AUTOMATED SHOULDER MORPHING TO ASSESS SUBJECT SPECIFIC BIOMECHANICS OF ROTATOR CUFF TEAR AND OSTEOARTHRITIS

Alexandra Oswald (1), Johanna Menze (1), Matthijs Jacxsens (2), Tomas Rojas (3), Matthias A. Zumstein (4,5), Stephen J. Ferguson (6) and Kate Gerber (1)

1. University of Bern, Switzerland; 2.Cantonal Hospital St. Gallen, Switzerland ; 3. Clinica Santa Maria, Chile, 4. Insel University Hospital Bern, Switzerland; 5.Orthopaedics Sonnenhof, Switzerland; 6.ETH Zurich, Switzerland

Introduction

Clinical metrics pertaining to scapula morphology, such as the critical shoulder angle (CSA), have been observed to differ between osteoarthritis (OA) and rotator cuff tear (RCT) patients. RCTs are associated with a CSA > 35°, compared to OA patients who are more likely to have a CSA < 30° [4]. Experimental testing has shown that increased CSA leads to increased glenohumeral shear stresses [1]. It is thus hypothesized that the ratio of shear to compressive forces (instability ratio) is increased in RCT patients compared to OA patients in the glenohumeral joint, however patient-specific analysis has never been performed. To this end, we present an automated pipeline for creating and analyzing the glenohumeral joint reaction forces for patient-specific shoulders, along with validation through a comparative study of RCT and OA patients.

Methods

Patient specific glenohumeral joint forces were calculated for 10 patients with a RCT (mean CSA of 39.63°), and 10 patients with OA (mean CSA of 17.3°). The scapula and proximal humerus were manually segmented from CT by a clinical expert. The CSA was calculated using a true anterior-posterior projected plane from the CT scans. Computational modelling was performed with the AnyBody Modeling System (ver 7.3.4, AnyBody Technology A/S, Aalborg, Denmark) [2]. For personalization of the shoulder model, patient scapulae were registered to the original AnyBody scapula using the deterministic atlas algorithm from Deformetrica [3]. The Hausdorff distance (with 26'000 points per scapula) was used to measure the global accuracy of the morphing.

To achieve a patient-adapted joint configuration in the musculoskeletal model, the radius of each humerus was calculated using a simple sphere fit to the medial aspect of the segmented humeral head and used to define the glenohumeral joint center.

The glenohumeral compressive (medial-lateral), vertical shear (inferior-superior), and horizontal shear (anterior-posterior) joint forces were calculated for each patient over a 0°-90° abduction in the scapular plane. Forces were then normalized by body weight (%BW).

Results

The mean Hausdorff distances for the registration of all the OA and RCT patients to the AnyBody scapula were 2.37 mm and 2.40 mm, respectively.

The joint reaction forces showed an increase in vertical and horizontal shear components in the RCT patient group, compared with the OA patients (Figure 1). The horizontal shear forces showed a difference of 6.5%BW, with a maximal force in the RCT group of 12.7%BW and 6.2%BW in the OA group. In the vertical plane, the difference was 3.8%BW with a maximal force of 23.9%BW in the RCT group, and 20.1%BW in the OA group. Compressive forces were similar between the groups, with a maximal compressive force of 42.5%BW in the RCT group, and 39.8%BW in the OA group, a 2.7%BW difference, mostly at higher humerus angles.

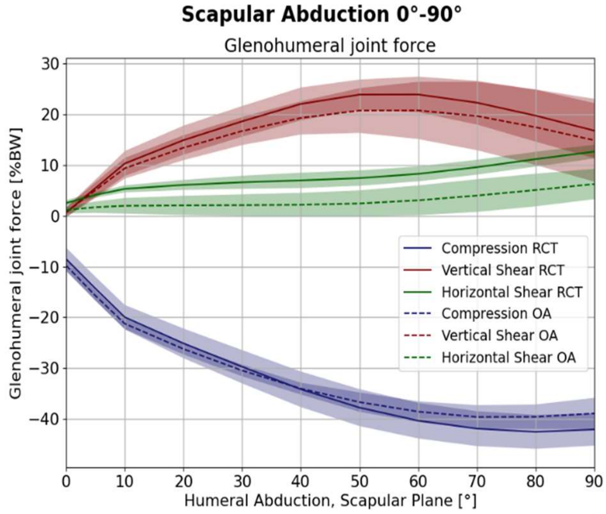

Figure 1: Comparison of glenohumeral joint forces between OA and RCT patient groups in a 0°-90° abduction motion in the scapular plane. The forces are given in % body weight [%BW].

Discussion

Results of this study are consistent with previous research showing increased shear forces for patients with higher CSAs and increasing instability ratios for patients with increasing CSAs [1]. Within this work, we present an automated pipeline to import patient-specific scapula and glenohumeral morphological information, extracted from CT imaging, into the AnyBody modelling system. The pipeline demonstrated robustness to large morphological variation in the patient scapulae and requires little manual input. Preliminary results show good agreement of glenohumeral joint forces and muscle forces to previous studies, with the potential to efficiently analyze larger numbers of individual subjects.

References

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