Supraspinatus Cord and Strap Tears Can Be Treated Conservatively: A Biomechanical Study

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INTRODUCTION:

The supraspinatus (SS) muscle-tendon is formed by an anterior bipennate muscle with a “cord” like tendon and a posterior unipennate muscle with a “strap” like tendon (Figure 1A) [1]. The anterior muscle’s cross-sectional area is 2.5x larger than the posterior muscle’s area. Studies show that anterior versus the posterior SS tears are associated with decreased abduction force, increased glenohumeral translation, and increased fatty infiltration. These above clinical findings could be a result of the anterior cord generating a greater abduction force than the posterior strap; the intact cord could compensate for a torn strap, but not the inverse. Yet, the relative mechanical contribution of the SS cord and strap tendons to shoulder abduction is currently unknown. We hypothesized that, under physiologic loading conditions, a simulated SS cord versus a SS strap tear will generate less shoulder abduction force; and further, an intact SS cord will offset the expect abduction loss from a SS strap tear, but the inverse will not be true.

METHODS:

Ten fresh-frozen cadaveric specimens (average age 78.80±14.50 years, 3 males) without shoulder pathology were dissected to the level of the rotator cuff. The insertional width of the cord and strap were measured using a scientific caliper (accuracy 0.01mm). The specimens were tested in a shoulder simulator with physiological load vectors applied to the upper (127N) and lower (108N) subscapularis, SS cord (56N), SS strap (24N), infraspinatus (90N), and teres minor (97N) tendons (Figure 1B) [1,2]. With applied muscle loads, the abduction force was measured at the distal humerus using a 6 DOF load cell (accuracy ± 0.1 N) and also reported as a ratio to the Native value. The role of the SS cord and strap were delineated by varying their loads, while keeping constant loads on other rotator cuff tendons. The testing trials were randomized and included: 1) Native (cord 56N, strap 24N), Case 1 (cord 56N, strap 0N), Case 2 (cord 80N, strap 0N), Case 3 (cord 0N, strap 24N), and Case 4 (cord 0N and strap 80N). Cases 1 and 3 simulate removal of the entire musculotendinous unit, while Cases 2 and 4 replicate a tendon tear with load transfer to the intact tendon. Testing was completed at both 0° and 30° of scaption in neutral arm rotation. C-arm imaging confirmed a centered glenohumeral joint during testing. Abduction force data was analyzed using a 2-factor ANOVA with load state and abduction angle as factors. Individual load states as well as measurements were analyzed using 2-tailed independent t-tests.

RESULTS: The insertional width of the SS cord and strap were 7.9±2.2mm and 9.6±1.8mm (p=0.060). Table 1 shows the humeral abduction force results for the Native and Cases 1-4. The humeral abduction force is dependent on the load state (p=0.029), but not the abduction angle (p=0.347). A simulated strap tear (Case 1) at 0° and 30° dropped the abduction force by 28% (p=0.001) and 30% (p=0.001), while a modeled cord tear (Case 3) at 0° and 30° decreased the abduction force by 61% (p=0.001) and 49% (p<0.001). The drop in abduction force was greater for the cord versus strap tear at both 0° and 30° (p=0.003) and (p=0.015). A simulated strap tear with all the SS force going into the intact cord (Case 2) showed an increase in abduction force and recovery to Native values at 0° and 30° to 11% (p=0.024) and 11% (p=0.118). Likewise, a modeled cord tear with all the SS force transferring to the strap (Case 4) showed improvement to Native values at 0° and 30° to 26% (p=0.006) and 15% (p=0.014). An intact cord with a torn strap, versus an intact strap with a torn cord, recovered more abduction force at 0° (p=0.040) but not at 30° (p=0.674).

