INTRODUCTION
Acromioclavicular (AC) dislocation is a frequent injury seen in athletes, with treatment of type III injury (AC capsule and coracoclavicular (CC) ligaments torn) being controversial with no universally accepted ‘gold standard’ [1]. Previous studies have shown that separation of the AC joint results in abnormal joint kinematics and load transmission [2,3], factors that may predispose the patient to post-injury pain, instability and early degenerative joint disease. Despite numerous options of surgery, there remains a deficit in the biomechanical knowledge that would address failures and complications of commonly used methods [4,5]. The objective of this study was to quantify the kinematics and forces of the AC joint after three common reconstruction procedures for the CC ligaments in response to an anterior, posterior and superior load.

MATERIALS AND METHODS
Twelve fresh frozen human cadaveric shoulders (n=12) were dissected at the glenohumeral joint, and the clavicle and scapula were dissected free of all soft tissue except the AC capsule, CC ligaments and the CA ligament. After fixing the scapula and clavicle in epoxy putty, custom-built clamps were used to fix the scapula to a robotic manipulator. The clavicle was rigidly fixed to the testing system base. Motion of the clavicle was described with respect to a coordinate system fixed to the scapula [5]. The robotic/UFS testing system first determined a joint reference position by minimizing the moment about the anterior/posterior (A/P) axis of the scapula, minimizing the forces in the A/P and superior-inferior (S/I) directions while achieving a force target of 10N of joint compression. Each loading test then applied an anterior, posterior, or superior load of 70N to the scapula with the use of the previously obtained reference position as the starting position for all tests.

The testing system recorded the A/P, S/I and proximal-distal translations of the intact AC joint as well as the resultant forces and moments at each position.

The AC capsule and CC ligaments were then transected. After each structure was cut, the previously determined kinematics of the intact AC joint were repeated by the robot for each loading condition and new resultant forces at the joint were measured. The difference in force measured by the UFS between each test represented the in situ force in each structure. The AC joint was then reconstructed with a CC Sling, Rockwood Screw or CA Ligament Transfer Complex. Using force control mode, the testing system determined the joint kinematics in response to the identical loading condition. After each reconstruction was removed, the recorded kinematics of the reconstructed AC joint were replayed and the difference in force measured by the UFS between these two tests represented the in situ force in each reconstruction. A two-factor repeated-measures ANOVA was used to assess effects of loading and joint condition on the amount of primary and coupled translation and in situ forces. Statistical significance was set at p<0.05.

RESULTS
Application of an anterior, posterior or superior load of 70N significantly increased anterior and posterior translation for the CC sling and decreased in the Rockwood Screw. Coupled translations increased between 168% and 800% for the CC sling. The Rockwood Screw decreased the coupled P-D motion by 92% in response to anterior loading. For the CA Ligament Transfer Complex, five of six coupled motions increased significantly, ranging from 184% to 930%.

In response to the same loading conditions, the magnitude of the in situ forces in the CC Sling was significantly (170%) greater than the intact CC ligaments in response to a posterior load (p<0.05) (Fig. 2) while the force in the Rockwood Screw was also significantly (24% and 170%) greater than the intact CC ligaments in response to anterior and posterior loads, respectively. The in situ force in the CA Ligament Transfer Complex was also significantly (192%) greater than the intact CC ligaments in response to a posterior load.

DISCUSSION
This study applied loads to the intact and reconstructed AC joint and measured the resulting kinematics and in situ forces. Our results showed that the CC sling may not be sufficient to maintain joint stability due to the large increases in translation, suggesting that an additional fixation may be justified to reduce this motion. The large forces transmitted through the Rockwood screw and minimal motion, suggest that this reconstruction provides a rigid fixation and may explain some of the complications frequently seen in clinical practice [3,4]. Due to the large increases in joint motion and removal of the articulating surfaces, the CA Ligament Transfer Complex appears to be inadequate in approximating the normal anatomy of the AC joint. In the future, novel procedures that use the hamstrings and palmaris longus tendons might be considered to better emulate the function of the CC ligaments.

REFERENCES

ACKNOWLEDGEMENTS
The support of the Aircast Foundation and the Musculoskeletal Research Center is gratefully acknowledged.