Clinical Biomechanics of Upper Extremity

Author: Ing. Adam Kratochvíl
Supervisor: prof. RNDr. Matej Daniel, Ph.D.
Field of study: Biomechanics

Motivation

Shoulder anatomy isn't inherently suited for an active life beyond 80 years, leading to problems that increasingly emerge with age, connected with reduced mobility and significant pain. Reverse total shoulder arthroplasty (RTSA) creates favourable biomechanical conditions to enhance mobility and increasing stability of the joint by shifting the center of rotation and prestressing the shoulder muscles. Existing studies addressing RTSA predominantly focuses on clinical outcomes rather than conducting in-depth biomechanical analyses. In instances where biomechanical analysis is considered, it often emphasizes changes in COR while overlooking the significant aspect of humeral prolongation. Humeral prolongation is crucial in the biomechanical context as it induces prestressing of shoulder muscles, thereby influencing force patterns in the shoulder, alongside with the shift of COR.

Aims of the thesis

This dissertation aims to develop a comprehensive biomechanical analysis of RTSA, incorporating humeral prolongation and COR shift, utilizing widely available clinical data from preoperative and postoperative examinations of patients who have undergone RTSA.

Methods

Radiographical Magnification in Shoulder Joint Region: A retrospective study included 98 patients that have previously undergone RTSA using the proximal part of reverse humeral body as a reference (Fig. 1).

Changes in Musculoskeletal Geometry after RTSA:

A retrospective study included 32 shoulders that have previously undergone RTSA. The verified semiautomatic method uses preoperative CT scan and X-ray alongside postoperative X-ray (Fig. 2).

Musculoskeletal Model and Kinematics:

Musculoskeletal model of the human shoulder was utilized (Fig. 3) with various muscle models and three distinct motions were examined.

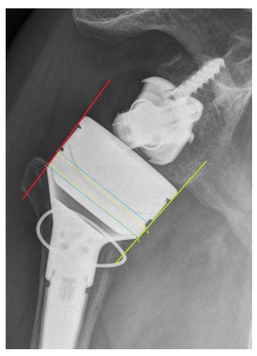

Fig. 1 Humeral body used as a reference

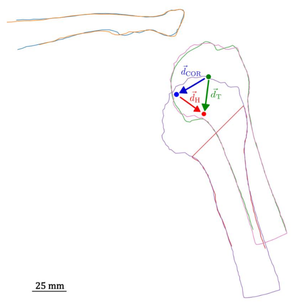

Fig. 2 Estimation of musculoskeletal changes after RSTA.

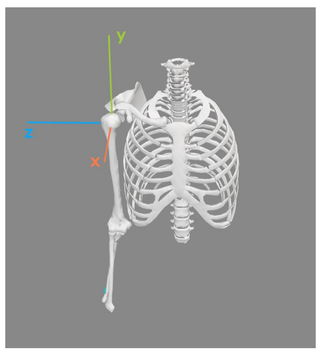

Fig. 3 Musculoskletal model of human shoulder with local coordinate systém of humerus.

Radiographical Magnification in Shoulder Joint Region

The average magnification factor was 11.91% (SD 3.24%, range 5.74%–20.31%).

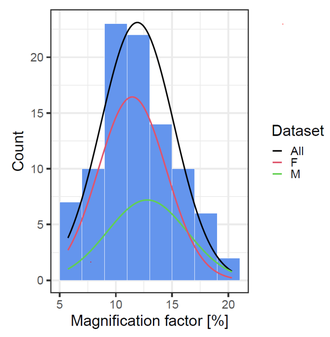

Fig. 4 Histogram of magnification factor for all patients and fitted Gaussian curves for all patients (All), female (F) and male (M)

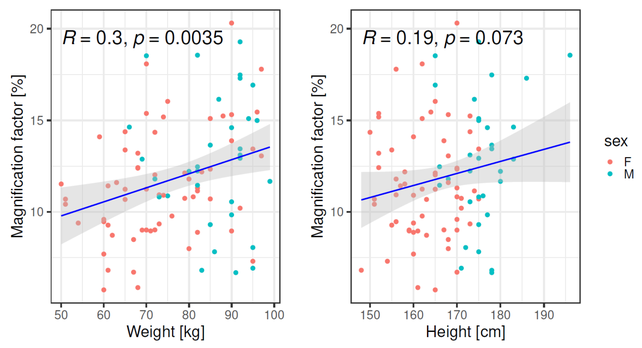

Fig. 5 Linear regression model illustrating the association between patients' weight (left) and height (right) with the magnification factor across all patients.

Changes in Musculoskeletal geometry after RTSA

The average shift of COR was 19.9 mm medially (SD 7.9 mm, range 2.9–36.9 mm) and 6.2 mm inferiorly (standard deviation 7.4 mm, range -11.6–18.3 mm).
The average total prolongation of humerus was of 19.7 mm (SD 6.4 mm, range 2.2–35.2 mm) in the meaning of the long axis of the bone.

