INTRODUCTION
Abnormal kinematics of the glenohumeral joint have been suggested as a causative factor in throwing shoulder injury [1, 2]. Recently, posterior shoulder tightness (PST) has drawn attention as a potential cause of throwing disorders such as subacromial impingement, SLAP lesion, and/or internal impingement. Superior migration of the humeral head [1, 2] and an increase of pressure in the coracoacromial arch [3] were induced by simulated PST in previous cadaveric studies. The downsides of the cadaveric studies were that the glenohumeral muscles and other superficial structures were removed and their effects on glenohumeral kinematics were ignored. To our knowledge, there have been no published studies investigating in vivo glenohumeral kinematics during a throwing activity. Therefore, the purpose of this study was to determine if increased superior migration of the humeral head exists in the injured throwing shoulders. We hypothesized that glenohumeral superior migration of the throwing shoulder is greater than that of the contralateral, uninjured shoulder.

MATERIALS AND METHODS
Twenty shoulders from 10 patients with throwing shoulder injury (mean age: 21.2 ± 1.3 y.o.) were enrolled in this IRB-approved study. Kinematics of the glenohumeral joint during a simulated cocking motion were compared between the dominant (throwing) and contralateral shoulders. Presence of pathological changes in the upper half of the glenoid (e.g. subacromial impingement, SLAP lesion etc.) was determined by an orthopaedic surgeon using MRI and physical exams. Exclusion criteria were an acute symptom of the shoulder injury, a loss of external rotation, and history of the shoulder surgery in either shoulder. We measured horizontal adduction and internal rotation angles.

To simulate the cocking motion, we developed a shoulder testing device, allowing for maximal passive shoulder external rotation and active internal rotation at 90° abduction. Shoulder motion was recorded using anteroposterior fluoroscopy at 7.5 frames/s.

Patients underwent CT scan at 1.0 mm slice pitch for the entire scapula and the proximal half of the humerus. Geometric bone models of the scapula and humerus were created using commercial software (3D-Doctor, Able Software Corp., MA). The origins and local coordinate systems of the glenoid and humeral head were defined using virtual oval and sphere as a reference, respectively [4].

Using a custom software program (JointTrack, University of Florida, FL), the 3D bone models were projected onto a distortion-corrected fluoroscopic image and matched with the contour of the scapula or humerus of the fluoroscopic images. After the matching procedure is complete, movies of the bone model motions were created for qualitative observation and 6-DOF kinematics of the shoulder were computed for quantitative analyses (3D-JointManager, GLAB corp., Hiroshima, Japan). Shoulder kinematics were analyzed as a function of glenohumeral external rotation angle.

Two-way repeated measure ANOVA was used for kinematics comparisons and Tukey/Kramer was used to detect pair-wise differences. Student’s t-test was used to detect differences of horizontal adduction range of motion between the throwing and contralateral shoulders. The level of significance was set at p<0.05.

RESULTS
There were greater inferior migrations of the humeral head at all angles in throwing shoulder than the contralateral shoulder (Figure). The humeral head of the throwing shoulder was consistently located at more inferior to the contralateral shoulder at all angles. There were significant differences in external rotation angle, internal rotation angle and horizontal adduction angle between throwing shoulder and contralateral shoulder (Table).

DISCUSSION
The purpose of this study was to determine if increased superior migration of the humeral head exists in the injured throwing shoulders. Surprisingly, there were significant greater inferior migrations in the throwing shoulder.

Previous cadaveric studies reported greater superior migration caused by simulated PST [1, 2]. The present study demonstrated the opposite. Although the reason for this discrepancy was not revealed in this study, potential reasons may include neuromuscular activity, tension of superficial muscles such as the deltoid and pectoralis major as well as superficial structures such as skin, subcutaneous and fat tissues. Also, a physical contact between the acromion and greater tuberosity should be taken into consideration as a factor that applied inferior force on the humeral head. Further studies are needed to reveal the reason for this.

This study enrolled only young adult and an evidence of joint contracture was absent in all subjects. Our 3D-to-2D registration technique allowed accurate analyses for in-plane shoulder kinematics during the simulated throwing motion in vivo, in which all joint structures and neuromuscular system were taken into considerations. The result of this study was contradictory to the result of previous cadaveric studies. It further requires more in vivo studies to reveal the pathokinematics of the symptomatic throwing shoulders.

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