DISCUSSION AND CONCLUSION:

This study shows that both cord and strap SS tears significantly lowers (p≤0.001) humeral abduction force; the greatest drop was 61% and this occurred with a cord tear at 0° of abduction. The cord or anterior SS muscle does transfer more abduction force to the humerus than the strap or posterior SS muscle (p≤0.015). The importance of the anterior SS cord helps us to explain why an anterior versus a posterior SS tear leads to a drop in experimental abduction force and glenohumeral translation, and clinical increased in SS fatty infiltration. Surprisingly, humeral abduction force is nearly returned to native values with either an anterior or a posterior tear during full SS loading. Because an intact cord can efficiently transfer the full SS force to the humerus despite a complete strap tear; and likewise, a intact strap can nearly offset complete cord tear by transmitting the cord’s muscle force to the humerus. In summary, a mechanical case can be made to treat SS small (<10mm width) anterior or posterior rotator cuff tears conservatively, because the remaining intact SS cord or SS strap tendon can effectively offset the potential abduction loss. This also explains why clinical abduction loss is only seen in tears ≥3mm [3].

References: 1) Roh MS et al, JSES. 2000;9(5):436-440. 2) Schmidt CC et al The Rotator Cable Does Not Stress Shield the Crescent Area During Shoulder Abduction. JBJS Published Ahead of Print 4/27/2022. 3) Kim HM et al, JBJS 2009;91(2):289-96.

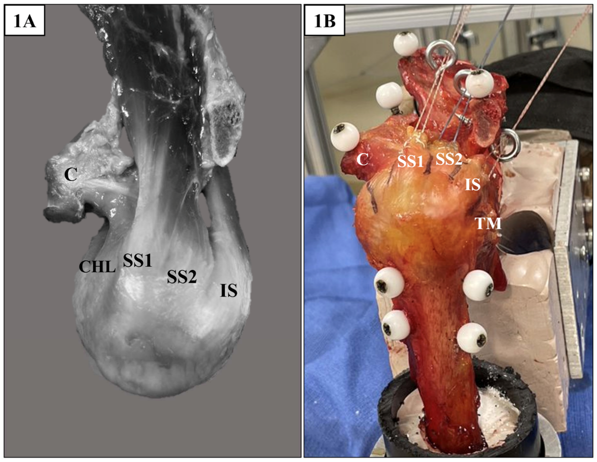

Figure 1A: Photo of a specimen after dissection. Coracoid (C), Coracohumeral Ligament (CHL), Supraspinatus Cord (SS1), Supraspinatus Strap (SS2), and Infraspinatus (IS). 1B: Photo of specimen in Figure 1A under load in the shoulder simulator. Teres Minor (TM).

Table 1: Abduction Force Results

Abduction Angle	Load State		Abduction Force (N)	Abduction Force Ratio*	P-value (vs Native)
0°	Native	(Cord 56N, Strap 24N)	8.1±5.6		
	Case 1	(Cord 56N, Strap 0N)	5.9±4.6	0.72	0.001
	Case 2	(Cord 80N, Strap 0N)	7.2±5.3	0.89	0.024
	Case 3	(Cord 0N, Strap 24N)	3.2±2.6	0.39	0.001
	Case 4	(Cord 0N, Strap 80N)	6.0±4.5	0.74	0.006
30°	Native	(Cord 56N, Strap 24N)	6.7±3.6		
	Case 1	(Cord 56N, Strap 0N)	4.6±3.6	0.70	0.001
	Case 2	(Cord 80N, Strap 0N)	5.9±3.9	0.89	0.118
	Case 3	(Cord 0N, Strap 24N)	3.4±2.8	0.51	<0.001
	Case 4	(Cord 0N, Strap 80N)	5.7±3.3	0.85	0.014

*Calculated by dividing the abduction force of the case by the Native abduction force.
ANOVA P-values for association of abduction force with load state = 0.029 and with abduction angle = 0.347.
P-values comparing Case 1 vs Case 3 at 0° and 30° = 0.003 and 0.015, respectively.
P-values comparing Case 2 vs Case 4 at 0° and 30° = 0.040 and 0.674, respectively.