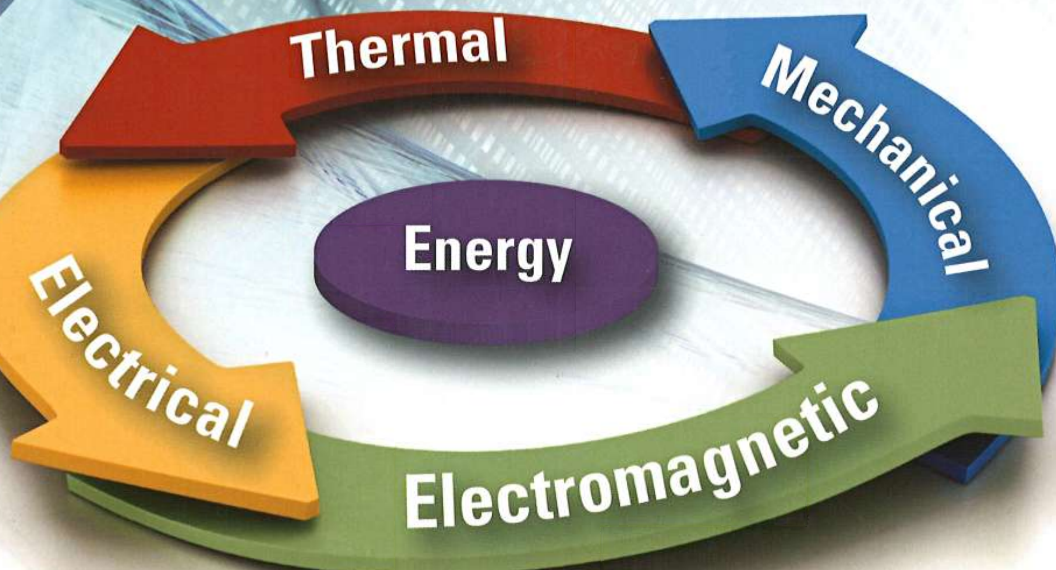
Therapeutic Electrophysical Agents

Evidence Behind Practice

THIRD EDITION



Alain-Yvan Bélanger

Wolters Kluwer
Health

thePoint

http://thePoint.lww.com/Belanger3e

Provides flexible learning solutions and resources for students and faculty using **Therapeutic Electrophysical Agents: Evidence Behind Practice, Third Edition**

Resources for students:

- Online Dosage Calculators
- Links to Video Clips
- Board-Style Review Questions

Resources for instructors*:

- Image Bank
- Test Bank

Scratch Off Below

WK24PSBT3G4X

Belanger

Note: Book cannot be returned once panel is scratched off.

Log on today!

Visit **http://thePoint.lww.com/Belanger3e** to learn more about thePoint™ and the resources available. Use the scratch off code to access the student resources.

Wolters Kluwer Health

**The faculty resources are restricted to adopters of the text. Adopters have to be approved before accessing the faculty resources.*

Therapeutic Electrophysical Agents

Evidence Behind Practice

THIRD EDITION

Therapeutic Electrophysical Agents

Evidence Behind Practice

THIRD EDITION

Alain-Yvan Bélanger, PhD, PT
Retired Professor
Laval University
Canada
Owner and Consultant
Physiométrix Inc.

Wolters Kluwer Health | Lippincott Williams & Wilkins
Philadelphia • Baltimore • New York • London
Buenos Aires • Hong Kong • Sydney • Tokyo

Acquisitions Editor: Emily Lupash
Product Manager: Matt Hauber
Marketing Manager: Leah Thomson
Production Project Manager: Marian Bellus
Design Coordinator: Terry Mallon
Illustration Coordinator: Jennifer Clements
Manufacturing Coordinator: Margie Orzech
Prepress Vendor: Aptara, Inc.

Third Edition

351 West Camden Street
Baltimore, MD 21201

Two Commerce Square
2001 Market Street
Philadelphia, PA 19103

Printed in China

9 8 7 6 5 4 3 2

Library of Congress Cataloging-in-Publication Data

Bélanger, Alain, author.
Therapeutic electrophysical agents : evidence behind practice / Alain-Yvan Bélanger.—Third edition.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-4511-8274-3 (alk. paper)
I. Title.
[DNLM: 1. Therapeutics—Handbooks. 2. Therapeutics—Outlines. 3. Evidence-Based Medicine—Handbooks. 4. Evidence-Based Medicine—Outlines. 5. Physical and Rehabilitation Medicine—Handbooks. 6. Physical and Rehabilitation Medicine—Outlines. WB 39]
RM841.5
615.8′3—dc23

2013035769

To purchase additional copies of this book, call our customer service department at (800) 638-3030 or fax orders to (301) 223-2320. International customers should call (301) 223-2300.

Visit Lippincott Williams & Wilkins on the Internet: http://www.lww.com. Lippincott Williams & Wilkins customer service representatives are available from 8:30 am to 6:00 pm, EST.

DEDICATION

I dedicate this third edition to all educators, students, and clinicians in their journey to become the best evidence-based teachers, students, and practitioners of therapeutic electrophysical agents they can be.

RRS1708

QUOTES

Learning never exhausts the mind.

Leonardo da Vinci

Any fool can know. The point is to understand.

Albert Einstein

I never learn anything talking. I only learn things when I ask questions.

Lou Holtz

Great things are not accomplished by those who yield to trends and fads and popular opinion.

Jack Kerouac

Absence of evidence is not evidence of absence.

Carl Sagan

ABOUT THE AUTHOR

Alain-Yvan Bélanger, BSc, MSc, PhD, PT is a retired Professor from the Department of Rehabilitation, Physiotherapy program, Faculty of Medicine, Laval University, Quebec City, Canada. Dr. Bélanger holds a bachelor's degree in physiotherapy from the University of Montreal, a master's of science degree in kinesiology from Simon Fraser University, and a doctoral degree in neurosciences from McMaster University. He has extensive experience as a teacher, researcher, consultant, and author in the field of human neuromuscular physiology and therapeutic electrophysical agents. Dr. Bélanger has held the positions of Scientific Editor of the journal *Physiotherapy Canada* and President of the Canadian Physiotherapy Association. He has also served as Associate Editor of several journals. He is the sole author of the first and second editions of this book. An avid golf and poker player, Alain still dreams of playing a sub 80s round of golf and winning the next World Series of Poker Seniors Championship!

ACKNOWLEDGMENTS

I want to express my deepest gratitude to all of you who chose the previous two editions of this textbook to learn, teach, and practice therapeutic electrophysical agents.

Thank you to Julie Stegman, LWW Publisher, for her continued trust and support, and to Emily Lupash, Acquisition Editor, for her dedication to see a third edition.

Thanks to all of the reviewers for their thoughtful comments and suggestions related to the preparation of this third edition.

I want to express a very special thank you to my Product Development Editor, Matt Hauber, for his advice, direction, skillful work, and professionalism.

To everyone at LWW, thank you for giving me the opportunity to make my work a published reality.

Alain-Yvan Bélanger, BSc, MSc, PhD, PT

REVIEWERS

Misha Bradford, PT, DPT, OCS
Assistant Professor (Clinical)
University of Utah
Salt Lake City, Utah

Joseph Gallo, DSc, ATC, PT
Director, Athletic Training Program
Salem State University
Salem, Massachusetts

Leigh Ann Hewston, PT, Med
Instructor
Thomas Jefferson University
Philadelphia, Pennsylvania

Paul Higgins, DPT, MPT, ATC, CSCS
Assistant Professor of Physical Therapy
University of Hartford
West Hartford, Connecticut

Martha Hinman, PT, EdD
Professor
Hardin-Simmons University
Abilene, Texas

Teresa Hoppenrath, PT, DPT, GCS
Assistant Professor, Director of Clinical Education
Ithaca College
Ithaca, New York

Carrie Hoppes, PT, DPT, NCS, OCS, ATC
Adjunct Professor
Baylor University
Fort Sam Houston, Texas

Michael S. Krackow, PhD, ATC, PTA, CSCS
Associate Professor
Virginia Military Institute
Lexington, Virginia

Scott Livingston, PhD, PT, ATC, SCS, LAT
Assistant Professor
University of Kentucky
Lexington, Kentucky

Sara Maher, PT, DScPT, OMPT
Associate Professor
Oakland University
Rochester, Michigan

Byron Smith, PT, DPT, MPE, OCS
Instructor
University of Miami
Coral Gables, Florida

Andrew Priest, EdD
Dean of College of Health and Human Services
Touro University Nevada
Henderson, Nevada

Robert Rowell, DC, MS
Associate Professor
Palmer College of Chiropractic
Davenport, Iowa

PREFACE

There are several electrophysical agent (EPA) textbooks on the market, and I truly appreciate your continued interest in this one. I am particularly excited by this third edition because it brings us to another level in our journey to become the best evidence-based learners and practitioners of EPAs we can be. In the first edition, my goal was to introduce the concept of evidence-based practice into the field of EPAs using a pocket-style format. It is fair to say that the focus of textbooks published prior to the year 2000 was much more on how to safely and effectively apply EPAs rather than on the treatment effectiveness related to these agents. In other words, texts on this subject were much more oriented to application safety and efficacy, and less oriented to treatment effectiveness based on the evidence—that is, on results of published research-based human trials. In the second edition, the goal was to expand on the concept of evidence behind the practice of EPAs by adding more content on key related topics such as pain and soft tissue healing, as well as case studies and an illustrated glossary of terms related to EPAs. The purpose then was to create a textbook that faculty could use to teach undergraduate and graduate students. With this third edition, my goal is to offer the most comprehensive and practical textbook in the field of EPAs by providing updated and new materials, as well as unique and practical ancillary tools.

ENHANCED AND NEW CONTENT PRESENTATION

This edition now offers a full-color presentation designed to maximize text and image quality, clarity, and accuracy. The textbook has also been reorganized into five logical parts containing 21 chapters. Part I, *Foundations*, includes six chapters. A new Chapter 2, Toward a Practice Based on Evidence, explains how the adoption of evidence can optimize the clinical decision making process. In addition, a new Chapter 5, Purchase, Electrical Safety, and Maintenance, consolidates the content of two former chapters, Purchase of Therapeutic Electrophysical Agents and Electrical Shocks, Safety Measures, and Maintenance of Line-Powered Devices. Part II, *Thermal Agents*, includes three chapters: Thermotherapy, Cryotherapy, and Hydrotherapy. The chapter on thermotherapy now integrates four previous chapters, Hot Pack and Paraffin Baths, Fluidotherapy, Skin Sensory Heat and Cold Discrimination Testing, and Skin and Electrophysical Agents Temperature Measurement. Part III, *Electromagnetic Agents*, is also composed of three chapters: Shortwave Diathermy, Low-Level Laser Therapy, and Ultraviolet. Part IV, *Electrical Agents*, includes four chapters. A new Chapter 13, Neuromuscular Electrical Stimulation, now integrates two former chapters, Russian Current Therapy and Interferential Current Therapy. The former chapter on Diadynamic Current Therapy has been deleted because of lack of evidence to support its therapeutic effectiveness. A new Chapter 15, Electrical Stimulation for Tissue Healing and Repair, incorporates two former chapters, Microcurrent Therapy and High-Voltage Pulsed Current Therapy. Part V, *Mechanical Agents*, includes five chapters. A new Chapter 21, Extracorporeal Shockwave Therapy, is added to cover the latest mechanical source of energy used for the management of chronic soft tissue disorders.

Learning objectives are rewritten to reflect recent updates made to Bloom's Taxonomy. The illustrated glossary of electrophysical terminology, formerly Chapter 5, is now integrated into related chapters to enhance the learning experience, meaning that there is no longer a need for readers to go back and forth to this chapter when studying a particular agent. Each chapter now incorporates a new feature, *The Bottom Line*, which highlights key elements. New updated and revised *Application, Contraindications, and Risks* boxes, coupled with *Research-Based Indications* boxes, eliminate some of the redundancies in the previous edition while concisely providing all essential elements required to enhance treatment safety, efficacy, and effectiveness. Revised *Case Studies* are now based on the concepts of evidence-based practice; the International Classification of Functioning, Disability, and Health (ICF) model; and SOAP (*s*ubjective, *o*bjective, *a*ssessment, *p*lan) note format.

NEW AND UNIQUE ANCILLARY MATERIAL

This third edition offers new and unique tools designed to help you master the practice of EPAs. Readers can now access *Online Dosimetric Calculators*, a unique tool in the field, to simplify the often complex and confusing dosimetric aspect of EPA practice while maintaining an emphasis on scientific-based treatment. By entering dosimetric parameters, you can obtain the results and chart them into a patient's file without the need for memorizing formulas or doing hand calculations. Also available are links to *Online Videos* to help students better visualize EPA equipment and accessories, as well as application to patients. Finally, *Online Board-Style Questions* are included to help students with the all-important preparation for licensing.

Alain-Yvan Bélanger, BSc, MSc, PhD, PT

CONTENTS

Chapter 13

Neuromuscular Electrical Stimulation

Chapter Outline

Learning Objectives

Remembering: Describe the biophysical characteristics associated with biphasic pulse, Russian, and interferential currents.

Understanding: Distinguish between electrically evoked versus volitional muscle contraction.

Applying: Demonstrate the four electrode configurations (monopolar, bipolar, quadripolar, multipolar) and the three stimulation modes (synchronous, reciprocal, overlap).

Analyzing: Explain how the current modulation underlying Russian current differs from the current modulation used to generate interferential current.

Evaluating: Formulate the dosimetric parameters that practitioners need to consider and calculate to deliver safe and effective neuromuscular electrical stimulation.

Creating: Discuss the evidence behind the therapeutic use of neuromuscular electrical stimulation.

I. FOUNDATION

A. DEFINITION

1. Neuromuscular Nerve Stimulation

The practice of NMES rests on the use of pulsed electrical currents applied to skeletal muscles with the objective to elicit contraction caused by the electrical depolarization of intramuscular nerve branches. Electrical stimuli are delivered using surface electrodes that are positioned over muscle bellies. The main purpose of NMES is to preserve and recover muscle function in patients and to improve muscle strength in healthy individuals (Bax et al., 2005; Gondin et al., 2011 Hortobagyi et al., 2011; Kim et al., 2010; Filipovic et al., 2011, 2012).

2. Functional Electrical Stimulation

The application of NMES for enhancing the control of movement and posture falls under the field of *functional electrical stimulation* (FES). More specifically, this therapeutic field focuses on the enhancement of impaired motor functions, such as hand grasping, locomotion, and respiration, using complex transcutaneous and percutaneous electrical muscle stimulation systems. The main purpose of FES is to enable motor function by replacing, or assisting, a patient's voluntary ability to execute or control the impaired functions. A subgroup of FES is the application of electrical current for *denervated* skeletal muscles, known as EMS, which stands for *electrical muscle stimulation* (APTA, 2001; Selkowitz, 2010). Coverage of FES, including EMS, is beyond the scope of this chapter because it usually requires complex and specially designed therapeutic equipment available for research purposes but not commonly available on the market for regular clinical applications (for an overview, see Glinsky et al., 2007; Roche et al., 2009; Selkowitz, 2010).

B. ELECTRICAL CURRENTS

The body of evidence presented in this chapter indicates that three types of electrical currents are commonly used to deliver clinical NMES. Practitioners can choose between **biphasic pulsed, Russian,** and **interferential** currents. When examining the force-generating capability of these electrical currents, similarities among electrical parameters must be considered before making any statement as to which current waveform is better than the other for muscle strengthening (Bellew et al., 2012). The biophysical characteristic of each of these currents is presented in the Biophysical Characteristics section.

C. ELECTRICAL STIMULATORS

NMES is delivered by using a variety of cabinet and portable electrical stimulators. Figure 13-1A illustrates a cabinet-type, multi-current, line-powered stimulator capable of generating Russian, interferential, and pulsed biphasic currents. The stimulator may be placed on top of a plain table or on a movable cart, as shown; the cart integrates with the stimulator in addition to providing storage bins and mobility. Also shown are two portable, battery-powered stimulators capable of generating Russian and interferential currents (see Fig. 13-1B,C). There is evidence to suggest that battery-powered stimulators are as effective as line-powered stimulators in producing current amplitudes necessary to generate the training muscle force outputs required for therapy (Laufer et al., 2001; Lyons et al., 2005). Additionally illustrated are a cabinet, line-powered interferential stimulator with a vacuum unit, which allows the use of stimulating suction-type electrodes (see Fig. 13-1D and later discussion), as well as the newer, all-in-one, garment-type electrical stimulator that is designed specifically for the treatment of the quadriceps muscle (see Fig. 13-1E).

Historical Overview

The foundation of neuromuscular electrical stimulation (NMES) rests on Italian Luigi Galvani's work on frogs, conducted in the 1790s, showing that electrical current (static electricity) can evoke muscle contraction. A few years later, the discovery of electromagnetic induction by British Michael Farady led to the development of modern electrical stimulators. Then came the work of French Duchenne de Boulogne, in the 1800s, on human muscle showing that faradic current (pulsed current) applied with moistened surface electrodes can evoke muscle contraction. In 1950, Austrian Hans Nemec patented a concept that led to the creation of the first interferential current (IFC) therapy device (Nemec, 1959; Hooke, 1998). IFC therapy was first introduced in Europe during the 1960s and then in Australia, Canada, and the United States in the 1980s. The mid-1970s saw the introduction of Russian current, by Russian scientist Yakov Kots. His work opened the door to the use of NMES for enhancing muscle strength to healthy nonathletic and athletic individuals who want to increase their muscle strength without submitting themselves to traditional regimens of voluntary muscle training (Delitto, 2002; Ward et al., 2002). In response to scientific and public interests for this newly discovered current, commercial production of Russian current stimulators began in Canada and the United States in the 1980s.

FIGURE 13-1 **A:** Cabinet-type, line-powered, multi-current stimulator mounted on cart, capable of generating Russian, interferential, and pulsed biphasic currents. Portable, battery-powered Russian (**B**) and interferential (**C**) stimulators. **D:** Cabinet-type, line-powered, interferential with vacuum unit, to which is attached a pair of suction electrodes. **E:** Newer, one size fits all, battery-powered, garment-based electrical stimulator designed specifically for the quadriceps muscle. (A–C: Courtesy of DJO Global; D: Courtesy of Astar; E: Courtesy of Neurotech Bio-Medical Research Ltd.)

FIGURE 13-2 Surface rubber carbon-impregnated electrodes (**A**) and pliable stainless steel knit fabric electrodes (**B**). Reusable intravaginal (**C**) and intrarectal electrodes (**D**). Electroconductive gel (**E**). (A, B, and E: Courtesy of DJO Global; C, D Courtesy of Enraf-Nonius.)

D. ELECTRODES AND COUPLING MEDIUM

NMES is applied by using a variety of reusable and disposable electrodes connected to the stimulator using various cables. Figure 13-2 shows common surface plate electrodes made of carbon rubber material (A) or pliable stainless steel knit fabrics (B). These electrodes may be applied over flat body areas, with the exception of the pelvic area, where attachment may be a problem. When the purpose is to deliver NMES to the pelvic floor muscles for conditions such as urinary incontinence, special stimulating electrodes may be required. One option is to use intravaginal and intrarectal electrodes (Fig. 13-2C,D, respectively). If patients are not comfortable with the invasive nature of these electrodes, practitioners may select suction cup electrodes as a second option. These electrodes, connected to a vacuum interferential unit (see Fig. 13-1D), can be quickly and easily attached without adhesive tape or straps, and adapt comfortably to the contours of the pelvic area, thus ensuring optimal contact between the electrode and the skin. For NMES of the quadriceps muscle, practitioners may select a "one size fits all" garment electrode with stimulator unit (see Fig. 13-1E) as an alternative to traditional surface plate electrodes. To optimize electrical conduction at the electrode–tissue interface, electrodes must be covered with a thin layer of electroconductive gel (Fig. 13-2E). Both intravaginal and intrarectal electrodes must also be covered with a sterile lubricant prior to use.

E. RATIONALE FOR USE

Common goals in the field of physical rehabilitation are to preserve, recover, and enhance muscle function in patients following disease and trauma, and in healthy individuals for recreational purpose. There is unquestionable evidence in the scientific literature to show that the best method practitioners can use to enhance muscle function (i.e., strengthening) is to submit individuals to bouts of muscle maximum voluntary contractions (MVCs), done under isometric, isotonic, or isokinetic conditions. Which muscle-strengthening method should clinicians use with patients who are unable to perform volitional exercise at adequate intensity and duration to gain benefits, because of related factors such as physical deconditioning, pain, severe muscle atrophy, or lack of motivation? The use of NMES provides practitioners with an *alternative* muscle-strengthening method that *mimics* volitional training methods. By using NMES alone, or by superimposing it on top of voluntary muscle contractions, practitioners can enhance muscle strengthening in both patients and healthy subjects by improving motor unit (MU) activation while inducing muscle hypertrophy. In other words, the main objective of NMES is to improve MU recruitment while inducing muscle hypertrophy through serial bouts of short duration maximal electrically evoked muscle contractions done against resistance or load.

II. BIOPHYSICAL CHARACTERISTICS

As mentioned earlier, the delivery of NMES rests on using three different electrical currents, namely biphasic pulsed, Russian, and interferential currents. To describe electrical current in terms of waveform and frequency is common in the field of NMES. Let us consider these two important concepts before addressing the biophysical characteristics of these three electrical currents.

A. CURRENT WAVEFORM

Waveform is the geometric configuration of a current, which is described based on its phase, symmetry, electrical balance, and shape. First, a current waveform may be monophasic or biphasic in nature. The word *phase* describes an electrical event that begins when the current departs from the isoelectric line and ends when it returns to the baseline (APTA, 2001). A *monophasic* current waveform is made of only one phase that moves in only one direction (+ or – polarity) from the zero baseline to return to it after a finite time (Fig. 13-3). A *biphasic* current waveform, on the other hand, is made of two phases: moving in one direction and then in the opposite direction from the zero baseline, then returning to that baseline after a finite time. Second, a biphasic current waveform may be symmetrical or asymmetrical. It is *symmetrical* when its positive phase is geometrically identical to its negative phase and *asymmetrical* when its two phases are geometrically different (Fig. 13-4). Third, a biphasic waveform may also be balanced or unbalanced. The waveform is *balanced* when there are equal electrical charges in each phase (see *A* in Fig. 13-4). Such a balanced waveform is often referred to as having "zero net charge" or "zero net DC," because the amount of positive charges minus the amount of negative charges equals zero (APTA, 2001). The waveform is said to be *unbalanced* when there are unequal electrical charges in each phase—that is, when there is a net accumulation of charges within the waveform (see *B* in Fig. 13-4). Fourth, biphasic waveforms may have various

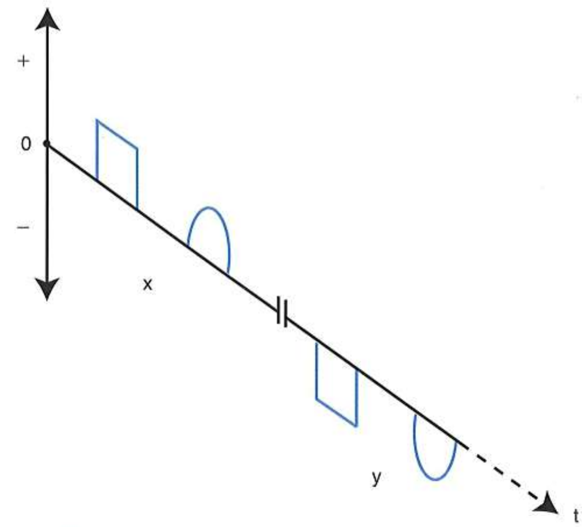


FIGURE 13-3 Monophasic waveforms with either positive (*x*) or negative (*y*) polarity.

shapes such as rectangular, square, triangular, sinusoidal, or exponential. To summarize based on the mentioned terminology, monophasic waveforms are neither symmetrical nor asymmetrical, but are always unbalanced. Moreover, biphasic waveforms are either symmetrical or asymmetrical. Finally, symmetrical waveforms are always balanced, whereas asymmetrical waveforms are either balanced or unbalanced.

