The Effect of the Rotator Cuff on Glenohumeral Function During Activities of Daily Living

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Introduction

In diseases like rheumatoid arthritis, the shoulder joint is often affected which leads to pain and loss of function of the upper extremity. To reduce pain and improve function, a shoulder endoprosthesis can be implanted. Although results in terms of pain reduction are satisfactory, several effect studies have indicated that functional results, characterised in terms of Activities of Daily Living (ADL), are often poor. Only 55 % of the patients are able to comb their hair post-operatively (Smits, 2000). A possible cause for the moderate function is a defective rotator cuff (Figure 1), which is the second most frequent complication of a total shoulder replacement (Wirth & Rockwood, 1994). The rotator cuff muscles have two functions. First, the rotator cuff muscles are able to prevent translation of the humeral head. A decrease in rotator cuff force could therefore influence the stability of the glenohumeral (GH) joint. Second, they generate force to accompany the prime movers of the humerus. The aim of this study was to evaluate the mechanical effect of the rotator cuff, in terms of stability and force, during activities of daily living.

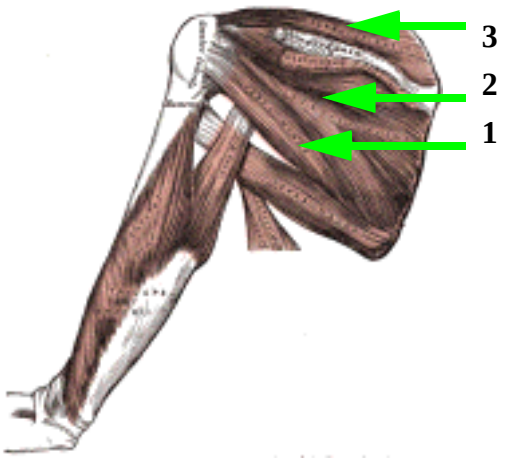

Figure 1: Dorsal view of rotator cuff muscles: 1 = Teres Minor 2 = Infraspinatus 3 = Supraspinatus 4 = Subscapularis (not visble)

Methods

Twentyfour healthy female subjects were measured. Sixteen subjects performed 5 ADL: combing hair, eating with a spoon, washing axilla, perineal care and lifting a 4 kg bag. Since the washing axilla task was very comparable to the eat with spoon task, the last eight subjects performed a reach above shoulder level task. The positions and orientations of the thorax, scapula, humerus, and forearm were measured during the execution of these tasks using a 6 DOF electromagnetic tracking device, the flock of birds (Ascension Technology Inc.). The bone angles of all subjects during the five ADL are input for the Delft Shoulder Model (van der Helm, 1994), which calculates the shoulder and forearm muscle forces and joint reaction forces. Subsequently, the ADL were simulated without the rotator cuff. A constraint of the shoulder model is that the glenohumeral joint reaction force vector must point inside the glenoid. If the model cannot find a solution, a lack of force or a lack of stability is the problem. By switching off the constraint, the cause of not finding a solution can be discovered.

Results & Discussion

After removing the rotator cuff from the model, two tasks could not be executed. For the perineal care task the model could not find a solution for the kinematics of 14 subjects because the glenohumeral joint reaction force vector was directed outside the glenoid cavity in anterior-superior direction. This will result in a subluxation of the humerus. Lifting a 4 kg bag could also not be executed by the model in four cases due to a lack of glenohumeral stability (Figure 2) and in four cases due to the fact that the deltoid muscles are not able to compensate for the external moments. The rotator cuff muscles, and in the lifting task especially the infraspinatus, are needed to generate the required external moments (Figure 3) .The rotator cuff muscles have relatively small moment arms, which means they can produce high compressive forces to prevent subluxation in the GH joint, while avoiding large antagonistic moments. If the GH joint stability requirement (keeping the joint reaction force vector inside glenoid) is omitted in the model, most motions can be executed without rotator cuff. However when forces other then gravity apply on the arm, the amount of muscle force is usually not sufficient. In this study a quasi-static analysis is done for the GH joint stability, in the near future also the resistance against force perturbations will be taken into account. It can be concluded that dysfunction of the rotator cuff will cause a decrease in GH joint stability and therefore will negatively influence the functional outcome of a shoulder replacement

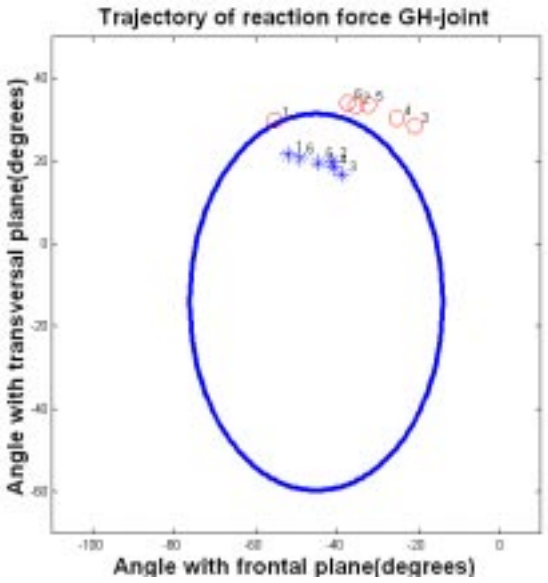

Figure 2: Joint reaction force inside glenoid for a lifting task. * = Intact rotator cuff; o = without rotator cuff

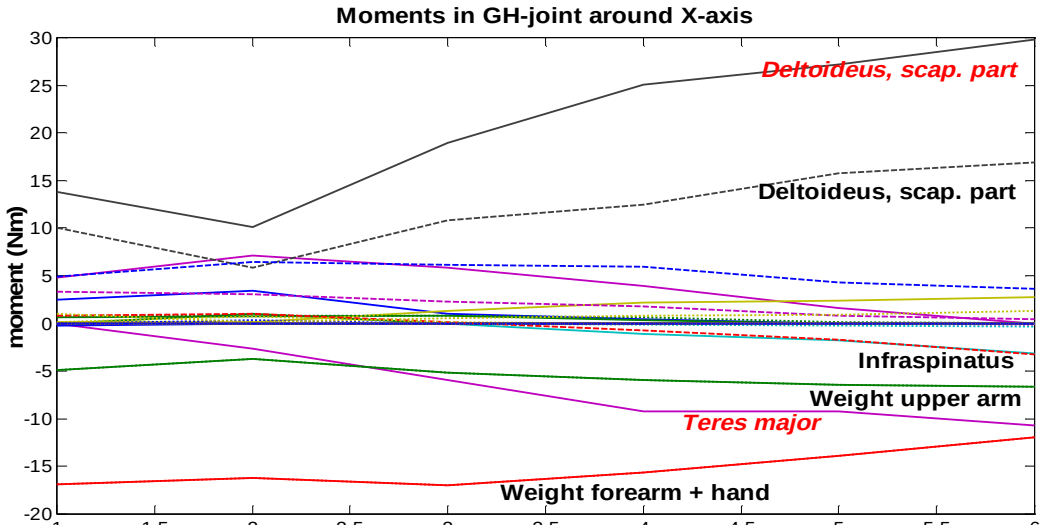

Figure 3: Moments around medio-lateral axis of glenohumeral joint for a lifting task. Muscles displayed in red are results of the simulation without rotator cuff

References

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