GLENOHUMERAL TRANSLATION AND MUSCLE FORCES IN EX VIVO SHOULDERS WITH ROTATOR CUFF INJURIES

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Introduction

Instability in the glenohumeral joint (GHJ) can be caused by muscle imbalance and weakness related to rotator cuff tears (RCT), which can lead to abnormal movement of the joint and further pathologies [1]. The goal of this study was to understand the effect of RCT on the GHJ biomechanics in an ex vivo model, specifically during a 30° abduction test with additional weights simulating in vivo load-bearing situations. We investigated superior-inferior GHJ translations in shoulders with RCT and active muscle forces that occur during this motion.

Methods

In this ex vivo study, ten human shoulders were placed into an advanced muscular, force-controlled shoulder simulator. The rotator cuff (RC) – with two attachment points to the subscapularis (SSC) – and other glenohumeral tendons as the deltoid – with attachment points on the clavicula ($DELT_{ant}$), acromion ($DELT_{mid}$) and spinae –, pectoralis major, and latissimus dorsi were connected to a motorized pulley system. The shoulders were tested in a 30° scapular plane abduction-adduction cycle, simulating motion with an intact RC and different types of RCTs (supraspinatus (SSP), superior portion of SSC (SSC_{sup}), infraspinatus (ISP), SSP&SSC_{sup}, SSP&ISP and ISP&SSC_{sup}&ISP) at four different weight levels (0–3 kg additional weight). The position of the GHJ center (GHJC) was determined using the instantaneous helical axis method. Linear regression models for each type of RCT were used to determine the effect of weight on GHJC motion ($log_{10}(1+x)$ transformed). The muscle forces during abduction were summarized in a boxplot at 30° abduction.

Results

During loaded abduction with additional weights, the average superior translation of the GHJC with an intact rotator cuff ranged from 3.3 to 6.8 mm. In shoulders with simulated SSP&SSC_{sup}&SSP, the average superior translation ranged from 4.0 to 9.3 mm. The results also showed that the superior translation of the GHJC was significantly affected by the weight-induced load in both RC intact shoulders (p=0.024) and shoulders with SSP&SSC_{sup}&SSP tear (p=0.004; Fig. 1).
Generally, the median and variability of the muscle forces increased with increasing weight (Fig.2, $DELT_{mid}$ as an example). A decrease of the $DELT_{mid}$, $DELT_{ant}$ and SSC was observed in the SSP tear.

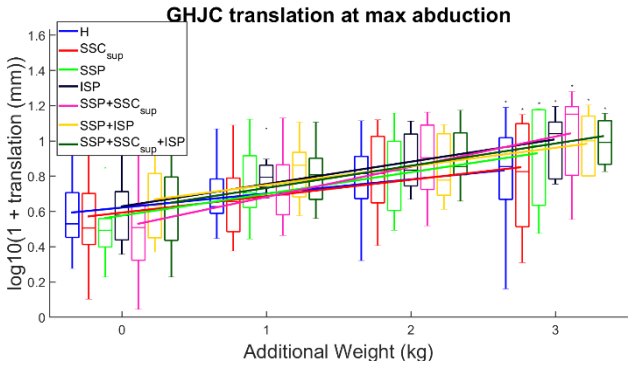

Figure 1: Linear regression of the motion of the GHJC for each RCT type; translation data is transformed with log10(x + 1)

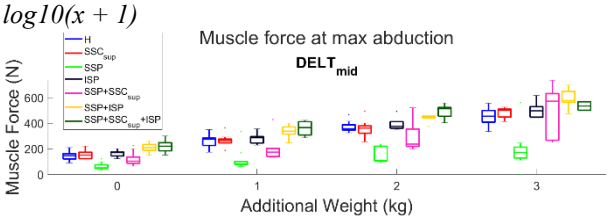

Figure 2: Boxplot of $DELT_{mid}$ forces at 30° abduction

Discussion

In our laboratory setting, both the presence of RCT and additional weights increased GHJC superior translation during abduction and thus the instability of the joint. Most curiously, the SSP tear reduced the muscle activations, however, the GHJC translation was increased in this tear type compared with the intact RC. It seems that the muscle activations were reduced at the expense of the GHJC translations. Based on our results, the $DELT_{mid}$ is the main compensating muscle for RCT and for additional weight during abduction. This also agrees with Moroder et al. [2]. Shoulder biomechanics is compromised in RCTs and potential overload of compensating muscle should be monitored in affected patients.

References

1. Ozel et al, BMC Musculoskeletal Disorders, 21(1):668, 2020.
2. Moroder et al, Orthop J Sports Med, 10(5):23259671221097062, 2022.