INVESTIGATING THE EFFECT OF REDUCED LOAD ON RAT ACHILLES TENDONS VISCOELASTIC PROPERTIES: A FINITE ELEMENT STUDY

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Introduction

The Achilles tendon (AT) is a mechanosensitive collagenous structure that adapts to its local mechanical environment [1]. For instance, changes in the loading cause alterations in the structural and compositional properties. However, the exact mechanisms remain unknown. Recently, *in-vivo* experiments were conducted to investigate the effect of reduced loading in AT properties by botox injection in combination with a metallic boot for 4 weeks [2].

In this study, we have developed finite element (FE) models based on data in [2] to understand the viscoelastic properties of the collagen network to investigate the adaptive mechanisms in AT due to reduced loading.

Methods

Two cylindrical FE models were generated in ABAQUS based on the average cross-sectional area (1.09±0.39 and 1.80±0.65 mm^2) and length (11.2±1.08 and 11.9 ±2.10 mm) of control tendons (fully loaded, FL) and unloaded tendons (UL), respectively [2]. The first part of the experimental mechanical protocol was mimicked, which included cyclic loading (6% strain, displacement rate 0.1 mm/s), followed by one step of stress relaxation (8% strain, displacement rate 1 mm/s).

The tendons were modelled using a fiber-reinforced poro-visco-hyperelastic model [3] with a transversely isotropic matrix [4]. The FL and UL models were fitted to the experimental data (reaction force vs time) and the R^2 was calculated to determine the quality of the fit (MATLAB 2022a).

Results

The FE models were able to capture the experimental behaviour of the FL and UL tendons for both cyclic loading (CL) and stress-relaxation (SR) separately (Fig. 1, Table 1). Overall, the UL model showed larger elastic energy and higher energy dissipation than the FL model based on higher E_1 and lower dampening η_0 (Table 1).

Model	E_1 [MPa]	E_2 [MPa]	k_1	k_2	η_0 [MPa·s]
CL FL	17.5	0.11	0.23	66.5	1053
CL UL	19.8	0.07	0.19	75.4	877
SR FL	45.0	0.18	0.83	37.5	2654
SR UL	53.1	0.19	0.67	34.8	2032

Table 1: Optimised parameters for cyclic loading (CL) and stress-relaxation (SR) for fully loaded (FL) and unloaded tendons (UL).

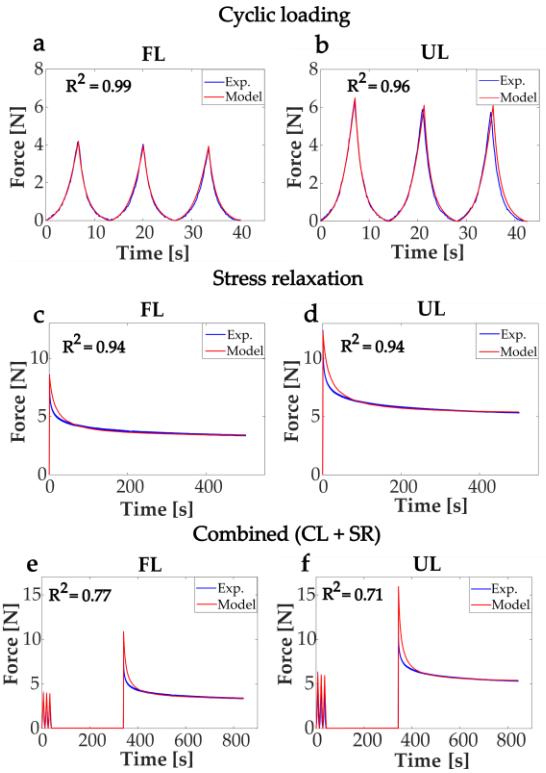

Figure 1: Optimised results for cyclic loading (a, b), stress-relaxation (c, d), combined protocol (e, f) for the fully loaded (FL) and unloaded (UL) model respectively.

Discussion

The main differences between optimised parameters for cyclic loading and stress-relaxation were increased time dependence for both models, with higher elastic energy (increased stiffness) and viscoelasticity seen for the UL model. Both models showed a better fit to the cyclic loading (Fig.1ab) compared to the stress-relaxation (Fig.1cd). For the combined protocol the models were able to capture peak forces but not the overall relaxation times (Fig.1ef). In the near future, mechanobiological models will be developed to predict adaptive processes in AT under reduced loading.

References

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