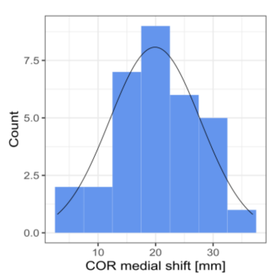

Fig. 6 Histogram of COR shift for all patients with fitted Gaussian curve

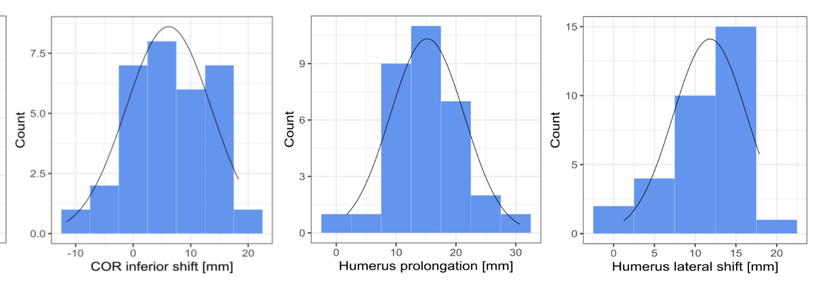

Fig. 7 Histogram of humerus prolongation and lateral shift for all patients and fitted Gaussian curves.

Influence of RTSA on Glenohumeral Joint Load

The impact of RTSA on muscle force in each muscle during active abduction is shown in Fig. 9. The most substantial impact of RTSA on muscle forces was observed in the middle deltoid, where the force was approximately halved compared to the anatomical shoulder.

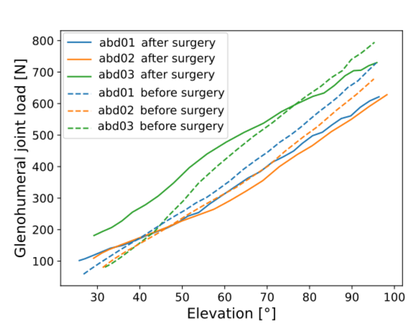

Fig. 8 The effect of RTSA on glenohumeral joint load in active abduction

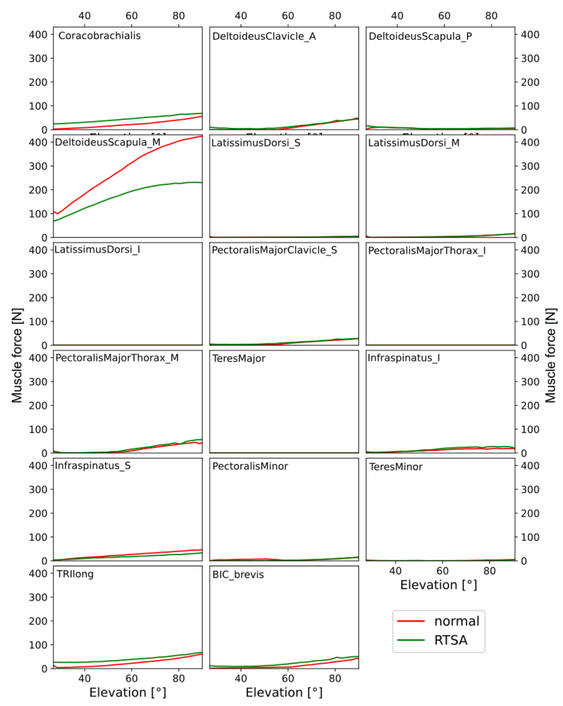

Fig. 9 Effect of RTSA on muscle force in each muscle during active abduction

Safe Zone according to Humerus Prolongation

A safe zone for humerus prolongation during RTSA was determined to prevent overloading the glenohumeral joint during movements.

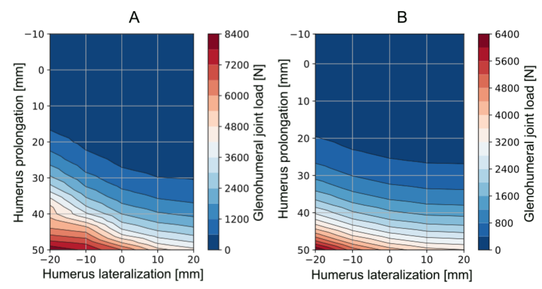

Fig. 10 Safe zone shown in 30 degrees of active abduction (A) and passive abduction (B)

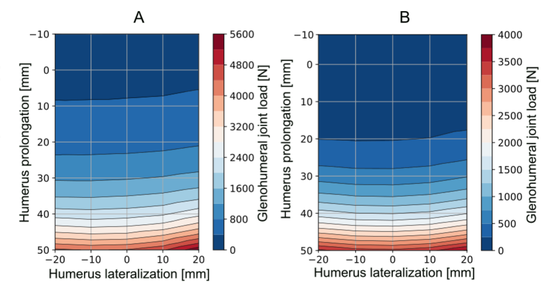

Fig. 11 Safe zone shown in 90 degrees of active abduction (A) and passive abduction (B)

Conclusions

In this thesis, our focus lied on the clinical analysis of reverse total shoulder arthroplasty. The real magnification measured from plain was approximately 12% (ranging from 5% to 20%), considerably differs from commonly used value of 5%. An average humerus prolongation of 15.2 mm (ranging from 1.8 mm to 30.6 mm) was revealed. Our research demonstrated that RTSA contributes to lower muscle force in the middle deltoid, a primary abductor, and glenohumeral joint load. However, extensive humerus prolongation (greater than 3 cm) could increase glenohumeral joint load more than three times.

Contact

Adam Kratochvíl
Czech Technical University in Prague, Faculty of Mechanical Engineering
Department of Mechanics, Biomechanics, and Mechatronics
adam.kratochvil@fs.cvut.cz
+420 224 352 653

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