

Contents

1	Dance and biomechanics — 1
2	The human body: Musculoskeletal and nervous systems — 5
2.1	Basic anatomical terminology — 5
2.2	Joint actions — 8
2.2.1	Segmental rotation around X-axes — 8
2.2.2	Segmental rotation around Y-axes — 9
2.2.3	Segmental rotation around Z-axes — 9
2.3	Human musculoskeletal system — 9
2.3.1	Bone and the skeletal system — 10
2.3.2	Joints — 15
2.3.3	Muscles — 18
2.4	The nervous system and motor control — 22
2.4.1	Energy for muscle activation — 23
2.4.2	Summary of factors contributing to total muscle force generation — 25
2.4.3	Stretching and neuromuscular function — 25
2.4.4	Sensory information and control strategies — 25
3	Center of mass kinematics and dynamics — 28
3.1	Center of mass — 28
3.2	Center of mass kinematics — 37
3.3	Center of mass dynamics: Forces and Newton's laws — 43
3.3.1	Force of gravity — 45
3.3.2	Ground reaction force — 48
3.3.3	Other external forces — 55
3.4	Impulse-momentum theorem — 58
3.4.1	Reducing injury risk — 64
4	Balance — 66
4.1	Simple inverted pendulum model — 67
4.2	Center of pressure and base of support — 68
4.3	Simple inverted pendulum dynamics — 71
4.4	Physical inverted pendulum — 76
4.5	Quiet balance and dynamic balance — 79
4.6	Double and triple inverted pendulum and kinematic strategies for balance maintenance — 83
4.7	Sensing balance and neuromuscular control — 85
4.8	Upright versus inverted balance maintenance — 90
4.9	Balance and dance training — 91

5 Rotations — 93

- 5.1 Rotational kinematics — **93**
- 5.2 Whole body rotational dynamics — **96**
- 5.3 Push off for a turn — **99**
 - 5.3.1 Torque — **99**
 - 5.3.2 Rotational impulse and motor control strategies — **103**
- 5.4 Turn phase — **106**
 - 5.4.1 Slowing frictional torque — **107**
 - 5.4.2 Balance maintenance during rotations — **108**
- 5.5 Spotting — **111**
- 5.6 Landing and transitioning out of turns — **112**
- 5.7 Turns in the air and conservation of rotational momentum — **112**
- 5.8 Inertia tensor — **115**
 - 5.8.1 Segmental analysis and whole body inertia tensor — **119**
 - 5.8.2 Modeling a dancer in pirouette position — **120**
- 5.9 Principal moments of inertia, principal axes, and dynamic balance during rotations — **124**
- 5.10 Body segment rotations around joint axes — **127**

6 Musculoskeletal forces — 131

- 6.1 Inverse dynamics — **132**
- 6.2 Net musculoskeletal force and torque — **138**
- 6.3 Musculoskeletal forces: physical forces inside of the body — **140**
 - 6.3.1 Muscle-tendon forces — **140**
 - 6.3.2 Capsuloligamentous forces — **141**
 - 6.3.3 Bone-on-bone forces — **142**
- 6.4 Creating physical models including musculoskeletal forces — **142**
 - 6.4.1 Static analysis: single muscle force — **144**
 - 6.4.2 Constant velocity analysis: single muscle force — **147**
 - 6.4.3 Dynamic analysis: single muscle force — **149**
- 6.5 Multiple muscle forces: the underdetermined system — **151**
 - 6.5.1 Muscle scaling — **152**
 - 6.5.2 Optimization methods — **159**
 - 6.5.3 Electromyography — **161**
 - 6.5.4 Musculoskeletal simulations — **165**
- 6.6 Musculoskeletal forces in dance and implications for training and dance injury — **165**

7 Energy — 168

- 7.1 Mechanical work — **169**
 - 7.1.1 Mechanical work done by a force — **169**
 - 7.1.2 Mechanical work done by a torque — **174**

7.2	Work-kinetic energy theorem —	177
7.2.1	Translational motion —	177
7.2.2	Rotational motion —	179
7.3	Power —	182
7.3.1	Net joint power —	184
7.3.2	Net muscle power at a joint —	186
7.4	Potential energy and mechanical energy —	188
7.5	Metabolic energy —	191
7.6	Metabolic rate —	192
7.7	Metabolic energy expenditure during dance —	198
7.8	Energy efficiency —	200
8	Lagrangian mechanics and applications in dance —	202
8.1	Principle of least action and the Lagrangian —	203
8.2	Inverted pendulum revisited —	205
8.3	Ignorable coordinates and momentum conservation —	209
8.4	Dancer as a spinning top: Lagrangian approach —	209

Bibliography — 215

Index — 221