Investigating the Physiological Effects on Dermal Tissues Following Simulated Prosthetic Loading in Intact and Trans-Tibial Residual Limbs

Bramley, J.L.[1], Worsley, P.R. [1], Bostan, L.[1], Bader, D.L.[1], Dickinson, A.S.[1]
[1] University of Southampton, UK

BACKGROUND

Post-amputation, reconstructed tissues are not conditioned to forces experienced during normal activity, potentially causing recurring damage[1]. Bioengineering tools enable physiological monitoring of loaded dermal tissues, including ischaemia and inflammation indicators[2]. However, a measurement array suitable for the distinct residuum-socket interface has not previously been reported, and understanding is limited regarding what constitutes safe loading protocols for early prosthetic rehabilitation. Ischaemia monitoring and inflammatory biomarker analysis have demonstrated potential to detect damage using a simulated skin-socket interface in intact limbs[3].

AIM

This study aims to establish an *in-vivo* protocol for assessing indicators of dermal tissue damage in residual and contralateral limbs representative prosthetic loading.

METHOD

Pressure was applied to both lower limbs of participants with unilateral trans-tibial amputation using a pressure cuff, inflated incrementally from 20-60 mmHg. These pressure magnitudes represent early prosthetic rehabilitation using the Pneumatic Post-Amputation Mobility (PPAM) Aid[4]. An array of measurements was applied at patellar tendon, lateral and posterior calf sites, including i) interface pressure (Oxford Pressure Monitor II, Talley, UK); ii) transcutaneous oxygen ($TcPO_2$) and carbon dioxide ($TcPCO_2$) tensions (Radiometer, Denmark) to characterise ischaemia[5]; and iii) sebum biomarkers, to assess inflammation.

RESULTS

Preliminary data are presented for one female participant aged 46yrs. Applied cuff pressure of 60 mmHg corresponded to measured interface pressures of 47-72 mmHg, representative of static PPAM Aid usage during early rehabilitation. These applied loads were shown to affect vasculature with greater than 25% reduction in $TcPO_2$ at all locations and increase in $TcPCO_2$ at the patellar tendons, indicative of an ischaemic response (Fig1).
The residual limb posterior calf was most tolerant to external loading. An ischaemic response was seen previously at 60 mmHg in 8/10 participants without amputation[3], and was observed in both of this participant's limbs despite long-term patellar tendon bearing prosthesis use on the amputated side.
At the time of writing inflammation markers were still under analysis.

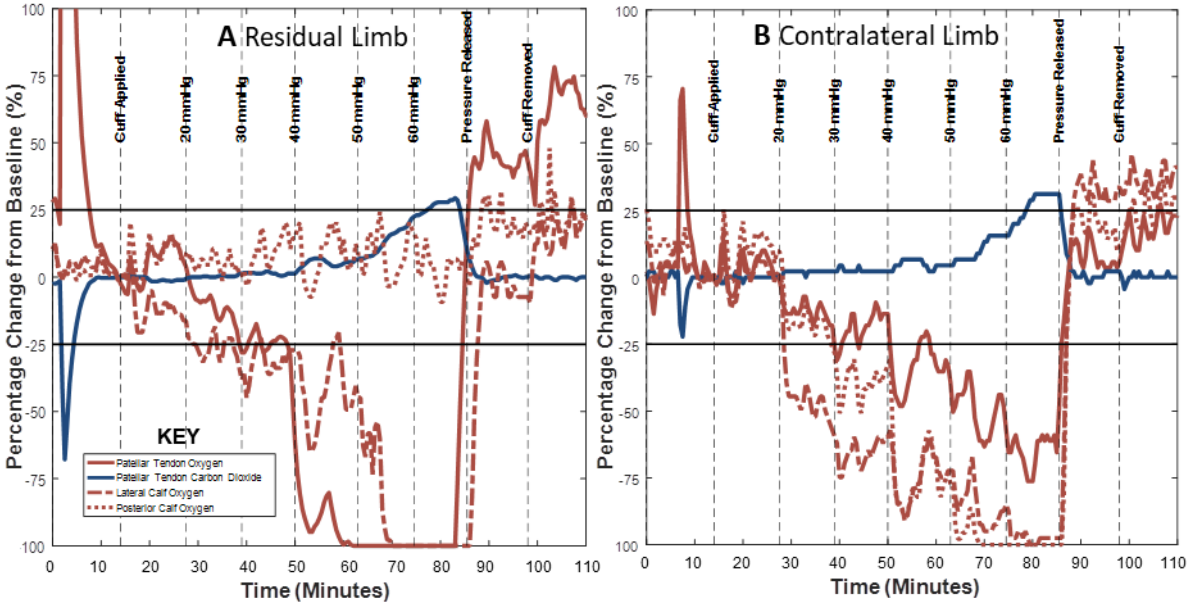

Figure 1 Transcutaneous Oxygen and Carbon Dioxide data for one participants' A: residual limb and B: contralateral limb calves under incremental cuff loading from 20-60 mmHg

DISCUSSION AND CONCLUSION

This work highlights the importance of load duration and relief, particularly during early prosthetic rehabilitation. Investigation of these measurements in more participants with consideration of cyclic loading will help to inform strategies that could be used in everyday life to minimise the risk of tissue damage.

REFERENCES

1. Meulenbelt; 2009, Arch.Phys.Med.Rehabil
2. Bader; 2018, Biomed.Eng.Online.
3. Bramley; 2018, ISPO UK ASM, Southampton
4. Scott; 2000, Prosthet.Orthot.Int.
5. Chai; 2013, J.Mech.Behav.Biomed.Mater.

ACKNOWLEDGEMENTS

Ethics: ERGO41864. Funders: EPSRC (EPN5097471, EPN02723X1), IfLS and RAEng (RF130).