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Deltoid Moment Arms During Abduction: A Subject-Specific Musculoskeletal Modeling Study in Healthy Shoulders and Shoulders with RTSA

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Deltoid Moment Arms During Abduction: A Subject-Specific Musculoskeletal Modeling Study in Healthy Shoulders and Shoulders With RTSA

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Reverse total shoulder arthroplasty (RTSA) is increasingly used in the United States since approval by the FDA in 2003. RTSA relieves pain and restores mobility in arthritic rotator cuff deficient shoulders. Though many advantages of RTSA have been demonstrated, there still are a variety of complications (implant loosening, shoulder impingement, infection, frozen shoulder) making apparent much still is to be learned how RTSA modifies normal shoulder function. The goal of this study was to assess how RTSA affects deltoid muscle moment generating capacity post-surgery using a subject-specific computational model driven by *in vivo* kinematic data.

A subject-specific 12 degree-of-freedom (DOF) musculoskeletal model was used to analyze the shoulders of 27 subjects (14-RTSA, 12-Normal). The model was modified from the work of Holzbaur et al. to directly input 6 DOF humerus and scapula kinematics obtained using fluoroscopy. Model geometry was scaled according to each subject's skeletal dimensions. *In vivo* abduction kinematics for each subject were input to their subject-specific model and muscle moment arms for the anterior, lateral and posterior aspects of the deltoid were measured over the arc of motion.

Similar patterns of muscle moment arm changes were observed for normal and RTSA shoulders. The moment arm of the anterior deltoid was positive with the arm at the side and decreased monotonically, crossing zero (the point at which the muscle fibers pass across the joint center) between 50°-60° glenohumeral abduction (Figure 1a). The average moment arm of the lateral deltoid was constant and positive in normal shoulders, but showed a decreasing trend with abduction in RTSA shoulders (Figure 1b). The posterior deltoid moment arm was negative with the arm at the side, and increased monotonically to a positive value with increasing glenohumeral abduction (Figure 1c). Subject-specific moment arm values for RTSA shoulders were highly variable compared to normal shoulders. 2-way repeated measures ANOVA showed significant differences between RTSA and normal shoulders for all three aspects of the deltoid moment arm, where the moment arms in RTSA shoulders were smaller in magnitude.

Shoulder functional capacity is a product of the moment generating ability of the shoulder muscles which, in turn, are a function of the muscle moment arms and muscle forces. Placement of implant components during RTSA can directly affect the geometric relationship between the humerus and scapula and, therefore, the muscle moment arms in the RTSA shoulder. Our results show RTSA shoulders maintain the same muscle moment arm patterns as healthy shoulders, but they show much greater inter-subject variation and smaller moment arm magnitudes. These observations show directly how RTSA configuration and implant placement affect deltoid moment arms, and provide an objective basis for determining optimal implant configuration and surgical placement to maximize RTSA function in a patient-specific manner.

Figures

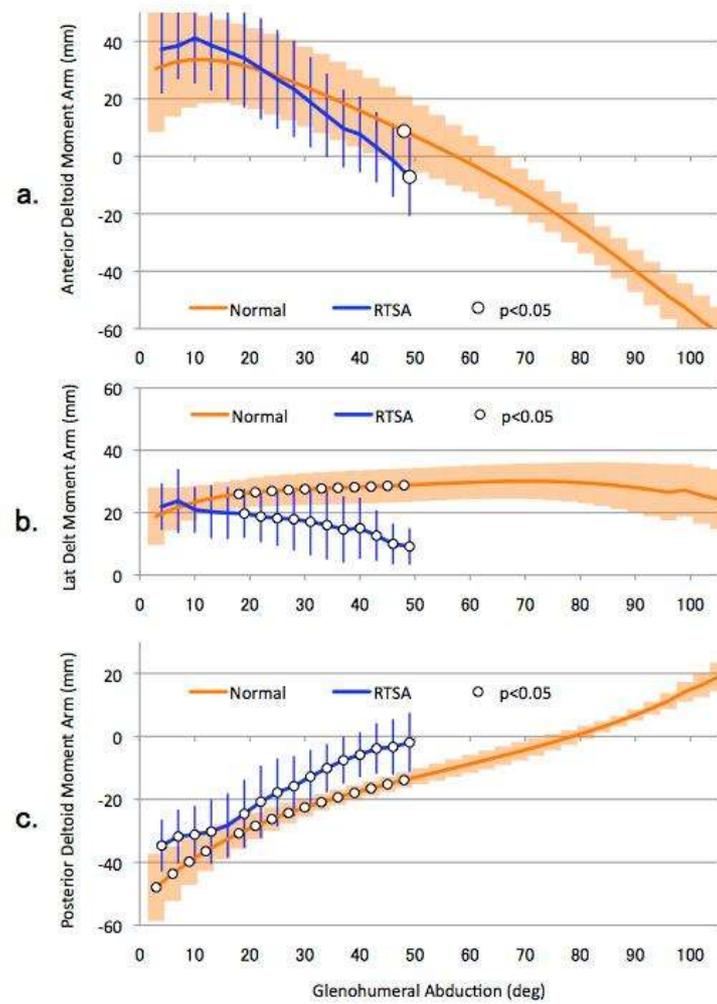


Figure 1. Deltoid moment arms varied over the arc of shoulder abduction. (a) The anterior deltoid showed a decreasing trend in both healthy and RTSA shoulders, and the RTSA moment arms were significantly smaller by mid-abduction. (b) The lateral deltoid was almost constant across the abduction arc in healthy shoulders, but was decreasing and smaller in magnitude in RTSA shoulders. (c) The posterior deltoid moment arm increased from initial negative values, but the magnitude was always greater in the healthy shoulders. The mean \pm 1stdev is shown for normal (orange) and RTSA (blue) shoulders, and pair-wise differences are denoted by open circles.

[Figure 1](#)