Compensatory muscle activation in patients with glenohumeral cuff tears

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Summary

Patients suffering tendon tears in the glenohumeral cuff muscles, the deep stabilizers of the shoulder, show activation of muscles which pull the arm downwards during arm elevation tasks (*chapter 2*). This so-called co-activation deviates from healthy controls, is triggered by pain and is not the response to increased maximal arm force magnitudes (*chapter 3*), which can occur after an intervention. A potential cause for pain is glenohumeral instability, in which the subacromial tissues get painfully impinged. Goal of this thesis was to demonstrate that deviating muscle activation in patients with glenohumeral cuff tears is related to shoulder instability. We hypothesized that these deviating muscle activations are compensatory for lost glenohumeral cuff functions, and that they restrict arm functionality.

Cuff-tear simulations using a musculoskeletal model (*chapter 4*) show increased deltoid activation to compensate lost elevation moments. This increased deltoid activation jeopardizes glenohumeral stability because of the increased cranial directed destabilizing forces on the humeral head. In simulations with an isolated supraspinatus tear, lost cuff functions could be compensated for by the remaining muscles without any consequences for glenohumeral instability. Shoulder stability is endangered when multiple muscles are involved in the tear. Activation of muscles pulling down the humeral head is then required to compensate lost stabilizing muscle forces (*chapter 4* and *chapter 7*), which is counterproductive for arm elevation (*chapter 5*). There is a conflict between glenohumeral **stability** and arm **mobility**.

A salvage procedure for irreparable cuff tears is a tendon transfer of the teres major. In such surgical procedures the original teres major arm depression moment reverses to an arm elevation moment, while downwards directed stabilizing forces are preserved. Patients use their transposed teres major according to its new insertion, i.e. activation during arm eleva-

tion tasks. This solution for the conflict between glenohumeral stability and arm mobility demonstrates shoulder function improvement and pain decrease (*chapter 5*).

Increased scapula lateral rotation, outwards rotation of the inferior angle of the scapula, during arm elevation tasks is related to both pain decrease and teres major co-activation increase, as opposed to latissimus dorsi co-activation increase (*chapter 6*). This suggests, beside the primary role in counteracting instability by pulling down the humeral head, also a roll for the teres major in a pain avoidance mechanism by increasing scapula lateral rotation. Scapula lateral rotation topples the acromion, enlarging the subacromial space, potentially preventing painful subacromial tissue inclination. Such secondary effect of the teres major could be an argument in preferring the teres major over the latissimus dorsi in tendon transfer surgery for patients suffering glenohumeral cuff tears, but this requires additional comparative research.

Loading the arm with constant forces but increasing moments showed that, not only in model simulations but also experimentally lost elevation moments caused by the cuff tear can be compensated for by an increase in deltoid activation (*chapter 7*). Increased deltoid activation in model simulations resulted in shoulder instability. Both in simulations and experiments the increased deltoid activation was related to co-activation of arm depressors, the compensatory response for lost stabilizing forces.

Patients suffering glenohumeral cuff tears are well capable of compensating lost elevation moments by increased deltoid activation. However, increased deltoid activation jeopardizes glenohumeral stability. To preserve stability patients co-activation, using arm depressor muscles during arm elevation tasks. Such compensatory muscle response for stability, restricts arm mobility. The concept of compensatory muscle activation provide insight in the underlying mechanisms of patients suffering glenohumeral cuff tears and potentially can be used, also at early symptoms like in impingement, as a diagnostic instrument or it can be applied in new treatment strategies.