Chapter 22

Rehabilitation in Sports Medicine

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INTRODUCTION

Perhaps when the team physician thinks about rehabilitation, he or she may not automatically consider its application to initial injury management. Rehabilitation begins at the time of injury and continues beyond the time the athlete returns to competition. What is done at field side may be more relevant to the athlete's recovery of musculoskeletal health than at any other time. We will discuss briefly the basic principles, phases, and techniques of rehabilitation. While they will be introduced individually, one must remember that rehabilitation occurs on a continuum with much overlap. For example, there is no sharp cutoff between acute and subacute management techniques. The team physician must regularly re-evaluate the athlete's status and progress him or her appropriately. Comprehensive management uses multiple approaches. Additional approaches can be added or deleted based on the athlete's response.

Our review summarizes the different modalities, medications and therapy techniques and the rationale for their use in the rehabilitation of sports injuries. The team physician chooses which modality to use based on the specific injury and feasibility. Athlete's require a rehabilitation approach that is based on physiologic principles, is directed by the individual's response, and goes beyond resolution of the acute injury to prevent repeat injury. It is important to note that the quality of the scientific evidence that supports the use of modalities and techniques in rehabilitation is variable.

The following are principles to guide sports rehabilitation: minimize damage/inflammation/pain at the site of injury; promote healing; maintain/increase range of motion (ROM); prevent atrophy/increase strength; maintain/increase endurance; facilitate functional recovery; and avoid maladaptive compensatory movement patterns.

Pathophysiology of Injury and Repair

Knowledge of the pathophysiology of tissue injury and the healing process are important in planning for treatment. The healing process involves three stages: the inflammatory stage; the fibroblastic-repair stage; and the maturation-remodeling stage. Understanding the chemical and physiological events can help the practitioner to select rehabilitation interventions that maximize restorative events and minimize maladaptive responses. One must identify the tissues injured and the extent of the injuries. Previous chapters of this book review diagnosis and management of injury by anatomic location. Injury classification guides the rehabilitation process. For instance, a fracture of the radius requires different management than a soft tissue injury of the forearm such as wrist extensor tendinitis.

THE STAGES OF INJURY

The Inflammatory Stage

The inflammatory response lasts for 2 to 4 days. It presents clinically as increased warmth, redness, swelling, and tenderness. The initial trauma to the tissue or primary injury is followed by secondary injury resulting from hypoxia and enzymatic activity. At the time of injury, a cascade of events is set into motion. After a 5-10 minute period of vasoconstriction, a locally mediated influx of cells presents at the injury site. Chemical mediators such as histamine from mast cells increase membrane permeability and vasodilatation. Phagocytic cells and leukocytes invade the area. Waste products are broken down and removed via local and vascular effects. At the site of vessel injury, platelets adhere to the exposed collagen fibers starting clot formation. Fibrin clot formation ensues via the cascade stimulated by thromboplastin. Eventually, a walling off effect facilitates the healing process. Clot formation begins about 12 hours post-injury and is complete within 48 hours.

Initial rehabilitation techniques focus on minimizing the inflammatory response. This is done to prevent further loss of function and to decrease pain. The influx of inflammatory mediators is necessary to keep up with the metabolic demands and remove waste products. This prepares for the fibroblastic-repair stage of healing. However, the resulting inflammation and tenderness can

cause impairments in strength, joint range of motion, endurance, and tissue mobility. If left unchecked these impairments can become a significant problem for the athlete. An exuberant inflammatory response can also compress tissues adjoining the injury widening the extent of the injury.

Let's consider the example of a soccer player with knee swelling. Swelling in the tibiofemoral and patellofemoral joint space can mechanically limit joint ROM. Inhibition of quadriceps contraction in the setting of knee effusion occurs via central mechanisms. If the effusion persists untreated, significant impairment in knee strength results. Pain can lead to muscle spasm and disuse. These impairments cause a disability in gait and sports specific movement patterns. A rehabilitation approach that limits the knee effusion, increases tibiofemoral and patellofemoral ROM, and improves quadriceps strength is the most effective.

The Fibroplastic-Repair Stage

The fibroplastic-repair stage begins during the inflammatory response and continues for the next 4 to 6 weeks. It starts by scar filling in the injury defect. The fibrin clot is replaced with granulation tissue made up of collagen and fibroblasts. Critical nutrients are delivered via new capillaries. The collagen fibers are randomly laid down in an extracellular matrix of proteins and ground substance produced by the fibroblasts. The tensile strength of the scar is based on the collagen deposition.

Let's consider a complete rupture of the Achilles tendon treated non-surgically in a tennis player. Application of a cast will control inflammation and enhance scar formation. By about three weeks, a firm strong non-vascular scar exists. After three weeks of complete immobilization, the tendon should be ready for a controlled remobilization process. Impairments minimally include decrease soft tissue mobility, loss of foot and ankle ROM, decreased strength of the foot and ankle muscles and limited ankle proprioception. Disabilities in position changes, gait, and sports specific movement patterns are to be expected. The rehabilitation process must address all of these issues.

The Maturation-Remodeling Stage

The maturation-remodeling stage begins as the tensile strength of the scar tissue increases and fibroblast activity declines. During this stage, stress on the collagen fibers causes them to realign in parallel to the forces applied, via Wolff's law. It may take months to years to normalize the strength of the tissue. Controlled mobilization at this time maximizes the reorientation of healing fibers, ultimately resulting in improved tensile strength and function. Pain can guide the rate of progression of stress on the remodeling tissue. While pain may be significant during the inflammatory response, it will typically subside during the repair and remodeling stages. Any exacerbation of pain in this stage indicates that the rehabilitation program is too stressful on the tissue for the level of maturation attained.

