INTRODUCTION: Alterations in scapular motion frequently are seen in association with various shoulder disorders, such as rotator cuff tears, impingement syndrome and instability. Clinically, it is common to compare the pathological shoulder with the contralateral shoulder, in spite of arm dominance, to characterize the disorder. However, there have been few articles that test the underlying assumption that dominant and nondominant shoulders exhibit comparable dynamic kinematics. The purpose of this study was to compare the three-dimensional (3D) scapular kinematics of dominant and nondominant shoulders during dynamic scapular plane abduction using 3D–2D registration techniques.

METHODS: Eleven healthy males with a mean age of 32 years (range, 27–36 years old) were enrolled in this study. All subjects provided informed consent to participate in this IRB approved study. All subjects were right-handed.

Fluoroscopic images of scapular plane abduction were recorded at 15 Hz for both shoulders in each subject. Bilateral CT scans of the shoulders were acquired with a 1.0 mm pitch, and 3D models of the proximal humerus and the scapula were created (ITK-snap, Penn Image Computing and Science Laboratory, Philadelphia, PA). Anatomic coordinate systems were embedded in each model according to reported conventions (Geomagic studio, Raindrop Geomagic, Research Triangle Park, NC) (1). In brief, the humeral origin was placed at the centroid of the humeral head. Y axis was parallel to the humeral shaft, and Z axis was defined as a line through intertubercular groove from the origin. The scapular origin was defined as the midpoint of the line connecting the most superior and inferior bony edges of the glenoid, and Y and Z axis were pointed superiorly and anteriorly, respectively.

The 3D position and orientation of the humerus and the scapula were determined using model-image registration techniques (Fig. 1 (2). The kinematics of the humerus and the scapula relative to the x-ray coordinate system were determined using Euler angles. Elevation of the humerus was defined as rotation about Z axis. Motion of the scapula was defined as anterior-posterior tilt about X axis, internal-external rotation about Y axis, and upward-downward rotation about Z axis. The angular data of the scapula were plotted as a function of the humeral elevation, and new values were calculated from the polynomial regression line of the plots in each 15° increments of the humeral elevation. SHR was defined as the ratio of the increment in glenohumeral elevation angle to the increment in scapular upward rotation, and was computed as the slope of the polynomial regression line using scapular upward rotation as the independent value and glenohumeral elevation angle as the dependent value.

The angular data of the scapula and SHR were compared between dominant and nondominant shoulders. Two-way repeated-measure analysis of variance was used for statistical analysis, and the level of significance was set at P<0.05 (PASW17.0, SPSS Inc., Chicago, IL).

RESULTS: As the arm was raised, the mean upward rotation, posterior tilt and internal rotation of the scapula increased almost linearly through the activity (Figure 2 a–c). The mean change in upward rotation angle from arm at side to maximum elevation was greater for dominant than nondominant shoulders, averaging 45° ± 8° and 40° ± 6°, respectively (p=0.03). The mean posterior tilt from arm at side to maximum elevation for dominant and nondominant shoulders was 26° ± 8° and 24° ± 7° (p=0.35). The mean internal rotation angle from arm at side to maximum elevation for dominant and nondominant shoulders was 6° ± 4° and 6° ± 6°, respectively (p=0.87).

The mean overall SHR from arm at side to maximum elevation for dominant and nondominant shoulders was 2.4 ± 0.7 and 2.7 ± 0.6, respectively. There was no significant difference in incremental SHR data between paired shoulders (P=0.17) (Figure 3).

DISCUSSION: Several studies have assessed the 3D kinematics of the scapula. Bone-fixed electromagnetic tracking sensors recently were used and found angles of upward rotation, posterior tilt and internal rotation during scapular plane abduction were 39°, 21° and -2°, respectively (3). Our data were quite consistent with this study except internal rotation.

There has been only one published article that assessed side-to-side difference in the dynamic scapular kinematics using 3D motion analysis with surface markers (4). This study showed no significant difference in scapular upward rotation and SHR between dominant and nondominant shoulders. However, we found a significant difference in upward rotation between shoulders. Arm dominance may have some influence on the scapular kinematics, such as differences in muscle coordination and muscle imbalance due to overuse.

The present study demonstrated a significant difference in upward rotation, but the difference might be too small (approximately 6°) to observe in the clinical setting. It is important to understand that healthy scapular motions may differ subtly with dominance, and further study might elucidate the contributing factors. At this time, practical clinical methods to precisely measure scapular motions do not exist, and we have not yet developed a diagnostic framework to use these measures. For now, we believe it is appropriate to continue the common clinical practice comparing pathologic and contralateral shoulders as the basis for diagnosis and outcome assessment.

REFERENCES: