SOFT TISSUE DAMAGE AND HEALING: THEORY AND TECHNIQUES

A. Mechanisms of Injury

Many factors produce mechanical injuries or trauma in sports. Soft tissue damage occurs through direct or indirect trauma to muscles, ligaments, and joint capsules. Usually, direct trauma refers to an injury occurring from blunt trauma or a sudden overload, and is known as macrotrauma, i.e., true muscle tear or ligament sprain. In contrast, indirect trauma results from repeated submaximal loading, leading to clinical signs and symptoms. Injury presents itself in three stages: acute, subacute/overuse, and acute/chronic.

The first, or acute, stage of direct trauma stems from sudden overloading, or macrotrauma (e.g. a 100 meter runner exploding out of the starting blocks). The subacute/overuse stage occurs when increased loads degenerate body tissues due to excessive cumulative loading, leading to microtrauma and an accompanying inflammatory response (e.g. achilles tendinitis in the endurance athlete or runner, Figure 9-1). The last type, acute/chronic stage, integrates both cumulative loading and sudden overloading (e.g. chronic achilles tendinosis that ruptures in a long jumper). Chronic tendinosis is a degenerative condition without inflammation.

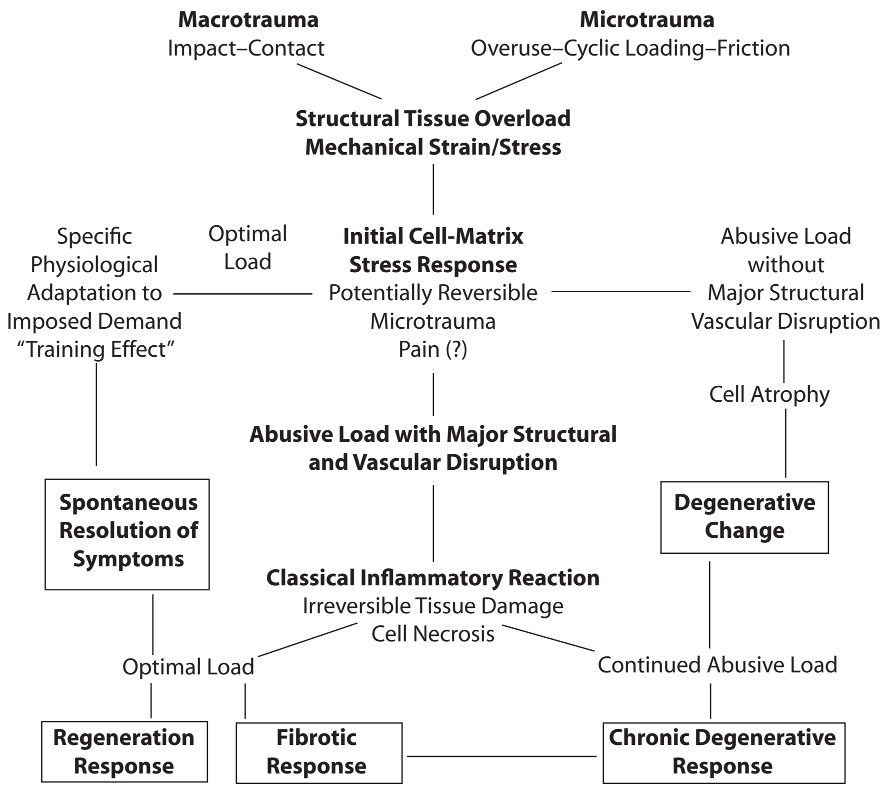

Figure 9-1. Schema demonstrating theoretical pathways of sports-induced tissue damage.

Whether muscle injury is caused by direct or indirect trauma, the end result is tissue dysfunction characterised by pain, inflammation, and altered internal tissue stress. The injury often results in functional disability, whereby an athlete may be able to carry on daily living routines, but is limited in his or her capacity to train and compete.

Any activity loads and deforms tissue, an effect known as a stress/strain, and described through a load and tissue elongation curve. As connective tissue is deformed it either stretches or tears, depending on the magnitude, rate, and intensity at which the loading occurs. Collagen deforms under low loading and fails at high loads. When the load is removed from normal tissue during the elastic phase, the material returns to its pre-stretch length. Injury occurs when the tissue is stretched into the plastic phase, causing tissue failure.

Of all the tissues involved, tendon is the least elastic. The most frequent site of injury in muscle strains is the myotendinal junction, because of increased collagen content at the transition zone of muscle sheath to tendon. This area has decreased local extensibility, as does scar tissue, and is frequently termed a stress riser. This transition in biologic tissues, which also appears at the tendoperiostial junction, is a point that is more susceptible to stress and injury.

The relatively new term "tendinopathy" has been adopted as a general clinical descriptor of tendon injuries in sports. In overuse clinical conditions in and around tendons, frank inflammation is infrequent and if seen, is associated mostly with tendon ruptures. Tendinosis implies tendon degeneration without clinical or histological signs of intratendinous inflammation, and is not necessarily symptomatic. The term "tendonitis" is used in a clinical context and does not refer to specific histopathological entity. Tendonitis is commonly used for conditions that are truly tendinosis, however, and leads athletes and coaches to underestimate the proven chronicity of the condition.

Paratendonitis is characterised by acute oedema and hyperemia of the paratendon with infiltration and inflammatory cells, and possibly the production of a fibrinous exsudate with the tendon sheath causing a typical crepitus, which can be felt on clinical examination.

The term "partial tear of the tendon" should be used to describe the macroscopically evident partial tear of a tendon. This is an uncommon acute lesion. Most articles describing the surgical management of partial tears of a given tendon in reality deal with degenerative tendinopathies. The combination of pain, swelling, and impaired performance should be labeled tendinopathy. According to the tissues affected, the terms tendinopathy, paratendinopathy, or pantendinopathy (from both the tendon and the surrounding tissues involved) should be used.

B. Examining Soft Tissue Injuries

Examination for injury in soft tissues such as muscle involves initial palpation with minimal force or compression (in the case of acute injuries), and progresses to firmer compression or higher loads if increased density has not been distinguished

or pain has not been provoked at the site of the suspected lesion (see Table 9-1 for examination steps). One can also have the athlete contract the muscle to increase the tension or passively stretch the myotendinal unit while palpating the area. The pain associated with palpation is secondary to the stimulation of free nerve endings with inflammation, decreased extensibility of tissue, or tissue insufficiency.

