

List of Contributing Authors xix Preface xxi Acknowledgments xxv Master Competency Checklist xxvi

PART ONE Foundations of Therapeutic Modalities

1. The Basic Science of Therapeutic Modalities 3 William E. Prentice and Bob Blake

Basic Science 3 Forms of Energy 4

Electromagnetic Energy 5 The Relationship Between Wavelength and Frequency 5 The Electromagnetic Energy Spectrum 6 How Is Electromagnetic Energy Produced? 7 Effects of Electromagnetic Radiations 9 Laws Governing the Effects of Electromagnetic Energy 9 Electromagnetic Energy Modalities 11 Thermal Energy 13

Thermal Energy Modalities 14

- Electrical Energy 14 Electrical Energy Modalities 14
- Sound Energy 15

Sound Energy Modalities 15

Mechanical Energy 16 Mechanical Energy Modalities 16

The Importance of Incorporating The Best Available Evidence Into Decisions About The Use of Therapeutic Modalities 16 Applying the Best Available Evidence in Making Clinical Decisions 17 Assessing the Patient Outcomes of a Treatment 17

Legal Concerns When Using Therapeutic Modalities 17

Summary 17

2. Using Therapeutic Modalities to Affect the Healing Process 23
William E. Prentice How Should the Clinician Use Therapeutic Modalities in Rehabilitation? 23
The Importance of Understanding The Healing Process 25 Inflammatory-Response Phase 25 Fibroblastic-Repair Phase 28 Maturation-Remodeling Phase 29
Factors That Impede Healing 30
 How Should Therapeutic Modalities Be Used Throughout The Rehabilitation Process? Using Modalities in the Immediate First Aid Management of Injury 32 Modality Use in the Inflammatory-Response Phase 34 Modality Use in the Fibroblastic-Repair Phase 35 Modality Use in the Maturation-Remodeling Phase 35 Other Considerations In Treating Injury 36 Summary 37
3. The Role of Therapeutic Modalities in Wound Healing 41 Pamela E. Houghton
Introduction 41
Thermal Agents 42 Hydrotherapy 43
Electrical Stimulation 44
Ultrasound 52
Photobiomodulation 54
Ultraviolet Light 57
Pneumatic Compression Therapy 60
Review of Clinical Research Evidence 60
Choosing the Best Modality for the Treatment of Delayed or Nonhealing Wounds 64 Contraindications 65
Summary 67
4. Managing Pain With Therapeutic Modalities 79 Craig R. Denegar and William E. Prentice
Understanding Pain 79 Why Does Classification Matter? 80 The Pain Experience 80 Pain Terminology 81
Pain Assessment 82 Pain Assessment Scales 82 Documentation 85

Goals In Managing Pain 85
Nociceptive Pain 85
Sensory Receptors 85
Neural Transmission 87
Facilitators and Inhibitors of Synaptic Transmission 88
Nociception 90
Neurophysiologic Explanations of Pain Control 92
The Gate Control Theory of Pain 92
Descending Pain Control 93
β-Endorphin and Dynorphin in Pain Control 93
Central Mechanisms 95
Summary of Pain Control Mechanisms 95
Pain Management 96
Nontraumatic and Persisting Pain 97

Summary 100

PART TWO Electrical Energy Modalities

5. Basic Principles of Electricity and Electrical Stimulating Currents 107 Daniel N. Hooker and William E. Prentice Components of Electrical Currents 108 Electrotherapeutic Currents 109 Devices That Generate Electrotherapeutic Currents 110 Electrical Circuits 111 Series and Parallel Circuits 111 Current Flow through Biologic Tissues 113 Choosing Appropriate Treatment Parameters 114 Waveforms 114 Current Modulation 118 Frequency 120 Intensity 121 Duration 121 Polarity 121 Electrode Setup 123 Physiologic Responses to Electrical Current 126 Direct and Indirect Physiologic Effects 126 Nerve Responses to Electrical Currents 127 Muscular Responses to Electrical Current 130 Biostimulative Effects of Electrical Current on Nonexcitatory Cells 132

