Impact of Reverse Shoulder Arthroplasty Design and Patient Shoulder Size on Moment Arms and Muscle Fiber Lengths in Shoulder Abductors

Jay Micael Levin[1], Mattia Pugliese, Fabrizio Gobbi, Marcus Gordon Pandy[2], Giovanni Di Giacomo[3], Mark A Frankle[4]
[1]Duke Health, [2]University of Melbourne, [3]CONCORDIA HOSPITAL, [4]Florida Ortho Institute

INTRODUCTION:

Reverse shoulder arthroplasty (RSA) increases the moment arm of the deltoid, however there is limited knowledge on the accompanying changes in muscle architecture that play a role in muscle force production. The purpose of our study is to use a geometric shoulder model to evaluate the anterior deltoid, middle deltoid, and supraspinatus regarding 1) differences in moment arms and muscle-tendon lengths in small, medium, and large native shoulders, and 2) impact of three RSA designs on moment arms, muscle fiber lengths, and force-length (F-L) curves.

METHODS:

A geometric model of a native glenohumeral joint was developed, validated, and adjusted to represent small, medium, and large shoulders. Moment arms, muscle-tendon lengths, and normalized muscle fiber lengths were assessed for the supraspinatus, anterior deltoid, and middle deltoid from 0 to 90 degrees abduction. RSA designs were modeled and virtually implanted, including a lateralized glenosphere with an inlay-135-degree humeral component (LGMH), a medialized glenosphere with an onlay-145-degree humeral component (MGLH), and a medialized glenosphere with an inlay-155-degree humeral component (MGMH). Descriptive statistics were used to compare moment arms and normalized muscle fiber lengths.

RESULTS:

As shoulder size increased, moment arms and muscle-tendon lengths for the anterior deltoid, middle deltoid, and supraspinatus increased. All RSA designs achieved greater moment arms for the anterior and middle deltoid, with MGLH achieving the largest increase. The resting normalized muscle fiber length of the anterior and middle deltoid was substantially increased in the MGLH (1.29) and MGMH (1.24), shifting the operating ranges of these muscles to the descending portions of their F-L curves, while LGMH maintained a resting deltoid fiber length (1.14) and operating range similar to the native shoulder. All RSA designs demonstrated a decrease in native supraspinatus moment arm in early abduction, with the largest decrease in MGLH (-59%) and minimal decrease in LGMH (-14%). The supraspinatus operated on the ascending limb of its F-L curve in the native shoulder and remained on this portion of the F-L curve for all RSAs.

DISCUSSION AND CONCLUSION:

Although MGLH maximizes abduction moment arm for the anterior and middle deltoid, overlengthening of the muscle may compromise deltoid muscle force production by forcing the muscle to operate on the descending portion of its F-L curve. In contrast, the LGMH design increases the abduction moment arm for the anterior and middle deltoid more modestly, while allowing the muscle to operate near the plateau of its F-L curve and maximizing its force producing potential.