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THE EFFECT OF A ROTATOR CUFF TEAR ON MUSCLE VOLUME, FATTY INFILTRATION, AND STRENGTH AND THEIR RELATIONSHIP IN OLDER ADULTS

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SUMMARY

Rotator cuff tears are a common injury in the older adult population. However, many of the consequences of this injury - including muscle atrophy, fatty infiltration, and reduced strength - are also associated with healthy aging. In this study, we used a case-control design to evaluate differences between older adults with and without a rotator cuff tear. We evaluated muscle volume, intramuscular fat volume, and % of intramuscular fat of the rotator cuff muscles and measured strength for the 6 functional groups for 3 degrees of freedom at the shoulder. Older adults with a rotator cuff tear demonstrated reduced muscle volume and a greater % of intramuscular fat compared to healthy controls. Subjects with a rotator cuff tear also maintained a linear relationship between joint moment and muscle volume which was consistent with that seen for controls. We conclude that measurements of muscle volume and the % of intramuscular fat are affected by rotator cuff tear in this group and may have implications for function that should be explored.

INTRODUCTION

It is estimated that 20-50% of older adults (age$\geq$60yrs) are affected by a rotator cuff tear [1]. A rotator cuff tear causes changes to the musculature, including atrophy, increased intramuscular fat (fatty infiltration), and reduced strength [1,2]. However, these changes are also consequences of healthy aging [3], and thus can be difficult to attribute to rotator cuff injury in this group. Muscle volume and strength in the upper limb of older adults have been described previously [4], but quantitative descriptions of volume and strength following this common injury have not been described. Understanding these relationships will clarify the biomechanical underpinnings of function in this group, and facilitate the development of computational models to further explore upper limb functional task performance and the role of movement compensation in this population.

METHODS

Twelve older adults (6M, 6F, mean age 64±1.6yrs) participated; 6 with a degenerative, full-thickness tear of the supraspinatus and 6 age- and gender-matched controls. Subjects were imaged supine with either a 1.5T (GE Healthcare, Milwaukee, WI) or 3T (Siemens Medical Solutions USA, Malvern, PA) MRI scanner. Images of the muscles crossing the glenohumeral joint were acquired with a flexed array long bone coil (1.5T; Invivo, Orlando, FL) or an 18-channel body matrix coil (3T; Siemens Medical Solutions USA, Malvern, PA) using the Three Point Dixon method [5]. We manually segmented (3D Doctor, Able Software Corp., Lexington, MA) the rotator cuff muscles (supraspinatus, infraspinatus, subscapularis, teres minor) on the images, and calculated muscle volume. Intramuscular fat was quantified for each muscle volume using a custom Matlab (The MathWorks, Natick, MA) program and Equation 1, where SI_{fat} and SI_{water} are the signal intensities for fat and water images of the Dixon method, respectively. This calculation was performed on a voxel-by-voxel basis then averaged across all voxels in the volume to determine the % fat within the muscle of interest.

$$\%\,fat = \frac{SI_{fat}}{SI_{fat}+SI_{water}} \qquad \text{[Equation 1]}$$

We assessed strength as the maximal voluntary isometric joint moment-generating capacity for 6 functional groups of muscle for 3 degrees of freedom at the shoulder with a Biodex dynamometer (Biodex Medical Systems, Shirley, NY). Three 3sec trials were collected for abduction/adduction (shoulder abducted to 30°, elbow braced in extension, forearm in neutral posture and wrist braced), flexion/extension (shoulder flexed to 30°, elbow braced in extension, forearm pronated to 90° and wrist braced), and internal/external rotation (shoulder abducted to 30°, elbow flexed to 90°, and forearm braced in neutral). The maximal moment maintained for at least 0.5sec across the 3 trials was determined with a custom Matlab program.

ANCOVA was used to evaluate mean differences between rotator cuff tear and control groups for muscle volume, fat volume, % intramuscular fat, and joint moment, with adjustment for sex. Regression analyses were used to evaluate relationships between muscle volume and joint moment. Significance was set to $p\leq0.05$, with Holm sequential Bonferoni corrections to account for multiple comparisons.

RESULTS AND DISCUSSION

Older adults with a rotator cuff tear had lower muscle volume than age-matched controls (supraspinatus, p=0.0065; subscapularis, p=0.0073). Although the volume of intramuscular fat was not different between groups, when considered as a %, subjects with a rotator cuff tear had a greater % fat than controls (supraspinatus, p=0.0022; infraspinatus, p=0.0035; teres minor, p=0.0075; subscapularis, p=0.0004) (Figure 1), suggesting that muscle atrophy and % intramuscular fat, rather that fat volume, are more affected by rotator cuff tear in older adults. Joint moment was also reduced compared to controls for all degrees of freedom, although no differences reached statistical significance.

