STRENGTHENING THE INFERIOR ROTATOR CUFF ENABLES ABDUCTION IN MASSIVE ROTATOR CUFF TEARS. RESULTS FROM A CADAVER MODEL OF ACTIVE NEUROMUSCULAR STEERING OF THE HUMERAL HEAD.

+*Hansen, ML; *Cordasco, FA; *Craig, EV; *Warren, RF
+*Hospital for Special Surgery, New York City, NY
mhansen@md.aaos.org

Introduction
This study investigates the stabilizing potential of the teres minor and inferior subscapularis in massive rotator cuff tears. It is hypothesized that glenohumeral abduction without excessive superior migration of the humeral head is possible in the presence of a massive rotator cuff tear if sufficient strength can be developed in the remaining intact cuff. This would help to explain the clinical observations that some patients with massive tears maintain the ability to abduct and that patients maintain good AROM postoperatively despite high re-tear rates after rotator cuff repair. The magnitude of strengthening required for stable abduction in the scapular plane is quantified for 6cm, 7cm, and 8cm three-tendon tears. A unique cadaver shoulder model was developed to perform the study.

Methods
The key premise for our shoulder model is that humeral head steering is under neuromuscular control. Such control requires a neuromuscular arc consisting of proprioceptors, afferent neurons, synapses for central signal integration, motor neurons, and muscle units to exert the desired effect upon the humerus. We modeled each element of this neuromuscular arc in *cadavera* with devices capable of measuring muscle force, muscle excursion, and glenohumeral angular and linear translation in three dimensions. Eight stepper motors simulate the action of scapulohumeral muscles—three heads of the deltoid, supraspinatus, superior subscapularis, inferior subscapularis, infraspinatus, and teres minor. Custom software automatically modulates the tension produced by the stepper motors by means of closed-loop feedback control, achieving the desired position with the minimum force necessary.

Six cadaver glenohumeral joint specimens (mean age 69 years) were tested in scapular plane abduction with the full weight of the upper extremity simulated. The humeral head steering model limited superior migration of the humeral head to 3mm while maintaining neutral internal/external rotation. Each specimen was tested in four rotator cuff conditions—intact, 6cm tear, 7cm tear, and 8cm tear. The tears were centered on the supraspinatus, extending symmetrically into the subscapularis anteriorly and into the infraspinatus posteriorly.

Results
Using the humeral head steering model, all six specimens achieved full abduction with less than 3.0mm superior migration of the humeral head for all tear sizes. The total rotator cuff force needed to stabilize the head is shown in figure 1. The greatest increase in rotator cuff force occurs at 15° for all tear sizes and is 25.5lbs for the 8cm tear (99% CI 20.9lbs to 30.1lbs.) Figure 2 shows the deltoid force required for abduction. The deltoid force increase also peaks at 15° and is 17.2lbs for the 8cm tear (99% CI 15.1lbs to 19.3lbs). Four factor ANOVA showed that the effect of cuff tear was significant at p<0.01 for all cuff tear sizes. In general, larger tears required greater force increases to maintain stability of the humeral head during active abduction, especially during early abduction.

Discussion
These results demonstrate that stable glenohumeral abduction is possible in the setting of massive rotator cuff tears so long as sufficient strength can be developed in the remaining teres minor and inferior subscapularis. The magnitude of the strength increase found in this study is within the range of many estimates of the force generating capacity of these muscles. The differential innervation and activation of the teres minor and inferior subscapularis indicate they may play specialized roles in stabilizing the humeral head. As confirmed in this study, the predominantly eccentric contraction of these two muscles in the setting of a massive tear suggests that rehabilitation should focus on eccentric training. The lower force requirements for smaller tears indicate that partial repair of massive tears is beneficial. These are important considerations as injury to the anterior cuff is being more frequently recognized in massive cuff tears.