Clinical Uses of Electrical Stimulating Currents 132 Therapeutic Uses for Electrical Stimulation of Motor Nerves 132 Therapeutic Uses of Electrical Stimulation of Sensory Nerves 141 Clinically Used Electrical Stimulating Currents 144 High Voltage Pulsed Current (HVPC) 145 Transcutaneous Electrical Nerve Stimulation (TENS) 146 Microcurrent 147 Russian Currents (Medium-Frequency Biphasic Current Generators) 150 Interferential Currents 151 Premodulated Interferential Current 155 Continuous Direct Current (CDC) 155 H-Wave Stimulation 156 Deep Oscillation Therapy (Hivamat) 156 Bone Growth Stimulators 157 Functional Electrical Stimulation 158 Clinical Uses of FES 159 Transcranial Electrical Stimulation 159 Placebo Effect of Electrical Stimulation 159 What Does the Most Recent Best-Available Evidence Say About the Effectiveness of Electrical Stimulating Currents as a Clinical Treatment Modality? 160 Safety in the Use of Electrical Equipment 161 Summary 164 6. Iontophoresis 189 James R. Scifers and William E. Prentice Iontophoresis Versus Phonophoresis 189 Basic Mechanisms of Ion Transfer 190 Pharmacokinetics of Iontophoresis 190 Movement of lons in Solution 190 Movement of lons Through Tissue 191 Iontophoresis Equipment and Treatment Techniques 192 Type of Current Required 192 Iontophoresis Generators 192 Current Intensity 194 Treatment Duration 195 Dosage of Medication 195 Electrodes 195 Selecting the Appropriate Ion 200 Clinical Applications for Iontophoresis 203

Treatment Indications and Contraindications 207 Sensitivity Reactions to lons 207 Treatment of Chemical Burns 208 What Does the Most Recent Best-Available Evidence Say About the Effectiveness of Iontophoresis as a Clinical Treatment Modality? 208 Summary 209 7. Biofeedback 219 William E. Prentice Motor Control and Feedback 219 The Role of Biofeedback 220 Biofeedback Instrumentation 220 Peripheral Skin Temperature 221 Finger Phototransmission 221 Skin Conductance Activity 221 Real-Time Ultrasound 222 Electromyographic Biofeedback 222 Motor Unit Recruitment 223 Measuring Electrical Activity 224 Separation and Amplification of Electromyographic Activity 224 Converting Electromyographic Activity to Meaningful Information 225 Processing the Electromyographic Signal 226 Biofeedback Equipment and Treatment Techniques 226 Electrodes 228 Displaying the Information 230 Wearable Biofeedback Devices 231 Clinical Applications for Biofeedback 231 Muscle Reeducation 231 Relaxation of Muscle Guarding 233 Pain Reduction 234 Treating Neurologic Conditions 234 What does the Most Recent Best-Available Evidence Say About the Effectiveness of Biofeedback as a Clinical Treatment Modality? 234 Summary 235 8. Principles of Electrophysiologic Evaluation and Testing 245 John Halle and David Greathouse Introduction 247 Electrophysiologic Testing Equipment and Setup 248 Electrodes 249 Amplifier 251

Visual Feedback (Oscilloscope) 251 Auditory Feedback (Speakers) 251 Testing Units 252 Eliciting an Action Potential 252 Generating a Record 253 Evaluation of the Peripheral Nervous System 253 Anatomy of the Spinal Nerve and Neuromuscular Junction 255 Sensory Receptor and Size of the Axon 256 Synapse 256 Alpha Motor Neuron 256 Neuromuscular Junction 256 Muscle Fiber 256 The Elements of the Spinal Nerve 257 Testing Procedures 258 Limb Temperature and Age Considerations 258 Nerve Conduction Study 258 Sensory Nerve Studies 259 Other Variations to Sensory Nerve Studies 263 Motor Nerve Studies 267 Other Motor Nerve Conduction Procedures 275 An Example of One Upper Quarter Examination Using Sensory and Motor Nerve Conduction Procedures 277 The Electromyographic Examination 278 Clinical EMG Procedures 280 Insertion 280 Sensitivity and Specificity of the NCS/EMG Examination 288 Limitations Associated with the NCS/EMG Process 289 Somatosensory Evoked Potentials 290 Electrophysiological Testing Complemented by the Addition of Neuromuscular Ultrasound 291 Electrophysiologic Testing Within the Operating Room 292 Other Electrophysiologic Testing Procedures 292 Requesting NCS/EMG Examinations 293 Conclusion 293 Summary 294

PART THREE Thermal Energy Modalities

9. Cryotherapy and Thermotherapy 311 Lisa Jutte and William E. Prentice

Mechanisms of Thermal Energy Transfer 312

Appropriate Use of Cryotherapy and Thermotherapy Modalities 312

Clinical Use of the Thermal Energy Modalities 313 Effects of Tissue Temperature Change on Circulation 314 Effects of Tissue Temperature Change on Muscle Spasm 315 Effects of Temperature Change on Performance 316

