Experimental Modelling of Viscoelastic Self-Heating in Healthy and Degenerate Bovine Intervertebral Discs

Dougill G[1], Reddy PN[1], Andrews K[1], Reeves ND[1], Le Maitre CL[2], Cooper G[3]
1 Manchester Metropolitan University. 2 Sheffield Hallam University. 3 University of Manchester.

Introduction

Degenerate intervertebral discs (IVD) have elevated levels of heat shock proteins (HSP), particularly within herniated tissue [1, 2]. A number of potential mechanisms for HSP upregulation exist but the exact mechanism(s) at play in the IVD are not known.

By artificially heating discs to 43°C for 20 minutes one potential mechanism, temperature, has been demonstrated to upregulate HSPs in IVDs [3]. Whether such temperatures are generated in the disc naturally has not been investigated.

The viscoelastic material behaviour of the IVD means that when the disc deforms under loading, some of the energy put in to the disc is dissipated as heat. If enough energy is dissipated it could induce temperature increases within the disc. This study aimed to investigate whether dynamic, cyclic loading typical of activities of daily living could result in sufficiently increased disc temperatures to upregulate HSPs.

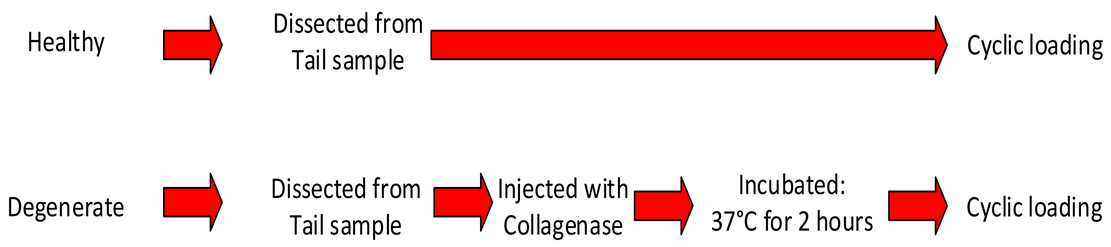

Figure 1 – Test procedure for healthy and degenerate test groups.

Methods

Bovine coccygeal discs were dissected whole from tail sections and split in to healthy and degenerate groups. Degenerate group discs received an injection of 2mg/ml collagenase/water solution and 2 hours incubation at 37°C so simulate degeneration. Healthy group discs were tested immediately following dissection.

All discs were cycled sinusoidally between 0.53 and 0.65 MPa at 2 Hz, simulating the load profile of human lumbar discs during walking [4].

Custom MatLab code was used to calculate the energy dissipated by discs during each load/unload cycle from mechanical test data.

Using the rate of energy dissipation and known thermal properties of the disc a simplified model of temperature within the disc was used to estimate potential temperature increases.

Results

Under loading, mean energy dissipation across all healthy discs was 4.13 mJs^{-1} and only 1.51 mJs^{-1} in degenerate discs.

Predicted temperatures within healthy discs achieved steady state after approximately 5 minutes and an increase of less than 0.045°C.

Lower energy dissipation in degenerate discs resulted in a longer time to steady state (approx. 15 minutes) and lower temperature increase (0.02°C).

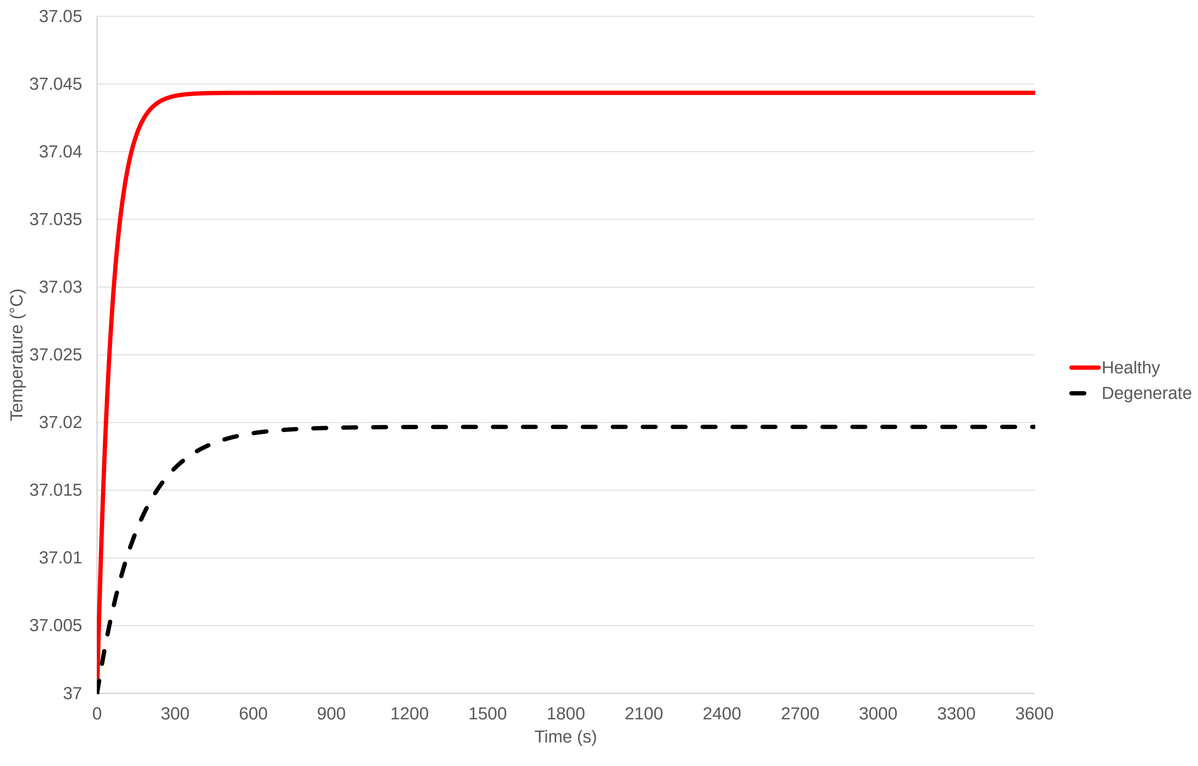

Figure 2 – Predicted temperature increase in discs over time.

Conclusions

Dynamic, cyclic loading simulating activities of daily living resulted in small (<5 mJs^{-1}) rates of energy dissipation that were larger in healthy discs than those which had undergone a degeneration phase.

The small predicted increases in temperature are far below those previously demonstrated to upregulate HSPs [3] and well within the normal range of core temperatures [5]. Meaningful increase in disc temperatures would require heavy and sustained loading well beyond that typical or even possible during activities of daily living.

Viscoelastic self-heating under loading is unlikely to be a factor in heat shock protein upregulation in the intervertebral disc.

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More Information

Contact the author for further information.

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