INTRODUCTION
Rotator cuff tears present a significant problem with greater than 50% incidence in patients older than 50 after a traumatic event [1]. Treatment strategies for rotator cuff tears remain controversial. Initial treatment with physical therapy has a high failure rate (25-50%). [2] One factor that could have implications for failure of physical therapy is tear size. Thus, a cadaver model of a small traumatic supraspinatus tear was created to assess whether physical therapy could cause potential propagation of a tendon tear. The objective of this study was to determine the magnitude of cyclic loading required to cause a critical-size tear of the supraspinatus tendon. Because of high failure rates of physical therapy treatments, it was hypothesized that tear propagation would occur during loads predicted in the supraspinatus during daily activities or physical therapy.

METHODS
Thirteen fresh-frozen, cadaveric glenohumeral joints (age 42-78 years) were dissected to the humerus-rotator cuff cuff complex. The humerus was potted in epoxy putty and tendon clamps were attached to the supraspinatus and infraspinatus tendons. Each specimen was mounted in a materials testing machine (Instron, Model 4502) to simulate 90° of glenohumeral abduction. The supraspinatus tendon clamp was attached to the crosshead and the infraspinatus clamp was attached to a constant 22 N load over a pulley system.

A preload of 50 N was applied to the supraspinatus tendon. Preconditioning of the intact tendon was performed by applying 50 to 100 N of loading for 100 cycles at a rate of 20 mm/min. (Figure 1) After again applying the preload, a full-thickness rotator cuff tear was created by sharply incising the central third of the supraspinatus tendon through the full thickness at its insertion to the greater tuberosity. Cyclic loading levels were applied starting from 50 to 100 N for 100 cycles. Once the cycle was complete, the maximum load was increased by 100 N increments until the critical tear size (2cm) in the lateral to medial direction was achieved.

Between each set of loading cycles, the preload was reapplied and digital images were obtained. Tear size was calculated using Image J software (NIH). The amount of elongation of the bone-tendon complex due to each cyclic loading set was evaluated at 50N by recording the difference in extension from the initial preload before the preconditioning cycle. Load-elongation curves during each loading cycle were also examined to characterize the behavior of the tendon and to assess if tissue damage had occurred. Paired t-tests were used to evaluate the area of each tear and preload extension between loading cycle. Significance was set at p<0.05.

RESULTS
After image and load-elongation analysis, the critical tear size was found to occur at 748±210N. However, the area of the tear did not show clinically significant changes (14±4mm² at the initial tear) until the last set of loading cycles (8±5cycles). During the last set of loading cycles, the area of the supraspinatus tear propagated to 102±75mm². Prior to critical failure, seven shoulders showed microstructural damage to the tendon based on the load-elongation curve. (Figure 2) Of the 7 shoulders that experienced microstructural damage in the load-elongation curve, the damage occurred at 529 ± 150 N, or 2 ± 1 level of cyclic loading before the critical tear size was achieved.

DISCUSSION
This study examined the response of the supraspinatus tendon with a small traumatic tear during increasing levels of cyclic loading. No macroscopic evidence of tear propagation occurred until the tear progressed to its critical size during the last set of loading (748±210N), disproving the hypothesis under study. However, mechanical testing revealed that intra-substance disruption occurred before the macroscopic failure as evidenced by the irregular loading pattern in the load-elongation curves. This damage did not have significant impact on the tear size as evidenced by the images obtained and analyzed but does signal irreversible damage to the tendon.

The supraspinatus tendon was also able to withstand high magnitudes of loads even with a small traumatic tear. These magnitudes of loads are higher than those loads predicted during normal shoulder motions such as abduction and internal and external rotation. [3, 4] Thus, supraspinatus tendons with a full-thickness tear in the central third of its insertion site might be able to withstand the loading experienced during activities of daily living and physical therapy. These findings might allow treatment protocols to be modified for these types of tears. Future studies will examine the effect of tear size and location on glenohumeral kinematics and clinical outcome.

SIGNIFICANCE
The results of this study may help in guiding treatment protocols for small, traumatic, full thickness rotator cuff tears.

REFERENCES:

ACKNOWLEDGEMENTS
Support from the Swanson School of Engineering and Department of Orthopaedic Surgery is gratefully acknowledged.