



**Universiteit
Leiden**
The Netherlands

Compensatory muscle activation in patients with glenohumeral cuff tears

Steenbrink, F.

Citation

Steenbrink, F. (2010, May 27). *Compensatory muscle activation in patients with glenohumeral cuff tears*. Retrieved from <https://hdl.handle.net/1887/15556>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/15556>

Note: To cite this publication please use the final published version (if applicable).

**Compensatory Muscle Activation
in Patients with Glenohumeral Cuff Tears**

Copyright © 2010 by Franciscus Steenbrink. All rights reserved.

ISBN/EAN 978-90-9025280-3

Cover design: Peter Krekel, Oshri Even-Zohar, Frans Steenbrink.

Layout: Charl Botha, Peter Krekel, Frans Steenbrink.

Financial support was provided by:

Anna Fonds Leiden

Biomet Nederland B.V.

DelSys Inc.

Clinical Graphics

DePuy JTE Johnson & Johnson

Dutch Arthritis Association

Motek Medical B.V.

Compensatory Muscle Activation in Patients with Glenohumeral Cuff Tears

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van de Rector Magnificus prof. mr. P.F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op donderdag 27 mei 2010
klokke 15.00 uur

door

Franciscus Steenbrink

geboren te Eindhoven
in 1978

Samenstelling promotiecommissie:

Promotores: Prof. dr. R.G.H.H. Nelissen
Prof. dr. P.M. Rozing

Co-promotor: Dr. ir. J.H. de Groot

Overige leden: Prof. dr. L.F. de Wilde (Universitair Ziekenhuis Gent, België)
Prof. dr. F.C.T. van der Helm (Technische Universiteit, Delft)
Prof. dr. H.E.J. Veeger (Vrije Universiteit, Amsterdam)
Dr. W.J. Willems (Onze Lieve Vrouwe Gasthuis, Amsterdam)
Prof. dr. J.H. Arendzen
Dr. C.G.M. Meskers

Aan mijn ouders.

Contents

1	General introduction	1
1.1	The Shoulder Laboratory	2
1.1.1	Background	2
1.1.2	Setting	4
1.2	Tools	5
1.2.1	Muscle function	5
1.2.2	Kinematics	5
1.2.3	Model simulation	6
1.3	Aim of this thesis	7
1.4	Outline of this thesis	7
2	Pathological muscle activation patterns	9
2.1	Introduction	11
2.2	Methods	11
2.2.1	Subjects	11
2.2.2	Procedure	12
2.2.3	Electromyography acquisition and parameterization	14
2.2.4	Statistics	15
2.3	Results	15

2.4	Discussion	16
3	Arm load magnitude vs. muscle activation	23
3.1	Introduction	25
3.2	Methods	26
3.2.1	Subjects	26
3.2.2	Experimental set-up	26
3.2.3	Protocol	27
3.2.4	Data post-processing	28
3.2.5	Statistical analysis	29
3.2.6	Model simulations	29
3.3	Results	31
3.4	Discussion	32
3.4.1	Comparison with previous research	34
3.4.2	Clinical consequences	34
3.4.3	DSEM: load sharing criteria	35
3.4.4	DSEM: gravitational loads	35
3.4.5	Possible error sources in the experiment	36
4	Glenohumeral stability in simulated rotator cuff tears	37
4.1	Introduction	39
4.2	Methods	40
4.2.1	Simulation design	40
4.2.2	Delft Shoulder and Elbow Model	40
4.2.3	The glenohumeral stability constraint	41
4.2.4	Model input	41
4.2.5	Simulated cuff pathologies	42
4.2.6	Data analysis	42
4.3	Results	44
4.3.1	Supraspinatus tear	44
4.3.2	Supraspinatus and infraspinatus tear	46
4.3.3	Supraspinatus, infraspinatus and teres minor tear	46
4.3.4	Supraspinatus, infraspinatus and subscapularis tear	46
4.3.5	Supraspinatus, infraspinatus, subscapularis and biceps longum tear	46
4.4	Discussion	48

4.4.1	<i>Abduction compensation</i>	48
4.4.2	Glenohumeral stability	49
4.4.3	Limitations of this study	50
4.4.4	Functional/clinical implications	50
4.5	Conclusion	51
5	Teres major activation relates to clinical outcome	53
5.1	Introduction	55
5.2	Methods	56
5.2.1	Surgical technique	56
5.2.2	Electromyography	57
5.2.3	Clinical assessment	58
5.2.4	Statistics	59
5.3	Results	60
5.3.1	Activation Ratios	61
5.3.2	Clinical results	62
5.3.3	Linear regression AR_{TMj} to clinical outcome	62
5.4	Discussion	62
5.5	Conclusion	67
6	Teres major activation relates to scapula lateral rotation	69
6.1	Introduction	71
6.2	Methods	72
6.2.1	Subjects	72
6.2.2	Kinematics	72
6.2.3	Data processing	73
6.2.4	Pain	73
6.2.5	Muscle activation	74
6.2.6	Statistics	74
6.3	Results	75
6.4	Discussion	76
6.5	Conclusion	79

7	Compensatory muscle activation	81
7.1	Introduction	83
7.2	Methods	84
7.2.1	Model simulations	84
7.2.2	Experiments	86
7.2.3	Signal analysis	86
7.2.4	Outcome parameters	87
7.2.5	Statistics	88
7.3	Results	88
7.3.1	Model simulations	88
7.3.2	Experiments	92
7.4	Discussion	92
7.5	Conclusion	97
8	General discussion	99
8.1	Introduction	100
8.2	Compensation for lost elevation moments	100
8.3	Glenohumeral instability	101
8.4	Compensation for stability lost	102
8.4.1	Teres major vs. latissimus dorsi tendon transfer	105
	References	107
	List of publications	121
	Summary	123
	Samenvatting (Dutch summary)	125
	Curriculum Vitae	127
	Acknowledgements	129