While palpating muscle tissue, one should search carefully through various layers of tissue to find remnants of injuries and healing. Subtle tissue texture abnormalities may exist, and might be missed if the tissue were examined erratically. These abnormalities must be considered in formulating an assessment. However, the clinician must avoid going too deep or hard with palpation, using pain as a guideline.

The clinician needs to apply pressure and to sense the reactivity of the tissue. Since scar tissue heals three dimensionally, it does not fall into place like a brick. Instead, scar tissue reaches in the direction of the fascia and the neighbouring muscle sheaths, binding these tissues together. For example, when a runner strains a hamstring, the sheath tear heals and binds to neighbouring muscle sheath. The hamstring muscle group still functions to flex the knee, yet the athlete complains of dull ache or pain in the posterior thigh. The reason may be that independent movement has been lost and the area of scar tissue has limited the extensibility of the myotendinal unit. Muscles do function and limbs do move, but the normal gliding that occurs between neighbouring tissues is lost. As a result, there is a constant low-grade inflammatory process at the site of the decreased mobility. Scar tissue has a poor blood supply and is not as strong or resilient as the primary tissue it replaces. This area will likely be a site of re-injury secondary to the transition zone of normal tissue to scar tissue.

Table 9-1. Examination of soft tissue injury.

1. History
   - onset
   - pain location
   - mechanism of injury
   - prior treatment and rehabilitation
   - goals of athlete
2. Physical exam
   - inspection
   - AROM/PROM
   - palpation
   - neurological; myotome, dermatome, peripheral nerve tests, deep tendon reflexes
   - strength and motor control
   - special tests
   - functional exam
   - gait analysis
3. Assessment
4. Treatment goals
5. Treatment plan
6. Treatment procedures

C. The Wound Healing Process

1. Reaction: The Inflammatory Phase

This first phase can last up to 72 hours, and involves a number of inflammatory responses, manifested by pain, swelling, redness, and increased local temperature. Accumulation of exsudate and oedema begins the process of tissue repair following injury when a blood clot forms and seals the area. In musculotendinous injuries, there is myofilament reaction and peripheral muscle fiber contraction within the first two hours. Oedema and anoxia result in cell damage and death within the first 24 hours, and the release of protein breakdown products from damaged cells leads to further oedema, tissue hypoxia, and cell death. Oedema and joint swelling, with or without pain, is associated with a reflex inhibition of spinal activation of skeletal muscle. Phagocytosis then begins to rid the area of cell debris and oedema.

2. Regeneration and Repair: The Fibro-elastic/Collagen-forming Phase

This phase lasts from 48 hours up to 6 weeks. During this time structures are rebuilt and regeneration occurs. Fibroblasts begin to synthesise scar tissue. These cells produce Type III collagen, which appears in about four days, and is random and immature in its fiber organisation. Capillary budding occurs, bringing nutrition to the area, and collagen cross-linking begins. As the process proceeds, the number of fibroblasts decreases as more collagen is laid down. This phase ends with the beginning of wound contracture and shortening of the margins of the injured area.

3. Remodelling Phase

This phase lasts from 3 weeks to 12 months. Gradually, cross-linking and shortening of the collagen fibers promote formation of a tight, strong scar. It is characterised by remodelling of collagen so as to increase the functional capabilities of the muscle, tendon, or other tissues. Final aggregation, orientation, and arrangement of collagen fibers occur during this phase.

Regeneration of the injured muscle does not fully restore muscle tissue to its prior levels, as fibrous scar tissue slows muscle healing. The two processes of healing and fibrosis compete with each other and impair complete regeneration. Transforming Growth Factor–Beta 1(TGF-β1) is an ubiquitous substance that initiates a cascade of events that activate both myogenesis and fibrosis.

Measures that may block fibrosis have been shown experimentally to alter the effects of TGF-β1 on the fibrotic process. Decorin is a proteo-glycan that impedes fibrosis by combining with TGF-β1. Suramin is an anti-parasitic drug that competes with TGF-β1 for its binding sites to the growth factor receptor. Interferon gamma disrupts the pathways involved in TGF-β1 signal transduction, and when given i-m 1–2 weeks after an injury improved muscle function in animal models. All of these agents are under active study, and have undergone clinical trials.

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Principles of Rehabilitation of the Injured Athlete

A. Rehabilitation: A Definition

A rehabilitation programme should be designed with individual short-term and long-term goals in mind. The overall programme and individual exercises should progress safely and effectively. Rehabilitation clinicians should know how to assess the patient's status, incorporate therapeutic modalities and exercises, and evaluate the program's outcomes. In general, the process of rehabilitation can be defined as the restoration of normal anatomical and physiological function (see Table 9-2 for a summary of steps involved in rehabilitation).

The rehabilitation process of an injured athlete may be divided into stages. This is convenient, but it should be noted that the boundaries between these stages are not clearly defined. Biological systems are more than just assemblages of discrete units: variability, overlap, and interaction are the rule and not the exception. From a pathophysiologic standpoint, tissue injuries can be conveniently divided into three stages or phases. For each phase, occurrences at the cellular level and their consequences at the system level determine the scientific rationale on which the rehabilitation plan is based. It is very important to understand the basic pathophysiology of each stage since our therapeutic interventions depend on it (see Part 1 of this chapter, *Soft Tissue Damage and Healing: Theory and Techniques,* for additional details).

Understanding the pathomechanics of injury through background knowledge in anatomy and biomechanics is critical in defining a rehabilitation programme. Using therapeutic modalities will enhance the athlete's chance of a safe and rapid return to competition. Use of medications to facilitate healing may aid the healing process. Understanding the concept of the kinetic chain as an integrated functional unit involving muscles, tendons, bones, ligaments, fascia, articular, and neural system will be essential for the evaluation and rehabilitation of a particular biomechanical movement or task.

Injury/illness produces a variety of emotional responses, demanding the clinician's understanding of the psychological aspect of rehabilitation. Therapeutic exercise is essential in athletic conditioning, injury prevention, and rehabilitation. Implementing rehabilitation tools will avoid the "cookbook" approach to rehabilitation.

B. Stages of a Sports-Related Injury: The Bases for Rehabilitation

1. Stage 1: Acute Inflammatory Phase

The first phase of most sports-related injuries is characterised by an inflammatory reaction that involves pain, redness, swelling, and an increased local temperature that can last up to 72 hours. Initial treatment of this phase usually includes some form of immobilisation or restriction of motion. It should be remembered, however, that immobilisation can cause early and significant negative effects on various organs and physiological systems. For example, metabolic processes leading to muscle catabolism, atrophy, and weakness of the quadriceps muscle start as early as 6 hours

Table 9-2. Summary of rehabilitation goals and treatment plan.