B. FREQUENCY

As discussed next, electrical currents used for NMES may be delivered in pulses, bursts, and beats. A *pulse* is a single momentary and sudden fluctuation of current. Pulses may have various shapes; when it has a sinusoidal shape, it is

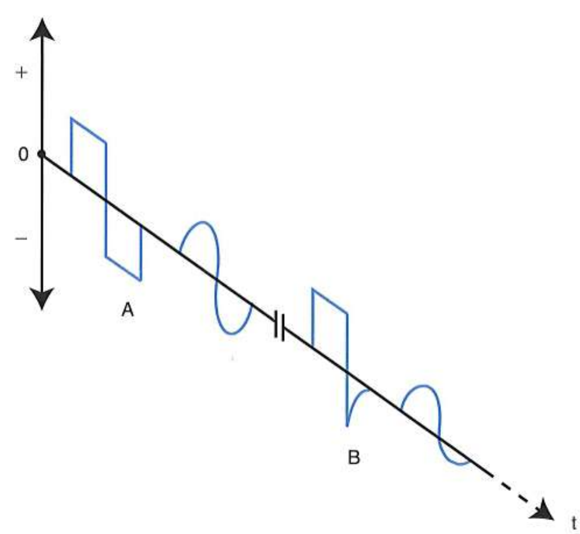


FIGURE 13-4 Biphasic symmetrical (*A*) and asymmetrical (*B*) waveforms.

called a *cycle*. A *burst*, as well as a *beat*, is a group of two or more successive pulses or cycles separated by a time interval during which no electrical activity occurs (APTA, 2001). *Duration*, whether it is pulse duration (PD), cycle duration (CD), burst duration (BuD), or beat duration (BeD), is the time elapsed between the beginning of the first phase and the end of the last phase. The time elapsed between each corresponds to interpulse duration (IPD), intercycle duration (ICD), interburst duration (IBuD), and interbeat duration (IBeD), respectively. *Frequency* (f) is defined as the number of times per second that a pulse, cycle, burst, or beat will repeat itself. It is calculated using the formula $f = 1/P$, where *P*, the period, is equal to the summation of either PD and IPD, CD and ICD, BuD and IBD, and BeD and IBeD, respectively.

C. BIPHASIC PULSED CURRENT

The use of biphasic pulsed currents is very common in the field of NMES. Figure 13-5 illustrates a typical biphasic pulsed waveform. This particular current waveform may be described as biphasic, asymmetrical, and unbalanced, with a rectangular positive phase and exponential negative phase. Shown is the delivery of successive pulses (Fig. 13-5A) and successive bursts of pulses (Fig. 13-5B), with each burst containing five pulses (see later discussion for details).

D. RUSSIAN CURRENT

The term *Russian current* stems from the work conducted in the field of NMES by Russian physiologist Yakov Kots (1971, 1977). Figure 13-6 illustrates the biophysical characteristics associated with this current. There is a consensus in the literature (Alon, 1999) that the *original* Russian current stems from the time modulation of a continuous alternating sine-wave current (AC), having a carrier frequency of 2,500 cycles per second (cps) or Hertz (Hz), in the form of bursts of electrical cycles. The technical term for Russian current is *burst-modulated sinusoidal alternating current*. As shown in the figure, the continuous sine-wave current underlying Russian current is modulated into bursts of cycles, with each burst containing several cycles. Each burst (Bu) has a fixed duration (BuD) of 10 milliseconds (ms) and a fixed interburst duration (IBuD) of 10 ms. Knowing that $f = 1/P$, where *P* is equal to the summation of BuD and IBuD, the result is a pulsed AC with a fixed-burst frequency of 50 bursts per second [bups] [$f = 1/(\text{BuD} + \text{IBuD})$; 50 bups = 1/(10 ms + 10 ms). The inset in Figure 13-6 shows this single typical burst of current, lasting 10 ms and made of 25 continuous biphasic symmetrical sinusoidal cycles. With a carrier frequency of 2,500 cps, the duration of each sine-wave cycle within a burst, of which the duration is equivalent to the period (P), is 400 μs ($P = 1/f$; 400 μs = 1/2,500 cps), with each half-cycle having a duration of 200 μs. In other words, the cycle duration (CD) and the phase duration (PhD) of this cycle equate to 400 μs and 200 μs, respectively.

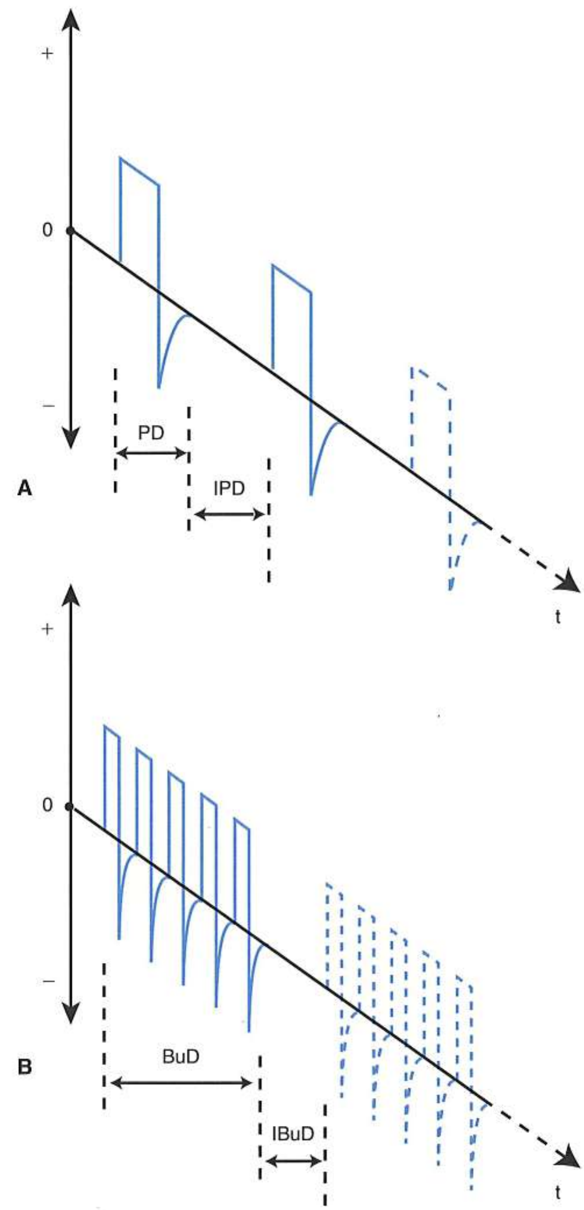


FIGURE 13-5 Typical biphasic pulsed current used for neuromuscular electrical stimulation. Pulse modulation (**A**) and burst modulation (**B**) are shown. PD, pulse duration; IPD, interpulse duration; BuD, burst duration; IBuD, interburst duration.

E. INTERFERENTIAL CURRENT

Interferential current, designated under the acronym IFC, is defined and described as a low-frequency, amplitude-modulated electrical current that results from the *interference* (hence, the word *interferential*) caused by crossing two or more medium-frequency alternating sine-wave

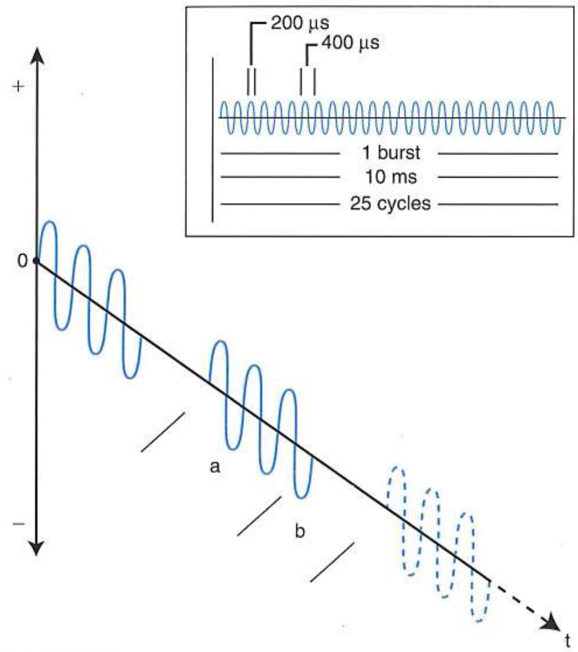


FIGURE 13-6 Original Russian current, with its sine-wave carrier frequency of 2,500 cps delivered in bursts of 10 ms (*a*) followed by 10-ms interburst duration (*b*), leading to a burst frequency of 50 bups (not drawn to scale). The inset shows the 25 cycles contained in each 10-ms burst, with each half-cycle and cycle in the burst lasting 200 and 400 µs, respectively.

currents with different carrier frequencies (Alon, 1999). The carrier frequency of these medium alternating sine-wave currents ranges between 3,000 and 5,000 cps. The technical term for IFC is *beat amplitude-modulated sinusoidal alternating current.*

1. Interference and Beat

The biophysical concept underlying the creation of an IFC is the *interference* caused by superimposing two (and sometimes three; see later discussion) medium-frequency sinusoidal currents generated by independent oscillatory circuits incorporated into the interferential devices (Alon, 1999; Lambert et al., 1993). The terms *low frequency* and *medium frequency* refer to a traditional and arbitrary classification stipulating that current output frequencies of less than 1,000 cps be designated as low-frequency currents, whereas those oscillating between 1,001 and 10,000 cps be classified as medium-frequency currents (Alon, 1999). Medium-frequency sinusoidal currents used today to generate IFC have a carrier frequency ranging from 3,000 to 5,000 cps. Figure 13-7 is the making of an IFC. For example, the first (C_1) and second (C_2) circuits have a carrier frequency (f_c) of 3,000 and 3,050 cps or Hz, respectively. By electronically allowing C_1 to interfere with C_2, and vice versa, a beat amplitude-modulated IFC is created. The beat frequency resulting from the interference of these two AC currents is calculated as the *absolute* frequency difference between the two circuits: *Beats per second (beps)* = $f_{C1} - f_{C2}$. In this example, the interferential beat frequency is equal to 50 beps (50 beps = 3,000 cps – 3,050 cps). The term *beat* (be) is borrowed from the acoustic literature to designate the characteristic "beat of sound" that can be heard when two acoustic waves of different frequencies interfere with each other (Hooke, 1998). The carrier frequencies of each AC circuit are programmable to deliver low amplitude-modulated beat frequency in the range of 1 to 200 beps.

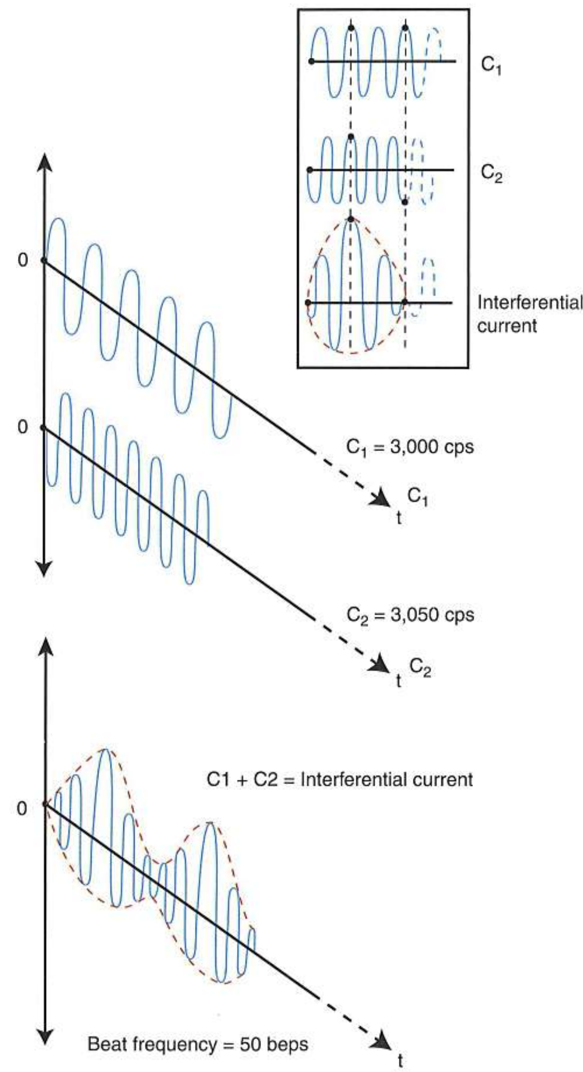


FIGURE 13-7 Bipolar, or premodulated, interferential current resulting from the interference, within the stimulator circuitry, of two medium-frequency sinusoidal currents with different frequencies leading to a beat frequency of 50 beps. Shown in the inset is the characteristic rhythmic rise and fall in the current amplitude (thus, the term *amplitude modulation*) resulting from mixing the two medium-frequency currents, creating an oval-shaped interferential current field.

2. Delivery Modes

There are four basic modes to delivery IFC to soft tissues: bipolar or premodulated, quadripolar or true interferential, quadripolar with automatic vector scan, and stereodynamic modes. Each mode has its unique biophysical characteristics, as shown next.

a. Bipolar or Premodulated Mode

This first mode is illustrated in Figure 13-7. The term *bipolar* means that this mode is delivered using two (bi) electrodes applied over the target muscle (see later discussion). The word *premodulated* means that electronic interference or modulation between the two medium-frequency sine-wave currents occurs within the electronic circuitry of the device, as opposed to within the soft tissues or muscles, as is the case with the other three modes (see later discussion). In other words, the resulting IFC is modulated before (thus, the word *pre*) being delivered to soft tissues. As shown in the figure, each bipolar or premodulated beat has an oval shape composed of several sinusoidal cycles of varying amplitudes.

b. Quadripolar or True Interferential Mode

This second mode is illustrated in Figure 13-8. It is called *quadripolar* because it is applied using four (thus, the word *quadri*) electrodes, each pair of electrodes connected to its respective circuit or channel of stimulation. This mode is also called *true interferential* because current interference occurs within the soft tissues, as opposed to the within the electronic circuitry, as was the case with the premodulated mode described earlier. The figure shows the electronic interference caused by crossing, using two pairs of electrodes or four electrodes (see circles) placed over the target muscle, one medium-frequency sinusoidal current set at 3,000 cps (C1) with another medium-frequency sinusoidal current set at 3,050 cps (C2). The interferences occurring between these two medium-frequency sine-wave currents lead to the formation of a low-frequency (50 beps) beat amplitude-modulated current. When the two medium-frequency sine-wave currents intersect at 90 degrees to each other, the maximum resultant amplitude of the IFC field is halfway between these two lines of current (in this case, at 45 degrees from each circuit). The resulting current field associated with this IFC mode is pictured as having a four-leaf clover shape.

c. Quadripolar with Automatic Vector Scan Mode

As with the previous mode, this third mode is also generated using two unmodulated medium-frequency sine-wave currents delivered using four electrodes. It differs from the true or quadripolar mode, as illustrated in Figure 13-9, by allowing current amplitude in one circuit to slowly vary between 50% and 100% of the maximum set value, with the current amplitude of the second circuit set automatically at a fixed value (e.g., 75% of its maximum amplitude). The automatic and periodic current amplitude variation in one circuit relative to the other creates an electronic phenomenon described as *vector scan*. As shown, the four-leaf clover–shaped current field, observed using the true or quadripolar mode, automatically rotates back and forth between the two lines of current, thus scanning the

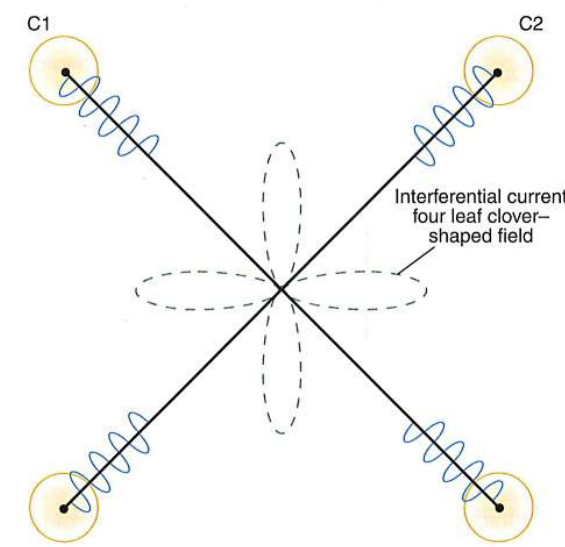


FIGURE 13-8 Quadripolar, or true, mode resulting from the interference, at the level of the targeted tissue, of two medium-frequency sinusoidal currents with different frequencies. The resulting interferential current field is pictured as having a four-leaf clover shape.

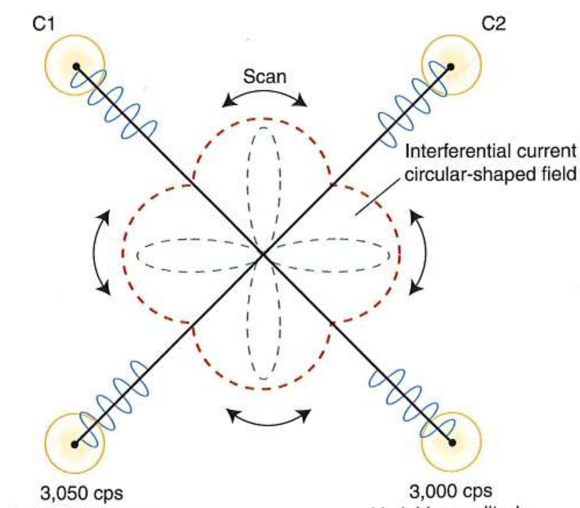


FIGURE 13-9 Quadripolar with automatic vector scan mode is identical to the quadripolar or true interferential current (IFC) except that the four-leaf clover–shaped field is now automatically rotating or scanning back and forth (see *arrows*). This vector scanning produces an enlarged field of IFC with the characteristic circular shape.

treatment surface within this area. This scanning action results in an enlarged treatment area due to the enlarged field of IFC. The purpose of using this mode over the quadripolar or true IFC mode is, therefore, to *enlarge* the stimulating treatment area. In the present example, because the carrier frequency of each circuit remains the same as with the two previous methods (3,000 and 3,050 cps), the beat frequency remains the same at 50 beps. The characteristic four-leaf clover–shaped current field seen in the true or quadripolar or true IFC mode is now pictured as having a more circular shape.

d. Stereodynamic Mode

This last delivery mode is much less common than the three already described and requires the use of a special type of IFC stimulator. This mode, illustrated in Figure 13-10, is created by adding a third (C3) medium-frequency sinusoidal current to interfere with the other two circuits. The resulting IFC mode is called *stereodynamic* because of the three-dimensional (3D) effect achieved within the targeted muscle tissues, as these three sinusoidal currents interfere with each other within the muscle. Because this mode requires simultaneous use of three circuits, six electrodes (or three pairs) are required for application. Two pairs of Y-shaped electrodes, each made of three poles, are commonly used to apply this delivery mode. The stereodynamic mode allows the effective IFC field, or stimulated area, to be enlarged three dimensionally, contrary to the quadripolar mode with automatic vector scan, which allows enlargement of the treatment field only two dimensionally. The IFC field pattern caused by mixing three medium-frequency circuits is pictured to have a six-petal flower shape.

3. Distinguishing Between IFC Modes

The four IFC delivery modes, with their respective numbers of output circuits and electrode requirements, are illustrated in Figure 13-11. The following distinguishing characteristics can be observed. First, only in the bipolar mode is the IFC premodulated. Second, only the quadripolar with vector scan mode offers a dynamic (i.e., rotating or scanning) interferential field; the other three modes offer a static field only. Third, only the stereodynamic mode offers a 3D interferential field. Readers should not confuse the terms *bipolar* and *quadripolar delivery modes* of IFC with the terms *bipolar and quadripolar electrode configurations* commonly used to apply NMES (see Application, Contraindications, and Risks).

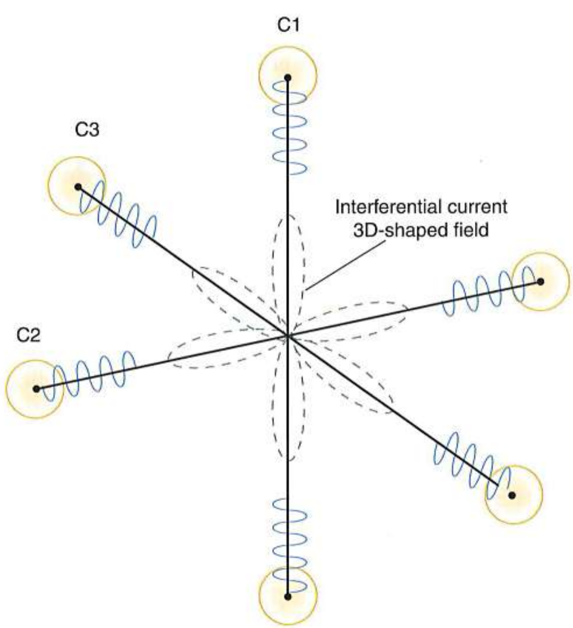


FIGURE 13-10 Stereodynamic mode refers to the interference, at the level of the targeted tissue, of three medium-frequency sinusoidal currents, leading to the characteristic three-dimentional (3D), six-petal flower–shaped field of interferential current. This method requires the use of six electrodes, which are presented as a pair of star- or Y-shaped electrodes. Each star or Y electrode has three poles or three electrodes, and each pair is connected to its respective channel.

