

MECHANICAL RESPONSE OF TENDON SUBSEQUENT TO RAMP LOADING TO VARYING STRAINS

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INTRODUCTION

Acute strain and cumulative trauma injury to tendon are a growing clinical problem. While the pathophysiology following these injuries is complex, it is believed that loading of the tissue beyond specific mechanical limits (4% Strain) can cause irreversible damage to the extracellular matrix and the tendon's mechanical properties (Rigby et al., 1959). However, the methods used to characterize these limits may have adversely influenced the results. Recent studies applying subfailure stretches of 80% of the failure deformation to bone-ligament-bone complexes have shown little differences in mechanical properties (Panjabi et al., 1996).

In an effort to reexamine the results of classic tendon studies while utilizing current testing methodologies, the following study was carried out to characterize mechanical changes in avian flexor tendon with subfailure ramp loading to varying strain limits.

METHODS

Feet from unprocessed chickens were acquired from a local poultry processing plant, and the flexor *digitorum profundus* tendon was isolated from the middle toe. Tendons were clamped by liquid nitrogen fed cryo-clamps and mechanically loaded by a materials

testing system. Two black sutures were stitched transversely, approximately 13mm apart at the longitudinal center of the tendon for midsubstance strain analysis. The suture displacement was monitored by a video strain analysis (VSA) system and the grip displacement was monitored by a LVDT within the actuator of the Instron. The load level, monitored by a 250lb load cell, and the two displacements were collected simultaneously at 60Hz for all mechanical tests.

Mechanical testing was preceded by first pretensioning the tendon at 0.25N, then preconditioning with 10 cycles of a 0.5% strain haversine waveform. The specimens were again pretensioned, then taken to a predetermined grip strain-level (1,2,3,4,6,8,10,12&14) by a 1% strain/sec ramp. A subsequent -1% strain/sec ramp brought the tendon back to the original rest state, where it was wrapped in saline soaked gauze and allowed to rest for 5 minutes to recover from any viscoelastic effects.

After the rest period, the specimens were again pretensioned to 0.25N, and then taken to failure by the same 1% strain/sec ramp. From the paired strain-limited and failure ramp loadings, differences in mechanical properties were evaluated based on suture marker (midsubstance) strains, grip strains and load level.

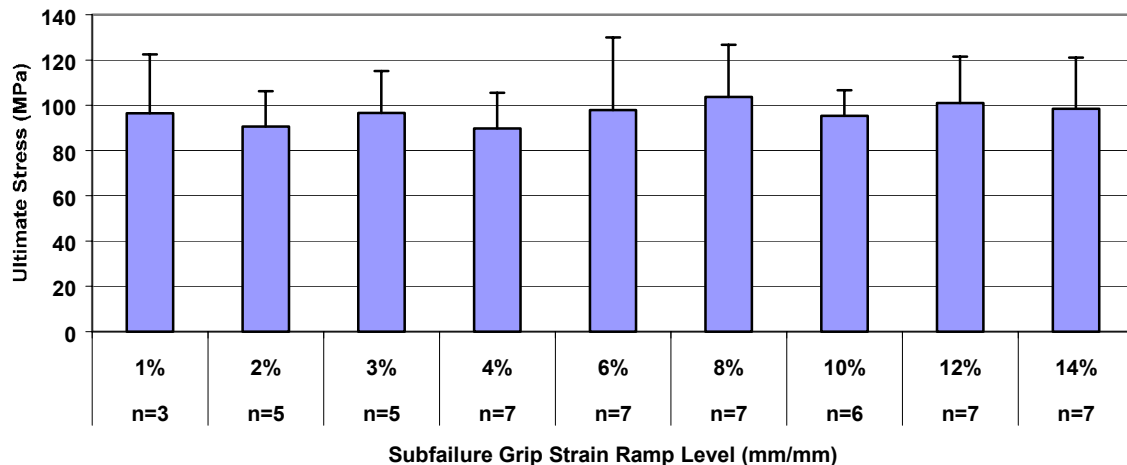


Figure 1: Average ultimate stress of tendons following various subfailure strain ramps.

RESULTS AND DISCUSSION

Varying the strain-limit of the subfailure ramp loading did not influence ($P>0.05$) the ultimate stress of the tendons (Fig 1). In addition, the elastic modulus based on midsubstance or grip strain was not found to differ ($P>0.05$) with the level of the strain-limit applied. The elastic modulus based on the midsubstance strain was found to be significantly stiffer than the modulus based on the grip strain ($P<0.05$). The midsubstance residual strain 5 minutes after each strain-limited subfailure ramp loading was not found to differ from zero ($P>0.05$), and this strain was not found to differ with the level of the strain-limit applied ($P>0.05$).

However, there was a minor change ($P<0.001$) in midsubstance strain between the strain-limited and failure ramp loadings when 10MPa of stress was applied, but this change in strain was not influenced by the level of the strain-limit applied. Neither the midsubstance and grip strain at failure (ultimate stress), nor the energy density at failure were influenced by the level of the strain-limit applied.

Overall averages at failure across all groups were 96.7 MPa for max stress, 16.4% for grip strain and 12.2% for midsubstance strain. One specimen did fail during the 14% ramp loading, and its data was discarded.

SUMMARY

In contrast to earlier reports, this study provides strong evidence that the basic tendon matrix displays an elastic response with minimal to no change in its mechanical properties when subjected to a single ramp loading to subfailure strain levels below 14%, and that tendon changes observed after such ramp loading *in vivo* may be due to the cellular response to load and not due to physical damage of the matrix.

REFERENCES

- Rigby, B.J. et al. (1959). *J General Physiology*, **43**, 265-283.
 Panjabi, M.M. et al. (1996). *J Orthop Res*, **14**, 216-22.

ACKNOWLEDGEMENTS

Whitaker Foundation Research Grant.