Goals

Physiological

Importance of Controlling Swelling
- Initial injury management and swelling control is critical

Reestablishing Neuromuscular Control

Restoring Range of Motion

Restoring Muscular Strength, Endurance and Power
- Isometric Exercise
- Isotonic Exercise
- Isokinetic Exercise
- Progressive Resistive Exercise
- Open versus Closed Kinetic Chain Exercises

Maintaining Cardiorespiratory Fitness

Functional

Restoring Postural Control and Stability
- Plyometric Exercise
- Core Stabilisation

Functional Progression
- Restore endurance and activity tolerance
- Regain ability to return to athletics with or without modifications and/or appliances

Treatment Plan

Therapeutic Exercises

- Strength training; isometrics, dumbbell, cuff weights, 'Theraband', surgical tubing, concentric/eccentric contractions, isotonic and isokinetic equipment, Swiss ball and plyometrics, and PNF (proprioceptive neuromuscular facilitation) exercises
- Stretching; active, passive, and PNF techniques
- Joint mobilisation
- EMG Biofeedback

Procedures

- Functional activities
- Neuromuscular re-education
- Gait training

Modalities

- Hot pack
- Cold pack
- Laser/Light Therapy
- Aquatherapy
- Ultrasound
- Electrical stimulation
- Iontophoresis
- Phonophoresis

Traction

- Manual or mechanical traction

Massage

- Soft tissue mobilisation

after immobilisation of the knee joint. Any rehabilitation modality—such as heat or deep massage—that may enhance or potentiate the inflammatory reaction, and thus slow the healing process, should be avoided. In addition, we should consider the psychological effects of injury. The post-injury period is very difficult for the competitive athlete whose goal is to return to the sport as soon as possible. It is important to provide the athlete with the details of the injury, and explain possible consequences, the importance of the rehabilitation process, and the prognosis and time frame regarding the return to competition.

2. Management and Rehabilitation of Stage 1

Rehabilitation goals during the first phase are as follows: 1) protect the athlete from further injury; 2) control pain; 3) limit swelling; and 4) promote normal healing. Therapeutic and rehabilitative strategies appropriate for this stage include pharmacologic intervention, use of physical modalities, immobilisation, and therapeutic exercise.

a. Pharmacological Intervention

The most frequently used drugs include non-steroidal anti-inflammatory medications, analgesics, local anesthetics, and in some cases injectable corticosteroids. The rationale, indications, and contraindications for use of these drugs are discussed elsewhere in this manual.

b. Physical Modalities

The most important physical therapy modality used in this stage is cryotherapy (cold therapy), usually accompanied by protection, rest, ice, compression, elevation, and support; this combination is commonly called the P.R.I.C.E.S. therapy (see also Chapter 8, Part 2, *First Aid Management of Acute Sports Injuries*, and Part 3 of this chapter, *Therapeutic Modalities*). Cold helps reduce tissue temperature, decrease blood flow and swelling, produce vasoconstriction, and alleviate pain and muscle spasm. In general, crushed ice should be used. Compression using an elastic bandage and elevation of the extremity above the level of the heart may help control swelling. Another modality used to alleviate pain at this stage is transcutaneous electrical nerve stimulation (TENS), which is sometimes applied in combination with ice (see Part 3 of this chapter, *Therapeutic Modalities*).

c. Immobilisation

As mentioned above, this stage may require the immobilisation of a joint or an extremity. Immobilisation accelerates formation of granulation tissue, limits scar size, and improves penetration of fibers through connective tissue, but as mentioned previously it also has negative effects. Early mobilisation increases tensile tissue strength, improves orientation of regenerating muscle fibers, stimulates resorption of connective tissue scar, improves recapillarisation, and decreases muscle atrophy and weakness.

d. Therapeutic Exercise

Therapeutic exercise may be beneficial during this early stage to minimise deconditioning and to promote rapid transition to the second stage. If symptoms permit, exercises to increase range of motion and static (isometric) exercises to minimise strength loss may be started in the injured part and related muscles. Conditioning of the uninjured body parts should be instituted. Transition to this second stage varies with the type and severity of injury. In general, it is desirable to start the second phase as soon as possible to promote faster recovery and return to training and competition.

3. Stage 2: Regeneration and Repair—The Fibro-Elastic/Collagen-Forming Phase

The second stage of an athletic injury is called the repair or fibroblastic phase. This phase lasts from 48 hours up to 6 weeks. During this time structures are rebuilt and regeneration occurs. Fibroblasts begin to synthesise scar tissue. The nature of the functional losses will determine the selection of therapeutic modalities and exercises needed for this phase. This is a risky period because the absence of pain may tempt the athlete (or the coach) to return to training and competition before the injured tissues are fully rehabilitated.

4. Management and Rehabilitation of Stage 2

The rehabilitation goals in the second phase are to: 1) allow normal healing (similar to the first phase); 2) maintain function of uninjured parts; 3) minimise deconditioning of the athlete; 4) increase joint range of motion or flexibility; 5) improve muscle strength, local muscular endurance, and power; 6) increase aerobic capacity and power; and 7) improve proprioception, balance, and coordination. These goals can be achieved by physical therapy and therapeutic exercise.

a. Physical Modalities

Physical modalities can be of great benefit during this stage (see Part 3 of this chapter, *Therapeutic Modalities*). Heat has been shown to increase temperature, blood flow, and extensibility of soft tissue. Therefore, heating modalities are useful at the start of the rehabilitation session and before stretching exercises are done. Hydrocollator packs, laser lamps, hydrotherapy with warm water, fluidotherapy and paraffin baths are used to increase the temperature of superficial tissues.

Ultrasound and short wave diathermy are examples of deep heat modalities. Ultrasound has been shown to enhance the tensile strength of healing tendons.

Electrical stimulation is another useful modality during this stage. Since the patient may still have pain and joint swelling, activation of motor units may be less than optimal. Electrical stimulation may enhance motor unit recruitment during exercise and facilitate muscle training.

b. Therapeutic Exercise

The most important component of rehabilitation during this stage (and perhaps all stages) is exercise training. The type of exercise used depends on the objective. For example, recovery of normal range of motion requires

stretching or flexibility exercises. Restoring flexibility should be a priority because later strength and aerobic conditioning may depend on first achieving full joint range of motion. As mentioned previously, stretching is more effective when tissues are warmed beforehand, which may require assistance from a therapist. A thorough stretching routine including all major parts of the body should be completed daily.