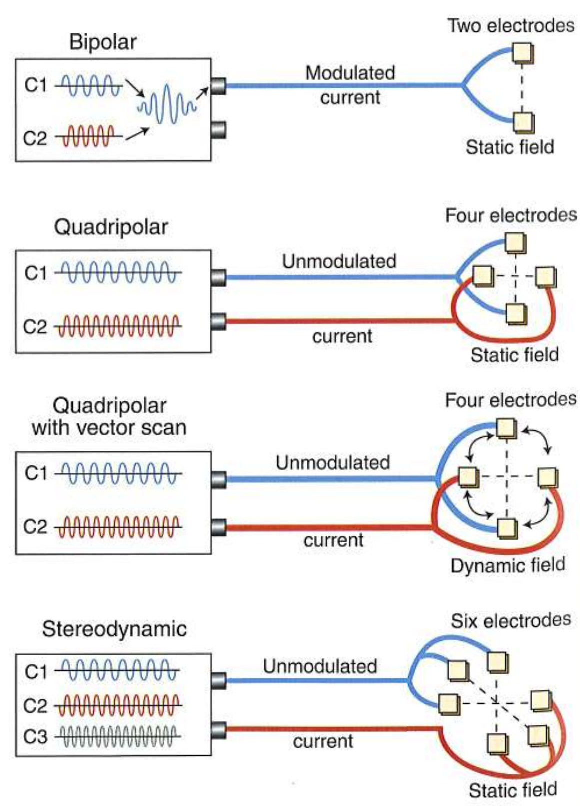


FIGURE 13-11 Interferential current delivery modes with electrode configurations.

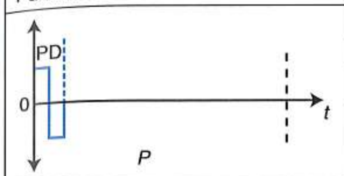
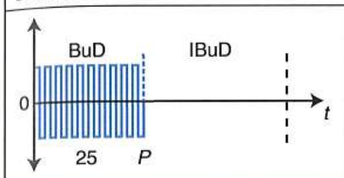
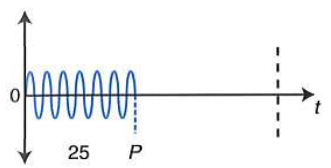
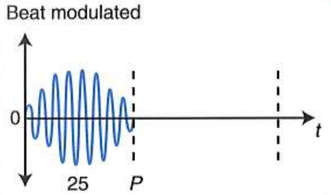
CURRENT	EXEMPLIFIED PARAMETER SETTINGS
Biphasic pulse	
Pulse modulated	*f* set at 50 pps, then *P* = 20 ms or 20,000 μs
	*f* = 1/*P*; *P* = 1/*f*; 20,000 = 1/50
	PD set at 400 μs, then IPD = 19,600 μs
	P = PD + IPD; 20,000 = 400 + 19,600
Burst modulated	*f* set at 50 bups, then *P* = 20 ms or 20,000 μs
	*f* = 1/*P*; *P* = 1/*f*; 20,000 = 1/50
	BuD set at 10,000 μs, then IBuD = 10,000 μs
	P = BuD + IBuD; 20,000 = 10,000 + 10,000
	PD set at 400 μs as above, then 25 rectangular biphasic pulses per burst (not shown to scale) Number of pulses per burst = BuD/PD; 25 = 10,000/400
Russian	
Burst modulated	Carrier frequency set at 2,500 cps or Hz, then cycle duration (CD) = 400 μs, and phase duration (PhD) = 200 μs (see Fig. 13-6)
	*P* = 1/*f*, where *P* = CD and PhD = CD/2 CD = 400 = 1/2,500; PhD = 200 = 400/2
	f set at 50 bups and BuD set at 10,000 μs, then *P* = 20,000 μs and IBuD = 10,000 μs
	BuD set at 10,000 μs, then 25 cycles per burst
	Number of cycles per burst = BuD/CD; 25 = 10,000/400
Interferential	
Beat modulated	C1 and C2 set at 3,000 and 3,050 Hz, respectively, then beat frequency equals 50 beps (see Fig. 13-7) and *P* = 20,000 μs
	
	IBeD = *P* − BeD; 10,000 = 20,000 − 10,000
	CD set at 400 μs; then 25 cycles per beat
	Number of cycles per beat = BeD/CD; 25 = 10,000/400

FIGURE 13-12 Current parameters and waveform modulation.

F. COMPARATIVE BIOPHYSICAL CHARACTERISTICS

To distinguish between biphasic pulsed, Russian, and interferential currents based on biophysical parameters such as waveform, frequency, pulse duration, interpulse duration, and period can be confusing. To appreciate the similarities and differences between these three currents, Figure 13-12 illustrates and exemplifies the characteristics of each current.

1. Biphasic Pulsed Current

Biphasic pulsed current can be *pulse modulated* or *burst modulated.* In the example for *pulse modulation,* pulse frequency (f) and pulse duration (PD) are set at 50 pulses per second (pps) or Hz and 400 μs, respectively. The current waveform is biphasic, symmetrical, balanced, and square. These settings yield a period (P) and interpulse duration (IPD) of 20,000 μs and 19,600 μs, respectively. In the example for *burst modulation,* burst frequency (bups) and burst duration (BuD) are set at 50 bups and 10,000 μs, respectively. With these settings, the period (P) remains the same at 20,000 μs, and the interburst duration (IBuD) now equates 10,000 μs. Keeping PD at 400 μs, each burst is composed of 25 rectangular biphasic pulses.

2. Russian Current

In the example presented for Russian current, the carrier frequency is set at 2,500 cps or Hz, which yields a cycle duration (CD) and phase duration (PhD) of 400 and 200 μs, respectively. Burst frequency is set at 50 bups, and burst duration (BuD) is equal to 10,000 μs. The interburst duration (IBuD) equals 10,000 μs, and each burst is composed of 25 cycles.

3. Interferential Current

In the example shown in Figure 13-12, beat frequency and beat duration (BeD) are set at 50 beps and 10,000 μs, respectively. Cycle duration (CD) thus equates 400 μs, and each beat is made of 25 cycles.

4. Overall Similarities and Differences

Figure 13-12 reveals great similarities between biphasic pulsed burst modulation, Russian burst modulation, and inferential beat modulation. Waveforms differ only in shape (square for biphasic pulsed current vs. sinusoidal for Russian and interferential currents) and current amplitude (constant for Russian current and modulated for IFC). Practically speaking, these three electrical current will deliver similar amount of electrical energy per second to the target muscle. Theoretically speaking, this means that selecting one burst-modulated current over another should makes no significant difference when comes the time to depolarize motor nerves, which will induce muscle contraction. If there were some significant differences between the capacities of these three currents to evoked muscle contraction, these should be attributed to other factors such as the ability to tolerate the discomfort or pain caused by the passage of electrical current (see later discussion).

III. THERAPEUTIC EFFECTS AND INDICATIONS

Figure 13-13 shows the proposed physiologic and therapeutic effects associated with the application of NMES. The main therapeutic effect, using all three currents, is to increase muscle strength in both patients and healthy individuals. Secondary therapeutic effects associated with the application of IFC are for pain modulation and bowel dysfunction (see later discussion).

A. MUSCLE STRENGTHENING

1. Evoked Motor Nerve Depolarization

Research has long established that nerves are excitable structures and that the passage of pulsed currents can excite or depolarize them (Robinson, 2008), thus triggering MU activation leading to evoked tetanic muscle contraction (see later discussion). Let us first consider the process of electrical nerve depolarization. Nerve fibers at rest are polarized, with the inside of their membranes being negatively charged. To *depolarize* a nerve means to reverse this polarized state, causing the inside of the nerve membrane to become positively charged. This reversal of potential across the nerve semi-permeable membrane leads to the formation of an action potential, or nerve impulse. Illustrated in Figure 13-14, and summarized next, are key physiologic events related to the process of electrically induced nerve depolarization.

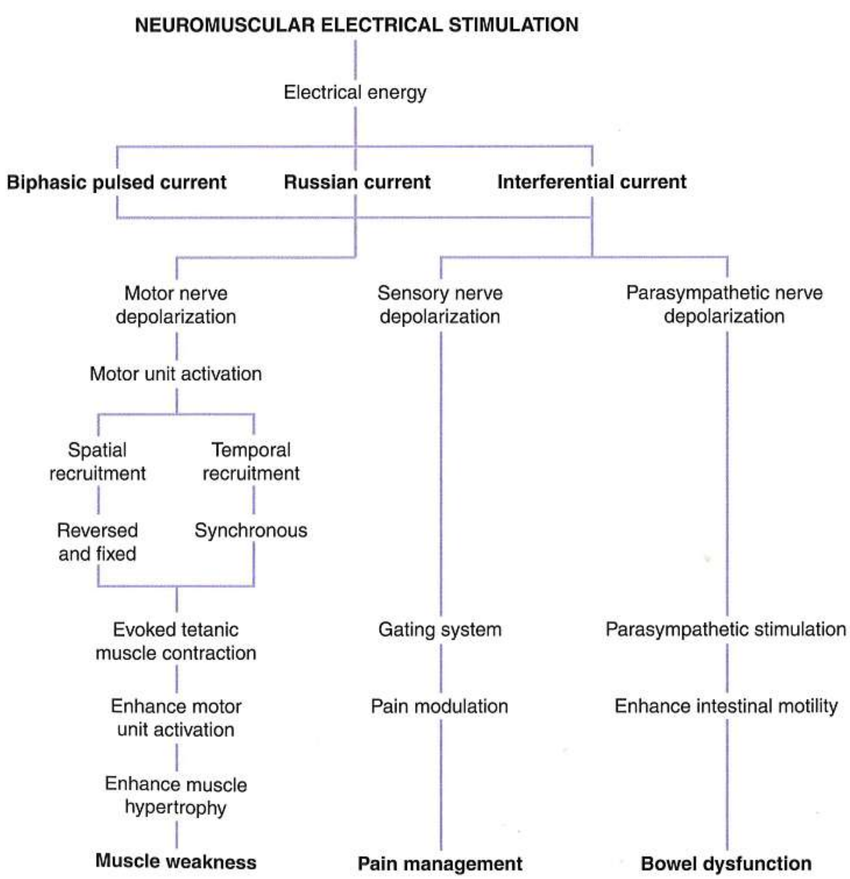


FIGURE 13-13 Proposed physiologic and therapeutic effects associated with neuromuscular electrical stimulation. *Note:* Please see text with regard to abbreviations used in the figure.

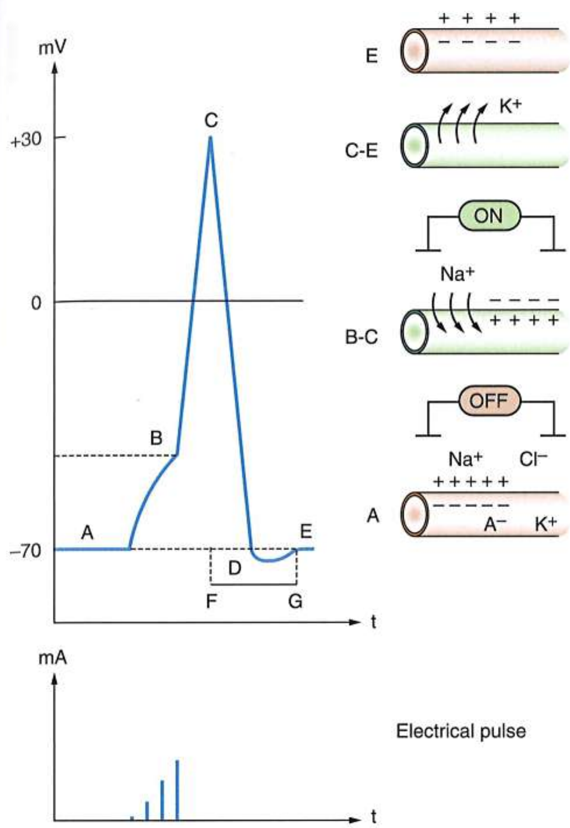


FIGURE 13-14 Electrically induced nerve depolarization. Schematized are key physiologic events leading to the production of an action potential or nerve impulse.

a. Resting Membrane Potential

At rest (stimulator OFF), excitable nerve membranes are readily permeable to potassium (K^+) ions, slightly permeable to sodium (Na^+) and chloride (Cl^-) ions, and impermeable to a number of large negatively (–) charged proteins and phosphates named *anions* (A^-). Research has shown that the flow, or gating, of Na^+ and K^+ ions in and out of the membrane is regulated by voltage-sensitive channels (Robinson, 2008; see later discussion). Because anions are trapped within the intracellular space, the inside of the nerve membrane remains negatively charged. A resting membrane potential (RMP) is thus established and measured, in humans, at approximately –70 mV.

b. Electrical Stimulation Threshold

What will happen to the nerve RMP if a pulsed electrical current of gradually increasing amplitudes is applied, as is the case with NMES? As illustrated in Figure 13-14, the gradual increase of current amplitude will decrease the RMP, passing from approximately –70 to –30 mV (A to B). When the nerve membrane potential finally reaches a critical voltage level (B), a cascade of events (B to E) triggers the process of nerve depolarization (B to C), which leads to the formation of an action potential or nerve impulse (B to E). This critical voltage level corresponds to the nerve membrane *threshold* of activation (B).

c. Depolarization

The process of depolarization (B to C) is caused by the rapid and massive opening of voltage-gated Na^+ channels, resulting in the reversal of potential inside the nerve membrane. In other words, the massive influx of positively charged sodium ions makes the inside of the nerve membrane more positive. This depolarization phase coincides with the beginning of the action potential (B to C).

d. Repolarization or Hyperpolarization

After being depolarized, the nerve membrane quickly repolarizes itself (C to D). This process begins with the complete closure of the voltage-gated Na^+ channels (C) and manifests itself by the rapid and massive opening of the voltage-gated potassium (K^+) channels. In other words, the massive efflux of positively charged potassium ions makes the inside of the nerve membranes more negative, until its RMP is once again restored (from C to D). During this repolarization phase, the nerve membrane is slightly hyperpolarized (D to E) for a very short period of time because the potassium channels stay open a bit too long in the process. The RMP is then quickly restored by the Na^+–K^+ ATPase pumps (E). The process of *depolarization–repolarization* is self-perpetuating, triggering a chain reaction of action potential along the nerve fiber. The influx of Na^+ depolarizes the axon and the outflow of K^+ repolarizes it (see Fig. 13-14).

e. Action Potential/Nerve Impulse Propagation

The passage of a pulse current through a nerve membrane results in the creation of an action potential (B to D), also called *nerve impulse*. Such nerve impulses propagate, or travel, along the nerves carrying neural information from organs to the central nervous system (CNS) or from the CNS to the organs. When the threshold for stimulation (B) is reached, an action potential of a fixed size will always be generated. In other words, there is no big- or small-amplitude action potential—all action potentials, for a given nerve, are of the same size. We have, therefore, two possibilities—either the nerve threshold for depolarization is not achieved (no action potential generated—*none*) or the threshold is achieved (full action potential generated—*all*). This all-or-none situation underlies the *all-or-none principle*. Thus, there is no such thing as a fraction of action potential generated—the potential is either full or none. This also means that increasing the electrical pulse amplitude (subthreshold to supramaximal levels) will not induce larger-size action potentials.

f. Nerve Refractory Period

Nerve fibers require a certain period to recover before they can be depolarized again. There is a short period of time, named the *refractory period* and illustrated in Figure 13-14 (F to G), during which the nerve fiber will

TABLE 13-1 VOLITIONAL VERSUS ELECTRICALLY EVOKED MUSCLE CONTRACTION

Contraction	Volitional	Electrically Evoked
Motor command	Upper motoneurons	Electrical stimulator
Spatial recruitment	Dispersed Smaller to larger MUs	Restricted Larger to smaller MUs
Temporal recruitment	Asynchronous	Synchronous
Onset of muscle fatigue	Slow	Rapid
Muscle force development	Optimal	Suboptimal
Muscle-strengthening mechanisms	*Neurotrophic* *Neural:* Enhanced MU recruitment *Trophic:* Enhanced muscle hypertrophy	

MUs, motor units.

be refractory to the delivery (incapable of being depolarized) of another subthreshold electrical pulse. Within this refractory period, which lasts less than 1 ms, there is an *absolute* period, during which it is impossible to depolarize the nerve, and a *relative* period, during which an action potential can be generated if one applies an electrical pulse having a greater amplitude. The refractory period limits the pulse frequency that practitioners can choose to depolarize peripheral nerve fibers.

2. Evoked Motor Unit Activation

There are fundamental differences, as shown in Table 13-1, between the neurophysiologic mechanisms at work during volitional versus electrically evoked muscle contraction. Skeletal muscle contraction, whether voluntary or electrically evoked, results from the activation, or recruitment, of motor units (MUs).

a. Spatial Recruitment

The term *spatial recruitment* refers to the number and order of MUs recruited during the process of muscle contraction. *Number* refers to the amount, or percentage, of MUs activated within a given muscle or muscle group. *Order* relates to the sequence of activation based on the size of each MU. A muscle may contain hundreds to thousands of MUs depending of its size and function. Research has established that a skeletal muscle is made of a mosaic of three types of MUs. The first type is the slow-twitch (S) unit made of slow-twitch oxidative (SO) fibers, which are very resistant to fatigue. The second type is the fast-twitch/fatigue-resistant (FR) unit made of fast-twitch, oxidative-glycolytic (FOG) muscle fibers. The third type relates to the fast-twitch/fatigable (FF) units made of fast-twitch glycolytic (FG) muscle fibers. FG and FOG muscle units contract faster and generate more force than SO units. In some textbooks, SO units are classified as type I units, whereas FF and FR units are classified as type IIB and type IIA units, respectively.

b. Temporal Recruitment

The term *temporal recruitment* refers to the rate of discharge, or frequency, with which MUs are recruited during the process of muscle contraction. Temporal recruitment is also referred to, in the literature, as rate coding.

c. Motor Unit Recruitment During Volitional Muscle Contraction

During a voluntary effort, the command for muscle contraction originates in the upper motoneurons (volition), which is then transmitted down to the spinal motoneurons. The number of MUs activated is proportional to the magnitude of the voluntary command, and MU activation is dispersed within the muscle. MUs are spatially recruited according to their size—that is, from the smaller (SO) to the larger (FG, FR) units. This is known as the size principle of MU activation (Henneman et al., 1965). Temporal recruitment is asynchronous, or random, meaning that a given MU may be activated several times per second, whereas another MU may be activated only a few times per second, or not at all, during a particular volitional muscle contraction.

d. Motor Unit Recruitment During Electrically Evoked Muscle Contraction

During an electrically evoked muscle contraction, the command for muscle contraction is given by the electrical stimulator, which is programmed to deliver electrical pulses of given amplitudes and frequencies, resulting in motor nerve depolarization. In such a case, the entire motoneuron pool (upper and lower) is bypassed, meaning that muscle contraction results from the local depolarization of motor nerves buried in the muscle. In contrast to the volitional process described earlier, spatial recruitment is restricted to the units that are closer to the electrodes and occurs in the reversed size order—that is, from the larger (FF, FG) to the smaller (SO) units (Delitto et al., 1990; Sinacore et al., 1990; Trimble et al., 1991). This order reversal is explained by the fact that the large-diameter motor axons of FF and FR units are more easily excited by imposed electrical current than are the small-diameter axons of the SO units (Maffiuletti et al., 2011). Also demonstrated is the fact that temporal recruitment is *synchronous*—that is, at a fixed frequency, which corresponds to the frequency setting on the electrical stimulator. In summary, electrical current passes through soft tissues and depolarizes motor nerve fibers, causing nerve impulses to reach neuromuscular junctions initiating muscle contractions. Spatial MU recruitment occurs in a reverse size order (from the larger to the smaller units), and temporal recruitment is synchronous (fixed frequency) in nature.

e. Physiologic Impact of Restricted and Reverse Order Spatial Motor Unit Recruitment

The fact that spatial MU recruitment is restricted and occurs in a reversed order during NMES implies that the same large fatigable MUs—that is, those FOG and FF units closest to the surface electrodes—are repeatedly activated by the same amount of electrical current that, over time, will hasten the onset of muscle fatigue (Maffiuletti et al., 2011). It is well established in the literature that muscle fatigue represents a major limitation to the use of NMES. What can the practitioner do to minimize muscle fatigue during NMES? From one therapeutic session to the next, the practitioner can (1) vary current amplitude, (2) modify electrode configuration and/or electrode placement, and (3) modify muscle length.

f. Physiologic Impact of Synchronous Temporal Recruitment

The temporal synchronous recruitment associated with NMES implies that these same more superficial and large MUs are firing at the same frequency during electrical stimulation. It is well established that SO units have a much lower tetanic fusion frequency (20 to 30 Hz) than FG and FF units (50 to 70 Hz) because their twitch contraction times are longer. This means that setting the stimulator's frequency at 40 Hz, for example, will be optimal for the temporal recruitment of SO units but less than optimal for the larger units. This will result in a suboptimal evoked muscle contraction because the greater force generating fast units (FOG and FF) will fire at their suboptimal frequency. One way to minimize this synchronous effect is to vary the current frequency from one therapeutic session to the next.

3. Evoked Muscle Contraction

The repeated delivery of pulses, bursts, or beats of current cause repeated motor nerve depolarization, triggering a series of muscle twitches that will combine to form an evoked smooth fused tetanic muscle contraction similar to that of maximal voluntary contraction. Neuromuscular research has shown that full tetanic muscle contraction of human skeletal muscles occurs at a fusion frequency of about 50 Hz (i.e., 50 pps; 50 bups; 50 beps). Some muscles may fuse at a higher frequency (i.e., 60 to 80 Hz) if their MU content is primarily made of FF and FR units, and some at lower frequency (i.e., 30 to 40 Hz) if their MU content is primarily made of SO MUs.

