

# Impact of Glenoid and Humeral Lateralization in Reverse Total Shoulder Arthroplasty on Deltoid and Rotator Cuff Torque Generation

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## INTRODUCTION:

Modern reverse total shoulder arthroplasty (rTSA) designs can lateralize either the glenoid and/or the humeral component and this affects the biomechanics of the deltoid and rotator cuff muscles. These implant design modifications affect both muscle moment arms and muscle lengths, and it is debated whether maximizing moment arms or restoring muscle lengths (which affects force production) optimizes post-operative function. As joint function depends on the torque that the muscles can generate (which is the product of the force and moment arm of a muscle) the aim of this study was to use a biomechanical shoulder model to evaluate the impact of the different rTSA lateralization strategies on the length-force relationship, moment arms, and torques produced by the deltoid and rotator cuff muscles.

## METHODS:

Computed tomography scans from 16 non-osteoarthritic subjects were used to build customized computational models based upon an established shoulder model.<sup>1</sup> Muscle parameters including optimal fiber length, tendon slack length, and pennation angle (all of which influence muscle force production) were sourced from literature<sup>2</sup> and then scaled to each of the 16 models using an optimization technique.<sup>3</sup> Physiological cross sectional area for all muscles was standardized to healthy values for all subjects. Four rTSA implant configurations were virtually implanted into each subject: 1) medialized glenoid-medialized humerus (MG/MH); 2) medialized glenoid-lateralized humerus (MG/LH); 3) lateralized glenoid-medialized humerus (LG/MH); and 4) lateralized glenoid-lateralized humerus (LG/LH) (Fig. 1). All configurations had a 135° neck-shaft angle humeral stem and 36 mm diameter glenoid sphere. Muscle length, maximum potential force, moment arm, and maximum potential torque (product of the force multiplied by the moment arm) were calculated for the middle deltoid during scapular plane elevation, and for the infraspinatus and subscapularis during external and internal rotation at 20° of abduction, respectively.

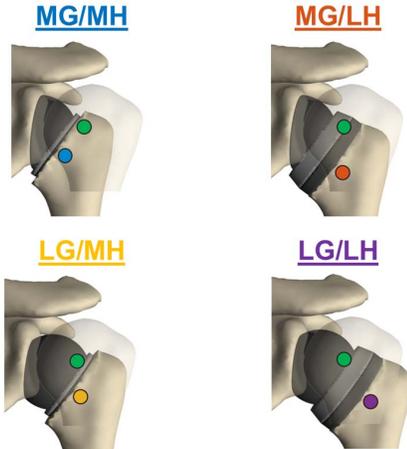
## RESULTS:

Post-operative humeral position changed across rTSA configurations compared to the native shoulder. Both MG/LH and LG/LH configurations resulted in greater humeral distalization compared to MG/MH and LG/MH ( $15.0 \pm 2.9$  mm and  $14.5 \pm 2.8$  mm vs  $20.7 \pm 3.5$  mm and  $20.1 \pm 3.5$  mm,  $p < 0.001$ ). Only LG/LH produced overall humeral lateralization relative to the native anatomy ( $5.2 \pm 4.3$  mm,  $p < 0.001$ ), which also produced the highest passive deltoid strain at 14.6% compared to normal with arm at rest ( $p < 0.001$ ). All rTSA configurations altered muscle mechanics compared to the native shoulder (Fig. 2) by shifting the range of active muscle length-force operation compared to native, although by varying rates. Deltoid force during early elevation ( $< 30^\circ$ ) was reduced in both the MG/LH and LG/LH configurations ( $p < 0.001$ ). At higher elevations ( $> 60^\circ$ ), MG/MH generated significantly less deltoid force, while LG/LH produced the highest force ( $p < 0.001$ ). Infraspinatus force was consistently reduced in all rTSA configurations during external rotation compared to native and subscapularis force was reduced during internal rotation for all configurations except for LG/LH. Moment arms were consistent with prior literature: glenoid lateralization reduced deltoid moment arms up to  $100^\circ$  of elevation, whereas humeral lateralization increased moment arms for both the subscapularis and infraspinatus during internal and external rotation compared to glenoid lateralization, respectively ( $p < 0.001$ ). Maximum potential torque production of the muscles was influenced by both force and moment arms. For the middle deltoid, MG/LH produced the greatest torque during early elevation ( $p < 0.001$ ) due to the large force and moment arm. However, LG/LH was the only configuration to exceed native torque generation throughout elevation. Lateralized glenoids produced less torque than medialized glenoids for elevation less than  $60^\circ$  due to the reduced moment arm. For the rotator cuff muscles, MG/MH yielded the lowest internal/external rotation torque.

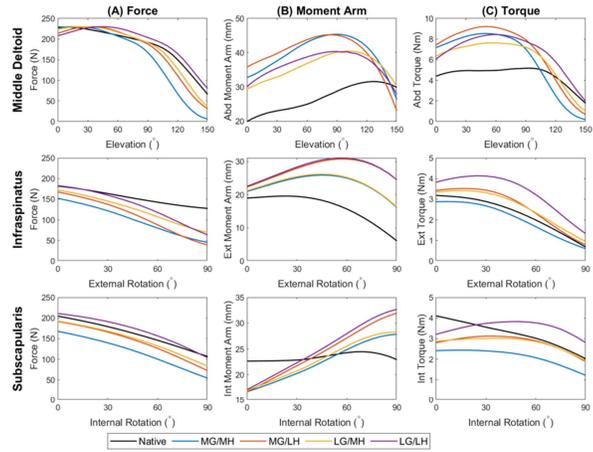
## DISCUSSION AND CONCLUSION:

The study introduced a novel method to investigate how lateralization affects not only the muscle moment arms but also the force generation (due to length changes) and the resulting torques. Unlike prior studies that assessed moment arms or muscle lengths in isolation, our approach provides an integrated analysis of torque production, offering a more comprehensive understanding of biomechanical function. The findings demonstrated that for the middle deltoid torque data trends mirrored moment arm changes more than the muscle length-force changes alone; whereas, for the rotator cuff muscles, the torque results highlight the benefits of progressive lateralization more than evaluating moment arms alone. It should be noted that the current results are specific to the implant geometry and any design changes may affect the data. Additionally, the study did not consider any potential post-operative changes to the muscle architecture (e.g., optimal fiber

length or pennation angle). Nonetheless, our findings highlight that both glenoid and humeral lateralization significantly alter muscle force and moment arms, which ultimately affects torque production.



**Figure 1:** Humeral center position of each RSA construct compared to native (green dot)



**Figure 2:** (A) Force, (B) Moment Arm, and (C) Torque of the Middle Deltoid, Infraspinatus, and Subscapularis.