# Muscle activation patterns during active external rotation after reverse total shoulder arthroplasty: An electrophysiological study of the teres minor and associated musculature

Polio W, Hajek B, Brolin TJ, Mihalko WM, Kunal S, Hughes S, Nelson A, Hayes T, Chiu C, Bernholt DL, Azar FM, Throckmorton TW

[1]University of Tennessee Health Science Center, Memphis TN

[2]Campbell Clinic, Memphis TN

**Introduction:**

Reverse total shoulder arthroplasty (RTSA) is a reliable treatment for restoring forward elevation in patients with end-stage shoulder conditions, particularly rotator cuff tear arthropathy. However, return of functional external rotation (ER) after RTSA has been less predictable. A previous study has identified pre-operative teres minor insufficiency as a predictor of unsatisfactory external rotation following RTSA. However, there has been little investigation of the muscle activation patterns that generate ER post-operatively. We proposed to determine the timing and relative activation levels of the shoulder girdle musculature during external rotation in patients who have a well-functioning RTSA. We hypothesized that the teres minor and posterior deltoid would be most significantly activated during ER.

**Methods**:

IRB approval was obtained for this prospective study. Patients from a single institution who were at least 1-year post-operative from an RTSA with intact functional external rotation based on patient reported outcomes and an ASES score over 70 were included in this study. Additional inclusion criteria included an operative indication of superior rotator cuff deficiency (massive rotator cuff tear or cuff tear arthropathy) and an intact teres minor (grade 0 or 1 fatty infiltration) based on pre-operative CT and/or MRI imaging. All RTSA's were performed using a medial glenoid/lateral humerus design.

Subjects were recruited to perform electrophysiological and kinematic analyses of their shoulder during external rotation in two starting positions: modified neutral (MN) and abduction (AB). In the MN position, the shoulder was tested with the arm at the side with 90 degrees of elbow flexion. For the AB position, the shoulder was abducted to 90 degrees with 90 degrees of elbow flexion. Seven surface EMGs (anterior deltoid, middle deltoid, latissimus dorsi, upper trapezius, middle trapezius, lower trapezius, and pectoralis major) and 3 needle EMGs (teres minor, teres major, posterior deltoid) were placed along the upper extremity prior to participation. At the respective positions, the patients were instructed to maximally externally rotate the operative shoulder. Patients performed AB and MN during dynamometer testing for 5 trials in each condition. Dynamometer recorded torque and position at 100 Hz were mathematically pattern-matched to electromyography (2000 Hz; EMG). Visual 3D was used to identify external rotation time series. Custom software (MATLAB, 2021a) was utilized to perform Teager-Kaiser energy operator on EMG signals to determine EMG onset and offset from which RMS (root mean square) and integrated EMG (in microvolts*msec with standard deviation (SD)) and median frequency ((MF) in Hertz (Hz) with SD) to determine muscle fiber recruitment strategies were calculated. Pairwise t-test analysis was performed to determine the activation of each muscle relative to each other. Differences with $p<0.05$ were considered statistically significant. A pre hoc power analysis with beta of 0.80 and alpha of 0.05 suggested a cohort of 16 subjects would be required to detect a difference in EMG muscle activation.

**Results**:

A total of 16 patients were included in the study. The study cohort was comprised of 10 females and 6 males with an average age of 71.9 years (range 52-80) at an average post-operative period of 24.8 months (range 12-60). 9 left shoulders and 7 right shoulders were tested. The average ASES score was 87.7 (range 70.8-100) and the average visual analog pain score was 0.5 (range 0-3). The average ASES subscore for external rotation in abduction ("comb hair") was 2.75 out of 3 (range 2-3).

In the AB position, the sequence of muscle activation from IR to ER began predominantly with the upper trapezius (48.8 microvolts*msec, SD 46.1), middle trapezius (56.4 SD 59.4), and latissimus dorsi (11.3, SD 9.8) followed by the anterior deltoid (52, SD 33.8), which activated until the arm reached neutral rotation. As the arm continued to externally rotate past neutral, the teres major (9.6, SD 9.2) initiated external rotation against gravity followed by the teres minor (14.1, SD 18.2) and then the posterior deltoid (11.1, SD 9.3) (Figure 1). MF analysis indicated that the teres major (1.1 Hz, SD 0.5), teres minor (1.2, SD 0.4), and posterior deltoid (1.1, SD 0.4) work as equivalent contributors to external rotation beyond neutral rotation. In MN position, the upper trapezius (22, SD 24.1) and middle trapezius (27.5, SD 28.3) were not recruited to same level as in AB. As external rotation beyond neutral was initiated, the teres major (9.5, SD 9, MF 1.1, SD 0.5), teres minor (11.4, SD 15.1, MF 1.1, SD 0.5), and posterior deltoid (8.5, SD 8, MF 1.2, SD 0.3) are activated in the same sequence and similar intensity as in AB. There were no statistically significant differences in the duration or intensity of muscle activation among teres major, teres minor, and posterior deltoid ($p>0.05$).

