ROTATOR CUFF INSUFFICIENCY DETERMINED FROM MUSCLE ACTIVATION

[1]Frans Steenbrink, [1]Rob G.H.H. Nelissen, [2]Carel G.M. Meskers and [2]Jurriaan H. de Groot[2]

[1]Dept. of Orthopedics & [2]Rehabilitation Medicine, Leiden University Medical Center, The Netherlands

email: f.steenbrink@lumc.nl

INTRODUCTION

Normal arm mobility requires glenohumeral (GH) stability. Rotator cuff injuries result in a compromised mobility-stability interaction [1, 3]. In case of massive cuff tears involving mm. Suprasinatus (SSp) and Infraspinatus (IS), lost cuff muscle *ab*duction moment is compensated by the deltoids (DE). The increased upwards directed force component on the humeral head jeopardizes GH stability [2]. We hypothesized that GH stability can be preserved at the cost of arm mobility by *ad*ductor muscle co-contraction during arm elevation tasks [3].

Goal of this study was to develop an experimental paradigm to determine in cuff tear patients the causal relation between increased deltoid activity (to compensate lost *ab*duction moment) and *ad*ductor muscle co-activation (to compensate GH destabilizing forces). We simulated and experimentally validated the effect of a constant upwards and downwards directed force at the arm, at short and long GH moment arms, on agonistic and antagonistic muscle activation.

METHODS

Alternating *ab*-and *ad*duction moments under constant force conditions (40N) were simulated using the Delft Shoulder Model [4] by applying respectively downwards and upwards forces proximally and distally at the longitudinal axis of the humerus. Thus relatively small and large GH-moments are simulated while controlling for external forces. We determined the Activation Ratio (AR) of the arm *ab*ductors, i.e. mm. deltoidei and the arm *ad*ductors, i.e. mm. teres minor (simulation only), teres major and latissimus dorsi from their agonist (*AG*) and antagonist (*AN*) muscle activation relative to the external force (Eq.1).

EMG recordings, while constant forces applied proximally and distally at a patients' upper arm, were used to experimentally validate the paradigm (Figure 1). We calculated activation ratios (AR) according to:

$$AR_i = \frac{ACT_i^{AG} - ACT_i^{AN}}{ACT_i^{AG} + ACT_i^{AN}} \quad [1]$$

Where: *ACT* is force (simulation) or EMG (experiment) for muscle group *i*: *ab*ductors or *ad*ductors; *AG* and *AN* indicate agonistic and antagonistic activation. *Ab*-and *ad*ductor muscles were expected mainly to be active, i.e. positive ARs, during respectively down-and upwards forces on the arm. Simulated ARs, both healthy and cuff tear (SSp & IS forces absent), as well as a healthy subject and a cuff tear patient (MRI proven SSp & IS tear) were compared.

RESULTS AND DISCUSSION

Positive ARs in the simulated and experimental healthy conditions (at short and long moment arms) indicate expected dominant muscle activation (Table 1). In cuff tear conditions, *ab*ductor AR increased with GH-moment coinciding with a negative *ad*ductor AR indicating high *ad*ductor activation during upward arm force. *Ad*ductor co-contraction compensating GH-instability.

Although GH (in)stability was not measured directly in the patient, similar ARs were observed in subject recordings.

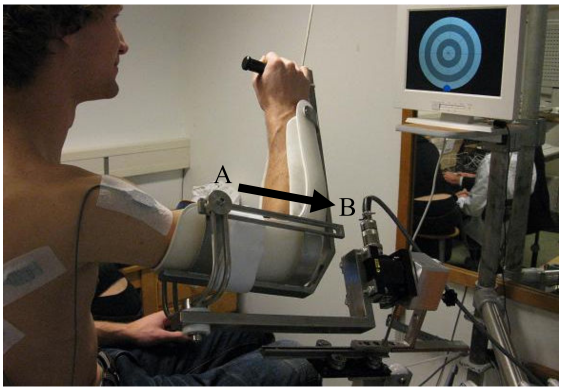

Figure 1: Experimental set-up, allowing force application at the arm at small (A) and larger (B) moment arms relative to GH. The magnitude and direction of the exerted force were controlled by visual feedback.

CONCLUSIONS

This study demonstrates that in patients with cuff tears *ad*ductor muscle co-activation increases with *ab*ductor muscle activation, in order to compensate for GH instability. The proposed paradigm has a clear potential for discerning patients with cuff disease from healthy subjects by arm force application at a short and a longer GH moment arms, which is currently validated by further patient inclusion.

REFERENCES

1. Veeger HEJ, et al., *J.Biomech.* 40:2119-29, 2007.
2. McCully SP et al., *J.Biomech.* 40: 1839-46, 2007.
3. de Groot JH, et al., *Clin.Biomech.* 21: S27-S32, 2006.
4. van der Helm, FC, *J.Biomech.* 27:551-69, 2004.

Table 1: Activation Ratios of the *ab*-and *ad*ductor muscles from model simulation and an *in vivo* experiment (n=1).

	SIMULATION				EXPERIMENT			
	healthy condition		cuff tear condition		healthy subject		cuff tear patient	
Moment arm	short	long	short	long	short	long	short	long
ABductors	.70	.84	.55	.86	.39	.83	.46	.71
ADductors	.74	.75	.19	-.20	.33	.67	.16	-.12