INTRODUCTION: Rotator cuff tendon tears are common conditions which can alter the mechanics of the shoulder joint and cause significant damage to joint tissues such as cartilage and other tendons. The mechanism by which this joint damage occurs is poorly understood and clinicians advise patients on conservative versus operative treatment without clearly understanding the potentially damaging effects on these important tissues. We have shown that a return to overuse activity following an isolated supraspinatus rotator cuff tear without repair decreased biceps tendon mechanical properties without altering joint function [1], consistent with an intact anterior-posterior force balance as described [2]. However, the effect of return to overuse on the adjacent (intact) rotator cuff tendons and the glenoid cartilage is unknown. Therefore, the objective of this study was to investigate the mechanical effects induced by a return to overuse following a supraspinatus rotator cuff tear on the infraspinatus and subscapularis tendons, as well as on the glenoid cartilage. We hypothesized that (H1) the remaining perforated tendons and (H2) the superior region of the glenoid articular cartilage would have inferior mechanical properties as a result of the excessive loading due to overuse following supraspinatus tear.

METHODS: Experimental Design and Sample Preparation: Following a two week training period, 20 adult male Sprague-Dawley rats (400-450 grams) underwent 4 weeks of overuse activity (downhill (10 deg) treadmill running at 17 m/min for 1 hr/day, 5 days/wk [3]) prior to unilateral detachment of the supraspinatus tendon in the left shoulder (IACUC approved). Animals were then randomized into cage activity or continued overuse experimental groups. The overuse group was gradually returned to their overuse protocol over a period of 3 weeks, followed by an additional 5 weeks of overuse activity. All rats were sacrificed 8 weeks after detachments and frozen. At the time of testing, the animals were thawed and the scapula and humerus were dissected out with the biceps, infraspinatus and subscapularis tendons intact.

Tendon Mechanical Testing: Stain lines, for local optical strain measurement, were placed on the infraspinatus and upper and lower bands of the subscapularis tendons[4]. Cross sectional area was measured using a custom laser device. To determine biomechanical properties, tensile testing of the tendon was performed as follows: preconditioning, stretching the tendon to 5% strain at a rate of 0.4 mm/sec (5 %/sec) for 600 sec, and ramp to failure at 0.3%/sec.

Cartilage Thickness Measurement: The scapula was secured in a fixture and immersed in PBS containing a protease inhibitor cocktail (5 mM Benz-HCl, 1mM PMSF, 1 M NEM) at room temperature. Specimens were scanned at 0.25 mm increments using a 55 MHz ultrasound probe (Visualsonics, Inc) in plane with the scapula. Captured B-mode images of each scan were segmented and combined using the software and bony surfaces. The 3D positions of these surfaces were reconstructed and used to determine cartilage thickness maps. Each thickness map was divided into six regions (center (C), postero-superior (PS), postero-inferior (PI), antero-superior (AS), antero-inferior (AI), and superior (SI)) and an average thickness was computed for each region.

Cartilage Mechanical Testing: Utilizing a 0.5 mm diameter, non-porous silicon indenter tip, cartilage indentation testing was performed as follows: preload (0.005 N), 8 step-wise stress relaxation tests (8 um ramp at 2 um/s followed by a 300 s hold). The scapula was repositioned for each localized region using angular, rotational, and linear stages such that the indenter tip was perpendicular to the cartilage surface in each region. Equilibrium elastic modulus was calculated, as described [5], at 20% indentation and assuming Poisson’s ratio (\(\nu=0.30\)).

Statistics: For tendon and cartilage mechanics, significance was assessed using a t-test. For cartilage thickness, significance was assessed using a Mann Whitney test (significance at p <0.05, trends at p < 0.1).

RESULTS: Following return to overuse, no differences in area or linear elastic modulus were observed in any tendon (Fig 1). Unexpectedly, glenoid cartilage equilibrium elastic modulus was greater in the superior region and both inferior regions (anterior and posterior) (Fig 2, RIGHT). In addition, a trend towards decreased cartilage thickness was observed in the center and both inferior regions (anterior and posterior) (Fig 2, LEFT).

DISCUSSION: Results of this study demonstrate that overuse, in the absence of disruption of the anterior-posterior force balance, leads to alterations in glenoid articular cartilage (in the superior and inferior regions) without altering adjacent (intact) rotator cuff tendons.

Glenomueral joint stability is aided by an anterior-posterior balance of the subscapularis and infraspinatus rotator cuff forces. Clinically, a supraspinatus only tear may not disrupt the normal balance of forces at the joint, allowing for concentric rotation of the humeral head on the glenoid. However, with a return to overuse activity following the tear, the absence of the supraspinatus abduction torque may require an increase in force generation, specifically compensation by the deltoid muscle. This may result in superior translation of the humeral head, altering superior-inferior loading of the glenoid and resulting in cartilage alterations localized to these regions. Specifically, altered loading (due to joint instability) and excessive loading (due to overload or overuse) have both been implicated as causative factors for the initiation and progression of osteoarthritis [6].

In our previous studies with this animal model, we have suggested that patients returning to a high level of use following an isolated supraspinatus tear may place the joint at a higher risk for cartilage injury.

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Figure 1: Return to overuse activity following supraspinatus tendon tear does not alter adjacent intact tendons (mean±SD) (*p<0.05, +p<0.1) (INFRA= infraspinatus, SUB=subscapularis).

Figure 2: Decreased cartilage thickness in the center (C) and inferior regions (AI and PI) and increased modulus in the superior (S) and inferior regions (AI and PI) of the glenoid were observed following a return to overuse (mean±SD) (*p<0.05, +p<0.1).