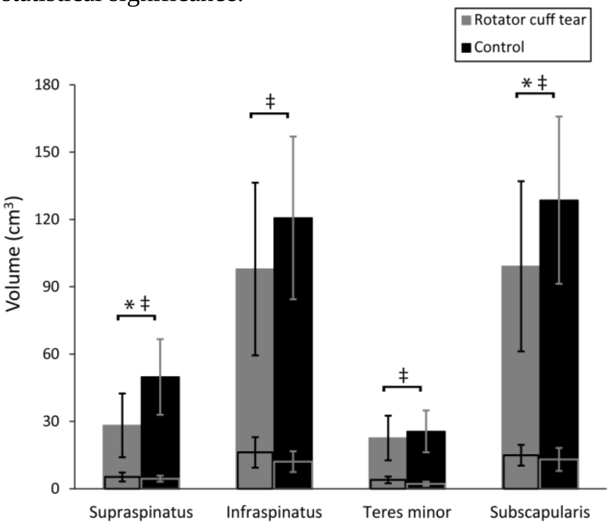

Figure 1: Mean ± SD muscle volume for rotator cuff tear (gray) and control (black) groups. Mean fat volume is overlayed with a hollow box. * indicates significant difference between groups for muscle volume; ǂ indicates significant difference between groups for % intramuscular fat.

Regression analyses were used to evaluate the relationship between joint moment and muscle volume. Parallel lines analysis with ANCOVA demonstrated a lack of difference in regression lines between groups, indicating that the muscle volume and strength reductions following a rotator cuff tear are proportional, and individuals with a rotator cuff tear maintain a linear relationship that is consistent with healthy older adults. Regression analyses performed for a single group including all subjects demonstrated significant linear relationships between rotator cuff muscle volume and joint moment for the 6 functional groups (Table 1). For example, each rotator cuff muscle demonstrated a significant linear relationship between the joint moment of its primary anatomical movement (Figure 2); 52% of the variation in abduction moment was accounted for by changes in supraspinatus volume (p=0.0086), 30% and 63% of the variation in external rotation moment were accounted for by changes in teres minor (p=0.0668) and infraspinatus (p=0.0022) volumes, respectively, and 73% of the variation in internal rotation moment was accounted for by changes in subscapularis volume (p=0.0004).

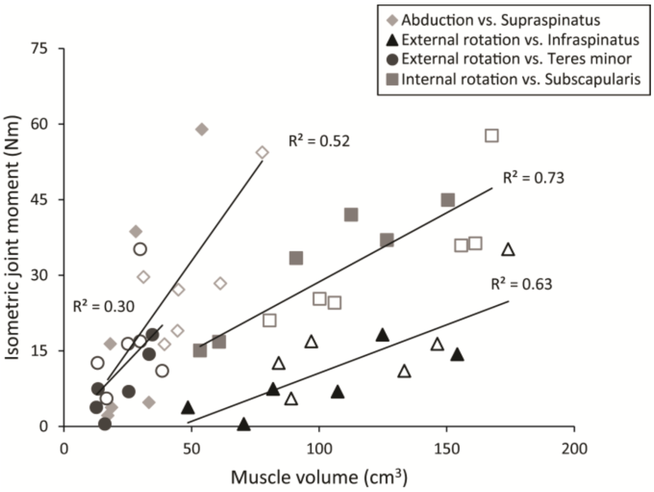

Figure 2: Regression analyses for all subjects, including rotator cuff tear (filled markers) and control (unfilled markers) groups. Isometric joint moment of each muscle's primary functional group is shown.

CONCLUSIONS

Older adults with a rotator cuff tear have reduced muscle volume and greater % intramuscular fat. However, despite these changes to the musculature, these older adults maintain significant linear relationships between volume and strength. This work is part of an ongoing study for a larger cohort to further evaluate these relationships, and explore their role in the performance of daily, functional tasks [1,6].

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Table 1: Correlation coefficients for rotator cuff muscles and isometric joint moment for 6 functional groups. * indicates significance after Holm sequential Bonferonni correction.

	Abduction	***Adduction***	***Flexion***	***Extension***	***Internal rotation***	***External rotation***
Supraspinatus	R^2 = 0.52*	R^2 = 0.78*	R^2 = 0.61*	R^2 = 0.37*	R^2 = 0.52*	R^2 = 0.71*
Infraspinatus	R^2 = 0.71*	R^2 = 0.62*	R^2 = 0.71*	R^2 = 0.56*	R^2 = 0.80*	R^2 = 0.63*
Teres minor	R^2 = 0.39*	R^2 = 0.26	R^2 = 0.52*	R^2 = 0.57*	R^2 = 0.41*	R^2 = 0.30
Subscapularis	R^2 = 0.61*	R^2 = 0.53*	R^2 = 0.65*	R^2 = 0.61*	R^2 = 0.73*	R^2 = 0.51*