Let's consider an overhead-throwing athlete with a partial tear of the supraspinatus tendon. In the maturation-remodeling stage, rehabilitation will shift to activity that will apply strain to the tendon along lines of tensile force parallel to the movements he will use in throwing. This can be achieved initially with bilateral activities like overhead toss with an exercise ball. This limits the degrees of freedom at the glenohumeral joint and the workload. A progression could include the same activity with a medicine ball or done unilaterally. Ongoing impairments in soft tissue mobility, glenohumeral and scapulothoracic ROM, scapular and upper extremity musculature strength, and shoulder proprioception must be addressed.

Sports specific training is necessary for neuromuscular reeducation in addition to tissue remodeling.

MEDICATIONS IN SPORTS MEDICINE

A comprehensive discussion of the medications used in sports medicine is beyond the scope of this chapter. Pharmacologic agents are used to minimize inflammation and provide analgesia. This allows the athlete to get on with the rehabilitation program. The use of medications to limit inflammation, control pain and limit muscle spasm is appropriate. There are multiple agents that are routinely used with injured athletes. These include the following categories: analgesics; non-steroidal anti-inflammatory drugs (NSAIDS); and muscle relaxants. The use of corticosteroids in the setting of athletic injury is controversial and will not be addressed.

Analgesics

Pure analgesic agents are used to decrease pain to allow participation in an active rehabilitation program as early as feasible. Centrally acting agents in the opioid group are used for a short course in severe pain. However, narcotics are banned substances by the International Olympic Committee. Acetaminophen is a peripheral analgesic without anti-inflammatory action. Because it does not interfere with prostaglandin synthesis, prostaglandin-related toxicities like gastric ulceration do not occur. In patients in which NSAID use is contraindicated, acetaminophen can be substituted.

Aspirin in low doses has an analgesic and anti-pyretic effect. In higher doses, it demonstrates significant gastrointestinal side effects. It also impairs platelet aggregation and can increase the bleeding associated with the initial injury.

Non-Steroidal Anti-Inflammatory agents (NSAIDS)

NSAIDS are the most frequently prescribed medication in the setting of sports medicine. They directly affect the inflammatory cascade by blocking the conversion of arachidonic acid to prostaglandin by inhibiting the action of cyclooxygenase. The main side effect, causing morbidity and mortality, is gastric ulceration. There is some theoretical concern that NSAID use may slow or delay healing by interfering with the inflammatory response but clinical studies with humans have not proven this. Newer NSAIDS and enteric-coated aspirin cause fewer gastrointestinal side effects. A more selective group of NSAIDS has been developed, the COX 2 Inhibitors, which block only a subset of cyclooxygenase enzymes. While they demonstrated a more limited gastrointestinal side effect profile, some studies have demonstrated a significant cardiovascular thrombogenic potential with particular COX 2 Inhibitors. Efficacy between different NSAIDS is user dependent and involves manner factors.

Muscle relaxants

Muscle relaxants are frequently prescribed in addition to an analgesic agent or NSAID. In the short run, reduction in muscle spasm is in keeping with other goals of the acute rehabilitation period. Sedation is the major side effect that may limit patient tolerance; they may be helpful acutely to improve sleep.

MODALITIES

The team physician can order many different physical modalities to treat athletes. Refer to Table 22.1 for an overview of modalities. The guiding principle for their use should be minimizing injury and time away from sport. They are helpful in managing pain and edema and promoting healing. A thorough understanding of the indications, contraindications, and expected physiological response ensures appropriate utilization. They are an adjunct to care and do not provide a cure. They do not replace active exercise and are used to promote activity. This philosophy should be conveyed to the coach and the athlete being treated. Coaches and athletes can be instructed in the proper use of modalities; some modalities require direct set up and monitoring by the physical therapist or athletic trainer. (Fig. 22.1)

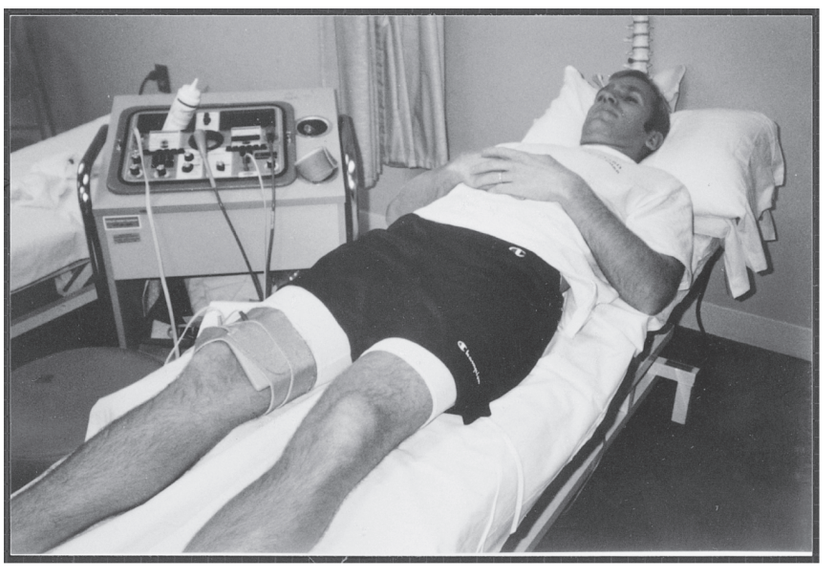

Fig. 22.1 Interferential current: electrotherapy modality requiring direct set-up and supervision.