Cryotherapy 316 Physiologic Effects of Tissue Cooling 316 Cryotherapy Treatment Techniques 321

Thermotherapy 337 Physiologic Effects of Tissue Heating 337 Thermotherapy Treatment Techniques 338

Counterirritants 349

What does the Most Recent Best-Available Evidence Say About the Effectiveness of Cryotherapy and Thermotherapy as Clinical Treatment Modalities? 350

Summary 351

PART FOUR Sound Energy Modalities

10. Therapeutic Ultrasound 391

Leamor Kahanov, William E. Prentice and David O. Draper (Deceased)

Ultrasound as a Heating Modality 392 Transmission of Acoustic Energy in Biologic Tissues 392 Transverse versus Longitudinal Waves 392 393 Frequency of Wave Transmission Velocity 393 Attenuation 393 Basic Physics of Therapeutic Ultrasound 395 Components of a Therapeutic Ultrasound Generator 395 Transducer 395 Effective Radiating Area 397 Frequency of Therapeutic Ultrasound 399 The Ultrasound Beam 400 Amplitude, Power, and Intensity 401 Pulsed versus Continuous Wave Ultrasound 402 Physiologic Effects of Ultrasound 404 Thermal Effects 404 Nonthermal Effects 405 Ultrasound Treatment Techniques 406 Frequency of Treatment 406 Duration of Treatment 407

Coupling Methods 408 Moving the Transducer 413 Recording Ultrasound Treatments 415 Clinical Applications for Therapeutic Ultrasound 415 Soft Tissue Healing and Repair 415 Scar Tissue and Joint Contracture 416 Stretching of Connective Tissue 417 Chronic Inflammation 417 Bone Healing 419 Ultrasound over Epiphyseal Plates 419 Ultrasonic Bone Growth Stimulators 419 Absorption of Calcium Deposits 420 Ultrasound in Assessing Stress Fractures 420 Pain Reduction 422 Plantar Warts 422 Placebo Effects 422 Portable Ultrasound Devices 423 Phonophoresis 423 Using Ultrasound in Combination with Other Modalities 426 Ultrasound and Hot Packs 426 Ultrasound and Cold Packs 426 Ultrasound and Electrical Stimulation 426 What does the Most Recent Best-Available Evidence Say About the Effectiveness of Therapeutic Ultrasound as a Clinical Treatment Modality? 428 Treatment Precautions 429 Guidelines for the Safe Use of Ultrasound Equipment 431 Summary 432 11. Extracorporeal Shock Wave Therapy 451 Charles A. Thigpen and Howard Kashefsky Shock Wave Generation 452 Focused ESWT (f-ESWT) 452 Radial ESWT (r-ESWT) 453 Physical Parameters of Shock Waves 454 Biologic Effects 456 Bone 457 Tendon 457 Clinical Applications 458 Dosing and Anesthesia Parameters 458

Bone Healing 458 Lower Extremity Tendinopathy 459 Medial Tibial Stress Syndrome 459 Plantar Fasciitis 459 Medial–Lateral Epicondylopathy 462 Rotator Cuff Tendinopathy 463

What does the Most Recent Best-Available Evidence Say about the Effectiveness of Extracorporeal Shock Wave Therapy as a Clinical Treatment Modality? 463

Summary 464

PART FIVE Electromagnetic Energy Modalities

12. Shortwave and Microwave Diathermy 473

Jennifer Ostrowski, William E. Prentice, and David O. Draper (Deceased)

Shortwave Diathermy Equipment 474 Shortwave Diathermy Electrodes 475

Pulsed Shortwave Diathermy (PSWD) 483

Treatment Time 484 Treatment Area 485

Clinical Applications and Physiologic Responses to Diathermy 485 Thermal Effects 487 Nonthermal Effects 488

Comparing Shortwave Diathermy and Ultrasound as Thermal Modalities 489

Microwave Diathermy 489

Diathermy Treatment Precautions, Indications, and Contraindications 490

What does the Most Recent Best-Available Evidence Say About the Effectiveness of Shortwave Diathermy as a Clinical Treatment Modality? 493

Summary 493

13. Photobiomodulation Therapy 507

Nathan Newman and Katie Homan

Physics of Lasers 508

Types of Lasers 509

Laser Treatment Techniques 512

Lasing Techniques 513

Parameters 514

Depth of Penetration 518

Clinical Applications for Low-Level Laser Therapy 519 Wound Healing Applications 519

