GLENOHUMERAL JOINT CONTACT CHARACTERISTICS IN ABDUCTION AND FORWARD FLEXION

*Hansen, M L; *Glousman, R E; **Hosseinzadeh, P; **Kornswiet, M; **McGarry, M H; *Tibone J E; **Lee, T Q
*Kerlan Jobe Orthopaedic Clinic, Los Angeles, CA
++Orthopaedic Biomechanics Laboratory, Long Beach VA Healthcare System and University of California, Irvine
tqlee@med.va.gov

INTRODUCTION:
Localized articular contact pressure may be more important than joint reaction force in understanding articular cartilage injury and wear patterns. Few investigations of joint contact characteristics such as peak pressure, mean pressure, and contact area, have been reported. Additionally, the preponderance of biomechanical investigations of the glenohumeral joint have been performed in scapular plane abduction, yet many activities-of-daily-living require motion outside of this plane. The hypothesis of this study was that out-of-plane motions result in significantly different articular contact characteristics compared to scapular plane abduction. Therefore, the objective of this study was to quantify the glenohumeral joint contact pressures in the scapular plane and in forward flexion.

METHODS:
A unique method for measuring and describing glenohumeral articular contact characteristics was developed. This method utilized an established cadaver loading model with simulated constant physiologic shoulder muscle forces. The model was enhanced by placing a thin pressure sensor (K-scan model 4000, Tekscan, Inc., South Boston, MA) between the glenoid and the humeral head to provide real-time mapping of glenohumeral joint contact characteristics with resolution of 62 sensels per cm² (figure 1). Contact area, peak contact pressure, and mean contact pressure were measured by the K-scan device. Six cadaver glenohumeral joints (mean age 69 years) were tested in two positions—60° of abduction in the scapular plane and 20° of forward flexion or the plane that is 20° anterior to the scapular plane. While constrained to these two positions, an external torque was applied to the humerus to sequentially position the humerus in 60°, 30°, and 0° of external rotation.

Figure 1: Anterior view of prepared cadaver glenohumeral joint demonstrating the cables used to mimic shoulder muscles. The K-scan device is placed into the glenohumeral joint through the incised rotator interval.

RESULTS:
Figure 2 illustrates typical output from the K-scan device for six positions of the glenohumeral joint. Mean contact area, peak contact pressure, and mean contact pressure in 20° forward flexion and scapular plane abduction for all six specimens are reported in table 1. According to four-factor ANOVA (α=0.01) rotation angle and specimen had significant effects while elevation plane and trial did not. Post-hoc Bonferroni analysis demonstrated significant differences between all characteristics measured at 0° external rotation and 30° external rotation and between 0° external rotation and 60° external rotation.

Figure 2: Representative glenohumeral articular contact pressure patterns for rotation in the scapular plane and in 20° forward flexion. Data shown are from one trial for one specimen.

DISCUSSION:
The glenohumeral articular pressure measurements reported herein are within the physiologic range of pressure measurements reported in other studies. These measurements are also consistent with reported values from other cadaver studies, leading to confidence in this technique. No differences were observed in the articular contact characteristics between scapular plane pressure and 20° forward flexion, yet there were differences resulting from increasing external rotation. This may reflect a greater degree of glenohumeral articular congruity or increased capsulo-labral contribution for motions in the flexion-extension plane compared to axial rotation.

<table>
<thead>
<tr>
<th>0° ER</th>
<th>30° ER</th>
<th>60° ER</th>
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<tbody>
<tr>
<td>Contact Area (mm²)</td>
<td>234 ± 70</td>
<td>257 ± 76</td>
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<tr>
<td>Mean Pressure (MPa)</td>
<td>1.09 ± 0.35</td>
<td>1.26 ± 0.43</td>
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<tr>
<td>Peak Pressure (MPa)</td>
<td>2.24 ± 0.83</td>
<td>1.85 ± 0.65</td>
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Table 1: Mean (± one standard deviation) articular contact characteristic values for six specimens. All differences were significant compared to the 0° external rotation position.

REFERENCES:

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