4. Claims Behind Interferential and Russian Currents

Several important claims have been made over the past decades with regard to the physiologic effects of these two electrical currents on soft tissues. Let us review these claims and look at the evidence behind them.

a. Interferential Current

Hans Nemec (1959) made remarkable claims related to his newly discovered IFC. He *first* claimed that crossing and superimposing two medium-frequency alternating sine-wave currents of different frequencies will cause the two currents to *interfere* with each other, producing an interferential or low-frequency beat amplitude-modulated current. His *second* claim was that IFC generated by crossing sine-wave currents with medium carrier frequencies (i.e., between 3,000 and 5,000 Hz) will *decrease skin impedance,* leading to deeper tissue stimulation with less current amplitude, thus making it more comfortable than the other currents.

i. Interferential Effect: Supported

There is biophysical evidence to support Nemec's claim that superimposing two medium-frequency alternating sine-wave currents, each with different medium frequency, will interfere with each other causing output interference, resulting in a newly formed amplitude-modulated frequency, or beat, IFC (see Fig. 13-8).

ii. Decreased Skin Impedance: Supported

There is also biophysical evidence to support the claim that the application of IFC, resulting from the interaction of medium-frequency sinusoidal alternating current (2,000 to 5,000 Hz) can decrease skin impedance because it lowers its capacitive reactance component. To assess this claim, brief considerations must be given to the concepts of impedance and capacitive reactance. Biophysicists see biologic tissues, such as the skin, as being made of a mix of resistors (R), capacitors (C), and inductors (L). *Impedance,* designated by the letter Z and measured in ohms (Ω), is defined as the total opposition offered by these three sources, namely, resistance (R), capacitive reactance (X_C), and inductive reactance (X_L), to the passage of an electrical current. The equation denoting capacitive reactance is as follows: $X_C = 1/2\pi fC$, where $\pi = 3.14$, f = current frequency, and

C = skin capacitance, measured in farads. This formula thus indicates that the higher the current carrier frequency, as is the case with IFC (2,000 to 5,000 Hz), the lower the capacitive reactance, thus the lower the skin impedance.

iii. Decreased Skin Impedance: Misleading

To claim that interferential current is the *only* current capable of decreasing skin impedance is misleading. As discussed earlier, impedance is inversely related to frequency ($Z = 1/f$), and frequency is inversely related to the period ($f = 1/T$). By substitution, it turns out that impedance (Z) is *proportional* to the period (*P*). Stated differently, the shorter the period, the lower the skin impedance. In pulsed currents, the period equals pulse duration plus interpulse duration. On the basis of $T = 1/f$, the period (T) of present IFC (2,000 to 5,000 Hz) will range between 500 and 200 μs. Theoretically speaking, it follows than any pulsed current (such as biphasic pulsed and Russian) having a period (T) ranging between 200 and 500 μs is also capable of reducing skin impedance. In summary, IFC does not reduce skin impedance and does not penetrate deeper than other pulsed currents having similar frequency or period.

b. Russian Current

Kots made three revolutionary claims, never before heard in the field of NMES, when he introduced the Russian current to the clinical and research communities (Kots, 1971, 1977; Belanger 1992; Ward et al., 2002). His *first* claim was that his Russian current, unlike all the other known neuromuscular stimulating currents, is *painless,* causing no sensory discomfort during maximal evoked muscle tetanic contraction. Because it is painless, Kots postulated that higher current amplitude can be delivered to soft tissues so that the deeper motor nerve fibers, which are associated with those larger high-force, fast-twitch MUs (FF, FR), can be depolarized, thus increasing the magnitude of the electrically evoked tetanic contraction. Kots's *second* claim was that his Russian current, delivered at a higher current amplitude (because it is painless) than all the other stimulating currents, could generate up to *30% more force* than that generated during the course of an MVC. He postulated that during a maximal voluntary effort, a percentage of those large FF MUs (FG muscle fibers) are not recruited. There is a substantial body of scientific evidence to support this postulate (Belanger et al., 1981; Rutherford et al., 1986; Dowling et al., 1994; Behm et al., 1996). Kots further theorized that applying his painless and deeply penetrating current would compensate for this lack of voluntary MU activation by activating, or depolarizing, those inactive large MUs, thus generating more muscle force. Kots's *third* and last claim was that a few weeks of muscle training using his Russian current can produce *lasting muscle strength gains* in healthy people.

i. Painless Current: Refuted

There is very strong evidence to refute the painless nature of Russian current (Curwin et al., 1980; Laughman et al., 1983; Owens et al., 1983; Currier et al., 1984; Boutelle et al., 1985; Selkowitz, 1985; Delitto et al., 1986a,b; Kubiak et al., 1987; Ferguson et al., 1989; Grimby et al., 1989; Snyder-Mackler et al., 1989; Brooks et al., 1990; Underwood et al., 1990; Franklin et al., 1991; Laufer et al., 2001; Delitto et al., 1992; Hartsell et al., 1992; Rooney et al., 1992). In fact, all subjects enrolled in the mentioned studies reported various levels of sensory discomfort and pain when subjected to Russian current stimulation. No studies could be found to support this claim.

ii. Greater Force: Refuted

Only one study (Selkowitz, 1985) supports Kots's claim that Russian current can evoke greater muscular force than that generated following a maximal voluntary effort. All of the following studies refute this claim (Owens et al., 1983; Noel et al., 1987; Snyder-Mackler et al., 1989; Laufer et al., 2001; Hartsell et al., 1992).

iii. Lasting Force Gains: Supported

There is evidence to support Kots's claim that that the gains of muscle force following Russian current are lasting, as is the case with voluntary muscle training (Currier et al., 1983Laughman et al., 1983; Selkowitz, 1985; Kubiak et al., 1987; Soo et al., 1988). Only one study refutes this claim (St-Pierre et al., 1986).

5. Muscle-Strengthening Mechanisms

Research has shown that repeated muscle contractions, whether voluntarily or electrically evoked, done against resistive external loads induces neurotrophic muscle adaptation (Maffiuletti, 2010; Gondin et al., 2011; Hortobagyi et al., 2011). In strenuous strength-training regimens using biphasic pulsed, Russian, or interferential currents, skeletal muscles get larger and stronger from the hypertrophy, or enlargement, of their muscle fibers, not from the addition of new muscle fibers (hyperplasia). In other words, muscle strengthening following NMES results from the interaction between a *neural* (improved MU recruitment and firing) and a *trophic* (hypertrophy) mechanism (Table 13-2). The patient's or subject's ability to improve MU activation and to enlarge muscle fibers through voluntary or electrically evoked training will determine the extent of muscle strengthening achieved.

6. Quadriceps Versus Pelvic Floor Muscle Strengthening

The evidence from the scientific literature shows that the use of biphasic pulsed and Russian currents has been primarily for the strengthening of lower muscles, primarily the quadriceps muscle, whereas that of IFC has been almost exclusively reserved for pelvic floor muscles

TABLE 13-2 RECOMMENDED DOSIMETRIC PARAMETERS FOR MUSCLE STRENGTHENING

Parameter	Biphasic Pulsed Current	Russian Current	Interferential Current
Carrier frequency	NA	2,000–5,000 Hz	
Pulse duration	100–600 µs	NA	
Burst/beat duration		5–10 ms	
Pulse/burst/beat frequency	30–60 Hz		
Current amplitude*	As high as tolerable—high enough to evoke muscle force equivalent to 40%–70% of maximum voluntary contraction (% MVC)		
ON time**	5–10 s		
OFF time**	5–50 s		
Ramp up time	0.5–2 s		
Ramp down time	0.5–2 s		
Treatment frequency	3 training sessions per week for 4–6 wk		
Acclimatization period	To optimize the application of NMES, subjects and patients need to accommodate to the delivery of electrical current. Training intensities (current amplitude and number of training sessions) should be increased step by step.		

Use the Online Dosage Calculator: Neuromuscular Electrical Stimulation.

NA, not applicable; MVC, maximum voluntary contraction; NMES, neuromuscular electrical stimulation.
*Can be expressed in milliamperes or as percentage of MVC. Usually expressed as peak amplitude (A_{pk}) for biphasic current. Usually expressed as root mean square (rms) amplitude (A_{rms}) for Russian and interferential current. $A_{rms} = 0.707 \times A_{pk}$; $A_{pk} = 1.414 \times A_{rms}$.
**ON time includes ramp up and down times, plus plateau time. Setting the ON time and OFF time automatically sets off the ON:OFF time ratio and duty cycle.

(Oh-oka, 2010; see Research-Based Indications box). Why is this so? The fact that most clinical studies using NMES have focused on the quadriceps muscle, as opposed to other muscle groups, is due to the influence of Kots's work, which focused on this muscle group. It can also be attributed to the fact that knee injuries are very common and that quadriceps strengthening is key to optimal rehabilitation in such cases. That IFC is used primarily for pelvic floor muscle weakness, mostly for cases of incontinence is explained by the fact that these muscles are located deeper in the pelvis and thus require a more penetrating current field for effective NMES. The delivery of IFC, using the quadripolar mode, provides such a penetrating current field that can be focused on these muscles. Moreover, using vacuum IFC with suction electrodes greatly facilitates electrode attachment in this particular body area (perineum). Another option for pelvic floor muscle stimulation is to use any currents with either intravaginal or intrarectal electrodes (see Application, Contraindications, and Risks box for details).

B. INTESTINAL MOTILITY

Aside for muscle weakness, there is limited evidence to suggest that IFC may effective for the treatment of bowel dysfunctions (see Research-Based Indications box). In 1987, Emmerson and colleagues reported diarrhea as a side effect of using IFC for urinary incontinence caused by overactive bladder (Emmerson, 1987). This observation led some clinicians and researchers to theorize that if IFC can induce diarrhea, this electrical current may be beneficial for the treatment of bowel dysfunction such as slow transit constipation (see Chase et al., 2005). They postulated that the deeply penetrating IFC is likely to stimulated vagal sympathetic and parasympathetic outflow to the intestine, thus facilitating bowel movement by increasing intestinal motility leading to defecation (see Fig. 13-13). To provoke this physiologic effect, the electrode configuration is such that current interference occurs, or is focused, at the intestinal level (see Application, Contraindications, and Risks box).

C. PAIN MODULATION

Survey research has demonstrated that IFC is often used clinically for the management of pain (see Beatti et al., 2010; Fuentes et al., 2010). It is postulated that sensory and motor nerve depolarization resulting from the passage of IFC could modulate pain, as is the case for transcutaneous electrical nerve stimulation (see Chapter 14), through various mechanisms, including the gate and opiate systems (see Fig. 13-13). Listed in the Research-Based Indications are human studies, on the effectiveness of IFC on pain.

1. Experimental Pain

Experimental or induced pain significantly differs from clinical or real pain because the former is lacking the all-important affective (cognitive and emotional) component of pain. Caution is advised, therefore, before inferring the effectiveness of IFC based on experimental pain findings. The body of evidence on the effectiveness of IFC for human experimental pain is conflicting, with approximately half of the studies showing no benefit (Stephenson et al., 1995; Johnson et al., 1997, 2003b; Johnson et al., 1999; Minder et al., 2002; Cheing et al., 2003; Johnson et al., 2003a,c; Stephenson et al., 2003; McManus et al., 2006; Shanahan et al., 2006; Fuentes et al., 2010; Fuentes et al., 2011). No clear conclusion, therefore, can be drawn on the effectiveness of IFC on experimental pain (see Beatti et al., 2010).

2. Clinical Pain

Conversely, there is substantial evidence to support the use of IFC for the management of human clinical pain (see Research-Based Indications box). Fuentes and colleagues' (2010) recent meta-analysis on this subject suggests that IFC, when applied concomitantly with other therapeutic interventions, is more effective than when applied alone.

D. RESEARCH-BASED INDICATIONS

The search for evidence behind the use of NMES, displayed in the *Research-Based Indications* box, led to the collection of 102 English peer-reviewed human clinical studies. The methodologies and criteria used to assess the strength of evidence and therapeutic effectiveness are described in Chapter 2. As indicated, the strength of evidence behind NMES is ranked as *moderate* for quadriceps muscle weakness in both healthy individuals and patients. There is also *moderate* evidence, primarily using IFC, for pelvic floor muscle strengthening, bowel dysfunction, and pain. Over all conditions treated using NMES, the strength of evidence is found to be *moderate* and its therapeutic effectiveness *substantiated*.

IV. DOSIMETRY

The main application of NMES is for muscle strengthening in patients suffering from disuse atrophy and in healthy individuals wanting to improve their muscle strength. The objective is to program the stimulator such as to generate an evoked muscle contraction, which resembles, or mimics, as closely as possible that gener-

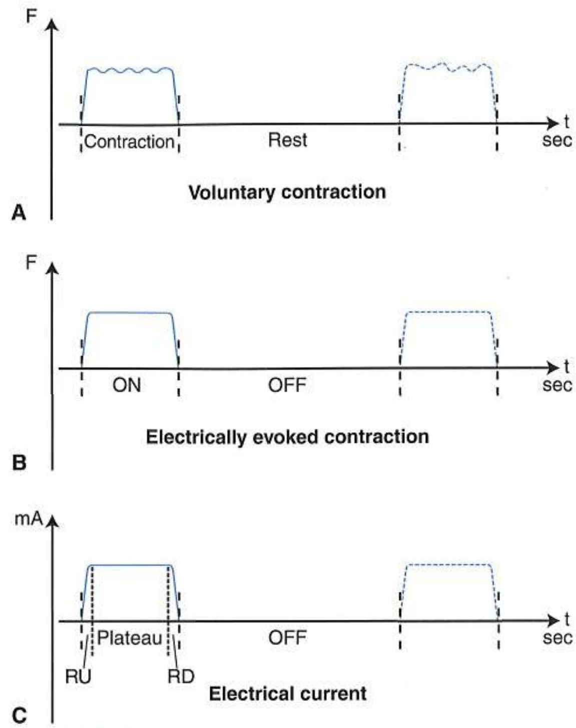


FIGURE 13-15 Interrelationship between maximum voluntary contraction **(A)**, maximum electrically evoked contraction **(B)**, and current amplitude **(C)**. Time modulation of electrical current allows the evoked muscle contraction to mimic voluntary contraction. ON time includes ramp up (RU) and ramp down (RD) times, as well as plateau time.

ated during volitional effort. Figure 13-15 illustrates this concept. During voluntary muscle strengthening (see Fig. 13-15A), patients perform a bout or series of muscle contractions, often under isometric condition, lasting a few seconds (3 to 6 s), with each contraction interrupted by a rest period equivalent to a multiple of contraction time (one to eight times longer). A voluntary muscle contraction is a smooth contraction characterized by a short gradual rise and fall of force at the beginning and end of contraction, respectively. For an electrically evoked muscle contraction to mimic such a smooth contraction (see Fig. 13-15B), several parameters need to be set on the electrical stimulator (see Fig. 13-15C). Let us consider each of them.

A. ELECTRICAL PARAMETERS

Practitioners, using any given type of electrical stimulator for NMES, need to set various electrical parameters prior to therapy. Those key parameters are illustrated and exemplified in Figure 13-12 and listed in Table 13-2. Common settings are carrier frequency (for Russian and interferential currents), pulse duration (for biphasic pulse current), pulse/burst/beat duration, pulse/burst/beat frequency, and current amplitude.

Research-Based Indications

NEUROMUSCULAR ELECTRICAL STIMULATION

	Benefit—Yes		Benefit—No	
Health Condition	**Rating**	**Reference**	**Rating**	**Reference**
Muscle weakness in healthy untrained and trained individuals	I	Laughman et al., 1983		
	I	Parker et al., 2003		
	I	Bircan et al., 2002		
	I	Gondin et al., 1995		
	I	Herrero et al., 2010a		
	I	Herrero et al., 2010b		
	I	Owens et al., 1983		
	I	Boutelle et al., 1985		
	I	Kubiak et al., 1987		
	I	Fahey et al., 1985		
	II	Caggiano et al., 1994		
	II	Halback et al., 1980		
	II	Hartsell, 1986		
	II	Lai et al., 1988		
	II	Nobbs et al., 1986		
	II	Eriksson et al., 1981		
	II	Cabric et al., 1987		
	II	Romero et al., 1982		
	II	Currier et al., 1983		
	II	St-Pierre et al., 1986		
	II	Fahey et al., 1985		
	II	McMiken et al., 1983		
	II	Parker et al., 2005		
	II	Laufer et al., 2001		
	II	Hortobagyi et al., 1992		
	II	Pfeifer et al., 1997		
	II	Selkowitz, 1985		
	II	Soo et al., 1988		
	II	Underwood et al., 1990		
	II	Ruther et al., 1995		
	III	Delitto et al., 1989		

Strength of evidence: Moderate
Therapeutic effectiveness: Substantiated

	Benefit—Yes		Benefit—No	
Health Condition	**Rating**	**Reference**	**Rating**	**Reference**
Muscle weakness following postoperative knee reconstruction	I	Jarit et al., 2003	II	Sisk et al., 1987
	II	Lieber et al., 1996		
	II	Wigerstad-Lossing et al., 1988	II	Paternostro-Sluga et al., 1999
	II	Fitzgerald et al., 2003		
	II	Delitto et al, 1988b		
	II	Feil et al., 2011		
	II	Anderson et al., 1989		
	II	Draper et al., 1991		
	II	Snyder-Mackler et al., 1995		
	II	Snyder-Mackler et al., 1994		
	II	Snyder-Mackler et al., 1991		
	II	Williams et al., 1986		
	II	Curwin et al., 1980		
	II	Avramidis et al., 2003		
	II	Martin et al., 1991		
	III	Petterson et al., 2006		
	III	Stevens et al., 2004		
	III	Lewek et al., 2001		
	III	Mintken et al., 2007		
	III	Delitto et al., 1988a		
	III	Eriksson et al., 1979		

Strength of evidence: Moderate
Therapeutic effectiveness: Substantiated

	Benefit—Yes		Benefit—No	
Health Condition	**Rating**	**Reference**	**Rating**	**Reference**
Pelvic floor muscle weakness following incontinence	I	Laycock et al., 1993	III	Sylvester et al., 1987
	I	Kajbafzadeh et al., 2009		
	I	Vahtera et al., 1997		
	II	Oh-oka, 2008		
	II	Dougall, 1985		
	II	McQuire, 1975		

Health Condition	Benefit—Yes Rating	Benefit—Yes Reference	Benefit—No Rating	Benefit—No Reference
	II	Demirturk et al., 2008		
	II	Switzer et al., 1988		
	II	Laycock et al., 1988		
	II	Dumoulin et al., 1995a		
	II	Dumoulin et al., 1995b		
	II	Olah et al., 1990		
	II	Wilson et al., 1987		
	II	Turkan et al., 2005		
	II	Van Poppel et al., 1985		
	III	Henella et al., 1987		
Strength of evidence: Moderate **Therapeutic effectiveness:** Substantiated				
Bowel dysfunction	I	Clarke et al., 2009a		
	I	Clarke et al., 2009b		
	I	Koklu et al., 2010		
	I	Kajbafzadeh et al., 2011		
	III	Chase et al., 2005		
Strength of evidence: Strong **Therapeutic effectiveness:** Substantiated				
Painful conditions	I	Gundog et al., 2011	I	Man et al., 2007
	I	Adedoyin et al., 2002	I	Van der Heijden et al., 1999
	I	Hurley et al., 2001	I	Taylor et al., 1987
			II	Gaines et al., 2004

Health Condition	Benefit—Yes Rating	Benefit—Yes Reference	Benefit—No Rating	Benefit—No Reference
	I	Defrin et al., 2005	II	Quirk et al., 1985
	I	Cheing et al., 2008	II	Werners et al., 1999
	I	Zambito et al., 2007		
	I	Zambito et al., 2006		
	II	Shafshak et al., 1991		
	II	Callaghan et al., 2001		
	II	Hurley et al., 2001		
	II	Ni Chiosig et al., 1994		
	II	Burch et al., 2008		
	II	Philipp et al., 2000		
	II	Tugay et al., 2007		
	III	Walker et al., 2006		
	III	Nitz et al., 1987		
Strength of evidence: Strong **Therapeutic effectiveness:** Substantiated				
Fewer Than 5 Studies				
Muscle weakness following chronic heart failure	I	Nuhr et al., 2004		
	I	Quittan et al., 2001		
	II	Dobsak et al., 2006		
	II	Harris et al., 2003		
Strength of evidence: Pending **Therapeutic effectiveness:** Pending				
ALL CONDITIONS **Strength of evidence:** Moderate **Therapeutic effectiveness:** Substantiated				

1. Pulse/Burst/Beat Frequency

Why is the concept of frequency very important in the field of NMES? Because the physiologic correlate of *frequency* is *temporal MU activation.* In other words, to set the pulse/burst/beat frequency is to set the frequency at which all the activated MUs will fire during the evoked muscle contraction. As shown in Figure 13-13, pulsed biphasic current may be delivered as pulses (pulse frequency) or bursts of pulses (burst frequency), Russian current as bursts of sinusoidal cycles (burst frequency), and IFC as beats of sinusoidal cycles (beps). Setting the frequency between 30 and 60 pps/bups/beps is necessary to obtain optimal temporal MU activation during the fused tetanic muscle contraction, because research has established that the mean fusion frequency for skeletal muscles is approximately 50 pps/bups/beps.

2. Current Amplitude

Why is setting current amplitude so critical in the field of NMES? Because the physiologic correlate of *current amplitude* is *spatial MU activation.* The higher the current amplitude used, the greater the number of motor units activated, and the larger the evoked muscle contraction output of force. A common procedure to set current amplitude is as follows. First, measure the force generated by the target muscle group during an MVC under isometric conditions (100% MVC). Second, increase current amplitude as high as tolerable or high enough to obtain an evoked muscle contraction force equivalent to 40% to 70% of that obtained under a maximal voluntary effort (MVC). Subsequently, express the level of each electrically evoked contraction as a percentage of the MVC force (% MVC). This important parameter provides an indication of the intensity of the NMES training (see Selkowitz, 1985; Stevens et al., 2004; Maffiuletti, 2010). The higher the current amplitude, the higher the effectiveness of NMES for muscle strengthening in both healthy individuals and patients (see Maffiuletti, 2010).

3. Constant Current Stimulator

Stimulators used for NMES are *constant current–type* (CC-type) stimulators, meaning that a set current amplitude (say, 80 mA read on the digital meter) remains constant (hence, the term *constant current*) during treatment, regardless of changes in tissue impedance over time. According to Ohm's law, defined by the formula $V = R \times I$ or $V = Z \times A$ (see below), to maintain current amplitude (I or A) constant during treatment, voltage (V) needs to be automatically adjusted to account for the fluctuation of soft-tissue impedance (R or Z) over time. Ohm's law can thus be rewritten as follows: $V = Z \times A$, where the letter R (resistance) is replaced by the letter Z (impedance), and where the letter I (intensity) is substituted for the letter A (amplitude). The main advantage of CC-type stimulators is that they deliver predictable levels of electrical stimulation, making therapy more predictable and comfortable for the patient (no surge of current).

B. ON:OFF TIME RATIO

Now that the electrical parameters mentioned earlier are set. Which other parameters need to be set? As shown in Figure 13-15C, practitioners need to set the ON and OFF times. The *ON time* is the time, measured in seconds, during which electrical current is delivered to the target muscle. Its duration corresponds to the duration of the volitional muscle contraction. Conversely, the *OFF time* is the time, also measured in seconds, during which there is no current flowing in the target muscle. Its duration corresponds to the duration of the rest period between two successive contractions. The relationship between ON time and OFF time is commonly expressed as a ratio. For example, setting a 5-second ON time and a 30-second OFF time would produce a ON:OFF time ratio of 10s:30s. Such a ratio means that the resting time between two successive evoked contractions is three times longer than that of contraction time (1:3). The term *ON:OFF time ratio* is not synonymous with *duty cycle*, as discussed later.

