Nonlinear Viscoelastic Relaxation and Recovery of Porcine Flexor Tendon

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Soft biological tissues such as tendon are known to be viscoelastic[1,2]. Most research in this area focuses solely on relaxation[3] and creep[2,3] behavior after applied loading but neglect the recovery behavior after loads are removed. This study uses the porcine digital flexor tendons to study recovery following stress relaxation. It also studies stress relaxation at various levels of strain in order to check the ability of quasi-linear viscoelastic (QLV) to robustly model tendon recovery behavior.

Twenty porcine flexor tendons were carefully dissected. Ten were used to study recovery, and ten to study relaxation at various applied strains. Prior to testing, tendons were placed in PBS solution and mounted for testing. They were preloaded to 1N, preconditioned to 2% strain, and returned to preload for 1000 seconds prior to further testing. To study recovery, involved tendons being pulled to 2% strain, relaxing for 100 seconds, returned to preload for 1000 seconds, pulled to 6% strain for 100 seconds, then dropped to 2% strain to recover. To study relaxation at various strains, tendons were pulled to 1, 2, 3, 4, 5, and 6% strains relaxing for 100 seconds, with unloaded periods of 1000 seconds between each test.

Testing shows that recovery curves are fit well with a power law equation, but proceed at a much slower rate than relaxation. Initial recovery proceeds quickly, almost elastically, then slows dramatically, never reaching predicted levels within the time allotted for the experiment. Testing at various strain levels shows that stress relaxation proceeds more quickly at higher strains (e.g. 6%) than at lower strains (e.g. 2%). This nonlinearity cannot be modeled with QLV.

References:

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