Surgically Repairing Achilles Tendon Ruptures Restores Plantar Flexor Function Better Than Non-Surgical Treatment in a Rat Model
My My Tang; Natalie Fogarty; Courtney Nuss; Todd J. Hullfish; Tejvir Khurana; Josh R. Baxter

Category: Basic Sciences/Biologics; Sports

Keywords: Achilles Tendon Rupture; Biomechanics; Achilles Tendon

Introduction/Purpose: Achilles tendon ruptures cause long-term functional deficits in nearly 2 out of 3 patients. Our group has established a complex muscle-tendon pathology following isolated Achilles tendon ruptures. Our long-term goal is to determine how rehabilitation loads can simultaneously accomplish 2 competing objectives: (1) prevent muscle remodeling while (2) not overloading the healing tendon that causes permanent tendon elongation - unloading the muscle and stimulating muscle remodeling. To do this, we developed a novel experimental framework to test the potential therapeutic effectiveness of different loading paradigms on the healing muscle-tendon following surgically induced Achilles tendon ruptures in an established rat model. We hypothesized that overloading the healing tendon would lead to worse functional outcomes compared to unloaded immobilization.

Methods: Achilles tendon rupture, repair, and immobilization. Male Sprague-Dawley rats underwent a surgically induced Achilles tendon rupture by blunt dissection followed by a modified Kessler repair in this IACUC approved study. The repaired limb was immobilized in either unloaded plantar flexion (n=7) to simulate the clinical standard of rehabilitative care or loaded dorsiflexion (n=5) to simulate clinically damaging rehabilitation. Structural analyses. Following 2 weeks of immobilization and 2 weeks of cage recovery, we sacrificed our study animals and measured tendon elongation and serial sarcomere count. Plantar flexor functional assessment. We developed an ankle dynamometer to quantify plantar flexor function that mirrored our clinical assessments in patients. To demonstrate the clinical relevance of this device, we tested 1 animal that was immobilized in unloaded plantar flexion for 1 week and 1 animal that was immobilized in loaded dorsiflexion for 1 week - both then completed 2 weeks of unrestricted cage activity.

Results: Muscle-tendon structural changes. Achilles tendon ruptures caused the tendon to heal in an elongated position with fewer sarcomeres in series (Fig. A). Tendon length increased by 73% following 2-weeks of loaded immobilization in dorsiflexion and 23% in unloaded immobilization in plantar flexion (p<.001). We measured sarcomere length in a subset of these animals but found similar trends in serial sarcomere reductions, where unloaded immobilization in plantar flexion caused 14% reduced serial sarcomeres (p<.01, n=4) and loaded immobilization in dorsiflexion caused 32% reduced serial sarcomeres (n=2). Plantar flexor function. Plantar flexor work was adversely impacted by the Achilles tendon ruptures (Fig. B). We found that unloaded immobilization in plantar flexion caused a 13% decrease in plantar flexor work with the detectable deficits occurring in ankle plantar flexion. Loaded immobilization in dorsiflexion caused greater plantar flexor work deficits (28%) with greater torque deficits in dorsiflexion and continuing through plantar flexion angles.

Conclusion: Our exciting experimental findings are the first of their kind to directly link muscle-tendon structural deficits with plantar flexor functional deficits in an animal model of Achilles tendon rupture using a clinically relevant ankle dynamometer. We established preliminary evidence that supports our overarching hypothesis that joint immobilization, whether unloaded or loaded, causes detrimental muscle-tendon structural changes that impose functional constraints on plantar flexor work. Our preliminary findings suggest that rehabilitation loading is critical to structural and functional outcomes following surgically repairing the Achilles tendon. Too little loading promotes muscle remodeling while too much loading elongates the healing tendon.
(A) Muscle-tendon structural changes following Achilles tendon rupture, repair, and immobilization. (B) Reduced planar flexor work following rupture.