Effect of the Scapulo-Humeral Rhythm on Anatomical and Reverse Shoulder Prostheses
+1Terrier, A; 1Aeberhard, M; 1Pioletti, D P; 2Farron, A
+1Laboratory of Biomechanical Orthopedics, EPFL, Switzerland, 2University Hospital Center and University of Lausanne, Switzerland
alexandre.terrier@epfl.ch

ABSTRACT:
During arm elevation, a rotation of the scapula is associated with the humerus abduction. The ratio between the gleno-humeral joint angle and the scapula-thoracic joint angle is referred to as the scapulo-humeral rhythm. For a healthy shoulder, this ratio has been reported to be 2:1 [1]. Several studies have reported important alteration of the normal ratio after total shoulder arthroplasty. This has been observed in anatomical and reverse shoulder prostheses, with some discrepancy [2, 3, 4].

An altered scapula-humeral might shorten the lifespan of total shoulder prostheses, but there are no clinical or biomechanical studies to support this hypothesis yet. It is especially a concern with reverse shoulder prostheses, since rotator cuff dysfunction is often present, and can alter scapula-humeral rhythms.

Therefore, the goal of this study was to evaluate the biomechanical consequences of an altered scapula-humeral rhythm on the gleno-humeral force and contact pattern, for an anatomical and reverse shoulder prosthesis.

METHODS:
A numerical musculoskeletal model of the shoulder was used to evaluate the effect of a perturbed scapula-humeral rhythm [5]. The model included the scapula, the humerus and 6 scapulo-humeral muscles: middle, anterior, and posterior deltoid, supraspinatus, subscapularis and infraspinatus combined with teres minor. Arm motion and joint stability were achieved by muscles, allowing for natural translation of the humeral head. The muscle activation patterns were derived from EMG data and controlled by a synchronization algorithm. The arm weight was 37.5 N, corresponding to 5% of the bodyweight (BW) and an extra load of 10 N was added in the hand, assuming that the elbow was fully extended. The reverse (RP) and anatomical (AP) Aequalis prostheses (Tornier Inc) were positioned by a senior surgeon in the numerical model, according to manufacturer recommendations. For the RP, the rotator cuff muscles were deactivated since this prostheses is used when these muscles are partly or completely deficient (Fig. 1). Two scapula-humeral rhythms were considered for each prosthesis: a normal 2:1 rhythm, and an altered 1:2 rhythm. For the 4 configurations, a movement of abduction in the scapular plane was simulated, from resting position to 90 degrees of elevation (arm in horizontal position). The gleno-humeral force and contact pattern, but also the stress in the polyethylene and cement were evaluated for the entire range of motion.

RESULTS:
With the anatomical prosthesis, the gleno-humeral force reached 971 N (1.3 BW) for a normal scapulo-humeral rhythm and 1201 N (1.6 BW) for the altered rhythm, resulting in an increase of 23%. The gleno-humeral contact pattern showed the classical up and down displacement of the humeral head. The muscle activation patterns were derived from EMG data and controlled by a synchronization algorithm. The arm weight was 37.5 N, corresponding to 5% of the bodyweight (BW) and an extra load of 10 N was added in the hand, assuming that the elbow was fully extended. The reverse (RP) and anatomical (AP) Aequalis prostheses (Tornier Inc) were positioned by a senior surgeon in the numerical model, according to manufacturer recommendations. For the RP, the rotator cuff muscles were deactivated since this prostheses is used when these muscles are partly or completely deficient (Fig. 1). Two scapula-humeral rhythms were considered for each prosthesis: a normal 2:1 rhythm, and an altered 1:2 rhythm. For the 4 configurations, a movement of abduction in the scapular plane was simulated, from resting position to 90 degrees of elevation (arm in horizontal position). The gleno-humeral force and contact pattern, but also the stress in the polyethylene and cement were evaluated for the entire range of motion.

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