tibial amputation.

METHOD

Pressure was applied to the lower limbs of participants with unilateral trans-tibial amputation using a cuff inflated to 60 mmHg, representing that experienced using the Pneumatic Post-Amputation Mobility (PPAM) Aid[6]. 3D printed indenters were positioned underneath the cuff at three sites relevant to prosthetic load bearing, and the indenter-skin interface pressures were measured (Oxford Pressure Monitor II, Talley, UK). T1-weighted MR images acquired on a 3T MRI scanner (MAGNETOM Skyra, Siemens, Germany) were recorded at baseline and 60 mmHg to characterise direct tissue deformation[5] and visualise morphology[3,4].

RESULTS

Preliminary MRI data are presented for one female participant aged 46yrs (Fig1). At 60 mmHg cuff inflation, interface pressures ranged from 47-72 mmHg, representative of static PPAM Aid usage during early rehabilitation. The indenters generated gross compressive strains in the contralateral and residual limbs, respectively, of approximately 4% and 5% at the patellar tendon, 14% and 21% at the lateral calf, and 9% and 15% at the posterior calf. The contralateral limb, with a cross-sectional area of ≈40.1 cm^2, consisted of ≈12% superficial adipose tissue with <1% adipose infiltration of muscle tissue, compared to the residual limb with a cross-sectional area of ≈17.1 cm^2 consisting of ≈8% superficial and ≈7% infiltrated adipose tissue.

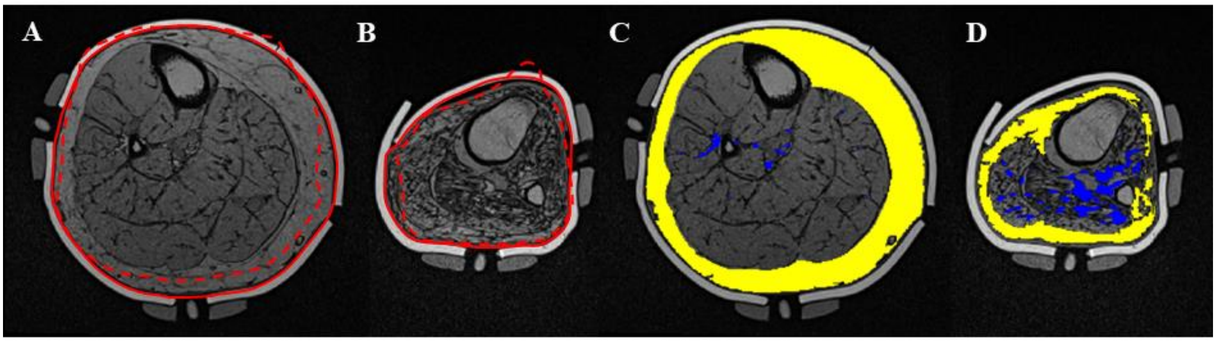

Figure 1 Corresponding transverse section MR images displaying one participant's intact (A & C) and residual limb (B & D) baseline, Note: red represents the limb outline at baseline (solid) and 60 mmHg cuff pressure (dashed), yellow represents superficial adipose mask and blue represents muscle infiltrating adipose mask

DISCUSSION AND CONCLUSION

MRI revealed marked soft tissue deformations at low representative pressures, greater than MRI resolution (0.6 mm). Significant adipose infiltration was observed in residual limb muscle tissue suggesting muscle atrophy post-amputation. The relatively low stiffness of adipose tissue would account for the increased deformation values. Investigation of morphology and deformation measurements in more participants will help to increase knowledge of adaptation post-amputation and inform techniques that could be used with individuals to reduce the risk of soft tissue damage.

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