Muscle strength can be developed using different types of muscle actions and equipment. Muscle actions can be classified as static (isometric) or dynamic (isotonic and isokinetic). Both have been shown to induce adaptations in skeletal muscle function and can be useful in different clinical situations. Dynamic muscle actions can be further divided into concentric and eccentric groups, both useful for conditioning. Recent evidence suggests that eccentric actions may be more effective, but must be used with caution due to the common effect of muscle soreness.

Methods or equipment used for strength conditioning include maximal voluntary contractions at different joint angles with no joint movement (static training), electrical stimulation during voluntary contractions (see Part 3 of this chapter, *Therapeutic Modalities*), gravity, resistance of the therapist, free weights, "isotonic" equipment such as pulleys and benches, surgical tubing, isokinetic equipment, and variable resistance equipment.

Rehabilitation strength conditioning requires a prescribed training plan outlining the type, intensity, duration, and frequency of exercise. Appropriate action and equipment depends on the clinical condition of the athlete (for example, if there is joint swelling, use static exercises with electrical stimulation). To induce significant gains in strength, exercise intensity should be above 60–80% of the one repetition maximum of the athlete. Usually, three sets of 8–10 repetitions are performed with each repetition including concentric and eccentric muscle actions. Free weight and machine weight lifting contain both concentric and eccentric muscle contractions. Each muscle group is usually trained three times per week.

Early strength gains are due to neurological factors, while muscle hypertrophy occurs only after several weeks of training. Restoration of optimal strength may require 3–6 months while maintenance training at a lower frequency (twice per week) should be a permanent component of the programme (see Stage 3: Remodelling Phase, below).

Local muscular endurance can be developed using exercises and equipment similar to those used to develop strength. The classical approach to developing tolerance to fatigue is to use lighter loads (less than 60% of the athlete's one repetition maximum) and higher repetitions (20 or more). Actually, strength conditioning contributes to muscular endurance. A stronger athlete can tolerate a higher absolute load for a longer period of time since that load represents a smaller percentage of his/her maximum strength. The relevance of local muscular endurance training depends on the particular demands of the event. It is more important to the sprinter and middle-distance runner than the long-distance runner or discus thrower.

Aerobic conditioning should be part of the rehabilitation programme for all athletes at this stage. Cycling (stationary), swimming, and rowing improve aerobic capacity and promote recovery of full joint range of motion. The exercise

programme should consider the type of exercise, intensity (60–85% of maximal heart rate), duration (20–60 minutes as tolerated), and frequency (3–5 times per week).

Rehabilitation during this stage should include exercises to develop proprioception, coordination, and balance. In particular, injuries to the ankle and knee joints can affect proprioception. Although the majority of this training occurs during the third phase, it can be started here.

c. Tissue Mobilisation in the Healing Process

The goal of mobilising soft tissue in the healing process is to reintroduce a controlled stress as the scar matures in an attempt to influence its final form and function. Non-mobilised scar tissue heals in an irregular formation, whereas tissues mobilised with modified stress heal with parallel fiber arrangement. This parallel fiber arrangement demonstrates more elastic qualities, whose redundant folds allow mobility without irritation or pain. Examples of good healing are gliding tendons and lengthy, elongated adhesions. Conversely, examples of poor healing are restricted tendons and short, dense adhesions.

Soft tissue mobilisation will not remove scar tissue, yet it will help restore more normal properties to that tissue. Soft tissue mobilisation is performed like massage, but is much more specific. The clinician uses his or her fingertips to identify the lesion, to monitor tissue changes, and to perform the treatment. When applying soft tissue mobilisation as a treatment choice, the clinician needs to identify the area of increased density, then distinguish the borders and document the feel and density of the tissue. The ability of the tissue to tolerate loading will give the clinician an idea of the level of reactivity and state of healing.

Two of the approaches to load application are:

- “Beach Erosion”: Application of a low load to gradually change the tissue density and promote remodelling.
- “Tidal Storm”: A high, forceful load to break adhesions; this is more applicable to old, dense scar.

When performing either of these techniques, the clinician should use an oil-based cream or lubricant to decrease dermal irritation. The clinician should make sure to clean the skin with alcohol after treatment to prevent possibility of dermal irritation.

Exercise in the form of controlled early mobilisation has been effective in minimising adhesions during healing. Exercise may cause injury; controlled exercise, however, will contribute to resolution and help prevent further injury.

5. Stage 3: Remodelling Phase

The third stage in the rehabilitation of a sports-related injury is called the remodelling phase. This phase lasts from 3 weeks to 12 months. It is characterised by remodelling of collagen so as to increase the functional capabilities of the muscle, tendon, or other tissues.

Critical issues to be considered during this phase are residual strength deficits in individual muscles, imbalance between agonist and antagonist groups of muscles, side to side asymmetry, loss of sports specific skills, and the need for a gradual return to training and competition as determined by the severity of the injury and the duration of the two preceding phases.

6. Management and Rehabilitation of Stage 3

The third stage of the rehabilitation process is characterised by the return of the athlete to training and competition. The rehabilitation goals of this stage are continued conditioning, development of sports-specific skills, and prevention of further injury. During this stage, the athlete returns to the training programme—physical conditioning, technical and tactical training, and psychological preparation—designed by his or her coach. Communication between health professionals and coaches is critical at this stage. Sports-specific exercises, drills, and technical skills must be re-introduced gradually depending upon the severity of the injury and the duration of the first two phases of rehabilitation. If possible, the therapist should attend a training session and evaluate the functional capacity of the athlete.

The return to competition is the final goal of rehabilitation, but several criteria must be considered before allowing the athlete to compete. These include the absence of symptoms, normal flexibility, adequate strength (90% of the uninjured side), and the ability to perform. Finally, to prevent recurrence of the injury, general conditioning should be maintained.

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Part 3

Therapeutic Modalities

The basic rule of therapeutic modality use is, “There is no cookbook protocol!”. Although the proceedings make general statements, it is still the practitioner’s knowledge that guides his or her clinical decision-making. The injuries that athletes incur are just as individual as the athletes themselves. Approach each injury as a separate entity and utilise the knowledge and clinical decision-making abilities to formulate a treatment protocol (Figure 9-2).

It is imperative to address safety issues in regards to therapeutic modality use. As healthcare practitioners, it is understood and expected to “cause no harm.” Precautions must be taken in all instances so that a situation of healing does not become a situation of harm. Each therapeutic modality introduced in this chapter will be accompanied by safety measures and possible side effects.