C. RAMP UP AND DOWN TIMES

As shown in Figure 13-15A, the time course of a volitional contraction begin with a gradual upward ramping, from the beginning to the plateau phase of contraction, followed by a similar smooth downward ramping at the end of contraction. This physiologic ramping effect is part of the full muscle contraction time or ON time. To mimic this ramping volitional effect during NMES (see Fig. 13-15B), practitioners need to adjust the stimulator's ramp up and down times accordingly. Note that the ON time *includes* the ramp up and down times, as well as the time during which the contraction is maintained relatively constant (plateau time). Setting ramp up and down times within the ON time *mimic* as closely as possible the gradual build up and relaxation phases seen at the beginning and the end of a voluntary muscle contraction, as shown in Figure 13-15C. Ramp up and down times are usually set between 0.5 and 2 seconds to prevent the sudden, or jerky, rise and fall of evoked muscle contractions, thus making its time course as smooth as possible (see Table 13-2).

D. DUTY CYCLE

Setting the ON:OFF time ratio automatically sets up the duty cycle, which is defined as the ratio of ON time to the combined ON and OFF times, expressed as a percentage, using the following formula: Duty cycle = [ON/(ON + OFF)] × 100. For example, an ON:OFF time ratio of 10s:50s sets up a duty cycle of 16.7% (16.7% = [10 s/(10 s + 50 s)] × 100). A duty cycle of 16.7% means that muscle contraction occurs during an amount of time (10 s) that is 16.7% of the elapsed time (60 s; 10 s + 50 s) between two successive electrically evoked muscle contractions. To document or chart only the duty cycle value *without* the corresponding ON:OFF time ratio is misleading because ON:OFF time ratios of 5 s:20 s and 10 s:40 s, for example, would yield exactly the same 20% duty cycle value but different ON and OFF times. Both the duty cycle and its corresponding ON:OFF time ratio must therefore be charted in the patient's file. To recap, an ON:OFF time ratio of 10s:50s means that the resting time between two successive evoked contractions is five times that of contraction time. The corresponding 16.7% duty cycle, on the other hand, implies that muscle contraction occurred during 16.7% of the time during two successive evoked contractions.

E. ONLINE DOSAGE CALCULATOR: NEUROMUSCULAR ELECTRICAL STIMULATION

As presented earlier, to set up the multiple dosimetric parameters related to the application of NMES requires the use of several formulas and implies multiple calculations. To facilitate dosimetry, this textbook offers the **Online Dosage Calculator: Neuromuscular Electrical Stimulation**. Log on, select the type of current, enter parameters, and let the calculator do the work for you!

V. APPLICATION, CONTRAINDICATIONS, AND RISKS

Prior to considering the application of NMES, practitioners must first check for contraindications, consider the risks, and then go through key application steps and procedures designed to optimize treatment safety, efficacy, and effectiveness. As discussed next, several important elements need to be taken into consideration to achieve optimal application.

A. SKIN PREPARATION

Adequate skin preparation prior to NMES is critical because in order to depolarize motor nerve fibers, electrical current must first flow through the skin. The skin provides the greatest opposition, resistance, or impedance to current flow because the epidermis contains very little fluid. Dry skin offers a much greater opposition than wet skin. Dry skin resistance may be in the mega ohm range (MΩ), whereas wet skin may in the kilo ohm range (KΩ). Cleansing the skin surface areas over which stimulation electrodes are placed with rubbing alcohol, or with a mixture of water and soap, will remove impurities (i.e., dirt, dry cells, and sebum) and significantly decrease skin resistance, thus facilitating current flow to the target muscles. Never apply stimulation electrodes without first cleansing the skin surface.

B. ELECTRODES AND CABLES

The delivery of electrical energy to the neuromuscular apparatus is done by using a variety of surface electrodes. *Electrodes* are the means by which the electron flow from the stimulator is converted to an ionic current flow in soft tissues. A minimum of two electrodes are required to direct the stimulator current to the target tissues, thus completing the electrical circuit. The most commonly used electrodes are made of flexible and reusable carbonized rubber and mesh flexible materials. They come in various shapes and sizes. Electrical connection is made between the stimulator output jacks and the stimulation electrodes using via lead wires or cables. *Bipolar cables* are used to connect pairs of electrodes to the stimulator output channels. Multiple electrodes can be connected to a single channel using *bifurcated cables*. The rationale for using bifurcated cables—that is, to connect more than two electrodes per channel—is to enlarge the stimulation area per channel. As was the case for the skin (see earlier discussion), electrodes and cables also offer opposition of resistance to current flow. Over time and repeated use, electrode material deteriorates and causes electrode resistance to increase, thus making electrical stimulation less effective. It is recommend to *discard* reusable stimulation electrodes after 6 months of use. Repeated use can also damage cables, causing a break in electrical continuity. Periodic checks of electrode resistance and cable electrical continuity, using a basic multimeter device, is strongly recommended to ensure optimal electrical stimulation.

C. ELECTRODE COUPLING

For a stimulation electrode to function properly, it must be coupled to the skin both electrically and mechanically. Electrical coupling is achieved by the application of an electrolytic gel between the electrode and the skin surface. In the past, water-soaked gauzes, sponges, or pads were used. Today, improved water-soluble electroconductive gels are commonly used. To ensure optimal electroconduction at the electrode–skin interface, all electrodes must be mechanically attached to the skin. Most surface electrodes are mechanically attached to the skin using regular hypoallergic tape, or pre-cut adhesive patches. Good skin surface attachment is necessary to ensure that the entire electrode stimulating surface area is in contact with the skin surface to avoid unintentional variations of current density in one region of the skin during the application.

D. ELECTRODE CURRENT DENSITY

Current density (CD) is the ratio of maximum current amplitude (A) to electrode stimulating surface area (S), expressed in milliamperes per square centimeter (mA/cm^2) and calculated as follows: $CD = A/S$. Research shows that the higher the current density under the electrode, the more discomfort or pain the patient feels beneath that electrode. Because current density under a given electrode often dictates whether the application is more or less comfortable, using larger sizes electrodes is recommended, especially when the current amplitude used to evoke muscle contraction is relatively high. Note that using larger stimulating electrodes may have the disadvantage of stimulating undesired muscles or muscle groups located in the immediate vicinity of the targeted muscle area. Note that a small electrode will focus the current over a small area, whereas a larger electrode will disperse it over a larger area.

E. ELECTRODE SPACING

Spacing between pairs of electrodes influences current dispersion within the tissues, which in turn affects the current's penetration depth. Generally speaking, the wider the spacing between electrodes, the more dispersed the current and the deeper the current penetration into the tissue. In contrast, the closer the spacing between electrodes, the less dispersed the current and the more superficial the stimulating effect.

F. ELECTRODE CONFIGURATION

Four electrode configurations are routinely used in the field of NMES: monopolar, bipolar, quadripolar, and multipolar. These configurations, each illustrated in Figure 13-16, are based on clinical situations in which one stimulator, with

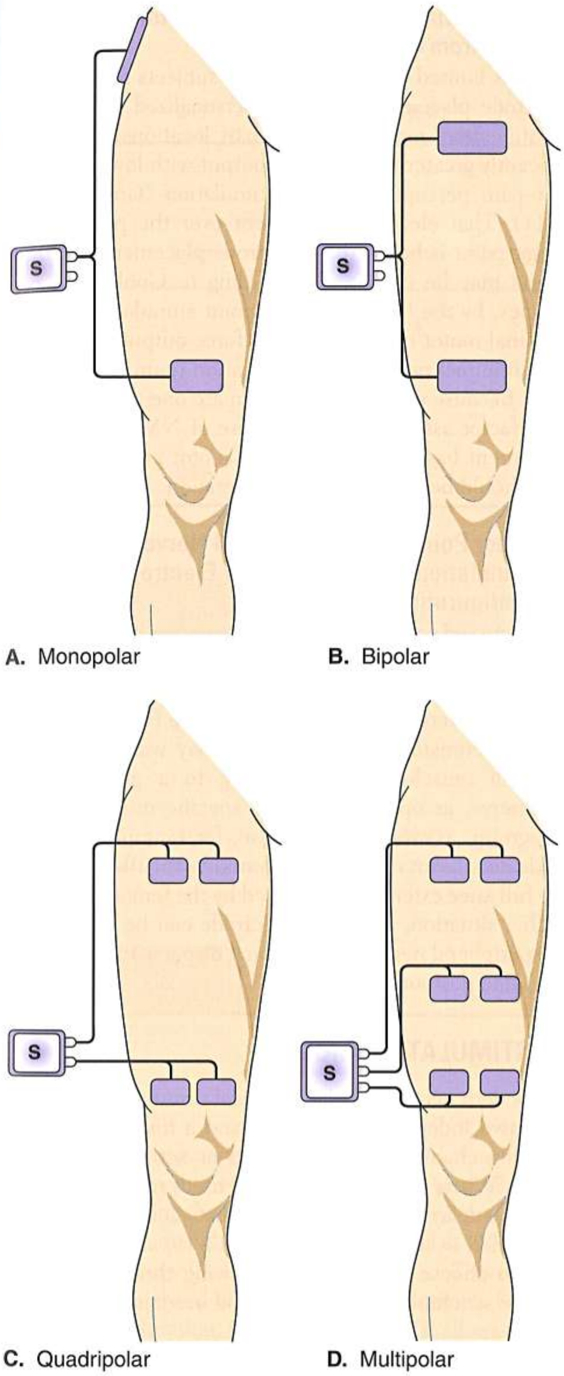


FIGURE 13-16 Monopolar (**A**), bipolar (**B**), quadripolar (**C**), and multipolar (**D**) electrode configurations.

two or three output channels, is used. Recall that each electrode has a pole; hence, the term *polar.*

1. Monopolar

One (mono-) electrode is placed *over* the targeted muscle contractile area with the other positioned at some distance away from the targeted muscle or muscle group. In the example illustrated in Figure 13-16A, one electrode is placed over the targeted quadriceps area with the other positioned away from the targeted area, over the upper lateral hip area.

2. Bipolar

Two (bi-) electrodes are placed *over* the targeted muscle area. Figure 13-16B shows a pair of electrodes positioned over the targeted quadriceps muscle area.

3. Quadripolar

Four (quadri-) electrodes are placed *over* the targeted muscle area. Figure 13-16C shows two pairs of electrodes positioned over the targeted quadriceps muscle area. Note that this method can also be applied via one channel only if a bifurcated cable is used.

4. Multipolar

In this configuration, *more than four* (multi-) electrodes are placed over the targeted muscle contractile area. In Figure 13-16D, six electrodes are positioned over the quadriceps contractile area by using a multichannel stimulator, to which three pairs of electrodes are connected with three pairs of bipolar cables. Note that this electrode placement method can also be applied using a bi-channel stimulator with two pairs of three electrodes, with each pair connected to the stimulator using a bifurcated cable. Figure 13-17 shows the application of the newer all-in-one garment-type NMES unit for quadriceps, which allows multipolar electrode configuration.

G. ELECTRODE PLACEMENT

When placing an electrode over the target muscle, practitioners should always consider placing it over the muscle's motor points. Why? Because the goal of NMES is to optimize the evoked muscle force output while minimizing discomfort during electrical stimulation. There is a consensus in the literature that one of the major factors limiting the clinical use of NMES is the pain, or discomfort, associated with the delivery of electrical current into

FIGURE 13-17 Application of all-in-one quadriceps garment neuromuscular electrical stimulation unit allowing multipolar electrode configuration. Courtesy of Neurotech Bio-Medical Research Ltd.

the soft tissues. By placing the stimulating electrodes over motor points as opposed to elsewhere over the muscle, less current amplitude is used to generate maximum muscle force output, thus making NMES more comfortable and effective.

1. Muscle Motor Point

Anatomically speaking, a *motor point* is defined as the surface entry point of a bundle of motor nerve fibers into a fascicle of muscle fibers. Electrophysiologically speaking, this motor point is defined as a specific skin area where the targeted muscle is best stimulated with the smallest amount of current amplitude. Research has shown that some human muscles may have more than one motor point. How can practitioners identify or locate motor points prior to NMES? They can refer to charts, published in textbooks and corporate brochures, illustrating motor point standard locations, which often quite markedly differ from each other (e.g., see Prentice, 2011; Botter et al., 2011; Gobbo et al., 2011; Starkey, 2013). Practitioners also can use the following motor point identification technique, recently described by Botter et al. (2011) and Gobbo et al. (2011), to perform individual or personalized motor point localization.

2. Motor Point Identification Technique

To identify motor points using the following technique requires less than 10 minutes and needs to be done only once—that is, prior to using NMES. First, set the electrical parameter as follows—waveform: rectangular pulsed biphasic; pulse duration: 0.15 ms; pulse frequency: 2 Hz. Second, use the monopolar electrode configuration—that is, one small-diameter stimulation pen electrode, such as the one shown in Figure 13-18, with one larger reference electrode placed over the antagonist muscle. Third, place the pen electrode somewhere over the targeted muscle area. Slowly increase the current amplitude while manually scanning the skin surface with the pen electrode, until a clear muscle contraction is visualized. Stop scanning and begin to slowly decrease current amplitude until the muscle contraction becomes barely visible. Mark this electrode position, which corresponds to a motor point, with a skin-marking pen. Continue scanning the targeted muscle surface area until another similar muscle contraction is identified, and mark it. Scan the entire targeted muscle area. Note that some muscles may have more than one motor point. Place the surface electrodes over those identified motor points for optimal NMES.

FIGURE 13-18 Motor pen electrode. (Courtesy of DJO Global.)

3. Personalized Motor Point Versus Motor Point from Charts

There is limited evidence in human subjects to show than electrode placement based on personalized motor point identification, rather than on chart locations, elicits significantly greater muscle force output with lower discomfort–pain perception during stimulation (Gobbo et al., 2011). That electrode placement over the personalized motor point is better than electrode placement based on charts may be explained, according to Gobbo and colleagues, by the fact that motor point stimulation triggers maximal motor nerve activation (force output) associated with minimal nerve sensory activation (pain and discomfort). Because discomfort and pain are one the major limiting factor associated with the use of NMES, electrode placement based on personalized motor point identification should be given strong consideration.

4. Motor Point Versus Peripheral Nerve Stimulation Using Monopolar Electrode Configuration

As discussed earlier, the classic monopolar electrode configuration is defined as one electrode (active) placed over the targeted muscle belly with the other electrode (dispersive or indifferent) placed elsewhere (see Fig. 13-16A). In some circumstances, practitioners may want to activate the full muscle group belonging to a given peripheral nerve, as opposed to some specific muscles within the group, as would be the case, for example, with the ankle dorsiflexor muscles innervated by the tibial nerve, or the full knee extensors innervated by the femoral nerve. In such a situation, the active electrode can be placed over the peripheral nerve while keeping dispersive electrode at the same position.

H. STIMULATION MODES

All modern neuromuscular electrical stimulators feature at least two independent channels and a *time-delay switch,* allowing channels to be triggered or activated independently. When such a stimulator is used, manually setting the time-delay switch (D for delay) between channel 1 and channel 2, as illustrated in Figure 13-19, allows practitioners to choose between the following three stimulation modes: synchronous, reciprocal, and overlapping.

1. Synchronous

The synchronous mode is illustrated in Figure 13-19A. It is achieved by setting D at 0 s, with the ON and OFF times of channel 1 equal to the ON and OFF times of channel 2 (e.g., D = 0 s; channel 1: ON = 5 s, OFF 15 s; channel 2: ON = 5 s, OFF = 15 s). Both channels are thus *synchronously* activated (ON) and deactivated (OFF) for the full duration of application. Practically speaking, this mode allows synchronous stimulation of two different muscle groups or two muscle parts within a muscle group.

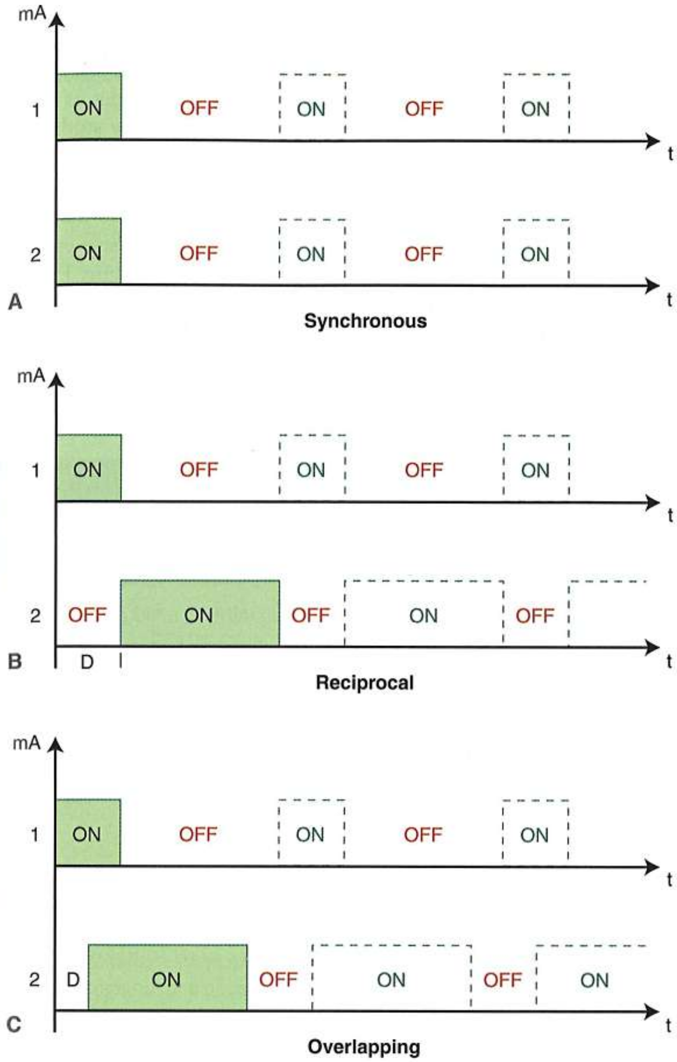


FIGURE 13-19 Synchronous (**A**), reciprocal (**B**), and overlapping (**C**) stimulation modes.

2. Reciprocal

The reciprocal mode, shown in Figure 13-19B, is achieved by setting the D value equivalent to the ON time of channel 1, while setting the ON time of channel 1 equal to the OFF time of channel 2 (e.g., D = 5 s; channel 1: ON = 5 s, OFF = 15 s; channel 2: ON = 15 s, OFF = 5 s). This setting results in a *reciprocal* activation of both channels for the full treatment duration. Clinically speaking, it allows reciprocal, or alternating, stimulation of two different muscles or muscle groups, such as the agonist versus the antagonist.

3. Overlapping

The overlapping mode, illustrated in Figure 13-19C, is achieved by setting the D value greater than 0 s but less than the ON time of channel 1, while keeping the ON and OFF times of both channels identical (e.g., D = 3 s; channel 1: ON = 5 s, OFF = 15 s; channel 2: ON = 5 s, OFF = 15 s). Both channels now *overlap*, as channel 2 is activated 3 seconds after channel 1, for the full duration of the treatment session. Clinically speaking, this mode allows overlapping, or concomitant, stimulation of two different muscles or muscle groups.

I. TRAINING METHODS

There are two methods to deliver NMES: NMES and NMES plus volition. *NMES* implies that that muscle contraction results solely from the electrical energy delivered to the target muscle. Conversely, *NMES plus volition* means that NMES is applied over a voluntarily contracting muscle or muscle group. In other words, this method consists of *superimposing* the electrical current on the patient's voluntary muscle contraction. The resulting muscle contraction reflects the combined effect of both the electrical energy delivered to the muscle and the volitional energy generated by the brain. The body of evidence presented in this chapter reveals that neither method is better than the other in enhancing muscle strength. If the goal is to educate patients about how to contract their muscles, then the NMES plus volition is the preferred method to use.

J. TRAINING PROTOCOL

Of all dosimetric parameters related to the practice of Russian current therapy, the training protocol originally described by Kots (1971, 1977) has received most attention in the literature. This protocol is known as the *10c/10s/50s protocol.* It stands for 10 electrically evoked contractions (c) per bout, with each contraction lasting 10 seconds and interrupted by a rest period of 50 seconds. In other words, this protocol calls for a series of 10 contractions with an ON:OFF time ratio of 10s:50s. Based on series of experiments on Russian athletes, Kots reported (1971, 1977) that this 10c/10s/50s protocol was the best protocol for achieving maximum strength gain without inducing significant muscle fatigue during training. Most investigators have faithfully applied this Russian protocol in their studies to either support or refute Kots's claims, and to determine the therapeutic effectiveness of Russian current therapy. It is important to set an adequate period of muscle inactivation or relaxation (OFF time) between successive evoked contractions (ON time) to prevent muscle fatigue. Practitioners may vary this ratio during the course of a strength-training program to accommodate muscle fatigability. The more fatigable the muscle, the shorter the ON time and/or the longer the OFF time.

APPLICATION, CONTRAINDICATIONS, AND RISKS

Neuromuscular Electrical Stimulation

IMPORTANT: There is a risk of electronic interference between neuromuscular electrical stimulation (NMES) units and rate-responsive pacemakers or implantable cardioverter-defibrillators (ICDs) (Crevenna et al., 2003, 2004). NMES units can be used with these patients *only if,* after cardiac monitoring during treatment, the electrocardiographic recording reveals no interference. **If no such cardiac monitoring is available in your working facility, obtain authorization from the patient's treating cardiologist before using NMES.** Note that NMES units can be used with patients wearing rate-responsive pacemakers or ICDs *only* if the ICD unit is *turned OFF* during therapy (Glotzer, 1998).

See **online video** for more details.

