FROM SUBTLE TO SEVERE: MAPPING THE CONTINUUM OF SYMPTOM EXPRESSION IN ROTATOR CUFF TEARS WITH BIOMECHANICS

Sarah M. Barron[1*], Joseph J. King[2], Federico Pozzi[2,3], Jennifer A. Nichols[1,2]
[1]J. Crayton Pruitt Family Department of Biomedical Engineering, [2]Department of Orthopaedic Surgery & Sports Medicine, [3]Department of Physical Therapy, University of Florida
*Corresponding author's email: sgormley@ufl.edu

Introduction: Some individuals with rotator cuff tears (RCT) experience poor clinical outcomes, with symptoms persisting after conservative treatments and high failure rates for surgical repairs. Yet, other individuals with RCT do not experience any significant symptoms [1]. This suggests that compensatory mechanisms, such as muscle activation patterns and joint kinematics, play an important role in symptom expression. However, despite various research efforts [e.g., 1-3], to what extent biomechanical compensations influence symptom expression in RCT is not fully understood. For this study, we employed a variety of biomechanical methods, including electromyography (EMG) and motion capture, to comprehensively investigate the relationship between RCT symptom expression and temporal biomechanical data during a diverse range of tasks. We hypothesized that the data from individuals with RCT would show considerable heterogeneity, but also elucidate differences in symptom expression.

Methods: To date, this IRB-approved study includes 4 participants (3 male, 66.8 ± 7.1 years old) with RCT (full-thickness supraspinatus) and 13 controls (6 male, 67.4 ± 6.4 years old). Each participant completed the Shoulder Pain and Disability Index (SPADI) questionnaire to measure symptom expression. Participants then completed 4 range of motion (ROM) (flexion, abduction, scaption, 5-lb weighted scaption) and 5 functional (drink, axilla wash, hair comb, back pocket reach, seatbelt reach) tasks following a 0.75 Hz metronome, with five repetitions per trial and two trials per task. Motion-capture data were collected at 120 Hz using a marker-set with 31 markers on the trunk and arm, including a 3-marker cluster on the acromion for scapular tracking [4]. Muscle activations were collected at 3000 Hz from 12 locations [Surface EMG: anterior/middle/posterior deltoid (A./M./P. Del), upper/lower trapezius (UT/LT), serratus anterior (SA), pectoralis major (Pec), latissimus dorsi (Lat). Intramuscular EMG: supraspinatus (Sup), infraspinatus (Inf), teres minor (TM), subscapularis (Sub)]. Maximum voluntary contraction (MVC) tasks [5] were collected for signal normalization.

Joint angles were calculated in OpenSim (v4.4) using inverse kinematics and scaled versions of the thoracoscapular shoulder model, which can describe pathological scapular motion [6]. Shoulder joint angles were transformed to reflect net scapular and humeral rotations relative to the trunk. EMG data were filtered and EMG envelopes from each trial were normalized to peak activations from MVC tasks. Statistical parametric mapping ($\alpha = 0.05$) was performed in Python (spm1d package [7]) to compare humeral and scapular kinematics and muscle activations over time between the RCT and control groups. Mean normalized muscle activation for each participant near end ROM (25-50% task completion), where the largest activations tended to occur, was also calculated for each muscle and task.

Results & Discussion: Glenohumeral kinematics and muscle activations differed significantly between RCT and control participants in all tasks. Scapular differences were the most prominent, with considerable heterogeneity present across RCT participants (Fig. 1). To fully understand the heterogeneity observed and identify commonalities between participants with similar symptoms, more data are needed. However, examination of the individual RCT participants collected to date is illuminating. Notably, the participants with the lowest (21) and highest (47) SPADI scores (0 is no pain/disability) demonstrated contrasting compensations. During abduction, the higher-SPADI participant (Fig. 1, dashed orange) had decreased lateral winging near end ROM compared to controls (Fig. 1, blue), while the lower-SPADI participant (Fig. 1, dotted orange) had increased winging. Similarly, near end ROM of seatbelt reach, the higher-SPADI participant was within 1 standard deviation of controls, while the lower-SPADI was again higher. Activations of the scapular rotators during end range abduction (Fig. 2, rectangles) of each RCT participant were also unbalanced in ways that mapped onto the kinematics. For example, the lower-SPADI participant (Fig 2., dotted) had decreased LT activation compared to controls, while the higher-SPADI participant (Fig. 2, dashed) had increased LT and UT activation. Past studies have shown increases in Sup activation for RCT patients compared to controls [1], but this was only seen in the lower-SPADI participant and was coupled with large increases in Pec activation (Fig. 2, dotted). These results, in combination with the fact that the difference in SPADI score between the two highlighted participants represents a clinically important difference [8], suggest muscle activations and scapular kinematics align with RCT symptom expression.

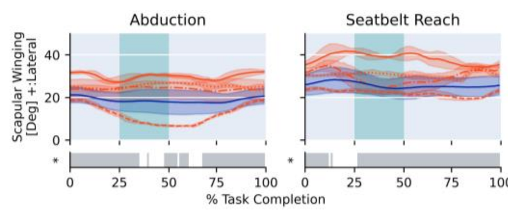

Figure 1: Scapular rotations for individual tear participants (orange) and control group (blue) during a selected ROM (left) and functional (right) task. Teal region represents where EMG averaging occurred.

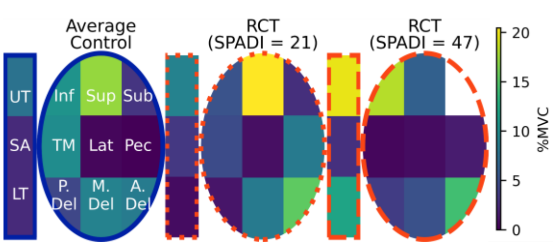

Figure 2: Muscle activations (scapular insertion: rectangle, humeral insertion: ellipse) near end abduction ROM for two tear (orange border) and all control (blue border) participants.

Significance: Viewing symptom expression as a dichotomous variable oversimplifies the complexity of RCT and the nuances of time-series biomechanical data can be lost in the process of averaging. Thus, this study highlights a need for personalized evaluation of individuals with RCT.

References: [1] Kelly et al. (2005) *J Shoulder Elbow Surg* 14(2); [2] Duc et al. (2014) *Physiol Meas* 35(12); [3] Alenabi et al. (2016) *Clin Biomech* 32; [4] Karduna et al. (2001) *J Biomech Eng* 123(2); [5] Boettcher et al. (2008) *J Orthop Res* 26(12); [6] Seth et al. (2016) *PloS One* 11(1); [7] Pataky (2010) *Comp Meth Biomech Biomed Eng* 15(3); [8] Roy et al. (2009) *AC&R* 61(5).