Individuals with Rotator Cuff Tears That Are Unsuccessfully Treated with Exercise Therapy Have Larger Superior Components of the Middle Deltoid Force During Scapular Plane Abduction

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INTRODUCTION: Exercise therapy is generally prescribed for individuals with rotator cuff tears and fails approximately 25-50% of the time[1-3]. One reason for failure may be the inability to balance and strengthen the muscle forces crossing the glenohumeral joint. Specifically, the intact rotator cuff muscles need to counteract the superiorly oriented force generated by the deltoid to prevent superior migration of the humeral head, which may lead to impingement. Subjects unsuccessfully treated with exercise therapy have more superiorly oriented net muscle forces[4], which may be due to differences in the deltoid forces in the superior-inferior direction. The objective of the study was to compare the superiorly oriented force generated by the middle deltoid during scapular plane abduction pre- and post-exercise therapy and compare between subjects successfully and unsuccessfully treated with exercise therapy. It was hypothesized that the superiorly oriented force generated by the middle deltoid during scapular plane abduction would be larger in subjects unsuccessfully treated.

METHODS: Twelve subjects with a symptomatic tear isolated to the supraspinatus tendon (6 unsuccessful (surgery, 60.0 ± 10.8 years), 6 successful (55.8 ± 11.6 years)) provided IRB-approved consent before participation in this study. Subjects completed a 12-week personalized exercise therapy program. Time to surgery for unsuccessful subjects was 1.6 ± 0.9 years. Tear size, thickness and location were measured via ultrasound and glenohumeral kinematics were quantified during scapular plane abduction using a biplane radiography system and validated model-based tracking technique[5]. Glenohumeral joint models were created in OpenSim[6] and incorporated subject specific in-vivo kinematics, bony geometries, muscle strength/lines of action and tear characteristics. The peak isometric force a muscle could produce pre-exercise therapy was based on muscle volume from computed tomography images and scaled post-exercise therapy by percent changes in isometric strength[8]. Peak isometric force for each supraspinatus unit was scaled by the amount of tendon torn[7,8]. The experimentally measured kinematics drove the model and muscle forces were determined (static optimization, minimizing muscle activation) throughout the movement (normalized minimum to maximum abduction). The force the middle deltoid generated in the superior-inferior direction was determined by multiplying the superior-inferior component of the muscle line of action (unit vector)[9,10] by the magnitude (normalized to bodyweight (BW)). Statistical parametric mapping was used to compare deltoid muscle forces between the successful and unsuccessful groups at both timepoints[11]. Significance was $p<0.05$.

RESULTS: The amount of superiorly oriented force generated by the middle deltoid pre-exercise therapy ranged between 0.01-0.15*BW and 0.07-0.16*BW for the successful and unsuccessful groups, respectively. For post-exercise therapy, the superiorly oriented force generated by the middle deltoid ranged between 0.00-0.14*BW and 0.06-0.16*BW for the successful and unsuccessful groups, respectively (Figure 1). The amount of superiorly directed force generated by the middle deltoid was greater in the unsuccessful group at both pre- and post-exercise therapy (p=0.012 and p=0.001, respectively). Specifically, the unsuccessful group had larger superior deltoid force components from 73-90% of the movement pre-exercise therapy (Figure 1), and from 33-36% and 54-100% of the movement post-exercise therapy (Figure 2, 54-100% of movement represented by vertical black dashed lines).

DISCUSSION: The main finding of the current study was that the superiorly oriented component of the force generated by the middle deltoid was larger during scapular plane abduction and at both timepoints in subjects unsuccessfully treated with exercise therapy that subsequently underwent rotator cuff surgery. The current findings demonstrate that individuals unsuccessfully treated with exercise therapy may rely on more superior force generation from the middle deltoid to abduct the arm in the scapular plane. One possible explanation for this may be that individuals unsuccessfully treated have less upward rotation of the scapula, necessitating maximization of the deltoid moment arm to abduct the arm past 90°[12]. Previous research has also demonstrated the presence of scapular dyskinesis and compensatory function of the middle deltoid in the presence of a rotator cuff tear[13,14,15]. Larger superiorly oriented components may also place subjects at risk of superior migration of the humeral head. Future work will compare scapulothoracic kinematics during scapular plane abduction between groups to determine the role of potential scapular dyskinesis that could be targeted during exercise therapy.

SIGNIFICANCE/CLINICAL RELEVANCE: Subjects unsuccessfully treated with exercise therapy who underwent rotator cuff surgery have larger superiorly oriented middle deltoid forces during scapular plane abduction which may increase the risk of superior migration and compensate for limited scapular upward rotation.

REFERENCES: [1] Itoi E J Orthop Sci. 2013, [2] Kuhn JE et al. JSES 2009, [3] Kuhn JE et al. JSES 2013, [4] Mattar LT et al. SB3C2023, [5] Bey MJ et al. J Biomech Eng. 2006, [6] Delp SL et al. IEEE Trans Biomed Eng. 2007, [7] Vidt ME et al. Clin Biomech 2018, [8] Pataky J Clin Biomech. 2021, [9] van Arkel RJ et al. JOR 2013, [10] Phillips ATM et al. Int Biomechanics 2015, [11] Pataky TC J Biomech. 2010, [12] Parsons IM et al. JOR 2002, [13] Pataky J et al. Clin Biomech 2022, [14] Kibler BW et al. JAAOS 2012, [15] Ludewig PM, Reynolds JF JOSPT 2009

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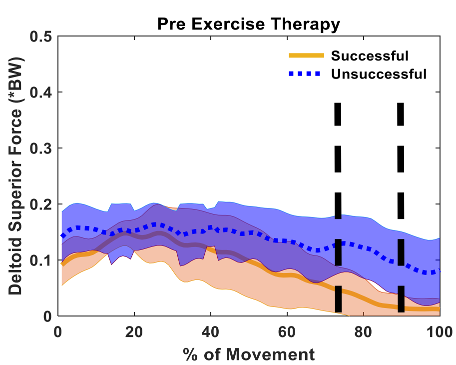

Figure 1: Force in the superior direction generated by the middle deltoid pre-exercise therapy **(**average ± 1 SD).

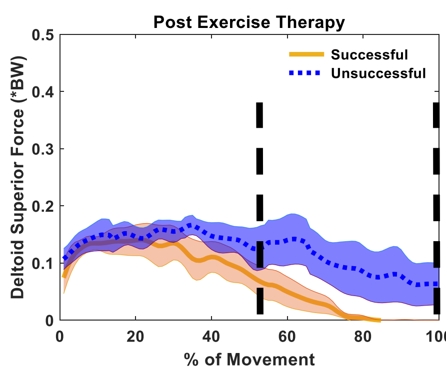

Figure 2: Force in the superior direction generated by the middle deltoid post-exercise therapy **(**average ± 1 SD).