STEP	RATIONALE AND PROCEDURE
1. Check for contraindications.	*Over anterior cervical area*—stimulation of key organs, such as the vagus nerve, phrenic nerve, and carotid sinuses, results in adverse effects, such as hypotensive reaction and laryngeal spasm
	Over thoracic area—affects normal heart function
	Over cranial area—affects brain function
	With patients wearing rate-responsive pacemakers or ICDs—electronic interference with units (for more details, see Chapter 14). Note that NMES can be used with these patients *only* if the ICD unit is *turned OFF* during therapy.
	Over abdominal, pelvic, or lumbar areas with women in their first trimester of pregnancy—induces labor
	Over metal implants—causes unnecessary pain due to electrical current–induced overheating of implants
	In patients with epilepsy—causes epileptic episode
	Over hemorrhagic area—enhances bleeding due to increased blood flow in the treated area
	Over cancerous area—increases and spreads the tumor due to increased blood flow in the treated area
	In patients who are confused and unreliable—complications during therapy that decrease treatment effectiveness
	Over damaged skin—causes unnecessary and severe pain

STEP	RATIONALE AND PROCEDURE
2. Consider the risks.	*Contact dermatitis and burn*—prolonged use of electrode, electroconductive gel, and adhesive tape over the same skin areas increase the risk of contact dermatitis. Change electrode positions over time. *Stimulator electronic interference*—keep all NMES units at least 3 m (10 ft) away from any functioning shortwave device *Temporary bruising*—the use of a vacuum electrode over fragile skin increases the risk due to the suction force (negative pressure) exerted on such fragile skin *Adverse effects such as fainting, nausea, skin rashes, increased swelling, and pain*—these risks were greater with IFC than with other common electrophysical agents, such as transcutaneous electrical nerve stimulation (TENS) and ultrasound (Partridge et al., 1999). Stimulation of the autonomic system may account for some of these adverse effects. *Muscle damage*—repeated mechanical stress imposed on the same motor units during electrical stimulation (specificity of stimulation) over time may cause muscle damage (Nosaka et al., 2011; Jubeau et al., 2012)
For Muscle Strengthening	
3. Position and instruct patient.	Ensure comfortable body positioning. Instruct not to touch the device, cables, and electrodes and to call for assistance if necessary.
4. Prepare treatment area.	Clean the skin surface in the area of the stimulating electrode with rubbing alcohol to remove impurities and sebum, thus reducing skin impedance. Clip hair to ensure optimal electrode–skin coupling.
5. Select stimulator type.	Choose between a cabinet line-powered or portable battery-operated device (see Fig. 13-1). There is evidence to suggest that portable battery-powered stimulators are as good as cabinet line-powered stimulators to deliver therapeutic NMES. Newer, battery-operated garment-base stimulators, designed for quadriceps muscle strengthening, can also be used (Fig. 13-1E). Plug line-powered stimulators into ground-fault circuit interrupter (GFCI) receptacles to prevent the risk of macroshock leading to electrocution (see Chapter 5).
6. Select current type.	Choose between biphasic pulsed, Russian, and interferential currents.
7. Select electrode type.	Use conventional plate electrodes (see Fig. 13-2A,B). Current density is the ratio of maximum current amplitude to electrode stimulating surface area (mA/cm^2). Research shows that the higher the current density under the electrode, the more discomfort or pain the patient feels beneath that electrode. Larger electrode size is recommended, especially when the current amplitude used to evoke the muscle contraction is relatively high.
8. Prepare stimulating electrode.	Cover surface with a thin and evenly distributed coating of electroconductive gel to optimize conduction at the electrode–skin interface. Note that some electrodes may be pre-gelled.
9. Proceed with electrode configuration and placement.	*Configuration:* Select between the monopolar, bipolar, quadripolar, and multipolar configurations. *Placement:* Localize motor points using electrical stimulation technique or charts. Place electrodes over motor point(s). Note that the distance between a pair of electrodes influences current dispersion within the tissues, which in turn affects the current's penetration depth. The wider the inter-electrode distance, the deeper the current penetration into the tissue. In contrast, the closer the two electrodes, the more superficial the stimulating effect. Positioning electrodes over motor points may decrease discomfort/pain perception during electrical stimulation as well as increase muscle force production (Gobbo et al., 2011). Use a pen electrode to locate motor points (see Fig. 13-18).
10. Attach and connect electrodes.	Attach electrodes to the skin using hypoallergic tape or pre-cut self-adhesive patches. Connect electrodes to the stimulator circuit output using regular or bifurcated lead wires. Optimal skin surface attachment is necessary to ensure that the entire electrode stimulating surface area is in contact with the skin surface to avoid unintentional variations of current density in one region of the skin during the application.

STEP	RATIONALE
11. Select stimulation mode.	Modern electrical stimulators feature at least two independent channels and a time-delay switch, allowing both channels to be triggered or activated independently. When such a stimulator is used, manually setting the time delay between the two channels allows synchronous, reciprocal, or overlapping stimulation modes (see Fig. 13-19). Select the *synchronous mode* when the synchronous or concomitant stimulation of two different muscle groups, or two muscle parts, within a muscle group, is needed. Select the *reciprocal mode* if reciprocal, or alternating, stimulation of two different muscles or muscle groups, such as the agonist versus the antagonist, is required. Select the *overlapping mode* if overlapping stimulation of two different muscles or muscle groups is needed.
12. Select stimulation method.	Choose between *NMES* and *NMES plus volition.*
13. Set dosimetry.	Set pulse/burst/beat duration, frequency, current amplitude, ON time, OFF time, ON:OFF ratio, duty cycle, and ramp up and down times (see Table 13-2 as a guideline). Increase current amplitude with patients who are overweight or obese because more current is needed to reach muscle motor points or motor nerve fibers (Miller et al., 2008). **Use the Online Dosage Calculator: Neuromuscular Electrical Stimulation.**
14. Determine training protocol.	The most common training protocol used to strengthen skeletal muscle, originally introduced by Kots is *10c/10s/50s,* which means 10 consecutive electrically evoked contractions, each lasting 10 seconds (ON time) and separated by a resting interval of 50 seconds (OFF time). Adapt this protocol to the case under treatment. Determine the number of training bouts per training session.
15. Apply treatment.	Ensure adequate monitoring. If home treatment, make sure that the patient is using a battery-operated stimulator and give a written sheet of directives to follow with regard to the overall application.
16. Conduct post-treatment inspection.	Remove the electrodes. Inspect the skin area exposed to the electrodes for any unexpected response. Wash and dry the treated surface areas. In the patient's file, document any unusual sensation that the patient felt during treatment. Wash and dry reusable electrodes.
17. Ensure post-treatment equipment maintenance.	Follow manufacturer recommendations. Immediately report any defects or malfunctions to technical maintenance staff. Routine use of common electrodes requires that clinicians adopt a strict maintenance program, including frequent visual inspection and periodic measurements using a basic multimeter device. Wash and dry reusable electrodes after each treatment to ensure optimal efficacy. Check cables and electrodes regularly for visible wear and tear to ensure optimal efficacy and prevent macroshock, if line-powered stimulators are used. Check electrode impedance monthly to ensure optimal electric conduction, because electrodes will deteriorate with use and time. Use an ohmmeter to check impedance. Discard all reusable electrodes after 6 months of use. Because transmission of microorganisms is likely if suction electrodes and sponges are used, these should be disinfected with 70% isopropyl alcohol after treatment of each patient to avoid cross-infection from one patient to another (Lambert et al., 2000).

For Pelvic Floor Muscle Strengthening

Contrary to most skeletal muscles (see earlier discussion), NMES of pelvic floor muscles is difficult because they lie deep under the genital organs. It is suggested that the preferred method to stimulate these muscles is to use vacuum interferential stimulator with suction cup electrodes (see Fig. 13-1D). The quadripolar, or true interferential mode, with or without scan, is often recommended. Place wet sponges in the cups, and moisten the edge for better adherence. Position the four suction electrodes to focus the resulting clover-shaped current field over the pelvic floor muscle area. Adjust the vacuum pressure level to ensure adequate fixation on the body.

For Gut Stimulation

It is suggested that the preferred method to stimulate the gut or intestinal area is to use an interferential stimulator with either plate or suction electrodes. The quadripolar, or true mode, with or without scan, is recommended because of its penetrating and focused electrical field. Position the four suction electrodes to focus the resulting clover-shaped current field over the gut area. Position the electrodes such that maximum current inference triggers parasympathetic stimulation.

CASE STUDIES

Presented are two case studies summarizing the concepts, principles, and applications of NMES discussed in this chapter. Case Study 13-1 addresses the use of NMES for quadriceps weakness following ACL reconstruction. Case Study 13-2 is concerned with the application of NMES for genuine stress incontinence. Each case is structured in line with the concepts of evidence-based practice (EBP), the International Classification of Functioning, Disability, and Health (ICF) disablement model, and SOAP (*s*ubjective, *o*bjective, *a*ssessment, *p*lan) note format (see Chapter 2 for details).

CASE STUDY 13-1: QUADRICEPS WEAKNESS AFTER ACL RECONSTRUCTION

EVIDENCE-BASED CLINICAL DECISION MAKING PROTOCOL

1. Formulate the Case History

A 26-year-old man is referred by his treating orthopedic surgeon for lasting problems related to decreased quadriceps muscle strength and function following right anterior cruciate ligament (ACL) knee reconstruction, done 12 weeks ago, following a ski accident. At discharge from the hospital, the patient was given a full home voluntary quadriceps muscle-strengthening program. Questioned about his compliance with the program over the past 8 weeks, the patient readily admits very poor compliance, thinking that doing his regular daily activities will be enough to regain full knee extension strength. The patient's chief complaints are right quadriceps muscle weakness and atrophy, combined with difficulty squatting, climbing stairs, and running. He is also frustrated with not being able to ski. Physical examination of the injured knee shows no sign of inflammation and complete range of motion. Measurements reveal a quadriceps force deficit of 40% and a thigh girth deficit of 1.5 cm on the affected side. The patient's goal is to rebuild the bulk and strength in his right quadriceps so that he can ski safely and effectively once again. He is now well motivated, realizing that just doing his daily activities will not restore full knee strength and function. To compensate for his lack of motivation and training, you propose NMES therapy.

2. Outline the Case Based on the ICF Framework

QUADRICEPS WEAKNESS AFTER ACL RECONSTRUCTION		
BODY STRUCTURES AND FUNCTIONS	**ACTIVITIES**	**PARTICIPATION**
Quadriceps muscle weakness	Difficulty squatting	Unable to ski
	Difficulty climbing stairs	
	Difficulty running	

PERSONAL FACTORS	ENVIRONMENTAL FACTORS
Young man	Recreational sports
Athletic character	Fitness and leisure
Competitive	

3. Outline Therapeutic Goals and Outcome Measurements

GOAL	OUTCOME MEASUREMENT
Increase muscle force	Dynamometry
Decrease muscle atrophy	Measuring tape
Increase ability to squat, climb, and run, and accelerate return to skiing	Knee Outcome Survey, which includes the Activities of Daily Living Scale (ADLS) and the Sports Activity Scale (SAS)

4. Justify the Use of Neuromuscular Electrical Stimulation Based on the EBP Framework

PRACTITIONER'S EXPERIENCE	RESEARCH-BASED INDICATIONS	PATIENT'S EXPECTATION
Experienced in NMES	*Strength:* Moderate	No opinion of NMES
Has used NMES in similar cases	*Effectiveness:* Substantiated	Hopes for good results
Is convinced that NMES will be beneficial		

5. Outline Key Intervention Parameters

- **Treatment base:** Private clinic
- **Electrical current:** Russian or burst-modulated alternating sinusoidal current
- **Stimulator type:** Cabinet, line-powered, multi-current electrical stimulator with two output channels
- **Current carrier frequency:** 2,500 Hz sinusoidal alternating current
- **Application protocol:** Follow the suggested application protocol presented for muscle strengthening in *Application, Contraindications, and Risks* box, and make the necessary adjustments for this case.
- **Patient's positioning:** Sitting on the training chair with hips at 90 degrees flexion; knee positioned at 70 degrees of flexion; isometric condition with ankle attached to the dynamometer
- **Application site:** Over right quadriceps muscle
- **Burst duration:** 10 ms
- **Burst frequency:** 50 bups
- **Current amplitude:** Amplitude (mA) set to evoke a muscle contraction force equivalent to approximately 60% of maximum voluntary force (MVF) developed by the affected muscle group (% MVF)
- **ON time:** 10 s; includes ramp up (RU) and down (RD) times because muscle contraction occurs during these two ramp times; RU time: 2 s; RD time: 2 s
- **OFF time:** 40 s
- **ON:OFF time ratio:** 10 s:40 s
- **Duty cycle:** 20%
- **Electrode type, shape, and size:** Plate carbon rubber electrodes covered with electroconductive gel; square; 2.5 × 2.5 cm (1 × 1 in)
- **Electrode configuration:** Quadripolar
- **Electrode placement:** Over motor points located with probe stimulation technique (see text)
- **Stimulation method:** Synchronous
- **Training method:** NMES alone
- **Training protocol:** 10 c/10 s/40 s × 3, meaning a bout of 10 evoked muscle contractions, each lasting 10 s and separated by a 40-s rest period, repeated 3 times. This is equivalent to an ON:OFF time ratio of 10 s:40 s that corresponds to a duty cycle of 20%. The duration of this exercise bout is 8.33 minutes or 500 s [(10 s + 40 s) × 10 c)]. The training regimen is composed of 3 consecutive bouts within a training session, each separated by a 5-minute (300-s) rest period. The full training session thus consists of 30 evoked muscle contractions induced over a 35-minute (2,100 s) period (500 s + 300 s + 500 s + 300 s + 500 s).
- **Number of treatment session per week:** 3 (Mon-Wed-Fri)
- **Concomitant therapy:** Home quadriceps strengthening in between NMES training (Tue and Thurs)
- Use the **Online Dosage Calculator: Neuromuscular Electrical Stimulation.**

6. Report Pre- and Post-Intervention Outcomes

OUTCOME	PRE	POST
Quadriceps force (% of deficit)	28%	10%
Muscle atrophy	1.5 cm	0.5 cm
Knee functional status (ADLS)	72%	95%
Knee functional status (SAS)	65%	90%
Scale: 100% = no difficulty		

7. Document Case Intervention Using the SOAP Note Format

S: Young active male Pt complains about R knee muscle weakness and poor function following ACL reconstruction. Frustrated with his therapeutic progress; well motivated to engage in therapy again.

O: *Intervention:* NMES applied over R quadriceps; Russian current with 2,500 Hz carrier frequency; burst duration: 10 ms; burst frequency: 50 bups; current amplitude equivalent to 60% MVF; ON:OFF ratio:

10s:40s; duty cycle: 30%; plate carbon rubber electrodes, quadripolar electrode configuration; electrode placement over motor points; synchronous 2 channel stimulation; training bout: 10c/10s/40s; 3 bouts per training session, NMES 3 times per week for 3 weeks. *Pre–post comparison:* Decreased muscle force deficit, decrease muscle atrophy, and improved R knee functional status.

A: No adverse effect. Treatment well tolerated with improved quadriceps function.

P: Pt advised to continue home quadriceps strengthening program and slowly resume skiing.

CASE STUDY 13-2: GENUINE STRESS INCONTINENCE

EVIDENCE-BASED CLINICAL DECISION MAKING PROTOCOL

1. Formulate the Case History

A 42-year-old healthy woman and mother to three young children is referred by her gynecologist for the management of genuine stress incontinence. This condition began 2 years ago after the birth of her third child. Her main complaint over the past 6 months is frequent urine loss, particularly with sneezing, coughing, or laughing and when doing strenuous physical home and recreational activities. Physical examination reveals severe pelvic floor muscle weakness of grade 1 on the Modified Oxford Scale palpation, leading to incomplete urethral closure. Muscle recruitment is slow, and the ability to hold is poor. She has difficulty in working out how to tighten or contract her pelvic floor muscle correctly and to hold on for more than a few seconds. The patient's goal is to regain control of her micturition. She wants to avoid the use of medication. She feels socially embarrassed with regard to this problem.

2. Outline the Case Based on the ICF Framework

GENUINE STRESS INCONTINENCE		
BODY STRUCTURES AND FUNCTIONS	**ACTIVITIES**	**PARTICIPATION**
Pelvic floor muscle weakness	Difficulty in controlling micturition	Difficulty with strenuous home activities Difficulty with strenuous recreational activities

PERSONAL FACTORS	ENVIRONMENTAL FACTORS
Middle-aged woman	Family
Mother	Home
Housewife	Recreation

3. Outline Therapeutic Goals and Outcome Measurements

GOAL	OUTCOME MEASUREMENT
Increase pelvic floor muscle strength Increase sphincter strength and control, thus enhancing urethral control	Force grading using palpation (Modified Oxford Scale)
Decrease episodes and severity of incontinence, thus decreasing social embarrassment and accelerating return to normal life	Daily voiding diary/continence chart

4. Justify the Use of Neuromuscular Electrical Stimulation Based on the EBP Framework

PRACTITIONER'S EXPERIENCE	RESEARCH-BASED INDICATIONS	PATIENT'S EXPECTATION
Moderate experience in NMES	*Strength:* Moderate	Wants to avoid medication
Has used NMES in a few similar cases	*Effectiveness:* Substantiated	Is looking for a noninvasive treatment
Believes that NMES will be beneficial		

5. Outline Key Intervention Parameters

- **Treatment base:** Private clinic
- **Electrical current:** Interferential or beat amplitude-modulated alternating sinusoidal current
- **Stimulator type:** Cabinet, line-powered, vacuum interferential
- **Application protocol:** Follow the suggested application protocol presented for pelvic floor muscles, and make the necessary adjustments for this case.
- **Patient's positioning:** Semi-supine, knees flexed, with thighs open, giving access to the perineum for electrode placement
- **Stimulation mode:** Quadripolar or true interferential
- **Stimulation method:** NMES superimposed onto voluntary contraction
- **Beat duration:** 10 ms
- **Beat frequency sweep:** 40 to 120 beps
- **Current amplitude:** At the level (mA) where the patient reports a strong but comfortable sensation
- **ON time:** 8 s; includes ramp up (RU) and down (RD) times because muscle contraction occurs during these two ramp times; RU time: 1 s, RD time: 1 s
- **OFF time:** 24 s
- **ON:OFF time ratio:** 8s:24s
- **Duty cycle:** 25%
- **Electrode type, shape surface area:** 4 circular cone suction electrodes; 12 cm^2 (4 in^2)
- **Electrode configuration:** Quadripolar
- **Electrode placement:** Electrodes placed around the perineum as follows: 2 electrodes adjacent to pubic symphysis, and 2 electrodes adjacent to each ischial tuberosity. With this quadripolar placement, the current of each channel is crossing (focused interference) the pelvic floor muscle and bladder areas for optimal stimulation. Suction electrodes kept in place over the skin using minimal suction or vacuum force.
- **Training regimen:** 12c/8s/24s × 3, meaning a bout made of 15 evoked muscle contractions superimposed onto voluntary pelvic floor muscle contractions, each lasting 8 s and separated by a 24-s rest period. This is equivalent to an ON:OFF time ratio of 8s:24s, which corresponds to a duty cycle of 25%. The duration of this exercise is 8 minutes or 480 s [(8 s + 24 s) × 15 c)]. The training regimen is composed of 3 consecutive bouts within a training session, each separated by a 5-minute (300-s) rest period. The full training session thus consists of 45 evoked muscle contractions, each superimposed on 45 voluntary contractions, produced over a 34-minute (2,040-s) period (480 s + 300 s + 480 s + 300 s +480 s).
- **Treatment frequency:** Daily
- **Concomitant therapy:** Daily home pelvic floor muscle strengthening exercises (Kegels).
- **Treatment duration:** 10 days
- Use the **Online Dosage Calculator: Neuromuscular Electrical Stimulation.**

6. Report Pre- and Post-Intervention Outcomes

OUTCOME	PRE	POST
Pelvic floor muscle strength (Modified Oxford Score)	1	3
Continence chart		Improved by 70%

7. Document Case Intervention Using the SOAP Note Format

S: Middle-aged active Pt, diagnosed with stress incontinence causing problem with bladder control and social embarrassment. Pt wants to avoid medication and surgery.

O: *Intervention:* NMES for urinary incontinence using quadripolar IFC; beat frequency sweep: 40 to 120 Hz; ON:OFF time ratio: 8s:24s; duty cycle: 25%; suction electrodes; quadripolar electrode configuration surrounding the perineum; training regimen: 12c/8s/24s × 3 bouts; treatment schedule: daily for 10 days. *Pre-Post Compraison:* NMES, applied concomitantly with a home regimen of Kegels, led to increase PFM force (1 to 3) and decreased micturition (70% improvement).

A: No adverse effect. Treatment well tolerated. By contraction during electrical stimulation, PT can now better contract her pelvic floor muscles and control the incontinence problem.

P: Pt strongly advised to continue her Kegel exercise regimen on a regular basis.

VI. THE BOTTOM LINE

- There is unquestionable scientific evidence to show that NMES can restore and increase muscle strength in patients and healthy individuals.
- NMES cannot be considered as a surrogate training method, but as an adjunct to voluntary muscle training.
- NMES is the delivery of electrical current through the skin causing motor nerve depolarization, which in turn evokes muscle contraction.
- NMES is commonly applied using three types of electrical current: biphasic pulsed, Russian, and interferential currents.
- Biphasic pulsed current may be pulse- or burst modulated. Russian current is burst modulated, and IFC is beat- or amplitude modulated.
- Electrically speaking, there is minimal difference between biphasic burst-, Russian burst- and interferential beat modulation. Given similar parameter settings, all three currents generate similar amounts of current per second.
- During NMES, and contrary to voluntary contraction, MU activation is synchronous and occurs in a reverse order, thus causing rapid onset of muscle fatigue.
- Of all dosimetric parameters, both pulse/burst/beat frequency (temporal recruitment) and current amplitude (spatial recruitment) may be the most important.
- Setting proper ON and OFF times, as well as ramp up and down times, is necessary for the electrically evoked muscle contraction to mimic voluntary contraction as closely as possible.
- Electrode placement over muscle motor point(s) is recommended. Identification of motor points can be personalized using motor point stimulation technique or based on published motor point charts.
- All line-powered neuromuscular electrical stimulators should be plugged into ground-fault circuit interrupter (GFCI) receptacles to prevent macroshock.
- Skin surface preparation before each treatment and periodic calibration of electric stimulators, including electrode resistance and cable continuity checks using a multimeter, are strongly recommended to ensure optimal treatment efficacy.
- Use of the **Online Dosage Calculator: Neuromuscular Electrical Stimulation** removes the burden of hand calculation and promotes the adoption of quantitative dosimetry.
- The overall body of evidence reported in this chapter shows the strength of evidence behind NMES to be *moderate* and its level of therapeutic effectiveness *substantiated*.
- As a modern training method, NMES or EMS training represents a promising alternative to traditional strength training for systematically enhancing strength parameters and motor abilities in patients as well as in healthy untrained and trained subjects, including elite athletes.

VII. CRITICAL THINKING QUESTIONS

Clarification: What is meant by neuromuscular electrical stimulation (NMES)?

Assumptions: Many of your colleagues assume that the use of Russian current stimulation causes less discomfort and generates greater tetanic force, and that IFC is more penetrating than the other current because it lowers skin impedance. How would you verify or disprove this assumption?

Reasons and evidence: What leads you to believe that MU recruitment during electrical stimulation is synchronous and occurs in a reverse size order?

Viewpoints or perspectives: How will you respond to a colleague who says that IFC is better than Russian current or biphasic pulse current for enhancing muscle strength?

Implications and consequences: What are the potential implications and consequences related to the following parameter settings: (1) increasing the ON time while keeping the OFF time the same during the course of the training program; (2) using 20 bups as opposed to 50 bups; and (3) setting no ramp up and down times?

About the question: Why is setting current frequency and current amplitude so important for optimal strength training using NMES? Why do you think I ask this question?

VIII. REFERENCES

Articles

Adedoyin RA, Olaogun MO, Fagbeja OO (2002) Effects of interferential current stimulation in management of osteoarthritic knee pain. Physiotherapy, 88: 493–499

Anderson AF, Lipscomb AB (1989) Analysis of rehabilitation technique after anterior cruciate reconstruction. Am J Sports Med, 17: 154–160

APTA (2001). Electrotherapeutic Terminology in Physical Therapy. Alexandria, VA. American Physical Therapy Association.

