IN VIVO SCAPULAR KINEMATICS DURING A SIMULATED COCKING MOTION IN THROWERS: A PILOT STUDY USING A 3D-TO-2D REGISTRATION TECHNIQUE.

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Introduction
Scapular dyskinesia has been suggested as a causative factor in throwing shoulder injury. A few studies demonstrated scapular 3D movement during throwing motion using a surface marker-based motion capture system [1, 2]. Throwing shoulders in baseball players demonstrated greater scapular pro traction, anterior tilting, and decreased upward rotation in their throwing shoulder as compared with the contralateral [3, 4]. However, no data currently exist that demonstrate scapular kinematics of simulated throwing motion using a technique that eliminates skin artifact. Therefore, the purpose of this study was to determine if there are any differences in scapular kinematics between symptomatic throwing shoulders and asymptomatic contralateral shoulders during a simulated cocking motion. We hypothesized that symptomatic shoulder demonstrates decreased scapular upward rotation and increased posterior tilt as compared with the contralateral shoulder.

Materials and Methods
Ten shoulders in 5 patients with throwing shoulder injury (age: 20.2 ± 4.4 years, height: 168.7 ± 6.3 cm, mass: 66.8 ± 5.0 kg) diagnosed as throwing shoulder injury by an orthopedic surgeon were enrolled in this IRB-approved study. Patients with an acute symptom of the shoulder, severe external rotation loss, history of the shoulder surgery, and history of contralateral shoulder injury were excluded. Informed consent was obtained from participants.

To simulate the cocking phase of a throwing motion, we developed a shoulder testing device allowing for passive shoulder external rotation (simulated late-cocking phase) followed by active internal rotation (simulated acceleration phase) with the shoulder at 90° abduction. Shoulder motion was recorded using anteroposterior fluoroscopy at 7.5 frames/s.

Patients underwent CT scan at 1.0mm slice pitch covering the entire scapula and upper half of the humerus. Geometric bone models of the scapula and humerus were created using commercially available software (3D-Doctor, Able Software Corp., Lexington, MA). The glenoid center and the humeral head center were used as origins for the scapular and humeral coordinate systems, respectively. Glenohumeral rotation angle was obtained from the humeral coordinate system relative to the scapular coordinate system, and scapular kinematics was obtained from the scapular coordinate system relative to the global coordinate system.

Using a custom software program (JointTrack, University of Florida, Gainesville, FL), the bone models were projected onto distortion-corrected fluoroscopic images and matched with the contour of the scapula and humerus. After the matching procedure is complete, movies of the model motions were created for qualitative observation, and 6-DOF kinematics of the shoulder were computed for quantitative analyses. Shoulder kinematics were analyzed as a function of external rotation.

Two-way repeated measure ANOVA was used for kinematics comparisons and Tukey test was used to detect pair-wise differences. We also used dependent t-tests to determine if the patients had significant differences in the glenohumeral range of motion. The level of significance was set at p<0.05.

Results
No significant differences were exhibited in scapular upward rotation between symptomatic and asymptomatic shoulders (Fig.1). Decreased scapular posterior tilt were observed at 40° and 30° of glenohumeral external rotation in acceleration phase (Fig.2). There were no significant differences in glenohumeral range of motion between the symptomatic and asymptomatic shoulders (Table).

Discussion
The purpose of this study was to determine if there was abnormal scapular kinematics in the symptomatic, throwing shoulders, and decreased scapular posterior tilt was observed. Scapular upward rotation angle were similar for both shoulders. These results partially agreed with some previous reports which compared forward scapular posture between dominant and non-dominant arms [3, 4].

This study was first attempt to reveal the scapular kinematics during throwing motion in detail. The measurement precision of our model-based 3D-to-2D registration technique was reported approximately 0.5 for rotations parallel to the image plane for knee kinematics [5]. Though similar results can be expected for shoulders, an overlap of the thorax and scapula in the fluoroscopic image may have reduced the accuracy. Limitations of this study included small sample size, slow shoulder motion, and restricted shoulder motion induced by the shoulder testing device.

In conclusion, scapular posterior tilt was decreased in the symptomatic, throwing shoulders as compared with the contralateral asymptomatic shoulders in patients with throwing shoulder injury.

![Figure 1. Relationship between glenohumeral external rotation angle and scapular upward rotation angle.](image1.png)

![Figure 2. Relationship between glenohumeral external rotation angle and scapular posterior tilting angle.](image2.png)

**Table. Glenohumeral range of motion (n=5)**

<table>
<thead>
<tr>
<th></th>
<th>Symptomatic shoulders (n=5)</th>
<th>Asymptomatic shoulders (n=5)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total arc</td>
<td>157.0</td>
<td>13.4</td>
<td>164.6</td>
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<tr>
<td>Horizontal adduction</td>
<td>78.7</td>
<td>10.3</td>
<td>87.8</td>
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<tr>
<td>Internal rotation</td>
<td>32.8</td>
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</tr>
</tbody>
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**References**