INTRODUCTION:
Shoulder internal impingement occurs when there is contact between the undersurfaces of the supraspinatus and infraspinatus tendons with the greater tuberosity, superior labrum, and glenoid rim. Magnetic resonance imaging (MRI) has shown that the contact between the undersurfaces of the supraspinatus and infraspinatus tendons and the glenoid rim occurs when the arm is in the abducted, externally rotated position as in the late cocking position of the throwing motion. Several studies have reported that external-to-internal rotator muscle force ratios are lower in a baseball player’s dominant extremity than in the non-dominant extremity. This lower ratio on the dominant side results from an increased strength in internal rotation without concomitant increase in external rotation strength for high performance of throwing. In addition, an electromyographic study showed that in throwing athletes those with shoulder pain elicited at the apprehension position had decreased activity of the subscapularis and pectoralis major muscles in the late cocking phase of throwing. Therefore, we hypothesized that changes in the internal rotator muscle force have a strong influence on the magnitude of forceful internal impingement in the late cocking position. The objective of this study was to quantify the effects of internal rotator muscle force on glenohumeral contact pressures and the internal impingement area.

METHODS:
Seven fresh-frozen cadaveric shoulders (36 to 59 years) were tested using a shoulder testing system (Figure 1). To simulate the glenohumeral position during the late cocking phase of throwing, the humerus was positioned at 90 degrees of shoulder abduction (30 degrees of scapular inclination and 60 degrees of glenohumeral abduction) and 30 degrees of horizontal abduction with respect to the scapular plane which was the simulated coronal plane.

Muscle forces were determined from previous published studies using the maximum muscle potential force from the physiological cross-sectional area of each muscle and shoulder muscle activity during throwing. Force conditions in the asymptomatic shoulder model were defined as the initial condition: 3 N for supraspinatus, 66 N for subscapularis, 25 N for infraspinatus and teres minor, 3 N for deltoid, 30 N for pectoralis major, 4 N for latissimus dorsi, and 3N for teres major. To assess the effects of changes in internal rotator muscle force, each internal rotator muscle force was varied. The subscapularis muscle force was decreased to 21 N and increased to 80 N; the pectoralis major muscle force was decreased to 21 N and increased to 36 N; the latissimus dorsi muscle force was decreased to 0 N and increased to 13 N; and the teres major muscle force was decreased to 0 N and increased to 9 N.

RESULTS:
Glenohumeral Contact Pressure
The glenohumeral contact pressure with decreased subscapularis muscle force was significantly greater by 0.31 ± 0.14 MPa than that with increased subscapularis muscle force (P < .01). Decreased pectoralis major muscle force also significantly increased the glenohumeral contact pressure by 0.21 ± 0.11 MPa compared with that with increased pectoralis major muscle force (P < .05).

Internal Impingement Area
Three out of four muscle groups showed significant increases in impingement area with decreasing muscle loads. Decreased subscapularis muscle force resulted in a significant increase in impingement area by 33.6 ± 15.3 mm² compared with that with increased subscapularis muscle force (P < .01). The internal impingement area with decreased latissimus dorsi muscle force was significantly greater by 29.5 ± 15.6 mm² than that with increased latissimus dorsi muscle force (P < .05). Decreased pectoralis major muscle force also significantly increased the internal impingement area by 26.7 ± 14.0 mm² compared with that with increased pectoralis major muscle force (P < .05).

DISCUSSION:
This study showed that glenohumeral contact pressure decreased significantly with increased force of internal rotator muscles, suggesting that strengthening of the internal rotator muscles may help prevent shoulder injuries caused by forceful internal impingement. Also the internal impingement area of supraspinatus and infraspinatus tendons decreased significantly with increased force of internal rotator muscles indicating that internal rotator muscle strengthening may be effective in preventing the extension of partial rotator cuff tears due to internal impingement. The changes in glenohumeral contact pressure and impingement area between decreased and increased muscle forces among all the internal rotator muscles were the largest for the subscapularis. Therefore, the subscapularis may be the most influential in shoulder internal impingement of the internal rotator muscles.

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