

# Contents

<b>Acknowledgements</b>	<b>i</b>
<b>Abstract (English/Deutsch/Français)</b>	<b>iii</b>
<b>List of figures</b>	<b>xiii</b>
<b>List of tables</b>	<b>xvii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Research Context . . . . .	1
1.2 State of the Art . . . . .	4
1.2.1 Human Shoulder . . . . .	4
1.2.2 Glenohumeral Osteoarthritis . . . . .	8
1.2.3 Rotator Cuff Tears . . . . .	11
1.2.4 Anatomic Parameters and Shoulder Diseases . . . . .	13
1.2.5 Musculoskeletal Shoulder Models . . . . .	13
1.2.6 Tissue Models . . . . .	15
1.3 Structure of the Thesis . . . . .	17
1.B Bibliography . . . . .	19
<b>2 Musculoskeletal Upper Limb Model</b>	<b>27</b>
2.1 Comparison of Muscle Force Estimation Methods . . . . .	27
2.1.1 Introduction . . . . .	27
2.1.2 Methods . . . . .	28
2.1.3 Results . . . . .	32
2.1.4 Discussion . . . . .	34
2.2 An Upper Limb Model for Muscle Force Estimation . . . . .	37
2.2.1 Introduction . . . . .	37
2.2.2 Extension of Existing Shoulder Model . . . . .	38
2.2.3 Results . . . . .	42
2.2.4 Discussion . . . . .	46
2.3 Conclusion . . . . .	48
2.B Bibliography . . . . .	50

<b>3</b>	<b>Cartilage Model</b>	<b>55</b>
3.1	Introduction . . . . .	55
3.2	Material and Methods . . . . .	57
3.2.1	Anatomy Reconstruction . . . . .	57
3.2.2	Material Properties . . . . .	57
3.2.3	Finite Element Model . . . . .	61
3.3	Results . . . . .	63
3.4	Discussion . . . . .	65
3.A	Appendix . . . . .	70
3.A.1	Computing Tait-Bryan Angles from Rotation Matrices . . . . .	70
3.B	Bibliography . . . . .	72
<b>4</b>	<b>Tendon Model</b>	<b>77</b>
4.1	Loading Capacity of Partially Torn Supraspinatus Tendon . . . . .	77
4.1.1	Introduction . . . . .	77
4.1.2	Methods . . . . .	78
4.1.3	Tendon Model . . . . .	79
4.1.4	Musculoskeletal Model . . . . .	81
4.1.5	Application . . . . .	82
4.1.6	Results . . . . .	85
4.1.7	Discussion . . . . .	85
4.2	Extension of Tendon Model . . . . .	89
4.2.1	Introduction . . . . .	90
4.2.2	Tendon Model . . . . .	90
4.2.3	Finite Element Model . . . . .	91
4.2.4	Results . . . . .	92
4.2.5	Discussion . . . . .	92
4.3	Conclusions . . . . .	96
4.A	Appendix . . . . .	98
4.A.1	Tensor Algebra . . . . .	98
4.A.2	Tensor functions . . . . .	99
4.A.3	Corotational Derivatives of Stress Tensors . . . . .	101
4.A.4	Incremental Form of Jaumann Stress Rate . . . . .	103
4.A.5	Numerical Approximation of Elasticity Tensors . . . . .	104
4.B	Bibliography . . . . .	106
<b>5</b>	<b>Effect of Anatomic Parameters on Shoulder Biomechanics</b>	<b>111</b>
5.1	Introduction . . . . .	111
5.2	Materials and Methods . . . . .	112
5.2.1	Musculoskeletal Model . . . . .	112
5.2.2	Cartilage Model . . . . .	114
5.2.3	Supraspinatus Tendon Model . . . . .	114
5.2.4	Acromion Index and Glenoid Inclination . . . . .	115

5.3	Results . . . . .	117
5.3.1	Musculoskeletal Model . . . . .	117
5.3.2	Cartilage Model . . . . .	118
5.3.3	Supraspinatus Tendon Model . . . . .	118
5.4	Discussion . . . . .	118
5.5	Conclusion . . . . .	123
5.B	Bibliography . . . . .	124
<b>6</b>	<b>Conclusions</b>	<b>127</b>
6.1	Summary of Findings . . . . .	127
6.2	General Discussion . . . . .	129
6.3	Future Work . . . . .	130
6.3.1	Musculoskeletal Model . . . . .	130
6.3.2	Cartilage Model . . . . .	131
6.3.3	Tendon Model . . . . .	131
6.3.4	Anatomic Parameter Study . . . . .	132
6.4	Clinical Perspective . . . . .	132
6.B	Bibliography . . . . .	133
	<b>Curriculum Vitae</b>	<b>135</b>