

Contents

1 Musculoskeletal Biomechanics, an Important and Interesting Discipline at the Interface between Medical and Natural Sciences	1
2 Basic Concepts from Physics and Mechanics	4
Force	4
Moment	8
Pressure	11
Mechanical stress	13
Mechanical work, energy and power	14
Stability and instability	16
3 Vector Algebra	17
The trigonometric functions sine, cosine, and tangent	17
Representation of vectors	19
Addition of vectors: graphical procedure in the two-dimensional case	21
Addition of vectors: numerical procedure	24
Decomposition of a vector into vector addends	25
Multiplication of vectors: scalar product and vector product	25
4 Translation and Rotation in a Plane	28
Translation	28
Rotation	29
Combined translation and rotation	29
Instantaneous center of rotation	31
Error influences when describing a motion	32
5 Mechanical Equilibrium	35
Conditions of static mechanical equilibrium	35
Example: calculation of an unknown moment in the state of static equilibrium	36
Example: calculation of an unknown force in the state of static equilibrium	36
Example: calculation of the joint force of a beam balance in static equilibrium	37
6 Material Properties of Solid Materials	40
Elongation and compression	40
Shear	42
Elastic, viscoelastic, and plastic deformation	42
Hardness	44
Friction	45
Fracture	45
7 Deformation and Strength of Structures	48
Experimental determination of deformation and strength	49
Deformation and strength of beam-like structures	52
Deformation of a beam under tension or compression	53
Bending of a beam fixed at one end	53
Torsion of a beam around its long axis	54
8 Estimation of the Load Transmitted by Joints of the Human Locomotor System by Means of a Biomechanical Model Calculation	57
Calculation of a joint load in the static case, illustrated with the example of the elbow joint	58
Determination of the joint force in the dynamic case, illustrated with the example of the ankle joint	61
Determination of the joint force if more than one muscle or ligament force has to be taken into account	66
9 Mechanical Aspects of the Hip Joint	69
Load on the hip joint in the stance phase of slow gait	69
Influencing the load on the hip joint by gait technique, walking aids, or surgical interventions	72
Determination of the load on the hip joint by gait analysis	74
Measurement of the load on the hip joint by instrumented joint replacement	77
Determination of the stress distribution on the surface of the hip joint	78
Measurement of the pressure distribution on the surface of the hip joint	82
Pressure on the articular surface as a primary cause of arthrosis of the hip joint	83

10 Mechanical Aspects of the Knee	85	Relationship between force and electromyography (EMG)	146
Features common to all joints, illustrated by the example of the knee joint	85	Muscle architecture	147
Motion of the knee joint	88	Skeletal muscle mechanics	150
Load on the femorotibial and femoropatellar joint	90	14 Mechanical Properties of Bones	155
Pressure distribution in the femoropatellar joint	96	Architecture of the bone tissue	155
Loading of the cruciate ligaments	97	Stress and strain of inhomogeneous, anisotropic materials	156
11 Mechanical Aspects of the Lumbar Spine	105	Material properties of cortical bone	158
Rotational and translational motion of the vertebrae in flexion and extension ..	105	Architecture and material properties of trabecular bone	159
Calculation of the loading of the lumbar spine: two-dimensional model	106	Measurement of bone density and bone mineral content <i>in vivo</i>	161
The role of intra-abdominal pressure ...	108	Determination of the fracture risk of proximal femur and lumbar vertebrae <i>in vivo</i>	163
Calculation of the loading of the lumbar spine: three-dimensional model	110	Adaptation of bones to mechanical demands	165
Determination of the loading of the lumbar spine from measurements of intradiskal pressure	110	15 Mechanical Aspects of Skin	169
Determination of the load on the lumbar spine from measurements of stature change	112	Anatomical basics	169
Recommendations for carrying and lifting	113	Material properties	170
Mechanical properties of lumbar intervertebral disks	117	Reaction of the skin to mechanical factors	173
Deformation of disks under load	117	Appendix	177
Pressure distribution over the vertebral endplates	118	A1 Loading of the Lumbar Spine when Sitting or Standing	178
Intradiskal pressure and mechanical function of the disk	119	Loading of the lumbar spine, determined by measurement of intradiskal pressure	178
Compressive strength of lumbar vertebrae	120	Loading of the lumbar spine, determined from measurement of stature change	180
Fracture of the vertebral arch	124	Loading of the lumbar spine, determined by an EMG-assisted model calculation	182
Sequence of events: overload injury – low back pain – work loss – disability? A warning	125	Biomechanical model comparing spinal loading in sitting and standing	182
12 Mechanical Aspects of the Shoulder ...	129	Conclusions	183
Joints of the shoulder girdle	129	A2 What do we Know about Primary Mechanical Causes of Lumbar Disk Prolapse?	185
Loading of the glenohumeral joint	131	Studies <i>in vitro</i>	185
Stability of the glenohumeral joint	132	Influence of posture on disk bulge and prolapse	186
13 Structure and Function of Skeletal Muscle	136	Epidemiological studies of the relation between heavy physical exertions and the prevalence of lumbar disk prolapse	186
Skeletal muscle morphology	136	Conclusions and outlook	188
The force – length relationship	138		
The force – velocity relationship	140		
Theoretical modeling of skeletal muscle behavior	141		
Mechanical properties of tendons	142		
Force regulation in skeletal muscles	143		

A3 Influence of Physical Activity on Architecture and Density of Bones. An Overview of Observations in Humans	190	Combined rotation made up of a sequence of rotations.	214
Methods for measuring bone density and bone mineral content.	190	Euler and Bryant-Cardan angles.	216
Effects of increased mechanical loading	191	Rotation about an arbitrary axis.	218
Effects of reduced mechanical loading ..	194	Motion in three-dimensional space, combined from rotation and translation. Chasles' Theorem	218
Summary and outlook	197	Calculation of the parameters of rotation and translation in three-dimensional space from the coordinates of reference points and their images	220
B1 Mathematical Description of Translation and Rotation in a Plane	199	Parameters of the motion of a body observed in a laboratory coordinate system	221
Cartesian coordinates.	199	Parameters describing the relative motion of two bodies.	224
Translation.	199	B3 Dealing with Errors	227
Rotation	200	Mean and variance.	227
Motion combining translation and rotation.	201	Biological variance	228
Determination of the imaging parameters from two points and their images.	202	Comparing precision among measuring methods or among investigators.	229
Matrix notation	203	Error propagation	230
B2 Mathematical Description of Translation and Rotation in Three-Dimensional Space	205	Calculation of a propagated error using the example of an angle defined by the end points of two straight lines.	231
Is it really necessary to deal with the description of three-dimensional rotations in the context of orthopedic biomechanics?	205	Method of least squares	232
Matrix notation	209	Regression line.	232
Coordinates and vectors	210	Fit of two sets of points by translation and rotation	234
Coordinate transformations	212	Designations and Units	237
Translation in three-dimensional space	213	Index	239
Rotation in three-dimensional space.	213		
Rotations about the coordinate axes ..	213		