Modalities can be grouped in the following way: cold, heat, electricity, and traction. Hydrotherapy can be used for both cold (cryotherapy) or heat transfer. Aquatherapy is a hybrid agent and will be discussed after exercise. An athlete can exercise in the water while benefiting from the modality.

Table 22.1 Modalities used in sports medicine

Modality	Physiologic Effects	Indications for Use	Contraindications
Superficial Cold	Slow nerve conduction ↓ blood flow due to cutaneous vasoconstriction ↓ firing muscle spindle and GTO* ↓ collagenase activity & ↓ collagen distensibility	Analgesia, ↓ pain ↓ swelling ↓ muscle spasm	Raynaud's phenomenon Cryoglobulinemia Cold allergy (cold based urticaria) Anesthetic skin PVD*/aortic insufficiency
Superficial Heat	Sedation and general relaxation ↑ blood flow via vasodilatation ↑ collagenase activity	↓ pain ↑ tendon distensibility & ↓ joint stiffness ↑ metabolism and tissue temperature	Impaired sensation Bleeding diathesis Directly over fetus, gonads Malignancy Impaired circulation Acute inflammation
Deep Heat	Same as superficial heat	Same as superficial heat	Near brain, eyes, heart, gravid uterus Near spine laminectomy site Skeletal immaturity/growth plate Methyl methacrylate High density polyethylene Near pacemaker
Electrotherapy	Promote muscle relaxation ↑ local blood flow Stimulate muscle contraction Drive ions into skin	↓ pain & ↓ muscle spasm Promote tissue healing ↓ disuse atrophy ↓ edema	Proximity to cardiac sinus, eyes, fetus Pacemakers Anesthetic skin Area with metal
Traction	Distract cervical vertebral facet joints Stimulate joint mechanoreceptors Elongate and improve blood flow to paraspinal muscles Decrease intradiscal pressure	Improve healing by nutrition of articular cartilage ↓ pain ↓ muscle guarding Improve alignment	Acute inflammation Lesion compromising spinal stability, for example: neoplasm, spondylolisthesis, spinal infection, rheumatoid arthritis

* Explanations for abbreviations: GTO = Golgi Tendon Organ; PVD = Peripheral Vascular Disease

Cold Modalities

Superficial Cold

Cold therapy or cryotherapy is a very helpful modality in the sports medicine practice. There are multiple applications of cryotherapy. Ice massage is using an ice cube or lolly to apply ice directly to the inflamed tissue with gentle stroking for 5-10 minutes. It combines the effects of cooling with massage. Crushed ice can be placed in a plastic bag to make an ice pack. Commercially available gel or silicon cold pack cooled in a freezer to -12°C can be applied. Packs are applied for 10-30 minutes at a time while monitoring tolerance. A compressive bandage may enhance the effect. Immersion in cold water provides circumferential cooling of a limb via convection with water temperature 4-10°C. Cryotherapy-compression units combine cold therapy and pneumatic compression. A cuff is used for 10-30 minutes through which cold water circulates while static or serial pneumatic compression is applied.

Heat Modalities

Superficial Heat

Superficial agents penetrate less than 2 centimeters. Maximal tissue temperatures are in skin and subcutaneous fat. Hydrocolllator pads are an example of superficial conductive heat transfer. They are made of silicone oxide in a canvas cover and immersed in water at 77 °C. They are applied with a layer of towels and maintain heat for about 30 minutes. Electric heating pads and paraffin are two other examples of superficial heating via conduction.

Whirlpool bath immersion is an example of a superficial heating modality that transfers energy via convection. The water temperature is based on the extent of the body immersed. For a distal limb, up to 45 °C is tolerated. For immersion to the waist, up to 41°C is tolerated. Maintaining a water temperature below 38°C is appropriate with immersion of most of the body or in a patient with cardiac precautions. Detergent or iodine can be added to the whirlpool for wound care. Fluidotherapy is another convective superficial heating agent. Like whirlpool, it allows active range of motion but provides protection from skin contamination. Cornhusks are circulated by warm air in an enclosed container with the extremity in an isolated sheath.

Deep heat

Deep heating agents penetrate deeper than 2 centimeters. Maximal temperatures are beneath the subcutaneous tissue with conversion to heat at the bone-muscle interface. There is a smaller margin between therapeutic temperature range and temperature for potential thermal injury. The thermal pain threshold is 45°C while the therapeutic goal temperature is 40°C.

Ultrasound is an example of a deep heating agent. Molecular vibration is converted to heat, which penetrates 6-8 centimeters. Dosage is expressed as intensity. The usual therapeutic intensity range is 0.5-3.0 W/cm^2. Ultrasound can be delivered via continuous or pulsed output and it is typically applied with a stroking technique. Non-thermal effects such as cavitation, media motion, and standing waves must be considered. Ultrasound waves can be used to deliver biologically active molecules into tissue via phonophoresis. Short wave diathermy is another deep heating modality where electromagnetic energy is converted to thermal energy. Its use is limited by its significant side effects including interference with pacemakers and focal heating of metal.

