# Aging Related Degenerative Mechanical Changes Manifest Earlier in Supraspinatus Tendons

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## Introduction:

Rotator cuff tendinopathy is a common condition affecting a large portion of the population and can result in pain and joint dysfunction. Advancing age is directly correlated with increased incidence of rotator cuff pathology, with over 90% involving injury to the supraspinatus tendon specifically.[1-4] However, the mechanism(s) by which tendon-specific changes with aging may predispose the supraspinatus to injury relative to the other rotator cuff tendons is unclear.[5] Therefore, the objective of this study was to define the age-related mechanical alterations in all four rotator cuff tendons to determine whether the supraspinatus is more susceptible to injury due to aging than the other rotator cuff tendons. We hypothesized that aging would preferentially affect supraspinatus tendon mechanics when compared to the subscapularis, infraspinatus and teres minor.

## Methods:

Experimental design and sample preparation: 7-month juvenile (n = 7-10), 18-month adult (n = 7-10), and 27-month old (n = 7-10) male F344XBN rats were obtained from the National Institute of Aging (IACUC approved). After 3 weeks of facility acclimation, all animals were sacrificed. Lower and upper subscapularis (LS & US, respectively), supraspinatus(SS), infraspinatus(IS), and teres minor (TM), muscle-tendon complexes were then each carefully dissected from the scapula of the right shoulder and removed with the proximal humerus for mechanical testing.[7] Muscle, along with extraneous tissue was removed from each tendon and cross-sectional area of each tendon was measured using a custom laser device.[8] Each humerus was potted in a custom acrylic cylinder secured with polymethyl-methacrylate, leaving the proximal humerus exposed. The head of the humerus was secured using a self-tapping screw to prevent failure at the growth plate. Mechanicaltesting: The LS, US, SS, IS,and TM from each animal were mechanically tested independently on an InstronElectroPuls E3000. The testing protocol consisted of a 0.1N preload, preconditioning (30 cycles, 0.125% to 0.375% strain, 0.25 Hz), stress relaxation at 3% strain magnitude for 600s, frequency sweep at 3% strain(+/−0.1875% strain at 0.1Hz, 1.0Hz, 2.0Hz, and 10.0Hz),stress relaxation at 6% strain magnitude for 600s, frequency sweep at 6% strain(+/− 0.1875% strain at 0.1Hz, 1.0Hz, 2.0Hz, and 10.0Hz), 300s rest at 0% strain, and a ramp to failure at 0.15% strain/second. Tendon toe and linear stiffness was calculated using a bilinear fit. Insertion site linear modulus was determined via optical tracking of stain lines at the insertion site. A 1-way ANOVA with Bonferroni post-hoc tests was used to compare the different ages for each tendon with significance set to $p < 0.05$.

## Results:

There were no significant differences in cross-sectional area between any tendons across all age groups(data not shown). There was a significant decrease in percent relaxation at 3% strain between SS juvenile and adult groups, as well as IS juvenile to adult, and juvenile to old

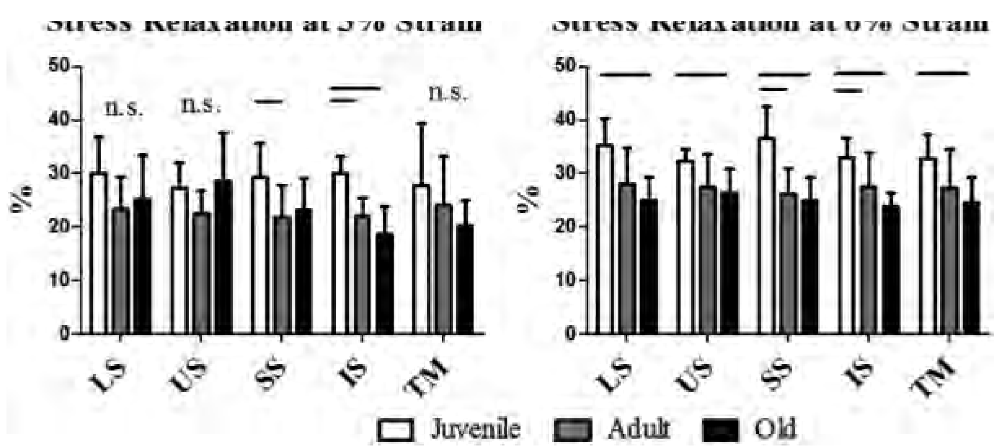


**Figure 1.** Percent relaxation of SS and IS is decreased at (**A**) 3% and (**B**) 6% strain between juvenile and adult. Percent relaxation of all tendons is decreased at (**B**) 6% strain from juvenile to old.