As every inventor and invention offers a new therapeutic modality, manufacturers attempt to package the device as a convenient option for the busy healthcare practitioner. While this chapter will review basic tenets of therapeutic modality usage, remember that today’s market offers a plethora of various models and types of therapeutic modalities, all with different characteristics. This chapter does not take the place of the operator’s manual published for each specific modality.

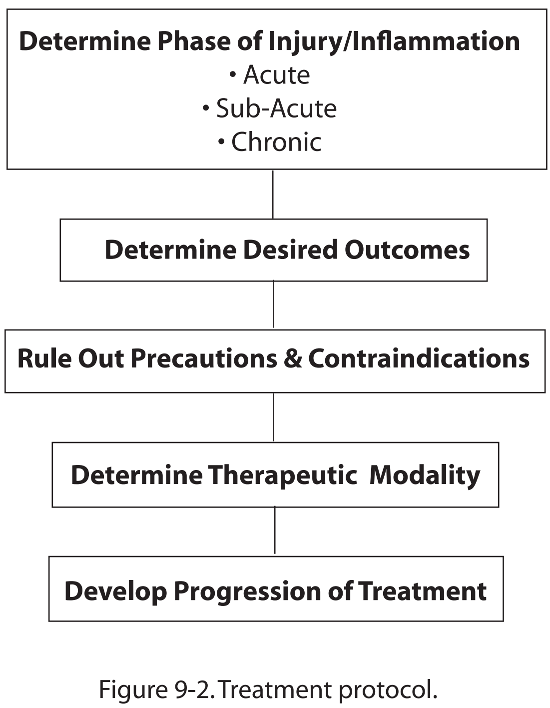

Figure 9-2. Treatment protocol.

A. Patient Preparation

1. Conduct a Thorough Evaluation

Along with the basic injury evaluation process, the clinician should review basic history of previous therapeutic modality treatments.

a. Has the athlete ever had ______?
b. If so, what was their reaction?
c. How many treatment sessions were needed?
d. Were there any negative outcomes?
e. Did the treatment work?
f. What medications are they presently taking?
g. Does the athlete have a history of any medical illness?

2. Observe

Inspect the area to be treated for any obvious precautions or contraindications such as:

a. Open wounds
b. Skin abrasions
c. Rash of unknown origin
d. Desensitised areas
e. Surgical implants (i.e., fixation devices)

B. Therapeutic Modality Set-up

After selecting the therapeutic modality, prepare the treatment area and modality equipment so that the athlete is safe, comfortable, and the area being treated is not compromised. If the modality chosen requires assistance, the clinician situates oneself so that they are comfortable as well (this becomes important when conducting an ultrasound treatment, for instance). The clinician should be able to access the therapeutic modality at any point during the treatment session to change parameters or cease the treatment.

C. Patient / Athlete Preparation

The area to be treated should be exposed and observable by the clinician at all times. In areas of discretion, sheets, towels or privacy curtains may be used.

D. Modalities

1. Hydrocollator

One of the most common forms of thermotherapy, the hydrocollator pack is typically used as a superficial heating therapeutic modality.

Indications: Chronic pain, muscular spasm, tissue extensibility, increasing blood flow.

Precautions: Thermal hypersensitivity.

Contraindications: Acute inflammation, malignancy, desensitised skin.

Preparation: Position the athlete so that the area to be treated is exposed. Do not allow athlete to position him or herself on top of Hydrocollator pack. Body weight decreases the tissue interface (area between modality and tissue) and increases heat conduction, thereby increasing risk for burns. The clinician should prepare the heating pack by applying six layers (i.e., towels) between the pack and the athlete.

Treatment Duration: 15–20 minutes or until heat has dissipated.

After Application: The clinician should monitor the athlete's reaction to treatment and manually check area underneath the hydrocollator pack at five minute intervals to prevent risk of burn. A post-treatment skin check should also be done.

2. Hydrotherapy (Warm Whirlpool)

Whirlpool units vary in size according to possible body parts able to be treated. Whirlpool units should be maintained at a temperature of 98°–108°F (37°–43°C) and checked periodically for tolerance. Care and appropriate measures must be taken when treating a body part that presents with open lesions or abrasions. The whirlpool should be thoroughly cleansed and disinfected prior to and post-treatment.

Indications: Pain, muscular spasm, tissue extensibility.

Precautions: Thermal hypersensitivity.

Contraindications: Malignancy, desensitised skin.

Treatment Duration: 15–20 minutes.

Preparation: Position the athlete on an elevated stool or seat depending on area to be treated. Allow athlete to acclimate him or herself to temperature.

After Immersion: The clinician should monitor the athlete's reaction to treatment and manually check area to prevent risk of burn. A post-treatment skin check should also be done.

3. Paraffin Bath

Paraffin wax can be used as a thermal agent for the extremities such as the hands and feet. Paraffin wax has a low melting point and specific heat that allows the athlete to gradually heat the extremity with low risk of burn. Paraffin wax should be mixed with mineral oil in order to ensure proper heating. The ratio of paraffin wax to mineral oil is 7:1 and temperature of the basin should be maintained at 48º–51°C (120º–125°F).

Indications: Chronic pain, muscular spasm, tissue extensibility, increasing blood flow.

Precautions: Thermal hypersensitivity, allergy to mineral oil or wax.

Contraindications: Acute inflammation, malignancy, desensitised skin.

Preparation: Athlete must thoroughly wash extremities to be treated and

remove all jewelry and accessories from the area. A towel and plastic bag should be prepared next to the athlete. The two most commonly used techniques include the multiple dip method and the dip and wrap method.

After Application: The clinician should monitor the athlete's reaction to treatment and observe the area for adverse reaction after the wax has been removed. The wax may be placed back in the basin and used again if uncontaminated.

4. Ultrasound

Ultrasound is a deep heating agent that utilises acoustic sound waves to generate mechanical disruption of tissues. Possible effects of ultrasound include deep tissue heating and non-thermal tissue manipulation. The parameters of common ultrasound units found in the athletic healthcare setting may be changed in order to achieve desired outcomes. The physical nature of acoustic energy generated from an ultrasound transducer has many clinical considerations.

The size of the transducer head should be chosen in regard to the structure being treated. If the area to be treated is larger that 2 to 3 times the transducer, the clinician should re-evaluate the choice of modality or protocol. Many ultrasound units' transducer size varies from 1 cm^2 to 10 cm^2.