Electrical Modalities

Electrotherapy has been used for centuries. Muscle and nerve respond differently to electrical stimulation. The team physician can take advantage of this and use different therapeutic electricity techniques. Depending on the goal of therapy, an agent is chosen. There are many types to choose between, with either alternating current (AC) or direct current (DC). The parameters such as waveform, amplitude, and duration can be manipulated. Transcutaneous electrical nerve stimulation (TENS) is used to treat painful conditions, with either local or segmental electrode placement depending on the underlying condition. High voltage galvanic stimulation (HVGS) transmits higher voltage with higher peaks than traditional TENS. This allows for deeper tissue penetration. Neuromuscular electrical stimulators (NMES) are used to maintain strength, limit atrophy, and re-educate injured muscles. Interferential current is used to increase blood flow in the region of intersecting waveforms and can be applied in conjunction with electrical muscle stimulation, with a massage effect. Neuroprobe can be used over motor points or trigger points as well as acupuncture points. It produces anesthesia via hyperstimulation. Percutaneous electrical nerve stimulation (PENS) is applied via acupuncture needles. Iontophoresis involves driving biologically active agents through the skin to treat conditions in the soft tissues. Laser (Light Amplification by Stimulated Emission of Radiation) therapy comes in two types, high powered versus low powered or cold. Gallium arsenide (GaAs) and helium neon (HeNe) are two types of cold lasers that are used for the treatment of localized injury in superficial tissue.

Traction

Manual traction treats painful conditions of the spine. Pain reduction most likely occurs due to relaxation of soft tissues overlying the spine. To achieve distraction of the vertebral bodies or facet joints, a mechanical apparatus with weights is necessary. Mechanical distraction may occur in the cervical spine if the weight is sufficient to overcome the weight of the head. The usefulness of mechanical traction in sports medicine is limited. Mechanical traction is contraindicated if any spinal instability, infection or tumor is present.

Stages of Rehabilitation and Management Principles

In general, rehabilitation follows a logical sequence. Pain and edema must be controlled initially. Modalities, medications and some form of immobilization may be necessary. Massage, manual therapy and acupuncture are useful to reduce pain and promote activity. Flexibility and ROM can be addressed once pain decreases. Once mobility is restored, strengthening can be achieved in the appropriate range with closed and open chain kinetics. Endurance training is added to the strengthening regiment. Finally, function and sports specific activities are integrated. This necessitates neuromuscular reeducation, balance, proprioception and agility training. We will review this progression in order.

ACUTE STAGE (FIRST 48 TO 72 HOURS)

Rehabilitation in this stage is focused on limiting the inflammatory response. The letters RICE summarizes the methods used to control inflammation and pain: **R**est, **I**ce, **C**ompression and **E**levation. (Fig. 22.2)

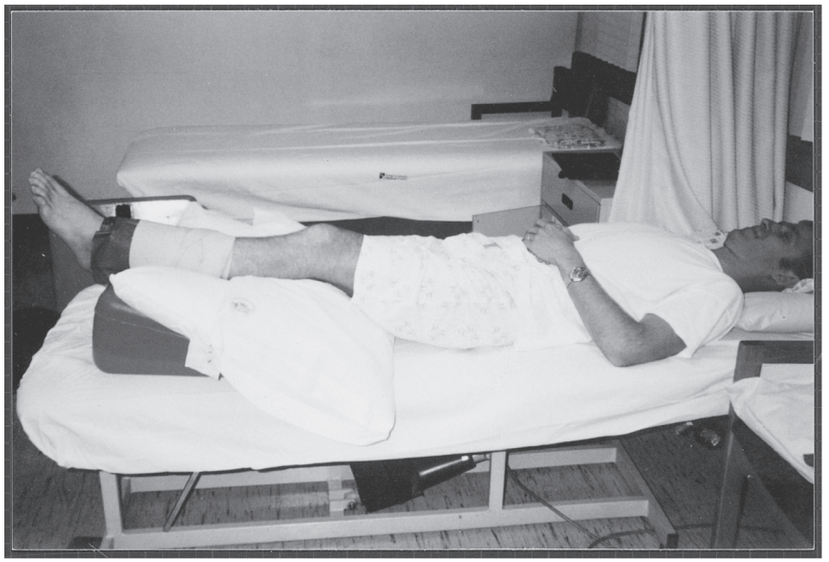

Fig. 22.2 RICE treatment: Rest, Ice, Compression, and Elevation.

Rest: Continued unlimited movement of the injured area will cause increased bleeding and swelling. Depending on the extent of the injury, partial or relative rest through complete rest with immobilization may be appropriate. The team physician faces the dilemma of balancing the protective effects of immobilization with its negative physiologic results.

Ice: The inflammatory response is brought about by vasodilatation and tissue exudates including white blood cells, breakdown products of damaged cells, and various chemical mediators. Ice decreases local metabolism and oxygen demand. A recent study showed that ice reduced the secondary injury that occurs after musculoskeletal trauma by retarding the hypoxia and enzymatic cascade. Ice controls pain and local muscle guarding. It is most effective minimizing the effects of inflammation when used with compression.

Compression: Compression with a firm material can reduce bleeding and swelling at the site of injury. Pain should not be increased with the dressing; if application of compression causes pain, it may be too tight. It should be applied with the greatest pressure distal to the injury site and with declining pressure proximally.

Elevation: Elevation decreases blood flow to and increases venous and lymph return from the injured body part. For lower limb injuries, the injured part should be positioned above the level of the pelvis. For upper limb injuries, the injured part should be positioned above the level of the heart.

Medications and modalities, especially cryotherapy and electrotherapy, are important tools during this stage. Maintenance of general flexibility, strength, and conditioning should be ongoing. For example, a runner with a tibial stress fracture can cross train with swimming instead of running. Cross training is also beneficial because of the cross over effect. Due to neural adaptation, flexibility and strength training with the contralateral uninjured limb has been shown to be beneficial to the injured limb. Other components of the acute management of injury include immobilization, massage, manual therapy and acupuncture. See Table 22.2 for the elements of rehabilitation in the acute stage.

