THE INFLUENCE OF AGING ON THE MATERIAL PROPERTIES OF TENDON

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INTRODUCTION

Our lab studies the effect cyclic and static mechanical loads have on soft tissue. Specifically, we are interested in quantifying how material properties of tendon change during development and aging. We have shown that the tibialis anterior (TA) tendons of rats have varying material properties along their length, and when loading was removed by functional denervation, the entire tendon stiffened up and displayed homogeneous material properties [1]. It has previously been shown that there are age related changes in the musculoskeletal system, but very little data exist specifically on tendon. In order to examine the effects of aging on both the average end-to-end response and the heterogeneity of the response of old tendon, we compared local and average σ-ε responses of young and old rat TA tendon.

METHODS

The TA tendon unit (TA muscle, TA tendon, and the 5th metatarsal) was removed from young (8 months) and old (38 months) Fisher x Brown Norway F-1 Hybrid rats and stored in sterile PBS prior to determination of the stress vs. strain response curve. The cross-sectional area (CSA) of the tendon was determined by placing the specimen in DPBS and measuring the diameter at three 60° orientations and calculating the area of the ellipse described by these data. The optical stress-strain device consisted of an optical force transducer of our own design with a force resolution of 0.2 to 200 mN, two uniaxial servomotors controlled using LabVIEW, and a Basler digital video camera connected to a Nikon (SMZ800) dissecting microscope. Spots of tissue marking dye were placed at equal intervals along the length of the tendon to allow optical measurement of tissue displacement. The samples were loaded at a constant strain rate until failure and the synchronized force and image recordings were compiled using LabVIEW. The raw load vs. optical displacement data were converted to nominal stress (load/CSA) vs. nominal strain (change in separation of ink marks/initial separation). The (maximum) tangent stiffness was determined by calculating the secondary slope of the nominal stress vs. nominal strain data.

Hydroxyproline concentration was determined following the method of Woessner [2]. Constructs were dried at 110°C, weighed immediately then placed in 6 N HCl and hydrolyzed for 3 hours 130°C. After neutralizing to pH = 7 with NaOH, Chloramine T was then added, and the tubes were incubated for 20 minutes at room temperature. The chloramine T was inactivated by the addition of perchloric acid before adding an equal volume of Ehrlich's reagent. The tubes were incubated at 60°C for 20 minutes, cooled, and absorbance measured at 560 nm. Results were converted to collagen concentration by assuming hydroxyproline accounts for 13.8% of the dry weight of collagen.

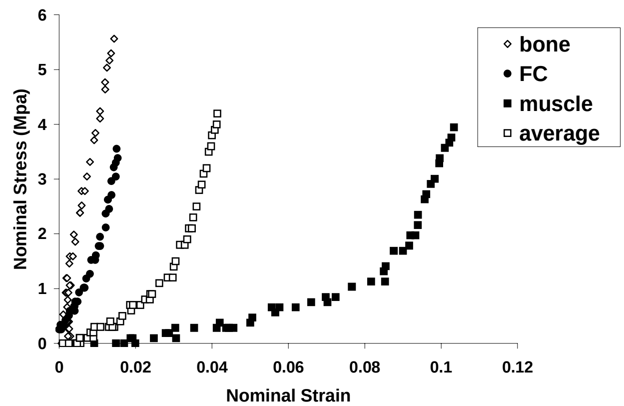

Figure 1: The young TA tendon displays heterogeneous material properties across the different regions of tendon. Bone = region closest to osteotendinous junction, FC= fibrocartilage region, Muscle = region closest to myotendinous junction.

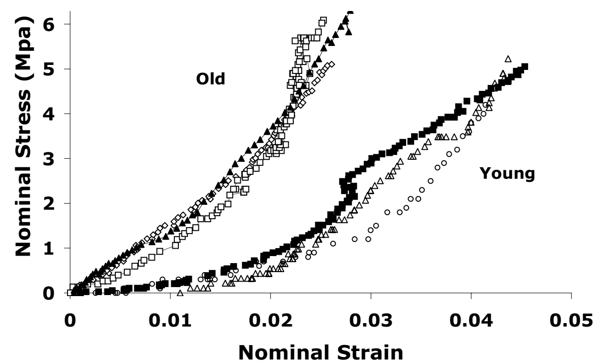

Figure 2: The stress-optical strain response reveals that the TA tendon becomes stiffer and less compliant in old rats.

RESULTS AND DISCUSSION

The old tendons maintained the graded mechanical response previously recorded for young adult TA tendon (Figure 1), but there was a significant reduction in the length of the toe region and an increase in tendon stiffness (Figure 2). The maximum tangent modulus increased from 195 +/- 36 MPa at 8 months to 461 +/- 193 MPa at 38 months. Interestingly, the collagen concentration did not change as the animal aged (data not shown). This pronounced extensibility of the tendon region nearest the muscle is presumed to protect the muscle fibers from injury. The loss in tendon extensibility with aging may partially explain the increased incidence of both muscle and tendon injury with aging [3].

REFERENCES

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