Effective Radiating Area (ERA) determines the actual area where radiating energy is transmitted. The ERA is less than the actual size of the transducer; therefore the clinician should incorporate this ratio when determining appropriate transducer size.

Frequency is commonly referred to as the number of wave cycles completed per second. Ultrasound frequencies found on most units range from 1 MHz to 3 MHz (2 MHz is offered on some units). The lower the frequency, the deeper the ultrasound beam penetrates. Therefore, 1 MHz is used as a deep heating frequency (2–5 cm) while 3 MHz is used to heat superficial structures (1–2 cm).

Duty Cycle is the ratio of "on" to "off" periods of time while the ultrasound unit is actively transmitting energy. Selecting a continuous setting indicates that the transducer is transmitting acoustic energy 100% of the time and producing thermal effects. Common "Pulsed" intervals ranging from 20–50% can also be selected to produce non-thermal effects of ultrasound. Intensity is the amount of acoustic energy that the ultrasound unit is producing over a given area. It is proportional to the area being treated as seen with Spatial Average Intensity (referring to the amount of energy watts) the ultrasound unit is producing over the spatial area of the transducer head. This parameter is measured in watts per squared centimeter, or w/cm^2. As one can see, this is a combination of both intensity and area and can be affected by choosing different intensities or transducer sizes.

Beam Non-uniformity Ratio (BNR) is an indication of the ultrasound beam's depth and homogeneity of energy transmitted across the transducer. One might imagine an uneven jagged mountain range as the area of the transducer head and the largest peak occurring in the range as the peak intensity of the beam. A low ratio,

such as 2:1, indicates that when using an intensity of 1 w/cm², the peak intensity of the ultrasound beam will reach as high as 2 w/cm². When using a unit with a larger BNR, the risk for developing "hot spots" or areas of intense heat increases. Clinicians must be aware of these factors to avoid burning the athlete and potentially causing more tissue damage.

Modality Preparation–Ultrasound

The clinician should position the ultrasound unit proximal to and on the athlete's affected side. Generous amount of ultrasound transmitting media, such as an aqueous gel, should be applied to the area and to the surface of the transducer to assure proper coverage. The gel increases the energy transmission of the ultrasound transducer and prevents reflection of acoustic energy. Other forms of liquid media have been identified to effectively transmit ultrasound waves. Alternative forms of media include a fluid filled bladder or underwater immersion. The parameters for the specific treatment session should then be selected (see Table 9-3 and Figure 9-3).

Athlete Preparation: The athlete should be seated or positioned comfortably so that the area to be treated can be accessed with the transducer head. The clinician should educate the athlete on the ultrasound treatment and instruct them to offer feedback as to how the treatment is progressing.

Indications (Thermal effects): Tissue extensibility, chronic pain, muscular spasm, increasing blood flow, inducing inflammatory response to resolve chronic injury.

Indications (Non-thermal Effects): Increase local metabolism, increase tissue-healing factors, bone healing.

Precautions: Units possessing a high BNR, thermal hypersensitivity, allergy to gel or transmission media.

Contraindications: Acute inflammation (thermal), malignancy, desensitised skin, eyes, reproductive organs and fluid filled cavity organs, epiphyseal plates, infection.

Treatment Method: The clinician should place the transducer head over the transmission gel and apply approximately 5–10 foot/lb of pressure and begin moving the transducer head in concentric circles at a slow steady pace making sure to stay within the imaginary 2–3 transducer sizes of the effective treatment area. The clinician should gather continual feedback from the athlete as the treatment progresses. Any indication of uneven heating or areas of intense heat should be assessed by the clinician.

5. Phonophoresis

A clinician might wish to add an anti-inflammatory medication to the coupling medium to solicit its effects combined with therapeutic ultrasound. Phonophoresis is the process by which ultrasound waves promote transdermal tissue absorption of the medication. It is believed that increasing local tissue metabolism and increasing vascular permeability allow for effective transmission of the medication into the

Table 9-3. Range of temperature increases at various intensities.

Intensity	**1 MHz**	**3 MHz**
0.5	0.04 C/min	0.3 C/min
1.0	0.2 C/min	0.6 C/min
1.5	0.3 C/min	0.9 C/min
2.0	0.4 C/min	1.4 C/min

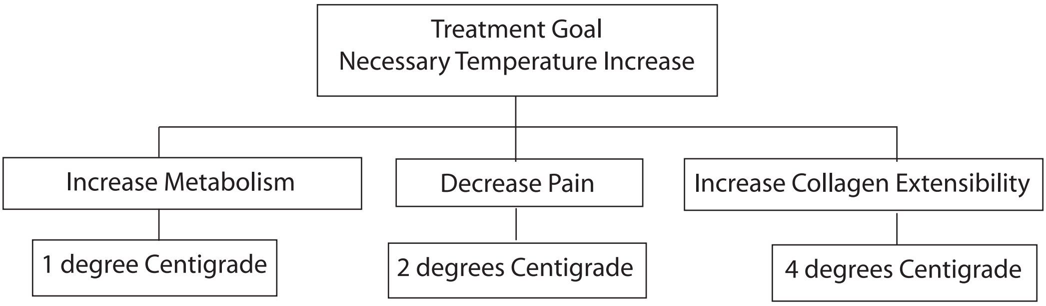

Figure 9-3. Ultrasound protocol.

blood stream. Phonophoresis has been shown to be effective when conducting both pulsed and continuous (100% duty cycle) ultrasound treatments, depending on whether heating the tissue is indicated. The procedures to conduct the ultrasound are the same, although duration might have to be increased to allow proper absorption. The clinician must be aware of the legal ramifications of using a prescription medication and act accordingly to laws and regulations. Some commonly used medications are 10% Hydrocortisone, salicylates and lidocaine.

6. Cryotherapy

Ice is a highly effective first aid agent. The application of ice to an acute (rapid onset) injury will decrease blood flow to the injured area resulting in reduced pain and decreased swelling. The body's natural response to a traumatic injury is to rush blood to the site of injury. Application of ice causes capillary constriction and reduces blood flow, and decreases the release of inflammatory cytokines. This means less blood is released into the injured area, resulting in less swelling and a quicker healing time.