Tensile Strength 521 Immunologic Responses 521 Inflammation 521 Scar Tissue 521 Orthopedic Applications 522 Tensile Strength 522 Inflammation 522 Pain Applications 523 Nerve Applications 523 Enhanced Muscular Performance and Recovery 524 Bone Response 524 Suggested Treatment Protocols 525 Wound Healing 527 Scar Tissue 528 Edema and Inflammation 528 Pain 528 Enhancement of Muscle Performance and Recovery 528 Clinical Applications for High-Intensity Laser Therapy 529 Treatment Protocols 530 Laser Safety 531 Indications, Contraindications, and Precautions 533 Light Emitting Diodes (LEDs) 533 LED Treatment Parameters 535 LED Clinical Applications 535 Comparing LED and Lasers 536 What does the Most Recent Best-Available Evidence Say About the Effectiveness of Laser and LED as Clinical Treatment Modalities? 537

Conclusion 538

Summary 538

PART SIX Mechanical Energy Modalities

14. Spinal Traction 555 Daniel N. Hooker

The Physical Effects of Traction 555 Effects on Spinal Movement 555 Effects on Bone 556 Effects on Ligaments 556 Effects on the Disk 557

Effects on Articular Facet Joints 558 Effects on the Muscular System 558 Effects on the Nerves 558 Effects on the Entire Body Part 559 Traction Treatment Techniques 559 Lumbar Positional Traction 559 Inversion Traction 561 Manual Lumbar Traction 562 Mechanical Lumbar Traction 566 Manual Cervical Traction 575 Mechanical Cervical Traction 577 Indications and Contraindications 578 What does the Most Recent Best-Available Evidence Say about The Effectiveness of Traction as a Clinical Technique? 580 Summary 582 15. Intermittent Pneumatic Compression Devices 591 Daniel N. Hooker The Lymphatic System 591 Purposes of the Lymphatic System 591 Structure of the Lymphatic System 592 Peripheral Lymphatic Structure and Function 592 Injury Edema 593 Formation of Pitting Edema 593 Formation of Lymphedema 594 The Negative Effects of Edema Accumulation 595 Treatment of Edema 595 Intermittent Pneumatic Compression Treatment Techniques 597 Inflation Pressures 598 On-Off Sequence 599 Total Treatment Time 599 Sequential Compression Pumps 600 Patient Setup and Instructions 601 Cold And Compression Combination 604 Indications and Contraindications for Use 605 Blood Flow Restriction (BFR) Training 606 Recovery Boots 606 What Does The Most Recent Best-Available Evidence Say About The Effectiveness of Intermittent Pneumatic Compression as a Clinical Treatment Modality? 608 Summary 608

16. Therapeutic Massage and Soft Tissue Mobilization 617 William E. Prentice Physiologic Effects of Massage 617 Reflexive Effects 618 Mechanical Effects 619 Psychological Effects of Massage 619 Massage Treatment Considerations and Guidelines 619 Equipment 622 Classic Massage Treatment Techniques 623 Swedish Massage (Hoffa Massage) 623 Soft Tissue Mobilization Techniques 630 Cyriax Deep Transverse Friction Massage 630 Connective Tissue Massage 631 Trigger Point Massage 633 Myofascial Release 637 Strain-Counterstrain 638 Positional Release Therapy 639 Active Release Technique® 640 Graston Technique® 641 Rolfing 641 Trager 643 Cupping Therapy 644 Percussive Massage 645 Indications and Contraindications for Massage 645

What Does the Most Recent Best-Available Evidence Say About the Effectiveness of Various Massage Techniques as Clinical Treatment Modalities? 646

Summary 648

17. Vibration Therapy 659

Troy Blackburn, Jonathan Goodwin, Chris Johnston, and Derek Pamukoff

Somatosensory Function 660 Effects of Vibration on Proprioception and Kinesthesia 660 Effects of Vibration on Balance 661 Effects of Vibration on Reflexive Neuromuscular Control 662 Effects of Vibration on Gait Biomechanics 662

Biological Effects 663 Muscle Function 663 Bone Health 663 Cartilage Health 665 Patient Self-Report and Functional Outcomes 665 Clinical Recommendations 665 Indications, Contraindications, and Precautions 667 What Does the Most Recent Best-Available Evidence Say about the Effectiveness of Vibration Therapy as a Clinical Treatment Modality? 668 Summary 669

Appendix A Location of Motor Points 680 Appendix B Units of Measure 683 Answers to Self-Test Questions 685 Index 687