Avramidis K, Strike PW, Taylor PN, Swain ID (2003) Effectiveness of electric stimulation of the vastus medialis muscle in the rehabilitation of patients after total knee arthroplasty. Arch Phys Med Rehabil, 84: 1850–1853

Behm DG, St-Pierre DM, Perez D (1996) Muscle inactivation: Assessment of interpolated twitch technique. J Appl Physiol, 81: 2267–2273

Belanger AY, Allen ME, Chapman AE (1992) Cutaneous versus muscular perception of electrically evoked tetanic pain. J Orthop Sports Phys Ther, 16: 162–168

Belanger AY, McComas AJ (1981) Extent of motor unit activation during effort. J Appl Physiol Respir Environ Exerc, 51: 1131–1135

Bellew JW, Beiswanger Z, Freeman E, Gaerte C, Trafton J (2012) Interferential and burst-modulated biphasic pulsed currents yield greater muscle force than Russian current. Physiother Thory Pract, 28: 384–390

Bircan S, Senocak O, Kaya PO, Tamci SA, Gulbahar A, Akalin E (2002) Efficacy of two forms of electrical stimulation in increasing quadriceps strength: A randomized controlled trial. Clin Rehabil, 16: 194–199

Botter A, Oprandi G, Lanfranco F, Allasia S, Maffiuletti NA, Minetto MA (2011) Atlas of the muscle motor points for the lower limbs: Implications for electrical stimulation procedures and electrode positioning. Eur J Appl Physiol, 111: 2461–2471

Boutelle D, Smith B, Malone T (1985) A strength study utilizing the Electro-Stim 180. J Orthop Sports Phys Ther, 7: 50–53

Brooks ME, Smith EM, Currier DP (1990) Effect of longitudinal versus transverse electrode placement on torque production by the quadriceps femoris muscle during neuromuscular electrical stimulation. J Orthop Sports Phys Ther, 11: 530–534

Burch FX, Tarro JN, Greenberg JJ, Carroll WJ (2008) Evaluating the benefits of patterned stimulation in the treatment of osteoarthritis of the knee: A multiple-center, randomized, single-blind, controlled study with an independent masked evaluator. Osteoarthritis Cartilage, 16: 895–872

Cabric M, Appell HJ, Resic A (1987) Effects of electrical stimulation of different frequencies on the myonuclei and fiber size in human muscle. Int J Sports Med, 8: 323–326

Caggiano E, Emrey T, Shirley S (1994) Effects of electrical stimulation or voluntary contraction for strengthening the quadriceps femoris muscles in an aged male population. J Orthop Sports Phys Ther, 20: 22–28

Callaghan MJ, Oldham JA, Winstanley J (2001) A comparison of two types of electrical stimulation of the quadriceps in the treatment of patellofemoral pain syndrome. A pilot study. Clin Rehabil, 15: 637–646

Chase J, Robertson VJ, Southwell B, Hutson J, Gibb S (2005) Pilot study using transcutaneous electrical stimulation (interferential current) to treat chronic treatment-resistant constipation and soiling in children. J Gastroenterol Hepatol, 20: 1054–1061

Cheing GL, Hui-Chan CW (2003) Analgesic effects of transcutaneous electrical nerve stimulation and interferential currents on heat pain in healthy subjects. J Rehabil Med, 35: 15–19

Cheing GL, So EM, Chao CY (2008) Effectiveness of electroacupuncture and interferential electrotherapy in the management of frozen shoulder. J Rehabil Med, 40: 166–170

Clarke MC, Chase JW, Gibb S, Hutson JM, Southwell BR (2009a) Improvement of quality of life in children with slow transit constipation after treatment with transcutaneous electrical stimulation. J Pediatr Surg, 44: 1268–1272

Clarke MC, Chase JW, Gibb S, Robertson VJ, Catto-Smith A, Hutson JM, Southwell BR (2009b) Decreased colonic transit time after transcutaneous interferential electric stimulation in children with slow transit constipation. J Pediatr Surg, 44: 408–412

Crevenna R, Mayr W, Keilani M, Pleiner J, Nurh M, Quittan M, Pacher R, Pialka-Moser V, Wolzt M (2003) Safety of a combined strength and endurance training using neuromuscular electrical stimulation of thigh muscles in patients with heart failure and bipolar sensing cardiac pacemakers. Wien Klin Wochenschr, 115: 710–714

Crevenna R, Wolzt M, Fialka-Moser V, Keilani M, Nurh M, Paternostro-Sluga T, Pacher R, Mayr W, Quittan M (2004) Long-term transcutaneous neuromuscular electrical stimulation in patients with bipolar sensing implantable cadioverter defibrillators: A pilot safety study. Artif Organs, 28: 99–102

Currier DP, Mann R (1983) Muscle strength development by electrical stimulation in healthy individuals. Phys Ther, 63: 915–921

Currier DP, Mann R (1984) Pain complaint: Comparison of isometric stimulation with conventional isometric exercise. J Orthop Sports Phys Ther, 5: 318–323

Curwin S, Stanish WD, Valinat G (1980) Clinical applications and biochemical effects of high frequency electrical stimulation. Can Athl Assoc J, 7: 15–16

Defrin R, Ariel E, Paretz C (2005) Segmental noxious versus innocuous electrical stimulation for chronic pain relief and the effect of fading sensation during treatment. Pain, 115: 152–160

Delitto A (2002) Russian electrical stimulation: Putting this perspective into perspective. Phys Ther, 82: 1017–1018

Delitto A, Brown M, Strube MJ, Rose SJ, Lehman RC (1989) Electrical stimulation of quadriceps femoris in an elite weight lifter: A single subject experiment. In J Sports Med, 3: 187–191

Delitto A, McKowen JM, McCarthy JA, Shively RA, Rose SJ (1988a) Electrically elicited co-contraction of a thigh muscular after anterior cruciate ligament surgery. A description and single-case experiment. Phys Ther, 68: 45–50

Delitto A, Rose SJ (1986a) Comparative comfort of three waveforms used in electrically eliciting quadriceps femoris muscle contractions. Phys Ther, 66: 1704–1707

Delitto A, Rose SJ (1986b) Electrically eliciting quadriceps femoris muscle contractions. Phys Ther, 66: 1704–1707

Delitto A, Rose SJ, McKowen JM, Lehman RC, Thomas JA, Shively RA (1988b) Electrical stimulation versus voluntary exercise in strengthening thigh musculature after anterior cruciate ligament surgery. Phys Ther, 68: 663–666

Delitto A, Snyder-Mackler L (1990) Two theories of muscle strength augmentation using percutaneous electrical stimulation. Phys Ther, 70: 158–164

Delitto A, Strube MJ, Shulman AD, Minor SD (1992) A study of discomfort with electrical stimulation. Phys Ther, 72: 410–421

Demirturk F, Akbayrak T, Karakaya IC, Yuksel I, Kirdi N, Demirturk F, Kaya S, Ergen A, Beksac S (2008) Interferential current versus biofeedback results in urinary stress incontinence. Swiss Med Wkly, 138: 317–321

Dobsak P, Novakova M, Fiser B, Siegelova J, Balcarkova P, Spinarova L, Vitovec J, Minami N, Nagasaka M, Kohzuki M, Yambe T, Imachi K, Nitta S, Eicher JC, Wolf JE (2006) Electrical stimulation of skeletal muscles. An alternative to aerobic exercise training in patients with chronic heart failure? Int Heart J, 47: 441–453

Dougall D (1985) The effects of interferential therapy in incontinence and frequency of micturition. Physiotherapy, 71: 135–136

Dowling JJ, Konert E, Ljucovic P, Andrews DM (1994) Are humans able to voluntary elicit maximum force? Neurosci Lett, 179: 25–28

Draper V, Ballard L (1991) Electrical stimulation versus electromyographic biofeedback in the recovery of quadriceps femoris muscle function following anterior cruciate ligament surgery. Phys Ther, 71: 455–461

Dumoulin C, Seabore DE, Quirion-de-Girardi C, Sullivan SJ (1995a) Pelvic-floor rehabilitation. Part 1: Comparison of two surface electrode placements during stimulation of the pelvic-floor musculature in women who are continent using bipolar interferential currents. Phys Ther, 75: 1067–1074

Dumoulin C, Seabore DE, Quirion-de-Girardi C, Sullivan SJ (1995b) Pelvic-floor rehabilitation. Part 2: Pelvic-floor reeducation with interferential currents and exercise in the treatment of genuine stress incontinence in postpartum women—a cohort study. Phys Ther, 75: 1075–1081

Emmerson C (1987) A preliminary study of the effect of interferential current therapy on detrusor instability in patients with multiple sclerosis. Aust J Physioth, 33: 64–65

Eriksson E, Haggmark T (1979) Comparison of isometric muscle training and electrical stimulation supplementing isometric muscle training in the recovery after major knee ligament surgery. Am J Sports Med, 17: 169–171

Eriksson E, Haggmark T, Kiessling KH, Karlsson J (1981) Effect of electrical stimulation on human skeletal muscle. Int J Sports Med, 2: 18–22

Fahey TD, Harvey M, Schroeder RV, Ferguson F (1985) Influence of sex difference and knee joint position on electrical stimulation-modulated strength increases. Med Sci Sports Exerc, 17: 144–147

Feil S, Newell J, Minogue C, Paessler HH (2011) The effectiveness of supplementing a standard rehabilitation program with superimposed neuromuscular electrical stimulation after anterior cruciate ligament reconstruction. Am J Sports Med, 39: 1238–1247

Ferguson JP, Blackley MW, Knight RD, Sutlive TG, Underwood FB, Greathouse DG (1989) Effects of varying electrode site placements on the torque output of an electrically stimulated involuntary quadriceps femoris muscle contraction. J Orthop Sports Phys Ther, 11: 24–29

Fitzgerald GK, Piva SR, Irrgang JJ (2003) A modified neuromuscular electrical stimulation protocol for quadriceps strength training following anterior cruciate ligament reconstruction. J Orthop Sports Phys Ther, 33: 492–501

Franklin ME, Currier DP, Smith ST, Mitts K, Werrell LM, Chenier TC (1991) Effect of varying the ratio of electrically induced muscle contraction time to rest time on serum creatine kinase and perceived soreness. J Orthop Sports Phys Ther, 13: 310–315

Fuentes J, Armijo-Olivo S, Magee DJ, Cross D (2010) Does amplitude-modulated frequency have a role in the hypoalgesic response of interferential current on pressure pain sensitivity in healthy subjects? A randomized crossover study. Physiotherapy, 96: 22–29

Fuentes J, Armijo-Olivo S, Magee DJ, Cross D (2011) A preliminary investigation into the effects of active interferential current therapy and placebo on pressure pain sensitivity: A randomized crossover placebo controlled study. Physiotherapy, 97: 291–301

Gaines JM, Metter EJ, Talbot LA (2004) The effect of neuromuscular electrical stimulation on arthritis knee pain in older adults with osteoarthritis of the knee. Appl Nurs Res, 17: 201–206

Glotzer TV, Gordon M, Sparta M, Radoslovich G, Zimmerman J (1998) Electromagnetic interference from a muscle stimulation device causing discharge of an implantable cardioverter defibrillator: Epicardial bipolar and endocardial bipolar sensing circuits are compared. Pacing Clin Electrophysiol, 21: 1996–1998

Gobbo M, Gaffurini P, Bissolotti L, Esposito F, Orizio C (2011) Transcutaneous neuromuscular stimulation: Influence of electrode positioning and stimulus amplitude settings on muscle response. Eur J Appl Physiol, 111: 2451–2454

Gondin J, Guette M, Ballay Y, Martin A (2005) Electromyostimulation training effects on neural drive and muscle architecture. Med Sci Sports Exerc, 37: 1291–1299

Grimby G, Wigerstad-Lossing I (1989) Comparison of high- and low-frequency muscle stimulators. Arch Phys Med Rehab, 70: 835–838

Gundog M, Atamaz F, Kanylmaz S, Kirazli Y, Celepoglu G (2011) Interferential current therapy in patients with knee osteoarthritis. Am J Phys Med, 91: 107–113

Hallback J, Straus D (1980) Comparison of electro-myo stimulation to isokinetic training in increasing power of the knee extensor mechanism. J Orhtop Sports Phys Ther, 2: 20–24

Hartsell HD (1986) Electrical muscle stimulation and isometric exercises effects on selected quadriceps parameters. J Orthop Sports Phys Ther, 8: 203–209

Harris S, LeMaitre JP, Mackenzie G, Fox KA, Denvir MA (2003) A randomized study of home-based electrical stimulation of the legs and conventional bicycle exercise training for patients with chronic heart failure. Eur Heart J, 24: 871–878

Hartsell HD, Kramer JK (1992) A comparison of the effects of electrode placement, muscle tension, and isometric torque of the knee extensors. J Orthop Sports Phys Ther, 15: 168–174

Henella SM, Hutchins CJ, Castleden CM (1987) Conservative management of urethral sphincter incompetence. Neurourol Urodyn, 6: 191–192

Henneman E, Somjen G, Carpenter DG (1965) Functional significance of cell size spinal motoneurons. J Neurophysiol, 28: 560–580

Herrero AJ, Martin J, Martin T, Abadia O, Fernandez B, Garcia-Lopez D (2010a) Short-term effect of strength training with and without superimposed electrical stimulation on muscle strength and anaerobic performance: A randomized controlled trial. Part I. J Strength Cond Res, 24: 1616–1622

Herrero AJ, Martin J, Martin T, Abadia O, Fernandez B, Garcia-Lopez D (2010b) Short-term effect of plyometrics and strength training with and without superimposed electrical stimulation on muscle strength and anaerobic performance: A randomized controlled trial. Part II. Strength Cond Res, 24: 1616–1622

Hortobagyi T, Lambert NJ, Tracy C (1992) Voluntary and electromyostimulation forces in trained and untrained men. Med Sci Sports Exerc, 24: 702–707

Hurley DA, Minder PH, McDonough SM, Walsh DM, Moore AP, Baxter DG (2001) Interferential therapy electrode placement technique in acute low back pain: A preliminary investigation. Arch Phys Med Rehabil, 82: 485–493

Jarit GK, Mohr KJ, Waller R, Glousman RE (2003) The effects of home interferential therapy on postoperative pain, edema, and range of motion of the knee. Clin J Sports Med, 13: 16–20

Johnson MI, Tabasam G (1999) A double blind placebo-controlled investigation into the analgesic effects of interferential effects (IFC) and transcutaneous electrical nerve stimulation (TENS) on cold-induced pain in healthy subjects. Physioth Theor Pract, 15: 217–233

Johnson MI, Tabasam G (2003a) A single blind investigation into the hypoanalgesic effects of different swing patterns of interferential currents on cold-induced pain in healthy subjects. Arch Phys Med Rehabil, 84: 350–357

Johnson MI, Tabasam G (2003b) An investigation into the analgesic effects of interferential currents and transcutaneous electrical nerve stimulation on experimentally induced ischemic pain in otherwise pain-free volunteers. Phys Ther, 83: 208–223

Johnson MI, Tabasan G (2003c) An investigation into the analgesic effects of different frequencies of the amplitude-modulated wave of interferential current therapy on cold-induced pain in normal subjects. Arch Phys Med Rehabil, 84: 1387–1394

Johnson MI, Wilson H (1997) The analgesic effects of different swing patterns of interferential currents on cold-induced pain. Physiotherapy, 83: 461–467

Jubeau M, Muthalib M, Millet GY, Maffiuletti NA, Nosaka K (2012) Comparison in muscle damage between maximal voluntary and electrically evoked isometric contractions of the elbow flexors. Eur J Appl Physiol, 112: 429–438

Kajbafzadeh AM, Sharifi-Rad L, Baradaram N, Nejat F (2009) Effect of pelvic floor interferential electrostimulation on urodynamic parameters and incontinency of children with myelomeningocele and detrusor overactivity. Urology, 74: 324–329

Kajbafzadeh AM, Sharifi-Rad L, Nejat F, Kajbafzadeth M, Talaei HR (2011) Transcutaneous interferential electrical stimulation for management of neurologic bowel dysfunction in children with myomeningocele. In J Colorectal Dis, 27: 453–458

Koklu S, Koklu G, Ozguclu E, Kayani GU, Akbal E, Hascelik Z (2010) Clinical trial: Interferential electric stimulation in functional dyspepsia patients—a prospective randomized study. Aliment Pharmacol Ther, 31: 961–968

Kots YM (1971) Training with the method of electric tetanic stimulation of muscle by orthogonal impulses. Theory Pract Phys Cult, 4: 66–72 (Translated from Russian and French)

Kots YM (1977) Electrostimulation. Babkin I, Timentsko N (Translators). Paper presented at the Symposium on Electrostimulation of Skeletal Muscles. Canadian–Soviet Exchange Symposium, Concordia University, December 6–10

Kubiak RJ, Whitman KM, Jonhson RM (1987) Changes in quadriceps femoris muscle strength using isometric exercise versus electrical stimulation. J Orthop Sports Phys Ther, 8: 537–541

Lai HS, De Domineco G, Strauss GR (1988) The effect of different electro-motor stimulation training intensities on strength improvement. Aust J Physiother, 34: 151–164

Lambert I, Tebbs SE, Hill D, Moss HA, Davies AJ, Elliott TS (2000) Interferential therapy machines as possible vehicles for cross-infection. J Hosp Infect, 44: 59–64

Lambert JL, Vanderstreaten GG, De Cuyper HJ (1993) Electric current distribution during interferential therapy, Eur J Phys Med Rehab 3: 6–10

Laufer Y, Ries JD, Leininger PM, Alon G (2001) Quadriceps femoris muscle torques and fatigue generated by neuromuscular electrical stimulation with three different waveforms. Phys Ther, 81: 1307–1316

Laughman RK, Youdas JW, Garrett TR, Chao EY (1983) Strength changes in the normal quadriceps femoris muscle as a result of electrical stimulation. Phys Ther, 63: 494–499

Laycock J, Green RJ (1988) Interferential therapy in the treatment of incontinence. Physiotherapy, 74: 161–164

Laycock J, Jerwood D (1993) Does premodulated interferential therapy cure genuine stress incontinence? Physiotherapy, 79: 553–560

Lewek M, Stevens J, Snyder-Mackler L (2001) The use of electrical stimulation to increase quadriceps femoris muscle force in an elderly patient following a total knee arthroplasty. Phys Ther, 81: 1565–1571

Lieber RL, Silva PD, Daniel DM (1996) Equal effectiveness of electrical and volitional strength training for quadriceps femoris muscles after anterior cruciate ligament surgery. J Orthop Res, 14: 131–138

Lyons CL, Robb JB, Irrgang JJ, Fitzgerald GK (2005) Differences in quadriceps femoris torque when using a clinical electrical stimulator versus a portable electrical stimulator. Phys Ther, 85: 44–51

Man IO, Morrissey MC, Cywinski JK (2007) Effect of neuromuscular electrical stimulation on ankle swelling in the early period after ankle sprain. Phys Ther, 87: 53–65

Martin TP, Gundersen LA, Blevins FT, Coutts RD (1991) The influence of functional electrical stimulation on the properties of vastus lateralis fibres following total knee arthroplasty. Scand J Rehabil Med, 23: 207–210

McManus FJ, Ward AR, Robertson VJ (2006) The analgesic effects of interferential therapy on two experimental pain models: Cold and mechanically induced pain. Physiotherapy, 92: 95–102

