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Impact of shoulder strengthening exercises on subacromial space height and on articular cartilages and labrum compression using motion capture analysis

N. Holzer[1], S. Chagué[2], A. Lädermann[3], J-L. Ziltener[1], P. Hoffmeyer[1], C. Charbonnier[2]

[1]Orthopedics and Trauma Service, University Hospitals of Geneva, Geneva, Switzerland
[2]Medical Research Department, Artanim Foundation, Geneva, Switzerland
[3]Division of Orthopedics and Trauma Surgery, La Tour Hospital, Meyrin, Switzerland and Faculty of Medicine, University of Geneva, Geneva, Switzerland

Introduction

Strengthening of shoulder muscles in rehabilitation protocols and sport practice can be achieved by a wide range of different exercises and several types of technique. In presence of a rotator cuff lesion, articular cartilage pathology or instability, recommendations for design of a shoulder strength training protocol aim at avoiding or minimizing subacromial impingement and stress on the articular cartilages or labrum. Very limited objective data is at disposable to emit such recommendations.

Our goal was to study the impact of the most common shoulder rehabilitation exercises on subacromial space height and on articular cartilages and labrum compression.

Methods

One healthy male volunteer (28 years old) underwent magnetic resonance (MR) arthrography and motion capture of the shoulder. Patient-specific 3D models of the shoulder bones, articular cartilages and labrum were reconstructed based on MR images. Motion data from the volunteer were recorded during 31 rehabilitation exercises targeting 11 most frequently trained shoulder muscles or muscle groups and using up to four different techniques when available: cable bar machine, dumbbell, body weight and TheraBand™.

Glenohumeral kinematics was computed from the markers trajectories using a validated biomechanical model based on a patient-specific kinematic chain and a global optimization algorithm with loose constraints on joint translations (accuracy: translational error <3mm, rotational error <4°), which accounted for skin motion artifacts. The resulting computed motions were applied to the subject's shoulder 3D models reconstructed from his MR images.

All measures were acquired on the entire range of motion during motion simulation. Subacromial space height was assessed by measuring the minimum distance between the inferior acromial surface and the humeral head surface. Cartilages and labrum contacts were monitored by means of a collision detection algorithm. Maximal surface-to-surface distance (i.e., penetration depth) between humeral, glenoid cartilages and labrum surfaces were computed to quantify the topographic extent of compression on each structure.

Results

Minimal subacromial height varied up to 14.1-fold for targeted muscles exercises according to the training technique used. Cartilages compression varied up to 6.6-fold and labral compression up to 5.7-fold. Contacts were all located between the antero- and postero-superior sectors of the glenoid. Least favorable target muscles training with respect to cartilages and labrum compression were biceps brachii, pectoralis major and supraspinatus. Overhead strength training resulted in significant decrease ($p=0.001$) of subacromial space height compared to non-overhead strengthening exercises, as expected.

Conclusion

According to the type of strengthening exercise, important variations in subacromial space height, as well as cartilages and labrum compression were observed. The simulation also confirmed the expected results of overhead strength training on subacromial space height. To our knowledge, this study represents the first screening of shoulder strengthening exercises to identify potential deleterious effects on the shoulder joint using motion capture analysis.