## **Contents**

	Preface		xiii
	Permissi	ons	XV
Part One	Biomechanics of Sports Injury		
	Intro	duction	1
	1 Cause	es of injury and the properties of materials	3
	1.1	Causes of injury	3
	1.2	Biological and other materials	5
	1.3	Response of a material to load	6
		1.3.1 Stress and strain	6
		1.3.2 Elastic modulus and related properties	11
		1.3.3 Plasticity and strain energy	12
		1.3.4 Toughness and crack prevention	13
		1.3.5 Hardness	14
		1.3.6 Creep	14
		1.3.7 Fatigue failure	14
		1.3.8 Non-homogeneity, anisotropy and viscoelasticity	15
		1.3.9 Stress concentration	17
	1.4	Bone	17
		1.4.1 Structure and composition	17
		1.4.2 Bone: loading and biomechanical properties	18
	1.5	Cartilage	20
		1.5.1 Structure and composition	20
		1.5.2 Biomechanical properties	20
	1.6	Muscle properties and behaviour	21
		1.6.1 Muscle elasticity and contractility	21
		1.6.2 Maximum force and muscle activation	22
		1.6.3 Mechanical stiffness	22
	1 7	1.6.4 The stretch-shortening cycle	23
		Ligament and tendon properties	24
	1.8	Factors affecting properties of biological tissue	27
		1.8.1 Immobilisation and disuse	27
		1.8.2 Age and sex	27
		1.8.3 Exercise and training	28
	1.0	1.8.4 Warm-up	30
		Summary Exercises	31 31
	1.10	LACICISCS	31

	1.11	References	32
	1.12	Further reading	35
2	Injur	ies in sport: how the body behaves under load	36
	2.1	Introduction	36
	2.2	Bone injuries	37
		2.2.1 Type of fracture	37
		2.2.2 Magnitude of load	40
		2.2.3 Load rate	40
		2.2.4 Bone properties	41
	2.3	Joint and soft tissue injuries	42
		2.3.1 Articular cartilage	42
		2.3.2 Ligaments	42
		2.3.3 Muscle-tendon unit	43
	2.4	Sports injuries to joints and associated tissues	45
		2.4.1 The pelvis and the hip joint	45
		2.4.2 The knee	45
		2.4.3 The ankle and foot	49
		2.4.4 The wrist and hand	50
		2.4.5 The elbow	51
		2.4.6 The shoulder	53
		2.4.7 The head, back and neck	53
	2.5	Genetic factors in sports injury	56
		2.5.1 Sex, age and growth	56
		2.5.2 Bony alignment	57
		Fitness and training status and injury	58
		Summary	60
		Exercises	61
		References	61
		Further reading	64
_		ndix 2.1 Musculoskeletal injury: some useful definitions	65
3		effects of sports equipment and technique on injury	67
	3.1	Sports surfaces	67
		3.1.1 Introduction	67
		3.1.2 Characteristics of sports surfaces	68 70
		3.1.3 Specific sports surfaces	70 71
		3.1.4 Biomechanical assessment of surfaces	71 74
	2.2	3.1.5 Injury aspects of sports surfaces	7 <del>4</del> 76
	3.2	Footwear: biomechanics and injury aspects	76
		3.2.1 Introduction	70 77
		3.2.2 Biomechanical requirements of a running shoe	77 77
		3.2.3 The structure of a running shoe	81
		3.2.4 Footwear and injury	82
		3.2.5 Impact and the running shoe	85
		3.2.6 Running shoes and rearfoot control	03

Other sports and exercise equipment and injury

3.3

87

		3.3.1 The head and neck	88
		3.3.2 The upper extremity	89
		3.3.3 The lower extremity	90
		3.3.4 Alpine skiing: release bindings	91
	3.4	Musculoskeletal injury – technique aspects	91
		3.4.1 Introduction	91
		3.4.2 The head and trunk	92
		3.4.3 The upper extremity	93
		3.4.4 The lower extremity	97
	3.5	Summary	99
	3.6	Exercises	99
	3.7	References	100
	3.8	Further reading	104
		endix 3.1 Artificial surfaces	105
		endix 3.2 Other surface characteristics	108
4		ulating the loads	109
	4.1	Introduction	109
	4.2	Forces acting on a body segment in two dimensions	110
		4.2.1 Static joint and muscle forces for a single segment	
		with one muscle	110
		4.2.2 Dynamic joint and muscle forces for a single	
		segment with one muscle	112
		4.2.3 Assumptions underlying the above models	115
		4.2.4 Forces acting on a body segment with more than	
		one muscle – the indeterminacy problem	116
		4.2.5 Planar joint reaction forces and moments for a	
		single segment	116
		4.2.6 Planar joint reaction forces and moments for	
		segment chains	119
		4.2.7 Joint reaction forces and moments in multiple-	
		segment systems	122
	4.3	Determination of muscle forces from inverse dynamics	124
		4.3.1 Solving the indeterminacy (or redundancy)	
		problem	124
		4.3.2 Inverse optimisation 4.3.3 Use of EMG to estimate muscle force	125
	4.4		133
	4.4	Determination of ligament and bone forces	134
	4.5	An example of the estimation of a load causing	125
		traumatic injury	135
		4.5.1 Patellar ligament rupture	135
	1.6	4.5.2 Concluding comments	138
	4.6 4.7	Summary Exercises	138
	4. <i>7</i> 4.8	References	138
			141
	4.9	Further reading	144

