INTRODUCTION
Shoulder rhythm, which is the coordinated movement of the scapula and humerus during arm elevation, may be affected by shoulder pathology. Ludewig and Cook have reported that impingement syndrome affects shoulder rhythm. Others have reported no difference in scapular orientation between patients with cuff pathology and controls (Graichen et al. 2001). Previous studies have focused on elevation in the scapular plane, and little work has been done to explore differences in shoulder rhythm between patients having impingement syndrome and full thickness rotator cuff tears (RCTs). The purpose of this study was to test the hypothesis that shoulder rhythm is affected by rotator cuff pathology (tendinopathy and RCT) during arm elevation in the sagittal and scapular planes.

METHODS
Forty-two subjects were divided into three groups for this study. Group 1 consisted of 15 healthy volunteers (9 F, 6 M, 47.8 ± 14.6 years) who had no history of shoulder pain or trauma in either shoulder, group 2 included 13 patients (3 F, 10 M, 52.5 ± 8.3 years) with chronic (more than 3 months) rotator cuff tendinopathy but without a full thickness tear as seen during imaging of cuff tendons, and group 3 consisted of 14 patients (4 F, 10 M, 54.7 ± 8.3 years) with chronic (more than 3 months) full-thickness rotator cuff tear greater than 1 cm$^2$ in size as seen during imaging of the cuff tendons.

Sensors from the MotionStar electromagnetic tracking system (Ascension Technology, Burlington, VT) were placed at subject’s sternum, scapula (Karduna et al. 2001), humerus (LaScalza et al. 2002), and forearm. Subjects were seated in a wooden chair and performed 3 trials of flexion in the sagittal plane and elevation in the scapular plane. The order of the trials was randomized.

Shoulder and arm kinematics were computed from the MotionStar sensor data. The digitized landmarks were used to construct anatomic coordinate systems (van der Helm and Pronk 1995), and these were represented in the local coordinate systems of each electromagnetic sensor. At each point in time, the anatomic coordinate systems were rotated using the rotation data of the electromagnetic sensors. Thus, at each point in time the anatomic coordinate systems were computed in the global coordinate system of the MotionStar transmitter. Euler angles were computed. For the scapula, the three angles were protraction, elevation, and AP tilt. For the humerus, the angles were plane of elevation, elevation, and axial rotation. Both scapula and humeral angles were computed with respect to the torso coordinate system.

Data was divided into three equal phases based on minimum and maximum humeral elevation. Linear curves were fit to each phase of the scapular elevation versus humeral elevation curve. The dependent
Slope (SEM) for Abduction in Scapular Plane

Figure 1: Average slope (SEM) of scapular elevation versus humeral elevation for each group during abduction in scapular plane. * indicates P<0.05.

Slope (SEM) for Elevation in Sagittal Plane

Figure 2: Average slopes (SEM) of scapular elevation versus humeral elevation for each group during sagittal flexion. * indicates P<0.05.

measure used in the analysis was the slope of the linear fit in each phase. A one-way ANOVA model was used to test for differences between experimental groups.

RESULTS AND DISCUSSION

Statistically significant differences in scapular contribution to arm elevation were found between experimental groups. The RCT group had higher slopes in Phases 1 and 2 for elevation in the sagittal plane and for Phase 2 during abduction in the scapular plane. No statistically significant differences were found between the tendinopathy group and healthy controls. Differences were found between the tendinopathy and RCT groups. These results suggest that for the RCT group, the scapula moves more for the same amount of humeral elevation. The difference in slopes between the tendinopathy and RCT groups suggests the change in shoulder rhythm is caused by loss of cuff function rather than pain, as both the impingement and RCT groups were symptomatic. It may be that the scapula is elevated more by the RCT group in the initial two-thirds of movement to change the length of remaining muscles so they operate on a more effective part of their length-tension curve. Scapular anterior-posterior tilt and protraction were also analyzed. However, no statistically significant differences were found between groups.

REFERENCES


ACKNOWLEDGEMENTS

This research was supported by the Clinical Research Partnership Fund grant from the University of Michigan.