**Discussion**

Active external rotation following RTSA is a complex interplay of the shoulder girdle musculature. The results of this study establish a sequence of muscle activation for external rotation in a well-functioning RTSA. In AB, the upper trapezius, middle trapezius and latissimus dorsi are likely initial scapular stabilizers, with the anterior deltoid powering external rotation towards neutral. Beyond neutral, the teres major, teres minor, and posterior deltoid function equally and sequentially to power maximal external rotation. In MN, activation of the scapula stabilizers is not as robust, likely due to the elimination of gravity. However, the teres major, teres minor, and posterior deltoid are activated in a similar fashion as in AB to power external rotation.

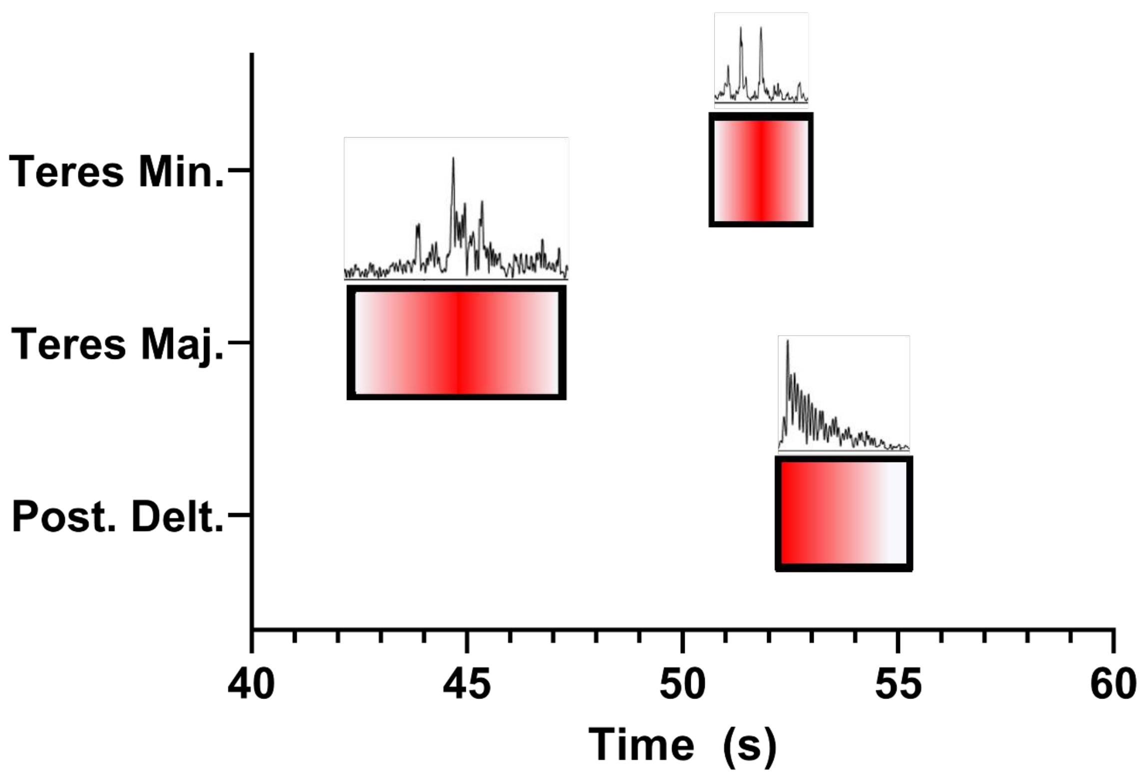


Figure 1: Muscle activation timing (seconds) and a representation of EMG intensity (microVolts*msec) demonstrates the sequence, duration, and intensity of muscle activation to power ER after RTSA.