Table 22.2 Acute Rehabilitation Stage

Intervention	Example	Indication
Modality	Superficial cold Interferential current	Decrease pain, decrease swelling Facilitate participation in active rehabilitation program
Medication	Analgesics NSAIDS Muscle relaxants	Decrease pain, decrease swelling Decrease muscle spasm Facilitate active exercise
Immobilization	Air cast Walking boot Fiberglass cast	Relative rest for injured joint/limb Protect from further injury Reduce swelling Allow overall mobility
Massage	Effleurage	Reduce swelling Decrease pain
Manual Therapy	Joint mobilization	Restore physiological movement
Acupuncture	Tendino-muscular meridian acupuncture	Decrease pain
Exercise	Static strengthening (Isometrics) Gentle static stretching	Reduce atrophy and weakness Limit loss of range of motion
Aquatherapy	Walking in pool	Maintain general cardiovascular endurance Limit weight bearing of affected lower extremity

Rehabilitation Techniques

Immobilization

Often in the acute stage of injury management, immobilization is necessary to prevent continuation of the inflammatory cascade, allow healing, or prohibit loading in particular planes while allowing other planes of movement. Complete immobilization is needed in the setting of a bony injury, especially an acute fracture. In a more subacute stage, it may be indicated, as with some stress fractures. Plaster casting has been used most for complete immobilization traditionally. Fiberglass casting also provides immobilization with a more lightweight and waterproof material. Alternative agents such as rigid braces, air splints, thermoplastic orthotics and taping provide less rigid stabilization but allow for easier wear, observation of the area and hygiene and are appropriate for protected mobilization. The team physician monitors healing and can progress the athlete from partial to complete mobilization when appropriate. Prolonged immobilization can cause side effects including muscle atrophy and weakness, loss of ROM, and degenerative changes in articular cartilage.

Manual Techniques

Manual Therapy

The application of manual therapy techniques to restore normal joint, soft tissue, and neural mobility is imperative to normalize the biomechanics of the musculoskeletal system. Manual therapy is done in conjunction with the re-education of muscle function. Joint mobilization is used to treat deficiencies in the accessory or physiological movements of a joint. It is graded in intensity and provides passive movement in the available ROM only. Joint manipulation includes movement through the barrier of available ROM. This is done via thrusting or high velocity translation of one component of a joint while the other component is fixed. Contraindications to joint mobilization and manipulation include: local malignancy; local bony infection or fracture; spinal cord or cauda equina compression; rheumatoid arthritis at C1-C2; vertebral artery insufficiency; spondylolisthesis; prepubertal children with open growth plates; and joint instability.

Massage

Massage involves direct physical action on an injured or painful area. It may decrease pain and facilitate healing by reducing muscle spasm, aiding in removal of chemical substances, promoting efficient scar formation, or breaking down abnormal scar tissue. It should be used to facilitate active exercise whenever possible. Various techniques are used including stroking or effleurage; kneading or petrissage; tapping or tapotement; and deep pressure or cross friction. Cross friction is contraindicated in the acute stage due to increased local blood flow and tissue reactivity.

Acupuncture

Acupuncture has been used for many centuries for the control of pain. It continues to have a role in the acute treatment of athletic injuries. Although its mechanism of action is not fully understood, it effects are related to stimulation of endorphins, the autonomic nervous system or pain control mechanisms at the local, meridian or segmental level. It can be used in a variety of settings. It is safe in the hands of a trained professional. It has few contraindications.

SUBACUTE OR RECOVERY STAGE (3 DAYS TO WEEKS)

The focus during this stage of rehabilitation is restoration of joint and soft tissue flexibility, strength endurance, and proprioception. These are the building blocks for normal movement and sports specific activity. After initial focus on inflammation control, protected mobilization begins. The focus shifts from resolution of clinical signs and symptoms to restoration of function. The athlete must be closely monitored in regard to his or her response to the treatment and any resumption of the inflammatory response signifies a need to reduce the level of rehabilitation activities. A gradated progression in force generation and degrees of freedom is necessary. Any setbacks can delay this phase of rehabilitation. It is generally the longest stage. Ongoing medications, modalities and therapy technique use is constantly reevaluated and minimized. Exercise prescription is the main feature of this stage of rehabilitation. A summary of interventions used in the recovery stage of rehabilitation is found in Table 22.3.

Table 22.3 Recovery Rehabilitation Stage

Intervention	Example	Indication
Exercise	Contract relax stretching Closed kinetic chain exercise Open kinetic chain exercise Medicine ball Exercise ball	Improve flexibility Improve limb strength and co-contraction Improve strength Prepare for sports specific activity Improve trunk strength
Aquatherapy	Flutter kick with kick board	Improve strength and conditioning
Modality	Superficial and deep heating Superficial cold	Facilitate stretching Decrease post-exercise swelling
Medication	Analgesics NSAIDS	Reduce exercise related pain and swelling
Immobilization	Taping Neoprene sleeve	Improve kinesthetic sense
Massage	Cross friction	Promote efficient scar formation
Manual Therapy	Joint mobilization and/or manipulation	Restore physiological movement

The Exercise Prescription

The team physician must identify deficits in flexibility, strength, and endurance. The exercise prescription is based on addressing these deficits. The components of the prescription are: type of exercise; frequency; duration; and intensity. See Table 22.4 for an overview.

Table 22.4 The Exercise Prescription

Element	Definition
Type of exercise	Specific activity the athlete will engage in
Frequency	# of times per week
Duration	**For strength training:** # of repetitions per set **AND** # of sets per session **For endurance training:** Total number of minutes
Intensity	**For strength training:** % of repetition maximum **For endurance training:** % VO_2 **OR** % maximum heart rate

Stretching

Athletes use stretching techniques to increase ROM and prevent injuries. In the setting of an injury, stretching decreases pain and reduces loss of ROM and flexibility. Vigorous stretching may be contraindicated with an acute muscle or myotendinous injury. Passive stretching is when another individual applies a stretch to a relaxed extremity; it must be done gently and slowly to avoid eliciting the stretch reflex. The stretch reflex is a protective reflex that prohibits injury to the muscle or joint after a rapid stretch. Heating modalities to increase the viscoelastic nature of collagen used prior to stretching can improve the results.