Remember, heat has the opposite effect and will increase blood flow to the injured area, increasing swelling and delaying the healing time. Heat should only be applied after the swelling and discoloration have been resolved, which is usually 2 days from the time of the initial injury. Guidelines for cryotherapy include the following:

- The application of ice to the affected area should begin as soon as possible.
- Apply the ice for 20 minutes at a time. Ice for no longer than 20 minutes at one time. Icing beyond 20 minutes offers no additional benefit. In fact, due

to a reflex vasodilation, the body will start to produce heat to the affected area, reversing the benefits of icing, resulting in increasing swelling and delaying the healing process. The application of ice can be repeated at least 3 times a day or more, but a 30 minute rest period of no icing needs to follow every ice treatment.

- Ice can be applied via ice bag, ice cups, frozen gel packs or cold whirlpool treatment. In the cases of gel packs and whirlpool treatments the affected area needs to be covered. In the use of ice bags or ice cups, no barrier is required.
- Elevate the area above the heart during the cold application treatment when possible.
- During the application of an ice treatment it is normal to experience the sensations of cold, burning, pain, and numbness. Redness will be present, but will subside in 15 minutes following the treatment. However, some individuals have an adverse reaction to cold and develop severe pallor (Raynaud's Syndrome) or even blisters.
- Never constrict blood flow when icing. Remove or loosen tight articles of clothing or tight tape surrounding the affected area. Also, ice bags should be applied on top of the affected area, verse lying on the ice. This can constrict blood flow.

a. Ice Pack

One of the most conventional therapeutic modalities, an ice pack can provide analgesia and prevent further swelling incurred from trauma. Both commercially made synthetic ice packs and natural ice-filled bags can be used in instances of inflammation.

Indications: Acute inflammation, chronic inflammation, hyperemia, excessive swelling.

Precautions: Hypersensitivity to cold.

Contraindications: Desensitised skin, allergic reaction to cold.

Athlete Preparation: Athlete should be lying down on treatment table in comfortable position so that injured area may be elevated. The clinician should apply the ice pack over the injured area and secure in place with an elastic bandage adding compression to the affected area. After application of the elastic bandage, the clinician should initially check for uninhibited circulatory flow distal to the injury site.

During Treatment: The clinician should monitor the athlete's feedback while the ice pack is applied and manually check for any adverse skin reactions to treatment.

Treatment Duration: Approximately 15–20 minutes.

Post Treatment: Remove ice pack and bandage and visually inspect area for adverse reactions brought on by exposure to cold. When applying commercial ice packs, it is important to check the integrity of the pack as many are made with harsh chemicals that might affect the skin.

b. Cold Whirlpool

Use of cold-water immersion has shown benefits of pain modulation and decreases in swelling by allowing active range of motion. Whirlpool units should be maintained at a temperature of 50°–60°F (10°–15.5°C) and checked periodically for tolerance. The athlete should not rest an extremity on the whirlpool in such a way that normal blood flow could be occluded. Care and appropriate measures must be taken when treating a body part that presents with open lesions or abrasions. The whirlpool should be thoroughly cleansed and disinfected prior to and post-treatment.

Indications: Pain, muscular spasm, prevent or decrease swelling.

Precautions: Hypersensitivity to cold.

Contraindications: Infection, desensitised skin.

Preparation: Position the athlete on an elevated stool or seat depending on area to be treated. Allow athlete to acclimate him or herself to temperature.

Treatment Duration: 15–20 minutes.

After Immersion: The clinician should monitor the athlete's reaction to treatment and manually check area to prevent adverse skin reaction. A visual inspection of the skin should also be performed following the treatment session.

c. Ice Cup

An ice cup decreases the tissue interface of the modality between the skin, has an equivalent temperature of ice, and provides for a mild massaging effect of the traumatised tissue. The effective area of an ice cup is small in comparison to other cryo-therapeutic devices.

Indications: Acute inflammation, chronic inflammation, hyperemia.

Precautions: Hypersensitivity to cold, large injured area.

Contraindications: Desensitised skin, allergic reaction to cold.

Athlete Preparation: Athlete should be lying down on the treatment table in a comfortable position so that injured area may be elevated. The clinician should apply the ice cup to the skin and begin stroking the ice cup over the injured area.

During Treatment: The clinician should monitor the athlete's feedback while the ice cup is moved over the area of trauma and manually check for adverse skin reactions to treatment.

Duration of Treatment: Approximately 10–15 minutes. Ice cup treatments can be considerably shorter due to the temperature of the modality.

Post Treatment: Remove ice cup and visually inspect area for adverse reactions brought on by exposure to cold. A general erythema or hyperemia over the treated area is normal in this case.

7. Electrical Stimulation

The use of electricity to treat pathology is a complex concept and should be further examined from the standpoint of physics and physiology. This section deals with the practical skills clinicians might use in the athletic healthcare setting when using electrical stimulation. As with all therapeutic modalities, extreme care and prudence must be priorities when treating an injury with electrical currents. It is wise for the clinician to experience the various types of electrical currents used in their facility to gain an appreciation of the specific device's capabilities and sense the athlete's perception of the treatment.

Choosing parameters is usually dictated by the feedback garnered from the athlete or the effects observed by the clinician (i.e., muscle contraction). The ranges associated with the following electrical currents should be used as starting points. The treatment goals determined by the clinician must be the deciding factor when selecting parameters on the modality (Figures 9-5–9-8). Parameters are specific to the device and manufacturer, but common elements of many electrical modalities include:

Intensity: amplitude of current
Pulse frequency: number of pulses per interval of time (minute)
Pulse duration: length of time of an individual pulse
Polarity: dominant net charge of a current

Indications: Pain modulation, wound healing, muscle re-education, oedema reduction, muscle recruitment, peripheral nerve injury.

Contraindications: Pacemakers, cancerous lesions, hemorrhage, pregnancy, metal implants in treatment area.

Athlete Preparation: The athlete's skin should be clean and excess hair should be cut short, but not shaved, to allow proper contact between the electrodes and the skin. Athlete should be positioned so that electrodes can be placed comfortably surrounding injury. The athlete should be educated about the effects of electrical stimulation and possible sensations they might experience.

a. Interferential Current (IFC)

Interferential current generates two high frequency waves from two separate channels in a quadpolar arrangement (four electrodes) to penetrate the initial impedance of the skin. The two carrier waves (varying in range from 4000–5000 Hz) eventually cross each other within the tissue producing a resultant wave or frequency (commonly 1–100 Hz). The resultant wave is a lesser frequency and effective in neuromuscular stimulation.

Indications: Pain, increase venous flow, muscle re-education.

Precautions: Skin irritation, hypersensitivity to electricity.

Contraindications: Dermatological diseases, idiopathic pain, cardiac pacemakers, thrombophlebitis, electrical current crossing the spine.