McMiken DF, Todd-Smith M, Thompson C (1983) Strengthening of human quadriceps muscles by cutaneous electrical stimulation. Scand J Rehabil Med, 15: 25–28
McQuire WA (1975) Electrotherapy and exercises for stress incontinence and urinary frequency. Physiotherapy, 61: 305–307
Miller MG, Cheatham CC, Holcomb WR, Ganschow R, Micheal TJ, Rubbley MD (2008) Subcutaneous tissue thickness alters the effect of NMES. J Sports Rehabil, 17: 68–75
Minder PM, Noble JG, Alves-Guerreiro J, Hill ID, Lowe AS, Walsh DM, Baxter GD (2002) Interferential therapy: Lack of effect upon experimentally induced delayed onset muscle soreness. Clin Physiol Funct Imaging, 22: 339–347
Mintken PE, Carpenter KJ, Eckhoff D, Kohrt WM, Stevens JE (2007) Early neuromuscular electrical stimulation to optimize quadriceps muscle function following total knee arthroplasty: A case report. J Orthop Sports Phys Ther, 37: 364–371
Nemec H (1959) Interferential therapy: A new approach in physical medicine. Br J Physiother, 12: 9–12
Ni Chiosig F, Hendricks O, Malone J (1994) A pilot study of the therapeutic effects of bipolar and quadripolar interferential therapy, using bipolar osteoarthritis as a model. Physiother Ire, 15: 3–7
Nitz AJ, Dobner JJ (1987) High-intensity electrical stimulation effect on thigh musculature during immobilization for knee sprain. A case report. Phys Ther, 67: 219–222
Nobbs LA, Rhodes EC (1986) The effect of electrical stimulation on isokinetic exercise on muscular power of the quadriceps femoris. J Orthop Sports Phys Ther, 8: 260–268
Nosaka K, Aldayel A, Jubeau M, Chen TC (2011) Muscle damage induced by electrical stimulation. Eu J Appl Physiol, 111: 2427–2437
Nuhr MJ, Pette D, Berger R, Quittan M, Crevenna R, Huelsman M, Wiesinger GF, Moser P, Fialka-Moser V, Pacher R (2004) Beneficial effects of chronic low-frequency stimulation of thigh muscles in patients with advanced chronic heart failure. Eur Heart J, 25: 136–143
Oh-oka H (2008) Efficacy of interferential low frequency therapy for elderly wet overactive bladder patients. Indian J Urol, 24: 178–181
Olah KS, Bridges N, Denning J, Farrar DJ (1990) The conservative management of patients with symptoms of stress incontinence: A randomized, prospective study comparing weighted vaginal cones and interferential therapy. Am J Obstet Gynecol, 162: 87–92
Owens J, Malone T (1983) Treatment parameters of high frequency electrical stimulation as established on the Electro-Stim 180. J Orthop Sports Phys Ther, 4: 162–168
Parker MG, Bennett MJ, Hieb MA, Hollar AC, Roe AA (2003) Strength response in human femoris muscle during 2 neuromuscular electrical stimulation programs. J Orthop Sports Phys Ther, 33: 719–726
Parker MG, Keller L, Evenson J (2005) Torque responses in human quadriceps to burst-modulated alternating current at 3 carrier frequencies. J Orthop Sports Phys Ther, 35: 239–245
Partridge CJ, Kitchen SS (1999) Adverse effects of electrotherapy used by physiotherapists. Physiotherapy, 85: 298–303
Petterson S, Snyder-Mackler L (2006) The use of neuromuscular electrical stimulation to improve activation deficits in a patient with chronic quadriceps strength impairments following total knee arthroplasty. J Orthop Sports Phys Ther, 36: 678–685
Pfeifer AM, Cranfield T, Wagner S, Craik RL (1997) Muscle strength: A comparison of electrical stimulation and volitional isometric contractions in adults over 65 years. Physiother Can, 49: 32–39
Philipp A, Wolf GK, Rzany B, Dertinger H, Jung EG (2000) Interferential current is effective in palmar psoriasis: An open prospective trial. Eur J Dermatol, 10: 195–198
Quirk A, Newham RJ, Newham KJ (1985) An evaluation of interferential therapy, shortwave diathermy and exercise in the treatment of osteoarthrosis of the knee. Physiotherapy, 71: 55–57
Quittan M, Wiesinger GF, Sturm B, Puig S, Mayr W, Sochor A, Paternostro T, Resch KL, Pacher R, Fialka-Moser V (2001) Improvement of thigh muscles by neuromuscular electrical stimulation in patients with refractory heart failure. Am J Phys Med Rehabil, 80: 206–214
Romero JA, Sanford TL, Schroeder RV (1982) The effects of electrical stimulation on normal quadriceps on strength and girth. Med Sci Sports Exerc, 14: 194–197
Rooney JG, Currier DP, Nitz AJ (1992) Effect of variation in the burst and carrier frequency modes of neuromuscular electrical stimulation on pain perception of healthy subjects. Phys Ther, 72: 800–806
Ruther CL, Golden CL, Harris RT, Dudley GA (1995) Hypertrophy, resistance training, and the nature of skeletal muscle activation. J Strength Cond Res, 9: 155–159
Rutherford O, Jones DA, Newham DJ (1986) Clinical and experimental application of the percutaneous twitch superimposition technique for the study of human muscle activation. J Neurol Neurosurg Psych, 49: 1288–1291
St-Pierre D, Taylor AW, Lavoie M, Sellers W, Kots YM (1986) Effects of 2500 Hz sinusoidal current on fiber area and strength of the quadriceps femoris. J Sports Med Phys Fitness, 26: 60–66
Selkowitz DM (1985) Improvement in isometric strength of the quadriceps femoris muscle after training with electrical stimulation. Phys Ther, 65: 186–196
Shafshak TS, El-Sheshai AM, Soltan, HE (1991) Personality traits in the mechanisms of interferential therapy for osteoarthritic knee pain. Arch Phys Med Rehab, 72: 579–581
Shanahan C, Ward AR, Robertson VJ (2006) Comparison of the analgesic efficacy of interferential therapy and transcutaneous electric nerve stimulation. Physiotherapy, 92: 247–253
Sinacore DR, Delitto A, King DS, Rose SJ (1990) Type II fiber activation with electrical stimulation: A preliminary report. Phys Ther, 70: 416–422
Sisk TD, Stralka SW, Deering MB, Griffin JW (1987) Effect of electrical stimulation on quadriceps strength after reconstructive surgery of the anterior cruciate ligament. Am J Sports Med, 15: 215–220
Snyder-Mackler L, Delitto A, Baily SL, Stralka SW (1995) Strength of the quadriceps femoris muscle and functional recovery after reconstruction of the anterior cruciate ligament. A prospective, randomized clinical trial of electrical stimulation. J Bone Joint Surg (A), 77: 1166–1173
Snyder-Mackler L, Delitto A, Stralka SW, Bailey SL (1994) Use of electrical stimulation to enhance recovery of quadriceps femoris muscle production in patients following anterior cruciate ligament reconstruction. Phy Ther, 74: 901–907
Snyder-Mackler L, Garrett M, Roberts M (1989) A comparison of torque generating capabilities of three different electrical stimulating currents. J Orthop Sports Phys Ther, 10: 297–301
Snyder-Mackler L, Ladin Z, Schepsis AA, Young JC (1991) Electrical stimulation of the thigh muscles after reconstruction of the anterior cruciate ligament. Effects of electrically elicited contraction of the quadriceps femoris and hamstring muscles on gait and on strength of the thigh muscles. J Bone Joint Surg (A), 73: 49–54
Soo CL, Currier DP, Threlkeld AJ (1988) Augmenting voluntary torque of healthy muscle by optimization of electrical stimulation. Phys Ther, 68: 333–337
Stephenson R, Johnson M (1995) The analgesic effects of interferential therapy on cold-induced pain in healthy subjects: A preliminary report. Physiother Theory Pract, 11: 89–95
Stephenson R, Walker EM (2003) The analgesic effects of interferential (IF) current on cold-pressor pain in healthy subjects: A single blind trial of three IF currents against sham IF and control. Physiother Theory Pract, 19: 99–107
Stevens JE, Mizner RL, Snyder-Mackler L (2004) Neuromuscular electrical stimulation for quadriceps muscle strengthening after bilateral total knee arthroplasty: A case series. J Orthop Sports Phys Ther, 34: 21–29
Switzer D, Hendricks O (1988) Interferential therapy for treatment of stress and urge incontinence. Ir Med J, 81: 30–31
Sylvester KL, Keilty SEJ (1987) A pilot study to investigate the use of interferential in the treatment of anorectal incontinence. Physiotherapy, 73: 207–208
Taylor K, Newton R, Personius W, Bush F (1987) Effect of interferential current stimulation for treatment of subjects with recurrent jaw pain. Phys Ther, 67: 346–350
Trimble MH, Enoka RM (1991) Mechanisms underlying the training effects associated with neuromuscular electrical stimulation. Phys Ther, 71: 273–280
Tugay N, Akbayrak T, Demirturk F, Karakaya IC, Kocaacar O, Tugay U, Karakaya MG, Demirturk F (2007) Effectiveness of transcutaneous

electrical nerve stimulation and interferential current in primary dysmenorrhea. Pain Med, 8: 295–300

Turkan A, Inci Y, Fazli D (2005) The short-term effects of physical therapy in different intensities of urodynamic stress incontinence. Gynecol Obstet Invest, 59: 43–48

Underwood FB, Kremser GL, Finstuen K, Greathouse DG (1990) Increasing involuntary torque production by using TENS. J Orthop Sports Phys Ther, 12: 101–104

Vahtera T, Haaranen M, Viramo-Koskela AL, Ruutiainen J (1997) Pelvic floor rehabilitation is effective in patients with multiple sclerosis. Clin Rehab, 11: 211–219

Van der Heijden G, Leffers P, Wolters P, Verheijden J, van Mameren H, Houben JP, Bouter LM, Knipschild PG (1999) No effect of bipolar interferential electrotherapy and pulsed ultrasound for soft tissue shoulder disorders: A randomized controlled trial. Ann Rheum Dis, 58: 530–540

Van Poppel H, Ketelaer P, Van-Deweerd A (1985) Interferential therapy for detrusor hyperreflexia in multiple sclerosis. Urology, 25: 607–612

Walker UA, Uhl M, Weiner SM, Warnatz K, Lange-Nolde A, Dertinger H, Peter HH, Jurenz SA (2006) Analgesic and disease modifying effects of interferential current in psoriatic arthritis. Rheumatol Int, 26: 904–907

Werners R, Pynsent PB, Bulstrode CJ (1999) Randomized trial comparing interferential therapy with motorized lumbar traction and massage in the management of low back pain in a primary care settings. Spine, 24: 1579–1584

Wigerstad-Lossing I, Grimby G, Jonsson T, Morelli B, Peterson L, Renstrom P (1988) Effects of electrical muscle stimulation combined with voluntary contraction after knee ligament surgery. Med Sci Sports Exerc, 20: 93–98

Williams RA, Morrissey MC, Brewster CE (1986) The effect of electrical stimulation on quadriceps strength and thigh circumference in menisectomy patients. J Orthop Sports Phys Ther, 8: 143–146

Wilson PD, Al-Samarrai T, Deakin M, Kolbe E, Brown AD (1987) An objective assessment of physiotherapy for female genuine stress incontinence. Br J Obstet Gyneacol, 94: 575–582

Zambito A, Bianchini D, Gatti D, Rossini M, Adami S, Viapiana O (2007) Interference and horizontal therapies in chronic low back pain due to multiple vertebral fractures: A randomized, double blind, clinical study. Osteoporos Int, 18: 1541–1545

Zambito A, Bianchini D, Gatti D, Viapiana O, Rossini M, Adami S (2006) Interferential and horizontal therapies in chronic low back pain: A randomized, double blind, clinical study. Clin Exp Rheumatol, 24: 534–539

Review Articles

Bax L, Staes F, Verhagen A (2005) Does neuromuscular electrical stimulation strengthen the quadriceps femoris? A systematic review of randomized controlled trials. Sports Med, 35: 191–212

Beatti A, Rayner A, Souvlis T, Chipchase L (2010) The analgesic effect of interferential therapy on clinical and experimental induced pain. Phys Ther Rev, 15: 243–252

Filipovic A, Kleinoder H, Dormann U, Mester J (2011) Electromyostimulation—a systematic review of the influence of training regimens and stimulation parameters on effectiveness in electromyostimulation training of selected strength parameters. J Strength Cond Res, 25: 3218–3238

Filipovic A, Kleinoder H, Dormann U, Mester J (2012) Electromyostimulation—a systematic review of the effects of different electromyostimulation methods of selected strength parameters in trained and elite athletes. J Strength Cond Res, 26: 2600–2614

Fuentes JP, Armijo-Olivo S, Magee DJ, Gross DP (2010) Effectiveness of interferential current therapy in the management of musculoskeletal pain: A systematic review and meta-analysis. Phys Ther, 90: 1219–1238

Glinsky J, Harvey L, van Es P (2007) Efficacy of electrical stimulation to increase muscle strength in people with neurological conditions: A systematic review. Phys Res Int, 12: 175–194

Gondin J, Cozzone PJ, Bendahan D (2011) Is high-frequency neuromuscular electrical stimulation a suitable tool of muscle performance improvement in both healthy humans and athletes? Eur J Appl Physiol, 111: 2473–2487

Hortobagyi T, Maffiuletti NA (2011) Neural adaptations to electrical stimulation strength training. Eur J Appl Physiol, 111: 2439–2449

Kim KM, Croy T, Hertel J, Saliba S (2010) Effects of neuromuscular electrical stimulation after anterior cruciate ligament reconstruction on quadriceps strength, function, and patient-oriented outcomes: A systematic review. J Orthop Sports Phys Ther, 40: 383–391

Maffiuletti NA (2010) Physiological and methodological considerations for the use of neuromuscular electrical stimulation. Eur J Appl Physiol, 110: 223–234

Maffiuletti NA, Minetto MA, Farina D, Bottinelli R (2011) Electrical stimulation for neuromuscular testing and training: State-of-the-art and unresolved issues. Eur J Appl Physiol, 111: 2391–239

Oh-oka H (2010) Neuromodulation in the treatment of overactive bladder with a focus on interferential therapy. Curr Bladder Dysfunct Rep, 5: 39–47

Roche A, Laighin GO, Coote S (2009) Surface-applied functional electrical stimulation for orthotic and therapeutic treatment of drop-foot after stroke—a systematic review. Phys Ther Rev, 14: 63–80

Selkowitz DM (2010) Electrical stimulation for enhancing strength and related characteristics of human denervated skeletal muscle. Phys Ther Rev, 15: 327–333

Ward AR, Shkuratova N (2002) Russian electrical stimulation: The early experiments. Phys Ther, 82: 1019–1030

Chapters of Textbooks

Alon G (1999) Principles of electrical stimulation. In: Clinical Electrotherapy, 3rd ed. Nelson RM, Hayes KW, Currier DR (Eds). Appleton & Lange, Stamford, pp 85–87

Hooke DN (1998) Electrical stimulating currents. In: Therapeutic Modalities for Allied Health Professionals. Prentice WE (Ed). McGraw-Hill, New York, pp 114–117

Prentice WE (2011) Location of motor points. In: Therapeutic Modalities in Rehabilitation, 4th ed. Prentice WE (Ed). McGraw-Hill Medical, New-York, pp 584–586

Robinson AJ (2008) Instrumentation in electrotherapy. In: Clinical Electrophysiology. Electrotherapy and Electrophysiological Testing, 3rd ed. Robinson AJ, Snyder-Mackler L (Eds). Lippincott Williams & Wilkins, Philadelphia, pp 57–58

Starkey C (2013) Motor Points. In: Therapeutic Modalities, 4th ed. Starkey C (Ed). FA davis, Philadelphia, pp 397–398

Internet Resource

http://thePoint.lww.com: Online Dosage Calculator: Neuromuscular Electrical Stimulation

UC San Diego

Katie L. Sepenoski
Library Document Delivery Specialist
ROPES & GRAY LLP
1211 Avenue of the Americas
New York, NY 10036-8704
USA

July 23, 2021

Dear Katie,

RE: Belanger, Alain. Therapeutic electrophysical agents: evidence behind practice. Philadelphia, Wolters Kluwer/Lippincott Williams & Wilkins Health, 2014. Third edition

According to our records, this item was received by the UC San Diego Library on March 25, 2014, and it would have been available for public use from that date.

Below is a screenshot of our library system which shows the title and the RDATE (Received date) field which indicates the date the item was received in the library.

Please note that we can only provide the date that the UC San Diego Library made this item available for public use; for the actual date of publication, please contact the publisher.

AUTHOR	Bélanger, Alain, author
TITLE	Therapeutic electrophysical agents : evidence behind practice / Alain-Yvan Bélanger, PhD, PT, Retired Professor, Laval University, Canada, owner and consultant, Physiométrix Inc
PUBLISHED	Philadelphia : Wolters Kluwer/Lippincott Williams & Wilkins Health, [2014]
PUBLISHED	©2014
IDENTIFIER	9781451182743 (pbk.)
IDENTIFIER	1451182740 (pbk.)
EDITION	Third edition
LIBRARY	bml

Summary | Record o12174166 | Receive o12174166 | Payments o12174166 | 0 Bib-Level Holds

☐ Queue P.O. | View Finances

o12174166 Last Updated: 03-31-2014 Created: 02-25-2014 Revisions: 4

ACQTYPE(O)	p	RENEWAL		RDATE	03-25-2014

Yours sincerely,

Judea Darnaud

Judea d'Arnaud
Interim Program Director, Content Acquisition and Resource Sharing
UC San Diego Library
jdarnaud@ucsd.edu

The Library • Communications & Engagement
University of California, San Diego • 9500 Gilman Drive # 0175G • La Jolla, California 92093-0175
Tel: (858) 534-3060 • Fax: (858) 534-6193 • library.ucsd.edu

From: "Wolters Kluwer Customer Service" <customerservice@lww.com> <customerservice@lww.com>
Sent: Thursday, July 22, 2021 9:13 AM
To: Sepenoski, Katie
Subject: RE: CCH Question [Case # 04009204] [ref:_00Dd0dixc._5003w1WWXVN:ref]

[EXTERNAL]

Dear Ms. Sepenoski,

Thank you for contacting Wolters Kluwer Health Learning, Research & Practice.

We are showing that the Therapeutic Electrophysical Agents: Evidence Behind Practice 3rd edition was published and became available on January 10th, 2014.

If you have any additional questions, please use the Online Help Center. For a full list of departments, contact phone numbers, and hours of operations, please click here.

Thank You,
Lori G.
Wolters Kluwer
Health Learning, Research & Practice

For our full line of products and services, please visit our online store at https://shop.lww.com.

Hi Katie,

It turns out that I can't help you as the publisher is Lippincott Williams & Wilkins. I have copied their customer service email address.

Will you be able to help Katie with a Statement of Public Availably for both the 2nd and 3rd editions of Therapeutic Electrophysical Agents: Evidence Behind Practice by Alain Yvan Belanger?

Thanks,

Theresa Paluch
CVP Account Administration
Legal & Regulatory, U.S.
2700 Lake Cook Road
Riverwoods, IL 60015
773-866-3534
theresa.paluch@wolterskluwer.com<mailto:theresa.paluch@wolterskluwer.com>
www.WoltersKluwerLR.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.wolterskluwerlr.com%2F&data=02%7C01%7CTheresa.Paluch%40wolterskluwer.com%7Ce225b3f421054d3ee94108d70ed4ae1a%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C636994178925613193&sdata=MLzrYF69sysF2ThPwVDBMYvrmneelc3iQ0s%2FfvPjNoU%3D&reserved=0>
[https://wolterskluwer.pmail7.com/PoliteMail6/images/logo_signature.jpg]<https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwolterskluwer.pmail7.com%2FPoliteMail6%2Fdefault.aspx%3Fpage%3DIgOcLmGJhkKJo17mxovIjw%26ref_id%3D38_3k2TILESLj4AHOnNrlA&data=02%7C01%7CTheresa.Paluch%40wolterskluwer.com%7Cb00dc2bdfec844c332e908d70c73aec3%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C636991563297310866&sdata=hDCpaKFt%2BtLisBXej4h%2B4xpjxRsMYBa1%2F6dVyr6MWRo%3D&reserved=0>
Join Wolters Kluwer on Facebook Twitter Linkedin Youtube

From: Sepenoski, Katie <Katie.Sepenoski@ropesgray.com>
Sent: Wednesday, July 21, 2021 3:23 PM
To: Paluch, Theresa <Theresa.Paluch@wolterskluwer.com>
Subject: RE: CCH Question

Hi Theresa,

Yes! Of course! They are looking for both the 2nd and 3rd editions of Therapeutic Electrophysical Agents: Evidence Behind Practice by Alain Yvan Belanger.

Thank you,
Katie

Katie L. Sepenoski
Library Document Delivery Specialist
ROPES & GRAY LLP
T +1 212 596 9456 | M +1 857 210 2662
1211 Avenue of the Americas
New York, NY 10036-8704
Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>
www.ropesgray.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.ropesgray.com%2F&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078700513%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=lAxNznC1HaRfwDrwr5TWgciM2d1czhQ3red0KFfeRlk%3D&reserved=0>

From: Paluch, Theresa <Theresa.Paluch@wolterskluwer.com<mailto:Theresa.Paluch@wolterskluwer.com>>
Sent: Wednesday, July 21, 2021 4:18 PM
To: Sepenoski, Katie <Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>>
Subject: RE: CCH Question

Thanks for the quick response Katie! But now I have a follow-up question. Can you provide a list of the specific title or titles?

Theresa Paluch
CVP Account Administration
Legal & Regulatory, U.S.
2700 Lake Cook Road
Riverwoods, IL 60015
773-866-3534
theresa.paluch@wolterskluwer.com<mailto:theresa.paluch@wolterskluwer.com>
www.WoltersKluwerLR.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.wolterskluwerlr.com%2F&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078700513%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=vM420QOA%2FFkc%2Bm5TQI3%2FxM49w%2FJFG5PnNi7lDS%2FRp3s%3D&reserved=0>
[https://wolterskluwer.pmail7.com/PoliteMail6/images/logo_signature.jpg]<https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwolterskluwer.pmail7.com%2FPoliteMail6%2Fdefault.aspx%3Fpage%3DIgOcLmGJhkKJo17mxovIjw%26ref_id%3D38_3k2TILESLj4AHOnNrlA&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078710506%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=3nNKAm65WcQn%2BqcHn6WpJU%2F%2FsGGLg1LsEiVFU5X5pU4%3D&reserved=0>
Join Wolters Kluwer on Facebook Twitter Linkedin Youtube

From: Sepenoski, Katie <Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>>
Sent: Wednesday, July 21, 2021 3:11 PM
To: Paluch, Theresa <Theresa.Paluch@wolterskluwer.com<mailto:Theresa.Paluch@wolterskluwer.com>>
Subject: RE: CCH Question

Hi Theresa,

We have copies of the sections of the book we need (purchased). But yes, we essentially need a declaration or statement of public availability to shown when a book may have officially been publically available.

Katie

Katie L. Sepenoski
Library Document Delivery Specialist
ROPES & GRAY LLP
T +1 212 596 9456 | M +1 857 210 2662
1211 Avenue of the Americas
New York, NY 10036-8704
Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>
www.ropesgray.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.ropesgray.com%2F&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078720500%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=3ka0KDAx9V2Bce24Xz9RND2%2FJq8LjVHeLJnW02UKbuE%3D&reserved=0>

From: Paluch, Theresa <Theresa.Paluch@wolterskluwer.com<mailto:Theresa.Paluch@wolterskluwer.com>>
Sent: Wednesday, July 21, 2021 4:06 PM
To: Walsh, Ellen <Ellen.Walsh@ropesgray.com<mailto:Ellen.Walsh@ropesgray.com>>; Sepenoski, Katie <Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>>
Subject: RE: CCH Question

Hi Ellen & Kate,

Thank you and I'll do my best to find someone that can help. I've started asking around and I have a question from my management.

Can you confirm that you are "alluding to a list of public libraries (or other locations) that have a current copy of the title"?

Thanks,

Theresa Paluch
CVP Account Administration
Legal & Regulatory, U.S.
2700 Lake Cook Road
Riverwoods, IL 60015
773-866-3534
theresa.paluch@wolterskluwer.com<mailto:theresa.paluch@wolterskluwer.com>
www.WoltersKluwerLR.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.wolterskluwerlr.com%2F&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078720500%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=cj0ooy0CeDyWR23SQ8OWuLe%2F%2FXLJRG168aaR%2F9JXvOM%3D&reserved=0>
[https://wolterskluwer.pmail7.com/PoliteMail6/images/logo_signature.jpg]<https://nam04.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwolterskluwer.pmail7.com%2FPoliteMail6%2Fdefault.aspx%3Fpage%3DlgOcLmGJhkKJo17mxovIjw%26ref_id%3D38_3k2TILESLj4AHOnNrlA&data=04%7C01%7CTheresa.Paluch%

40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078730499%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=c%2FNhULBGYX0rkkCTVm5iVHYzMo34OeVrConVLWpmQpg%3D&reserved=0>
Join Wolters Kluwer on Facebook Twitter Linkedin Youtube

From: Sepenoski, Katie <Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>>
Sent: Wednesday, July 21, 2021 2:56 PM
To: Walsh, Ellen <Ellen.Walsh@ropesgray.com<mailto:Ellen.Walsh@ropesgray.com>>
Subject: CCH Question

Hey Ellen,

The Declaration drama continues…

Do you have a good contact at Wolters Kluwer that could point me in the direction of someone who might be able to help me with a Statement of Public Availably for a book they published? I have some libraries working on the declarations / statements, but David mentioned that WK (the publisher) might also be willing to create something.

Thanks!
Katie

Katie L. Sepenoski
Library Document Delivery Specialist
ROPES & GRAY LLP
T +1 212 596 9456 | M +1 857 210 2662
1211 Avenue of the Americas
New York, NY 10036-8704
Katie.Sepenoski@ropesgray.com<mailto:Katie.Sepenoski@ropesgray.com>
www.ropesgray.com<https://nam04.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.ropesgray.com%2F&data=04%7C01%7CTheresa.Paluch%40wolterskluwer.com%7C3a563f1ff7e846a3849308d94c856493%7C8ac76c91e7f141ffa89c3553b2da2c17%7C0%7C0%7C637624958078750486%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C1000&sdata=AKtlshZqJrr9K88JxV7z35ZoPvzRWASQvtRFyV5UiC8%3D&reserved=0>