Prolonged static stretching is a commonly used technique by athletes. With hands-on assistance or after instruction in correct positioning, the stretch should be held at the end of the available ROM for 30-60 seconds. Recognizing and utilizing physiologic responses can maximize the results. For example, reciprocal inhibition involves static stretching with contraction of the antagonist muscle group. The athlete moves the joint to the end of the available ROM and then isometrically contracts the antagonist muscle group for 30 seconds. This reduces the tendency to elicit the stretch reflex in the muscle being stretched. One type of Proprioceptive Neuromuscular Facilitation (PNF) technique involves static stretching with contraction of the agonist muscle group. The athlete moves the joint to the end of the available ROM and then isometrically contracts the muscle group being stretched. The isometric contraction may increase the flexibility by relaxing the muscle via the golgi tendon organ or via stretching the connective tissue about the joint. Studies with athletes demonstrate the efficacy of this type of stretching. Flexibility can be addressed in post-surgical patients using a Continuous Passive Machines (CPM) when active range of motion is contraindicated or too painful. It minimizes joint stiffness and encourages nourishment of articular cartilage. The CPM encourages alignment of healing fibers via Wolff's law.

Strengthening

Strength is the maximal force that can be generated by a muscle at a specific velocity. Throughout the rehabilitation stages, an athlete should continue with her usual resistance training programs with the exception of the injured extremity or region.

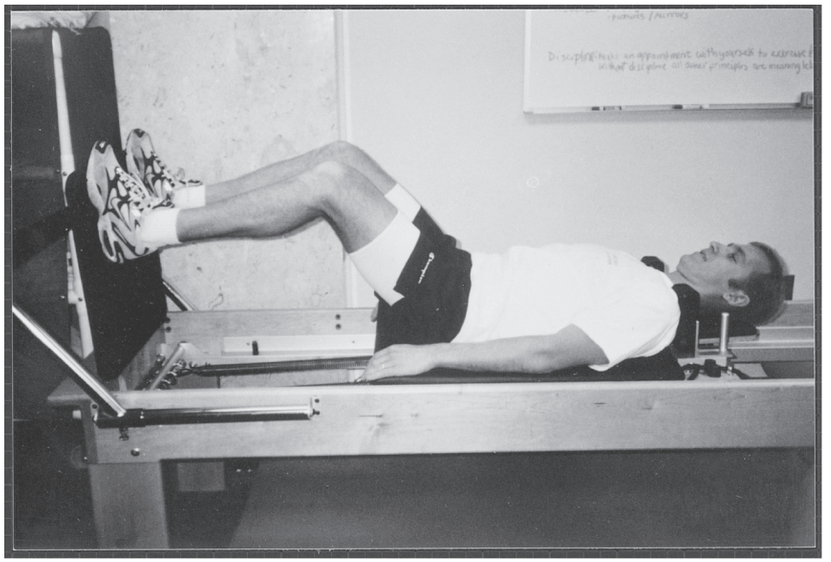

Fig. 22.3 Closed kinetic chain (CKC) exercise: distal lower extremity is fixed.

In the injured limb, static strengthening with isometric muscle contraction can be done during the acute stage and beyond, since in some instances, limited joint stress but continued strengthening may be appropriate. For example, exercises such as straight leg raises can be done in the setting of a ligamentous knee injury. Dynamic strengthening can begin once the athlete tolerates static strengthening. Closed kinetic chain (CKC) exercises are introduced first. (Fig. 22.3) The distal component of the extremity is fixed, thereby limiting the degrees of freedom of the extremity and joint forces. Once through the phase of protected mobilization, open kinetic chain (OKC) exercises can be prescribed. (Fig. 22.4) The distal component of the limb is free, increasing the degrees of freedom of movement and increasing joint forces. The transition from CKC to OKC is particularly important in the upper extremity, which functions primarily in an open kinetic chain manner.

The SAID (Specific Adaptation to Imposed Demand) principle requires that a muscle must be worked at a level higher than it is accustomed in order to increase strength. The workload can be varied to meet a particular goal. For example, exercising with a lower resistance and higher number of repetition builds endurance. Low repetition, high resistance workouts build strength.

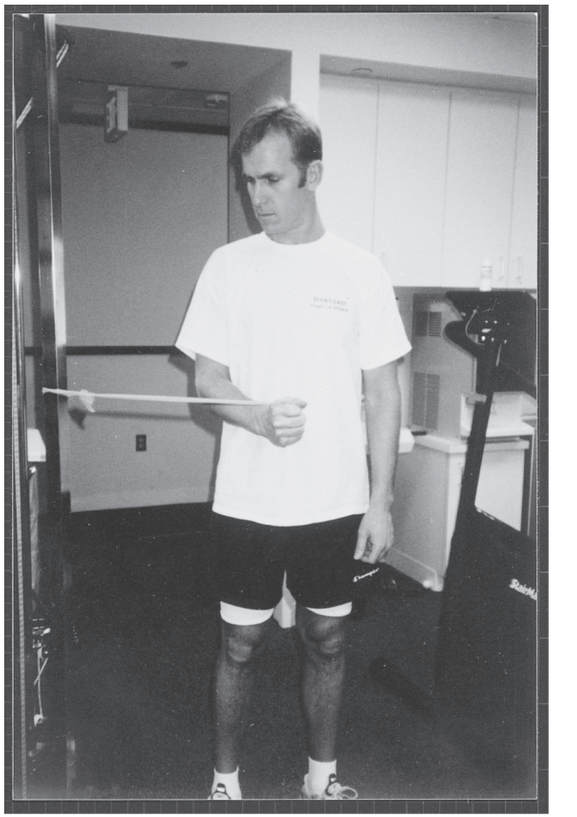

Fig. 22.4 Open kinetic chain (OKC) exercise: distal upper extremity is free.

