Biomechanical Evaluation of Rotator Cuff Tear Progression and the Influence of Parascapular Muscle Loading

INTRODUCTION

Rotator cuff disorder is a disease of spectrum, running from subacromial bursitis, rotator cuff tendinitis, partial and full-thickness tear, and cuff tear arthropathy. Early detection and proper management including surgical treatment will improve the outcome of disease. However, it is unknown at which stage of rotator cuff tear (RCT) progression the shoulder biomechanics become altered. Previous biomechanical studies have not considered cuff tear progression based on the footprint anatomy, rotational joint kinematics, and the influence of anatomy-based muscle loading including pectoralis major and latissimus dorsi. Therefore, the purpose of this study was to determine the relationship between progressive RCT and glenohumeral joint biomechanics using a RCT progression model and anatomically based muscle loading.

METHODS

Specimen Preparation: Eight cadaveric shoulders were used (mean age of 54 years, range 34-69). All soft tissues were removed except the glenohumeral joint capsule, insertion of rotator cuff muscles, deltoid (DEL), pectoralis major (PEC) and latissmus dorsi (LAT). Suture loops were made at the insertion of each muscle: 1 for teres minor (TM), 2 for supraspinatus (SSP) and infraspinatus (ISP), and 3 for remaining muscles in order to load anatomically based on fiber orientation and multiple lines of action. An aluminum rod was secured in the medullary canal of the humeral shaft, and was placed in a custom device which allows axial rotation and abduction of the shoulder. The scapula was fixed in the anatomical resting position with 20° of anterior tilt.

Rotator Cuff Tear Progression Model: Four progressive stages of rotator cuff tear (RCT) were created based on footprint anatomy (Fig. 2).

Stage I was a tear of the anterior cord of SSP. Stage II was a tear of the entire SSP. Stage III was a tear of the entire SSP with detachment of 50% of the ISP, and Stage IV was a tear of the entire SSP and ISP.

Muscle Loading Conditions: The amount of muscle loading was determined based on the physiological muscle cross-sectional area: supraspinatus 20N, subscapularis 30N, infraspinatus/teres minor 30N, deltoid 60N, pectoralis major 30N, and latissimus dorsi 30N. Three muscle loading conditions were performed: rotator cuff only (RC), rotator cuff with deltoid (RC+DEL) and rotator cuff, deltoid, pectoralis major and latissimus dorsi (RC+DEL+PEC+LAT).

Testing Positions: Testing was performed in the scapular plane (30° anterior to the coronal plane) with 0°, 30°, and 60° shoulder abduction with a 2:1 ratio of glenohumeral to scapular abduction.

Testing Procedure, Dependent Variables and Statistics: The maximum internal rotation (Max IR) and external rotation (Max ER) were measured with 3.4 Nm of torque using a torque wrench. The position of the humeral head apex (HHA) with respect to the glenoid was measured using a Microscribe 3DLX at each position from Max IR to Max ER in 30° increments. The abduction capability at each tear progression was determined as the abduction angle achieved by increasing the middle deltoid load. A repeated measures ANOVA with a significance level of 0.05.

RESULTS

Rotational Range of Motion (ROM): Max ER was significantly increased after Stage II tear (p<0.05). Max IR was significantly increased after only Stage IV tear with RC+DEL and RC+DEL+PEC+LAT loading (p<0.05). Abduction Capability (Fig. 3): In the smaller deltoid loading conditions (<50N), abduction angle decreased significantly after Stage I tear (p<0.05); however, in the higher loading conditions (60N and 70N), the abduction angle decreased significantly after Stage II tear (p<0.05).

Path of Humeral Head Apex: The HHA shifted posteriorly after Stage III tear at the mid-range of rotation in 0° and 30° abduction with RC and RC+DEL loading conditions (p<0.05). In the conditions of RC+DEL+PEC+LAT loading and 60° abduction, there were no differences in AP position of the HHA. At Max IR the HHA shifted superiorly after Stage III tear for all muscle loading conditions in 30° and 60° abduction (p<0.05, Fig. 4). At 0° abduction the HHA shifted superiorly after Stage IV tear at Max IR for all muscle loading conditions (p<0.05). The HHA shifted laterally after Stage IV tear at Max IR with every abduction and muscle loading condition (p<0.05).

Role of PEC & LAT: ROM: Max IR and total range of rotation statistically decreased with the addition of DEL loading (p<0.05) in each abduction angle and in all tear stages. There was a tendency to be further decreased with additional PEC/LAT loading in each abduction position and in all tear stages (p<0.05). Addition of DEL, PEC, and LAT loading did not affect the Max ER in all abduction angles. HAA kinematics: Deltoid loading elevated the HHA at every rotation in all abduction regardless of the tear stage. PEC and LAT reversed the abnormal HHA kinematics demonstrated above.

DISCUSSION

The current study is a novel biomechanical analysis of rotator cuff tear progression with anatomical based muscle loading. By evaluating rotational range of motion and rotational kinematics the critical rotator cuff tear stages that altered biomechanical characteristics were identified. Specifically, Stage II tear (entire supraspinatus) was the critical tear size for increasing external rotation and for decreased abduction capability with higher deltoid muscle load. Stage III tear (entire supraspinatus and 50% infraspinatus) was the critical tear stage for significant changes in humeral head kinematics. Furthermore, the pectoralis major and latissimus dorsi played an important role to stabilize the shoulder with rotator cuff tear progression. In patients with massive cuff tears, adductors including the PEC and LAT may help to counteract superior migration of the humeral head that is commonly seen clinically. Early detection of rotator cuff tear stage, prior to the critical tear stage, followed by proper management may prevent detrimental biomechanical alterations and improve patient outcome.

REFERENCES


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