EFFECT OF GLENOID INCLINATION ON SUPERIOR HUMERAL HEAD MIGRATION

INTRODUCTION
Anatomic features of the scapula have been shown to be associated with rotator cuff pathology. Recent research has demonstrated a statistical relationship between rotator cuff tears and the angle of the glenoid in the plane of the scapula ("glenoid inclination"), where shoulders with full-thickness tears had an inclination angle 7.6 degrees larger than contralateral shoulders without cuff tears.  In theory, having a more superiorly facing plane of the scapula ("glenoid inclination"), where shoulders with full-thickness tears had an inclination angle 7.6 degrees larger than contralateral shoulders without cuff tears.  That would make it more difficult for the rotator cuff muscles to maintain joint stability. The objective of this project was to test the hypothesis that increased inclination angle decreases the amount of deltoid force required to produce superior humeral head migration when rotator cuff forces are held constant.

METHODS
A planar analytical model was developed to determine the effect of the superior inclination of the glenoid on superior stability of the glenohumeral joint. The model was constructed based on three assumptions: (1) the glenohumeral joint reaction force acts perpendicular to the articular surface, (2) the glenohumeral joint has negligible friction, and (3) superior humeral head migration would occur when the net force vector (sum of forces due to gravity and muscle contraction) is superior to a line perpendicular to the tangent of the superior glenoid. To construct this model, the radius of the glenoid articular surface (26.3 mm) and the distance from inferior to superior glenoid (39 mm) were taken from data reported by Iannotti et al. The radius of the humeral head was 24 mm, and the joint was modeled as a congruent joint. Rotator cuff forces were estimated from muscle physiologic cross sectional area, muscle specific tension, and electromyographic (EMG) measurements for the initiation of abduction with a 20N weight in the hand. The contraction force of a muscle was modeled as the mathematical product of the fraction of maximum EMG, muscle physiological cross sectional area, and a specific tension of 42N/cm². The infraspinatus and teres minor muscles were grouped together for this analysis. Muscle lines of action were taken from Poppen and Walker. The shoulder rhythm was assumed to be two degrees of glenohumeral elevation for every degree of scapulothoracic elevation. Keeping all other components unchanged, the model was used to calculate the minimal deltoid force required to produce superior migration of the humeral head while modifying the superior inclination angle of the glenoid.

An experiment was conducted to evaluate the model. Eight unpaired cadaver shoulders with no existing shoulder pathology were tested using a custom test fixture mounted on an MTS frame. The mean age at death was 73.8 (16.6) years; four were male and four were female. Each shoulder was rigidly mounted after removing all soft tissue except rotator cuff tendons. Nylon lines were attached to the tendons, and weights were applied to the tendons to simulate muscle contraction. The humerus was transected at the mid-diaphysis and potted in methylmethacrylate to a fixture attached to the MTS load cell. A slot was cut in the scapula immediately medial to the glenoid. A planar analytical model was developed to determine the effect of the superior inclination of the glenoid on superior stability of the glenohumeral joint. The model was constructed based on three assumptions: (1) the glenohumeral joint reaction force acts perpendicular to the articular surface, (2) the glenohumeral joint has negligible friction, and (3) superior humeral head migration would occur when the net force vector (sum of forces due to gravity and muscle contraction) is superior to a line perpendicular to the tangent of the superior glenoid. To construct this model, the radius of the glenoid articular surface (26.3 mm) and the distance from inferior to superior glenoid (39 mm) were taken from data reported by Iannotti et al. The radius of the humeral head was 24 mm, and the joint was modeled as a congruent joint. Rotator cuff forces were estimated from muscle physiologic cross sectional area, muscle specific tension, and electromyographic (EMG) measurements for the initiation of abduction with a 20N weight in the hand. The contraction force of a muscle was modeled as the mathematical product of the fraction of maximum EMG, muscle physiological cross sectional area, and a specific tension of 42N/cm². The infraspinatus and teres minor muscles were grouped together for this analysis. Muscle lines of action were taken from Poppen and Walker. The shoulder rhythm was assumed to be two degrees of glenohumeral elevation for every degree of scapulothoracic elevation. Keeping all other components unchanged, the model was used to calculate the minimal deltoid force required to produce superior migration of the humeral head while modifying the superior inclination angle of the glenoid.

RESULTS
The experimental data agreed well with the mathematical model (Figure 1). The force required to superiorly sublux the humeral head decreased significantly (p<0.001) as the glenoid inclination angle increased. The percent decrease in force was 14.2, 29.9, and 37.5% for the 5, 10, and 15 degree wedges, respectively. The average reductions predicted by the mathematical model for the three wedge angles were 12.5, 28.3, and 39.9%, respectively.

DISCUSSION
The data support the hypothesis that increases in glenoid inclination angle increase the potential for deltoid contraction to produce superior humeral head migration, which may cause rotator cuff pathology. Therefore, glenoid inclination angle may be a critical parameter in mathematical models of rotator cuff pathology. Our results are consistent with the "concavity compression" theory of glenohumeral stability.

REFERENCES

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