Trunk (core) stabilization strengthening exercises are an important part of the rehabilitation process. When you consider the kinetic chain and the transmission of forces from the distal extremity to the proximal extremity to the trunk, it is key to maintain or increase core stability. The core is defined anatomically by the diaphragm superiorly, pelvic floor inferiorly, abdominals anteriorly and lumbar extensors posteriorly. Core strengthening programs incorporate specific exercises, some that isolate and others that combine the muscular activation of the core. The muscles most frequently targeted include the transverses abdominus, multifidus, lumbar paraspinals, gluteus maximus and medius, and the pelvic floor musculature.

Eccentric Exercise (Plyometrics)

Eccentric exercise uses the viscoelastic properties of muscle to increase force production. An eccentric action is applied to the muscle just prior to a concentric action. (Fig. 22.5) This loads the sarcomeres and connective tissue. This type of contraction sequence is utilized in sports specific activities. For example, basketball player will pre-load their calf muscles prior to jumping to rebound. Plyometric activities can be progressed by adding height to jumping surfaces or increasing the speed of the activity.

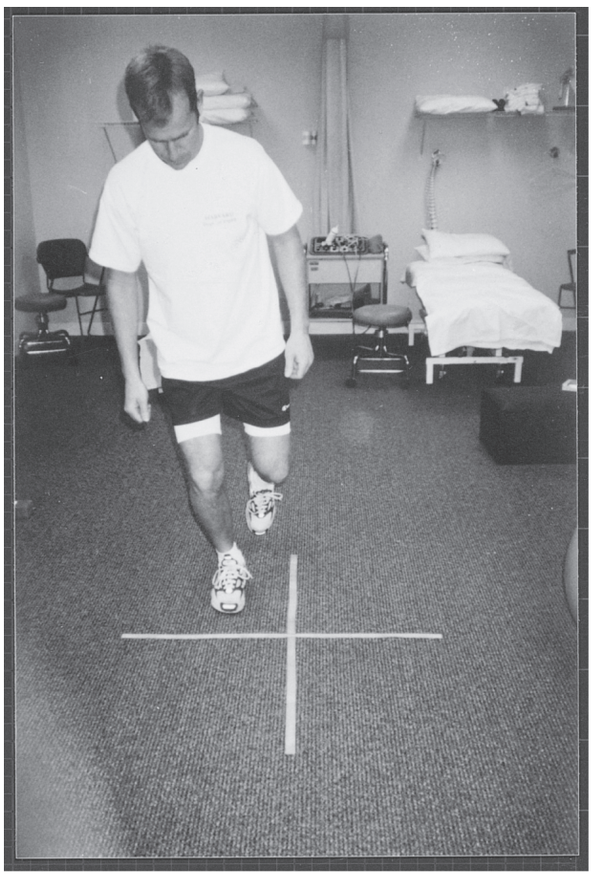

Fig. 22.5 Plyometric exercise: eccentric gastrocnemius-soleus action prior to concentric action.

Endurance

Even with a brief injury time frame, significant deconditioning occurs. The muscles at the site of injury and muscles proximal and distal to the site are affected. Cross training, or ongoing endurance training utilizing a different exercise type, should begin immediately. Aquatherapy, including water jogging or swimming, an upper body exerciser (UBE) or one legged exercycle can be used in the setting of a lower extremity injury. For upper extremity injuries, walking, running or exercycle can continue if tolerated.

As recovery continues, high repetition, low resistance strength training programs can target involved muscles. Taping or bracing provides protected mobility. As recovery continues, conditioning deficits must be addressed prior to safe return to sport. A structured stepwise progression of training time and activity level should be set and followed.

Aquatherapy

Aquatherapy is a hybrid technique used in rehabilitation. As reviewed previously, whirlpool can be used for heating or cooling modalities. More importantly, the injured athlete can take advantage of the properties of the water to exercise. (Fig. 22.6) Exercise in water facilitates movement, prevents muscle atrophy, and limits loss of ROM. The aquatic environment can also be used generally for cross training and earlier and more aggressive rehabilitation of sports injuries. Buoyancy supports body weight and can allow active exercise even when reduced weight bearing through an injured extremity is necessary. Hydrostatic pressure can reduce edema and aid in removal of cellular waste products. Viscosity of the water can add to the athlete's proprioceptive joint sense. It allows progression of resistance proportional to the effort exerted, flotation device applied, and direction of movement. Control of water temperature can be helpful for pain management. There are significant effects on the cardiac and pulmonary systems with immersion in water and this should be taken into account.

Fig. 22.6 Aquatherapy: using properties of water to facilitate exercise.

FUNCTIONAL STAGE (WEEKS TO MONTHS)

The focus of this stage of rehabilitation includes improved neuromuscular control, sports specific and multiplane activity and cessation of maladaptive behaviors that could lead to a future injury. The athlete completes this stage when he or she can meet the return to play criteria. Therapeutic modality and medication use is only needed intermittently related to exacerbation. An exercise program including flexibility, strengthening and proprioception is well established. Progression of sports specific activity allows for successful return to play. The focus on correct technique will prevent future injury.

