



The relation between increased deltoid activation and adductor muscle activation due to glenohumeral cuff tears

Frans Steenbrink^{a,b}, Carel G.M. Meskers^{a,c}, Rob G.H.H. Nelissen^{a,b}, Jurriaan H. de Groot^{a,c,*}

^a Laboratory for Kinematics and Neuromechanics, Leiden University Medical Center, Leiden, The Netherlands

^b Department of Orthopaedics, Leiden University Medical Center, Leiden, The Netherlands

^c Department of Rehabilitation Medicine, Leiden University Medical Center, Leiden, The Netherlands



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ABSTRACT

In patients with rotator cuff tears lost elevation moments are compensated for by increased deltoid activation. Concomitant proximal directed destabilizing forces at the glenohumeral joint are suggested to be compensated for by 'out-of-phase' adductor activation, preserving glenohumeral stability. Aim of this study was to demonstrate causality between moment compensating deltoid activation and stability compensating 'out-of-phase' adductor muscle activation.

A differential arm loading with the same magnitude of forces applied at small and large moment arms relative to the glenohumeral joint was employed to excite deltoid activation, without externally affecting the force balance. Musculoskeletal modeling was applied to analyze the protocol in terms of muscle forces and glenohumeral (in)stability. The protocol was applied experimentally using electromyography (EMG) to assess muscle activation of healthy controls and cuff tear patients.

Both modeling and experiments demonstrated increased deltoid activation with increased moment loading, which was higher in patients compared to controls. Model simulation of cuff tears demonstrated glenohumeral instability and related 'out-of-phase' adductor muscle activation which was also found experimentally in patients when compared to controls.

Through differential moment loading, the assumed causal relation between increased deltoid activation and compensatory adductor muscle activation in cuff tear patients could be demonstrated. 'Out-of-phase' adductor activation in patients was attributed to glenohumeral instability. The moment loading protocol discerned patients with cuff tears from controls based on muscle activation.

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1. Introduction

Arm mobility requires muscle forces to generate joint moments whilst preserving glenohumeral stability. Arm elevation moments are mainly generated by the deltoids and arm depression moments by the latissimus dorsi, teres major and pectoralis major, all muscles with large moment arms (Kuechle et al., 1997). Glenohumeral stability is controlled for by the rotator cuff muscles (Ackland and Pandy, 2009; Poppen and Walker, 1976). Because of their short moment arms and perpendicular orientation to the glenoid, the rotator cuff muscles can generate compressive joint-forces with relatively small moments, providing glenohumeral stability by directing the resultant force vector through the glenoid fossa.

Tears of the rotator cuff result in loss of stabilizing forces and abduction moment. The deltoids seem to compensate for the lost abduction moments, resulting in an increased proximal directed force component on the humeral head (Liu et al., 1997). This jeopardizes glenohumeral stability by proximal rotation of the resultant force vector outside the glenoid fossa (Parsons et al., 2002; McCully et al., 2007; Steenbrink et al., 2006, 2009a). In patients with massive cuff tears, pectoralis major, latissimus dorsi and/or teres major adductor muscle activation was observed during arm elevation tasks (de Groot et al., 2006; Steenbrink et al., 2006). This unexpected activation is adverse, or 'out-of-phase', with respect to the muscle moment arm. 'Out-of-phase' adductor activity was also observed in cuff tear model simulations with a constraint stable glenohumeral joint (Steenbrink et al. 2009a). We hypothesized that glenohumeral stability during arm elevation tasks was preserved by 'out-of-phase' adductor muscle activation, which seems to be mechanically related to increased deltoid activity.

Glenohumeral joint stability is a common factor between increased deltoid activity (McCully et al., 2007) and adverse adductor activity (de Groot et al., 2006; Steenbrink et al., 2006,

* Corresponding author at: Department of Rehabilitation Medicine (B0-Q), Leiden University Medical Center, PO Box 9600, 2300 RC Leiden, The Netherlands. Tel.: +31 71 526 3447; fax: +31 71 526 6697.

E-mail address: J.H.de_Groot@lumc.nl (J.H. de Groot).