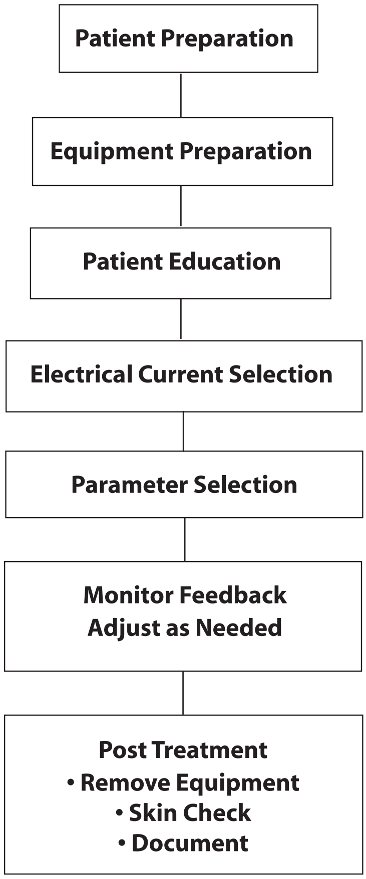

Figure 9-4. Electrical stimulation protocol.

Electrode set up: When conducting a quadpolar IFC treatment, pairs of electrodes should be placed on opposite ends of the injury site so that a crossing "X" pattern is formed.

During Treatment: The clinician should monitor the athlete's feedback and be sure that the sensations the athlete is experiencing are in line with the intended treatment goals. Any deviation should be noted and adjusted appropriately.

Post Treatment: Remove equipment, conduct a skin check and document treatment.

b. Premodulated Current

The premodulated current is a form of interferential current albeit, using a bipolar (two-electrode) set-up. The resultant wave is created within the generator and transmitted through the electrodes into the tissue. The same indications, contraindications, and parameters apply for premodulated current. The clinician must incorporate body part and size when deciding between IFC and premodulated modalities.

Treatment Duration
20–30 minutes

Intensity
1–100 mA

Beat Frequency
0–299 Hz

Sweep Frequency
10–500 microseconds

Figure 9-5. Premodulated current protocol.

c. Transcutaneous Electrical Nervous Stimulation (TENS)

To dispel any confusion, TENS is a "non-specific" term that refers to all forms of electrical stimulation. However, there are small, portable, battery powered units referred to as TENS units.

Indications: Pain.

Precautions: Same as for electrical currents.

Contraindications: Same as for electrical currents.

Electrode set up: TENS units consist of two channels, both able to supply two leads (electrodes). The clinician must be aware of the injury location and size in order to choose electrode placement.

Treatment Duration
15–30 minutes

Intensity
0–100 mA

Beat Frequency
1–150 pulses per second

Pulse Duration
10–500 microseconds

Figure 9-6. TENS protocol.

During Treatment: The clinician should slowly increase intensity until the athlete can feel the current. The clinician should then monitor the athlete's feedback and be sure that the sensations the athlete is experiencing are in line with the intended treatment goals (i.e., pain control). Any deviation should be noted and adjusted appropriately.

Post Treatment: Remove equipment, conduct a skin check and document treatment.

d. High Voltage Pulsed Current (HVPC)

A form of functional electrical stimulation, HVPC is commonly used to induce a motor response (i.e. muscle contraction) but can also be used for sensory stimulation (i.e., pain modulation) and oedema control. HVPC is a monophasic current that requires the use of a dispersive pad.

Indications: Muscle re-education, muscle strengthening, increased blood flow, pain, and wound healing.

Precautions: Same as for electrical currents.

Contraindications: Movement would worsen injury**,** same as for electrical currents.

Electrode set up: The clinician must decide what polarity the active electrode will be according to the treatment goal. A dispersive electrode, typically 2–3 times the size of the active electrode, should be placed on the ipsilateral side of the injury.

During Treatment: The clinician should slowly increase intensity until the athlete can feel the current and observable contractions are noted. The clinician should then monitor the athlete's feedback and be sure that the sensations the athlete is experiencing are in line with the intended treatment goals (i.e., muscle contraction). Any deviation should be noted and adjusted appropriately.

Post Treatment: Remove equipment, conduct a skin check and document treatment.

Treatment Duration
15–30 minutes

Intensity
1.5 mA

Pulse Frequency
1–200 pulses per second

Pulse Duration
5–100 microseconds

Phase Duration
20–45 microseconds

Figure 9-7. HVPC protocol.

e. Russian Current

Another form of functional electrical stimulation, Russian stimulation has been recorded to have effective results in motor muscle contraction and re-education. Peripheral nerve injury, disuse atrophy and post-surgical cases have shown improvements in muscle recruitment. The pulses of Russian current are grouped into bursts and delivered to the tissue in 5:1 intervals. This process allows for a smooth, pain-free muscle contraction.

Indications: Muscle re-education, muscle strengthening.

Precautions: Same as for electrical currents.

Contraindications: Movement could worsen injury, same as for electrical currents.

Electrode set up: The clinician should become acquainted with neuromuscular motor points of the affected muscle(s) and apply the electrodes accordingly.

During Treatment: The clinician should slowly increase intensity until the athlete can feel the current and an observable contraction is noted. The clinician should then monitor the athlete's feedback and be sure that the sensations the athlete is experiencing are in line with the intended treatment goals (i.e., muscle contraction). Any deviation should be noted and adjusted appropriately.

Post Treatment: Remove equipment, conduct a skin check and document treatment.

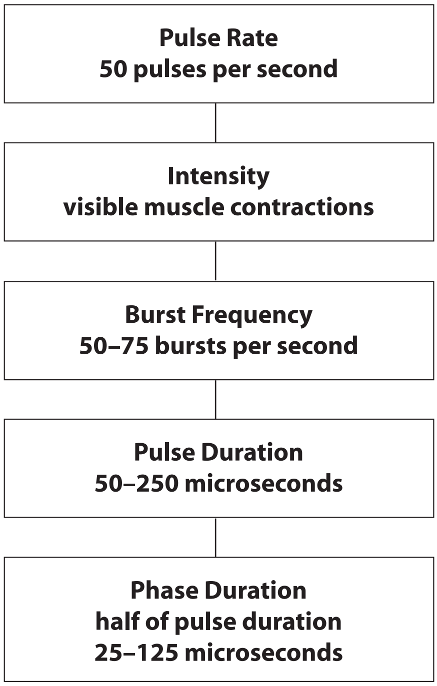

Figure 9-8. Russian current protocol.

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