Part Two	В	iomec	chanical Improvement of Sports Performance	147
		Intro	oduction	147
	5	Aspe	ects of biomechanical analysis of sports performance	149
		5.1	Principles of coordinated movement	149
			5.1.1 How is movement controlled?	150
			5.1.2 Structural analysis of movement	152
		5.2	Biomechanical principles of coordinated movement	153
			5.2.1 Universal principles	154
			5.2.2 Principles of partial generality	155
		5.3	Temporal and phase analysis	156
			5.3.1 Phase analysis of ballistic movements	157
			5.3.2 Phase analysis of running	159
			5.3.3 Phase analysis of other activities	160
			5.3.4 Concluding comments	161
		5.4	Kinesiological analysis of sports movements	162
			5.4.1 An approach to kinesiological analysis	162
			5.4.2 A formalised kinesiological analysis procedure	163
			5.4.3 The analysis chart	166
			5.4.4 Examples	168
		5.5	Some limitations to kinesiological analysis	168
			5.5.1 What muscles really do	168
			5.5.2 Open and closed kinetic chains	173
		5.6	Summary	174
		5.7	Exercises	174
		5.8	References	176
		5.9	Further reading	1 <i>77</i>
	6		nechanical optimisation of sports techniques	178
		6.1	Introduction	178
		6.2	The trial and error approach	179
		6.3	Statistical modelling	181
			6.3.1 Types of statistical model	181
			6.3.2 Limitations of statistical modelling	183
			6.3.3 Theory-based statistical modelling	184
			6.3.4 Hierarchical model of a vertical jump	186
		6.4	Mathematical modelling	189
			6.4.1 Simulation	190
			6.4.2 Optimisation	192
			6.4.3 Conclusions – future trends	195
		6.5	Summary	196
		6.6	Exercises	196
		6.7	References	198
	_	6.8	Further reading	200
	7		nematical models of sports motions	201
		7.1	Introduction	201

	7.2	Optimal javelin release	202
		7.2.1 The javelin flight model	202
		7.2.2 Simulation	204
		7.2.3 Optimisation	205
		7.2.4 Sensitivity analysis	205
		7.2.5 Simulation evaluation	209
	7.3	Simple models of the sports performer	210
		7.3.1 Introduction	210
		7.3.2 The thrower model	211
		7.3.3 Simulation, optimisation and sensitivity analysis	213
		7.3.4 Simulation evaluation	218
		7.3.5 Concluding comments	220
	7.4	More complex models of the sports performer	220
		7.4.1 Introduction	220
		7.4.2 Linked segment models of aerial movement	221
		7.4.3 Hanavan's human body model	223
		7.4.4 Hatze's anthropometric model	226
		7.4.5 Yeadon's mathematical inertia model of the	
		human body	228
		7.4.6 Conclusions	231
	7.5	Models of skeletal muscle	231
		7.5.1 Introduction	231
		7.5.2 The computed torque approach	231
		7.5.3 Muscle models	232
		7.5.4 A more comprehensive model of skeletal muscle	234
		7.5.5 Evaluation and uses of Hatze's model of skeletal	
		muscle	236
		7.5.6 Concluding comments	239
	7.6	Summary	239
		Exercises	240
		References	241
		Further reading	242
8	Feedl	back of results to improve performance	244
	8.1	The importance of feedback	244
	8.2	Technique assessment models and their limitations in	
		feedback	247
		8.2.1 Live demonstrations	248
		8.2.2 Serial recordings	248
		8.2.3 Parallel representations	248
		8.2.4 Textbook technique	249
		8.2.5 Graphical (diagrammatic) models	250
		8.2.6 Computer simulation models	251
		8.2.7 Analysis charts	251
		8.2.8 Concluding comments	252

8.3 The role of technique training

254

	8.3.1 Learning or relearning a technique	255	
	8.3.2 How to plan technique training	257	
8.4		258	
8.5	Use of computer-based feedback	260	
	8.5.1 Overview	260	
	8.5.2 The uses of computer simulation and optimisation	200	
	in feedback	261	
8.6	Summary	262	
8.7	Exercises	262	
8.8	References	263	
8.9	Further reading	265	
Author in	ndev	267	
Subject i	Subject index		