INTRODUCTION:
Rotator cuff tears are a common condition that have a major impact on function, comfort, and medical care costs. Treatment procedures rely implicitly on the belief that restoring normal glenohumeral joint (GHJ) mechanics is necessary to obtain a satisfactory clinical result. While functional measures (e.g., strength, patient satisfaction) have been shown to be predictive of a satisfactory clinical outcome [1], it is unknown if there is a relationship between clinical outcomes and GHJ mechanics. Thus, the objective of this study was to determine the extent to which measures of strength and dynamic GHJ mechanics are predictive of clinical outcome. We hypothesized that GHJ mechanics and shoulder strength are correlated with conventional measures of clinical outcome.

METHODS:
Testing Procedures: Following IRB approval and informed consent, 22 patients (age: 63.5±9.7) enrolled in this study. Each patient had arthroscopic surgical repair of an isolated supraspinatus tendon tear prior to testing. Each patient’s contralateral shoulder was asymptomatic. Biplane x-ray images were acquired for each shoulder during coronal-plane abduction from full adduction to 120°. Isometric shoulder strength was measured during coronal-plane abduction (ABD), sagittal-plane elevation (ELEV), external rotation (ER), and internal rotation (IR). Conventional clinical outcomes were assessed using the Western Ontario Rotator Cuff (WORC) Index, where lower scores indicate a more satisfactory clinical outcome. All data were collected at 3, 12, and 24 months post-surgery. Bilateral CT scans of the humerus and scapula were acquired for each patient at 3 months post-surgery.

Data Analysis: The 3D positions of the humerus and scapula were tracked from the biplane x-ray images using an accurate (±0.4 mm, ±0.5°) CT model-based technique [2]. Using these data, conventional GHJ kinematics (i.e., translations and rotations of the humerus relative to the scapula) were determined for each shoulder [3]. The conventional kinematic outcome measures included the anterior/posterior (A/P) and superior/inferior (S/I) translation of the center of the humeral head. To account for differences in patient size, the A/P and S/I translations were normalized relative to the glenoid width and height, respectively. In addition, GHJ contact patterns were determined by combining joint motion measured from the biplane x-ray images with the patient-specific bone models [4]. The GHJ contact center was determined by calculating the centroid of the minimum distance between humerus and glenoid surfaces for each frame of data. The contact center position was calculated over the entire trial and normalized with respect to the glenoid width and height. The contact pattern outcome measures included the average A/P and S/I contact center position, the A/P and S/I contact center range, and the A/P and S/I contact center standard deviation. Normalized shoulder strength was calculated as repaired shoulder strength as a percentage of the contralateral shoulder strength.

Statistical Analysis: The relationship between the WORC Index and measures of GHJ mechanics or shoulder strength was assessed for all shoulders at all three time points after surgical repair with linear regression and correlation. Significance was set at p<0.05.

RESULTS:
Clinical Outcome vs. GHJ Mechanics: There was a significant association between the WORC Index and normalized S/I humeral translation (r=-0.29, p=0.03, Fig. 1), with greater translation associated with increased traditional outcome (r=-0.47, p<0.001). There were also unexpected associations between WORC Index and the standard deviation (r=-0.47, p<0.001) and range (r=-0.48, p<0.001) of S/I translation, with increases in these parameters associated with a lower WORC Index. The study did not detect associations between the WORC Index and S/I or A/P contact centers, standard deviations or ranges.

Clinical Outcome vs. Shoulder Strength: There were significant associations between the WORC Index and normal shoulder strength for ABD (r=-0.4, p<0.001), ER (r=-0.47, p<0.001, Fig. 2) and IR (r=-0.48, p<0.001).

DISCUSSION:
The data indicated that an increase in superior translation of the humeral head was indicative of a less satisfactory clinical outcome. Superior migration of the humeral head has been shown to be greater in asymptomatic rotator cuff tears than asymptomatic [5]. Therefore, it is possible that an increased superior translation of the humeral head is related to not only the development of symptoms following a rotator cuff tear, but to a patient’s satisfactory clinical outcome following rotator cuff repair. Additionally, the data indicated that increased shoulder strength is positively associated with improved clinical outcome. The data failed to detect a relationship between GHJ contact center and clinical outcome. Previous studies have shown that compared to the contralateral shoulder, repaired shoulders have a more superiorly located joint contact center. This is evident as early as 24 months post surgery when all repairs were found to be intact as measured by ultrasound [6]. The data presented here suggest that this altered pattern of joint contact may not be detrimental to the subjective assessment of clinical outcome in this particular patient population. Ongoing research will further characterize the complex relationships between GHJ mechanics, shoulder strength, and clinical outcome.

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