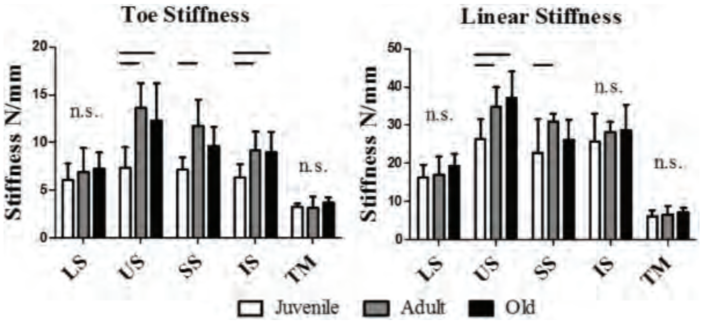


**Figure 2.** Toe **(A)** region stiffness increased in US, SS, and IS with age. Linear (**B**) stiffness also increased in US and SS with age.

(Figure 1). A significant decrease in percent relaxation at 6% strain was detected in all tendons between juvenile and old animals, and the SS and IS from juvenile to adult as well (Figure 1). Toe stiffness of the US, SS, and IS was increased from juvenile to adult animals, and from juvenile to old animals in the US and IS (Figure 2). Linear stiffness also increased in US and SS juvenile to adult, and US juvenile to old (Figure 2). No differences in insertion site modulus were observed for any of the tendons across age (Figure 3).

## Discussion:

This study defines the effect of aging on the mechanical properties of the subscapularis, supraspinatus, infraspinatus, and teres minor tendons of the rotator cuff in a rat model. Supraspinatus structural properties (toe and linear stiffness) and its viscoelastic response (stress relaxation) displayed degenerative changes earlier in the aging process with consistent differences between juvenile and adult ages. These earlier changes were also observed in the upper subscapularis and infraspinatus, but not as consistently across properties. Surprisingly, these changes were not exacerbated further into old age, with no differences between the adult and old group in any of the tendons for any of the properties examined. Previous studies reported a steady and dramatic increase in supraspinatus tears in the aging human population.[1-4] Results from the animal model presented here demonstrate that supraspinatus tendon health is consistently affected earlier in the aging cycle, which may predispose the supraspinatus to injury due to other factors not present in this study such as overuse, high cholesterol, and diabetes.[9-11] Future studies will investigate the effect of aging on the healing response of the supraspinatus compared to the other rotator cuff tendons.

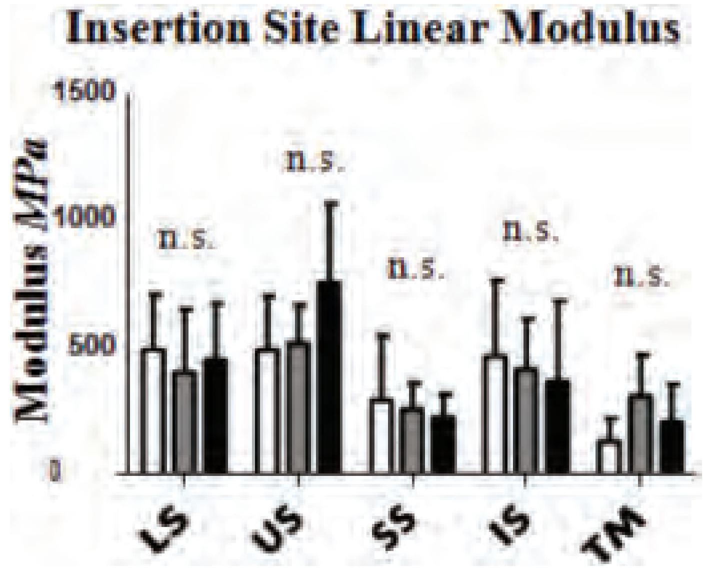


**Figure 3.** Insertion site linear modulus showed no changes.

## Significance:

This study highlights that supraspinatus degeneration initiates early in the aging cycle. These findings could potentially guide timely preventative therapeutic interventions to arrest the continued degeneration of this important rotator cuff tendon.

## Acknowledgement:

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