Effects of Scapular Orientation on Shoulder Internal Impingement: A Study on Cadaveric Models

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INTRODUCTION:
Discrepancies in scapular orientation are thought to result in loss of center of rotation, diminished function of the kinematic chain between the upper and lower extremity, and decreased muscular function, thereby increasing the risks of shoulder injury. Despite the recognized importance of proper scapular motion in throwers, the biomechanical mechanism underlying glenohumeral injuries secondary to altered scapular orientation remains unclear. To our knowledge, no study had investigated the biomechanical effects of scapular orientation on throwing injuries in the glenohumeral joint. Our previous cadaveric studies showed that increased glenohumeral horizontal abduction and rotator cuff muscle imbalance resulted in increased glenohumeral contact pressure and contact area between the greater tuberosity and glenoid during shoulder internal impingement. Here, we hypothesized that altered scapular orientation led to changed glenohumeral kinematics and contact pressure, and thus affected internal impingement areas. The objective of this study was to assess the effects of scapular orientation, (upward/downward rotation, anterior/posterior tilt and external/internal rotation), on shoulder internal impingement.

METHODS:
Seven fresh-frozen cadaveric shoulders (47 to 66 years) were tested using a shoulder testing system (Figure 1). To simulate the shoulder position during the late cocking phase of the throwing motion, the humerus was positioned at 90° of shoulder abduction, with the humerus externally rotated from 90° to the maximum angle. An initial scapular position during the simulated late cocking phase was defined based on clinical data as upward rotation at 30°, anterior tilt at 10°, and internal rotation at 30°. To assess the effects of scapular orientation on glenohumeral contact pressure and area of impingement, all measurements were performed and compared by changing each scapular orientation: increased upward rotation to 40°, decreased upward rotation to 20°, increased internal rotation to 40°, decreased internal rotation to 20°, and decreased anterior tilt to 0°.

Muscle forces were determined from previously published studies: we used the maximum muscle potential force from the physiological cross-sectional area of each muscle, and shoulder muscle activity during throwing. From these studies, we calculated the proportional shoulder muscle forces in the late cocking phase by multiplying the maximum muscle force by muscle activity: 8 N for supraspinatus, 72 N for subscapularis, 24 N for infraspinatus, 6 N for teres minor, 20 N for deltoid anterior and middle, 4 N for deltoid posterior, 21 N for pectoralis major, 15 N for latissimus dorsi, and 15 N for teres major.

Glenohumeral contact pressure and the amount of internal impingement area were quantitatively calculated (Figure 1). Glenohumeral contact pressure at maximum external rotation position was measured using Tekscan. To measure the area of internal impingement, the location of the rotator cuff insertion on the greater tuberosity relative to the glenoïd was digitized and tracked. The area of internal impingement was then reconstructed and calculated with Rhinoceros software.

Repeated-measures analysis of variance (ANOVA) was performed for each independent variable, including maximum glenohumeral contact pressure and maximum area of impingement. Fisher’s post hoc analysis was performed to identify the differences between scapular orientations when a significant main effect was found.

RESULTS:
Glenohumeral contact pressure increased with increasing internal rotation of the scapula (20°, 1.45±0.13MPa; 30°, 1.82±0.13MPa; 40°, 2.08±0.20MPa). The glenohumeral contact pressure at 20° of internal rotation was significantly less than that at 40° of internal rotation (p < 0.01). Glenohumeral contact pressure was not significant different among 20°, 30° and 40° of upward rotation and between 0° and 10° of anterior tilt.

The impinged area decreased with increasing upward rotation of the scapula (20°, 226±28mm²; 30°, 197±32mm²; 40°, 140±26mm²). The internal impingement area at 40° of upward rotation was significantly less than that at 20° (p < 0.0001) and 30° (p < 0.01) of upward rotation. The area of internal impingement increased with increasing internal rotation of the scapula (20°, 167±22mm²; 30°, 197±32mm²; 40°, 239±45mm²). The internal impingement area at 20° of internal rotation was significantly less than that at 40° of internal rotation (p < 0.05). There was no significant difference in internal impingement area between 0° and 10° of anterior tilt (p = 0.23).

DISCUSSION:
The increase in glenohumeral contact pressure with increased internal rotation of the scapula suggests that throwing athletes who show a prominent medial scapular border, which is a physical sign of increased internal rotation of the scapula, need scapular exercise to prevent forceful internal impingement. The increase in the internal impingement area with decreased scapular upward rotation, and with increased scapula internal rotation, indicates that scapula exercise for athletes that use a throwing action may be effective in preventing extension of the articular-sided partial thickness rotator cuff tear that results from internal impingement.

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Image 1: Shoulder testing system. Image 2: Internal impingement area and contact pressure with upward rotation. Image 3: Internal impingement area and contact pressure with internal rotation.

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