THE EFFECT OF ROTATOR CUFF TEARS ON GLENOHUMERAL JOINT REACTION FORCES DURING ACTIVE ABDUCTION


**Musculoskeletal Research Center, Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, 210 Lothrop St., E1641 BST, P.O. Box 71199, Pittsburgh, PA 15223 Ph: (412) 648-2000, Fax: (412) 648-2001, Email: dlecenzo@upmc.edu

INTRODUCTION: Rotator cuff (RC) tears have been shown to result in glenohumeral (GH) degenerative joint disease [3]. Prior clinical and experimental studies have demonstrated that isolated tears of the supraspinatus (SS) have little effect on concentric GH rotation, while advancement of the tear into the infraspinatus (IS) and subscapularis (SubS) tendons results in abnormal articular kinematics of the GH joint. It is believed that aberrated GH kinematics are due to loss of stabilizing dynamic joint compressive force provided by an intact rotator cuff [1,4]. These changes may contribute to eventual degenerative changes at the GH articulation.

MATERIALS AND METHODS: A 6 DOF Universal Force-Moment Sensor (UFS) (JR3 Inc, Woodland, CA) was incorporated into the scapula mount of the Dynamic Shoulder Testing Apparatus (DSTA) to directly measure the magnitude and direction of GH joint reaction forces. The DSTA simulates active physiologic joint motion in full upper extremities by applying forces to the tendons of RC and the middle deltoid (MD) muscles (Fig. 1). Nine fresh-frozen cadaveric upper extremities (age range 60-82 years) without glenohumeral joint pathology were dissected, exposing the tendons of RC and the middle deltoid (MD) while preserving the other soft tissues. The scapula was potted in epoxy and mounted on the DSTA. The tendons of the RC and MD muscles were attached to computer-controlled hydraulic cylinders using clamp, cable, and pulley systems to simulate muscle action. A small arthrotomy vented the glenohumeral joint. All joint reaction forces in full arm specimens were normalized to the weight of the upper extremity. For RC tear conditions, no force was applied to the involved tendon to prevent the tendon from contributing any isometric muscle force.

RESULTS: The maximum abduction angle achieved for the intact RC condition was 82.7 ± 9.6° (mean ± S.D.). The results confirm our hypothesis that advancement of the RC tear beyond the SS tendon causes a significant alteration in the magnitude and direction of the GH joint reaction forces during active abduction. Large rotator cuff tears, which involve both the IS, SubS and SS, result in imbalance in the normal functional relationship between the SS and deltoid muscles. SS and partial IS tears resulted in an inability to abduct the arm past 38.6 ± 10.5° with no significant differences in the magnitude or direction of the joint reaction force between intact RC, Partial SS and IS tear conditions. Conversely, the magnitude of the joint reaction force for SS+Partial IS tear and Global tear conditions significantly decreased by 61% and 73% relative to the intact RC condition, respectively (Fig. 2). Figure 3 shows the direction of resultant forces in the scapular plane for the intact RC condition (Fig. 2). Figure 3 shows the direction of resultant forces in the scapular plane for the intact RC and SS+Partial IS tear conditions in relation to GH joint anatomy reconstructed from specimen CT scans. The direction of the joint reaction force for the intact RC condition was 30.6 ± 5.1° measured from the sagittal plane. However, for the SS+Partial IS tear condition, the reaction force was significantly more tangential to the glenoid face, at 17.3 ± 5.6° (similar results were seen for the Global tear).

ANNOVA followed by multiple contrasts to evaluate the effect of each test condition on GH reaction forces. Statistical significance was set to p < 0.05.

DISCUSSION: These results confirm our hypothesis that advancement of the RC tear beyond the SS tendon causes a significant alteration in the magnitude and direction of the GH joint reaction forces during active abduction. Large rotator cuff tears, which involve both the IS, SubS and SS, result in diminished joint reaction force thus reducing dynamic humeral head compression. Loss of the mechanical function compromises not only the ability of the rotator cuff to maintain concentric GH abduction, but also its ability to resist the superior pull of the deltoid during abduction. This imbalance in the normal functional relationship between the SS and deltoid results in a significant increase in the component of the resultant force directed tangentially to the glenoid articular surface. The decreased magnitude and altered direction of GH joint reaction forces after large rotator cuff tears may contribute to eventual degenerative changes at the GH articulation.

ACKNOWLEDGMENTS: Financial support of the University of Pittsburgh Medical Center IS tear and Global tear conditions significantly decreased by 61% and 73% relative to the intact RC condition, respectively (Fig. 2). Figure 3 shows the direction of resultant forces in the scapular plane for the intact RC condition (Fig. 2). Figure 3 shows the direction of resultant forces in the scapular plane for the intact RC and SS+Partial IS tear conditions in relation to GH joint anatomy reconstructed from specimen CT scans. The direction of the joint reaction force for the intact RC condition was 30.6 ± 5.1° measured from the sagittal plane. However, for the SS+Partial IS tear condition, the reaction force was significantly more tangential to the glenoid face, at 17.3 ± 5.6° (similar results were seen for the Global tear).