See Table 22.5 for a review of interventions in this phase.

Table 22.5 Functional Rehabilitation Stage

Intervention	Example	Indication
Exercise	Balance beam	Improve balance
	Minitrampoline	Increase proprioception
	Figure 8 drills	Improve agility and foot placement
	Jump training	Improve tensile strength of muscle-tendon unit and ligaments Improve force production
	Overhead throwing	Regain sports specific neuromuscular control
	Exercise ball program	Maintain proximal stability and alignment Prevent future injury

Functional Retraining

The athlete must go beyond the improvement in flexibility, strength, and conditioning and practice sports specific activity prior to returning to play. Forces of gravity, momentum, and ground reaction in multiple planes of motion dictate sports-related function. Functional or sports specific retraining includes kinetic chain, balance, proprioception, and agility drills. The athlete must be closely supervised during this critical period and progressed appropriately.

Kinetic Chain

The team physician must evaluate the entire kinetic chain of movement. Biomechanical deficits in joints outside of the injured limb can lead to re-injury. In fact, this may have led to the current injury. For example, a baseball pitcher transmits forces from the lower limbs via the trunk to augment force production in the upper limb. Therefore, identifying and treating flexibility and strength deficits in the lower limbs and trunk are an important part of the rehabilitation process. Motion analysis using videotaping can also be helpful in reinforcing correct movement patterns once biomechanical deficits have been addressed. Lower extremity weight bearing exercise must be done in the frontal, sagittal and transverse planes, training both concentric and eccentric lower extremity musculature in a functional way. Eccentric contractions are crucial in slowing or decelerating segments of the body that have acquired kinetic energy, such as the lower limbs in running. Let's consider an athlete with an ACL injury. The

goal of rehabilitation is to provide exercise training that simulates sports-related activities. This expands her biomechanical and neurophysiological repertoire so she is prepared to return to the field of play with enhanced performance and reduced re-injury rate.

Balance and Proprioception

Balance is a dynamic component of sports performance. Early dynamic balance activities such as wobble board training are followed by activity at varying speeds and intensities. (Fig. 22.7) Simulation of sports specific movement patterns can help identify functional balance deficits. Proprioceptive deficits result from injury depending on the tissue injured and the length of immobilization. Injuries

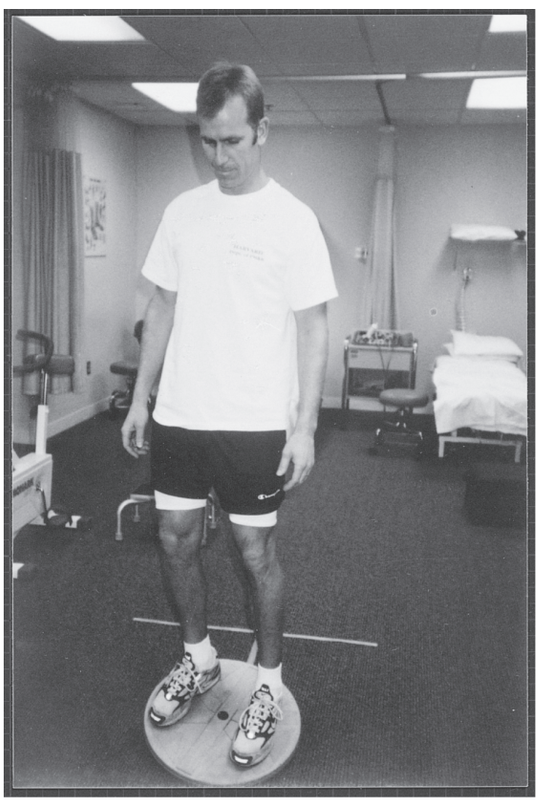

Fig. 22.7 Wobble board: retraining balance and proprioception.

to the anterior talofibular ligament (ATFL) or anterior cruciate ligament (ACL) can impair sensory feedback from the ankle or knee. Unilateral stance or step ups and downs allow co-contraction about the lower extremity joints, increasing the joint position sense. Upper extremity proprioception and co-contraction can be enhanced with closed chain weight bearing activities over an exercise ball.

Agility Drills

Agility drills are incorporated prior to returning to play. Tasks such as figure 8 or star drills require cutting and pivoting, causing rotational and translation moments in many planes at the joints. Hand-eye coordination and appropriate foot placement are required. This improves the neuromuscular control of the athlete. The athlete should perform sport specific agility drills on the surface of play and with the correct sporting equipment prior to returning to competition.

CONCLUSION

The purpose of our chapter is to acquaint the reader with rehabilitation in sports medicine. We have covered the stages of injury and repair. We have discussed the use of medications, physical modalities and therapy techniques. We have defined the three stages of sports rehabilitation, the acute, recovery and functional stage, and reviewed the management for each. We hope this review provides a practical framework from which the team physician can prescribe treatment. This treatment should be based on physiologic principles. The ultimate goal of rehabilitation is the safe, expedient return of the athlete to the field of play. The team physician should focus on treatments that limit the inflammatory response and promote healing to provide functional recovery as early as possible. By identifying and treating biomechanical deficits, the team physician can also strive to prevent future injuries in the athlete. Rehabilitation truly does begin at the time of injury and continues beyond the time of return to play.

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Internation Federation of Sports Medicine (FIMS) would like to acknowledge the collaboration of *The Chinese University of Hong Kong - World Health Organization (CUHK-WHO) Collaboration Centre for Sports Medicine and Health Promotion* in the production of the 2nd Edition of this Manual.