Glenohumeral Impingement Risk During a Simulated Volleyball Spike

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INTRODUCTION: Human tendons require mechanical loading to adapt.[1] Compressive tendon loading may reduce resistance to tension thought to be the most common strain mechanism in most human tendons.[2] Subacromial and internal (glenoid contact) impingement are proposed mechanisms of rotator cuff tendon compressive deformation.[3,4] Elevation angle influences both mechanisms but the role of axial rotation is less clear.[5] The arm-cocking phase of a volleyball spike places the shoulder joint complex into high elevation angles at maximum external rotation (maxER) while scapular plane abduction (SAB) achieves end range elevation without the extremes of axial rotation. The purpose of this study is to illustrate the effect of glenohumeral (GH) kinematics on bone-to-bone tendon insertion region minimum distance at the instant of arm-cocking (maxER) of a simulated volleyball spike as compared to SAB at an equivalent elevation angle (EEA).

METHODS: This study was approved by an Ethics Committee; all subjects provided informed consent prior to participation. *In vivo* GH kinematics were obtained from 6 experienced volleyball players (4F) using a custom biplanar videoradiography system (Imaging Systems & Services) during a simulated volleyball spike and scapular plane abduction (SAB). A sampling rate of 100 Hz with a 1 ms pulse width was used; velocity of both activities was controlled by a metronome. Subject-specific bone models of the humerus and scapula were reconstructed from computed tomography scans of the dominant upper extremity. Three-dimensional kinematics were obtained from semi-automated 2D-3D shape matching. The acromion, glenoid, and combined supraspinatus/infraspinatus bony footprint (SIF) were identified from bone models to calculate bone-to-bone distances.[6,7] A glenoid-based coordinate system was used to describe GH orientation and position.[8] Raw kinematic data were processed using a median filter followed by a 4th order, 10-Hz low-pass Butterworth filter prior to calculating relative kinematics. A custom MATLAB algorithm[9] extracted GH kinematics using a X-Z-Y rotation sequence (i.e. elevation, plane of elevation, axial rotation) and calculated the minimum distance between the acromion or glenoid and SIF at the instant of spike maxER (arm cocking) (**Fig. 1**). The elevation angle at maxER was used to identify an equivalent elevation angle during the elevation phase of SAB for comparison. A bone-to-tendon footprint minimum distance $\leq$ 6 mm was deemed indicative of impingement risk based on reported RC thickness measurements.[10] Paired t-tests compared proximities, axial rotation, and elevation plane angles at this instant of spike maxER.

RESULTS SECTION: Visual inspection and Shapiro-Wilk tests confirmed the data were normally distributed. External rotation was significantly greater at spike arm cocking compared to the equivalent elevation angle (EEA) of SAB as expected (mean difference = 35.42°, $p = 0.002$). Elevation plane was not significantly different between tasks (mean difference = -4.89°, $p = 0.53$). There was no difference in internal impingement minimum distance between arm cocking and SAB at an equivalent elevation angle (mean difference = 1.47 mm, $p = 0.59$). The subacromial minimum distance was larger at arm cocking of the spike (mean difference = 2.54 mm, $p = 0.03$) (**Fig. 2A**).

DISCUSSION: Increased glenohumeral external rotation at the instant of spike arm cocking was protective against subacromial impingement but did not impact internal impingement risk as compared to SAB at an EEA. This is surprising as an abducted and externally rotated humeral position is thought to contribute to internal impingement.[4] Previous 3D studies have demonstrated conflicting results regarding the impact of humeral axial rotation on subacromial proximities.[11,12] The elevation angle at which maxER occurred (**Fig. 2B**, red)–and thus the EEA of our SAB comparator (**Fig. 2B**, blue)–varied substantially between participants (range: 78.1 - 106.1°). Our results generally agree with previous work demonstrating that subacromial compression is more likely at lower GH elevation angles.[7,12] The primary limitations of this preliminary report are the small sample size and simulated nature of the spike.

SIGNIFICANCE/CLINICAL RELEVANCE: The arm cocking position of a volleyball spike may not recreate internal impingement as described in throwers. Axial rotation may reduce the likelihood of subacromial rotator cuff compression when GH elevation angles are controlled. While increased axial rotation may induce more stress/strain deformations on these tissues, the preliminary results found in this analysis suggest that it is not a cause of subacromial impingement during a simulated spike task.

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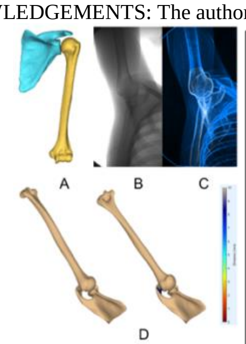

Figure 1. CT-derived bone models (A); Videoradiography (B); 2D-3D Shape Matching (C); Proximities (D)

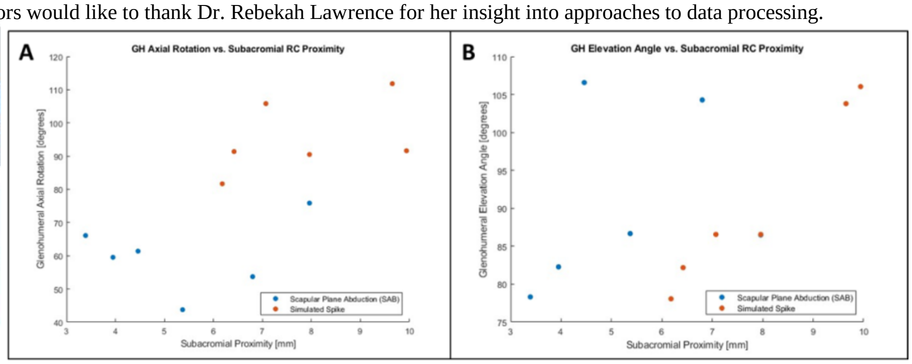

Figure 2. Glenohumeral external rotation (A) and elevation angle (B) relative to subacromial proximity.