An In-Vitro Study of the Effect of Reverse Shoulder Arthroplasty Glenosphere Size on Joint Load, Muscle Force, and Range of Motion

G. Daniel G. Langohr, MASc1, Joshua William Giles, PhD2, George S. Athwal, MD1, James A. Johnson, PhD1.
1The University of Western Ontario, London, ON, Canada, 2Imperial College London, London, United Kingdom.


Introduction: Reverse shoulder arthroplasty (RSA) is an established and effective treatment for rotator cuff tear arthropathy [1-3]. RSA reverses the natural geometric anatomy of the glenohumeral joint, and as such, selection of optimal implant characteristics and size cannot be directly guided by attempting to replicate the native geometry. Current commercially available RSA implant systems offer sizes ranging from 32 to 53 mm in diameter, with the most widely used designs providing two size options including a smaller 36 or 38 mm and a larger 40 or 42 mm size. Increased glenosphere diameter has been shown to increase range of motion (ROM) and improve joint stability using computer models [4-6], physical models [7,8], and an in-vitro cadaveric model [9]; however there is little knowledge regarding the effects of RSA size on muscle and joint loads. The purpose of this in-vitro biomechanical study was to investigate the effects of RSA glenosphere diameter on joint load, load angle, glenosphere moment, total deltoid force required for active abduction, and ROM in internal/external rotation and abduction for two common glenosphere sizes (38 & 42 mm). Our hypothesis was that increased glenosphere diameter would increase ROM while not significantly affecting the resultant joint loads and muscle forces since both sizes share almost identical centers of rotation. Additionally, we hypothesized the joint load angle (or shear component) would increase with the larger glenosphere diameter due to the increased stability and ability of the deeper cup to resist applied shear loading.

Methods: A custom, modular, instrumented RSA implant system capable of measuring joint load and varying glenosphere diameter (38, 42 mm) and glenoid offset (neutral, lateral) was implanted in 6 fresh-frozen cadaveric shoulders (average age: 60 ± 21 yrs). Neutral was defined with the glenoid base plate placed on the inferior rim of the glenoid, the center of rotation at the glenoid articular surface, and a neutral version humeral component with a 155° head-neck angle. The three deltoid heads were sutured at their insertion, and the subscapularis and infraspinatus/teres minor musculotendinous junctions were secured using a running locking stitch. The scapula was cemented to a custom shoulder simulator and all muscles were connected to load actuators in physiologically accurate lines-of-action. The simulator produced independent muscle loading that was controlled via a multi-PID control system, which provided accurate and repeatable muscle driven active glenohumeral motion with associated scapular rotation [10]. All possible RSA implant configurations were tested with active and passive motion protocols and shoulder kinematics and joint loads/moments were recorded.

Results: At both neutral and lateral glenosphere positions, increasing glenosphere diameter significantly increased RSA joint force (+12±21N & +6±9N respectively, p<0.01) and total deltoid load required for active abduction (+9±22N & +11±15N respectively, p<0.02), while the angle of joint loading was not affected (p>0.8, Figure 1). Passive internal rotation was reduced as glenosphere diameter was increased
at both neutral and lateral glenoid offsets (-6±6° & -12±6° respectively, p<0.002); however, external rotation was not significantly affected (p>0.5). In the neutral glenosphere position, increasing glenosphere diameter significantly increased the adduction angle by 1.4±1.2° (p=0.03), and increased the maximum abduction angle by 7.8±9° (p<0.05, Figure 1), however significant differences were not detected when the glenosphere was in the lateral position. Lateralization of the glenosphere also increased abduction ROM compared to the neutral position (p<0.01).

**Discussion:** Although increasing glenosphere diameter significantly increased joint force and deltoid load, the clinical impact of these changes is unclear at present. However, internal rotation was reduced when glenosphere diameter was increased, which contradicts previous modeling studies. This decrease in internal rotation ROM was postulated to be due to posterior soft tissue tension, which increased when the tissues wrapped over and around the larger 42 mm implant assembly. External rotation, conversely, was not significantly affected with changes in glenosphere size. Abduction ROM was increased with larger glenosphere diameter due to the increased radial distance from the glenosphere centre to the cup articular surface. Additionally, glenosphere lateralization also increased abduction ROM.

**Significance:** Increasing glenosphere diameter can increase abduction range of motion, but also result in significant, although relatively small, increases in joint force and deltoid muscle loading.

![Figure 1: Mean changes (± 1 std dev) in all outcome variables when glenosphere diameter was increased from 38 to 42 mm for medial (light grey) and lateral (dark grey) glenosphere positioning.](image)

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