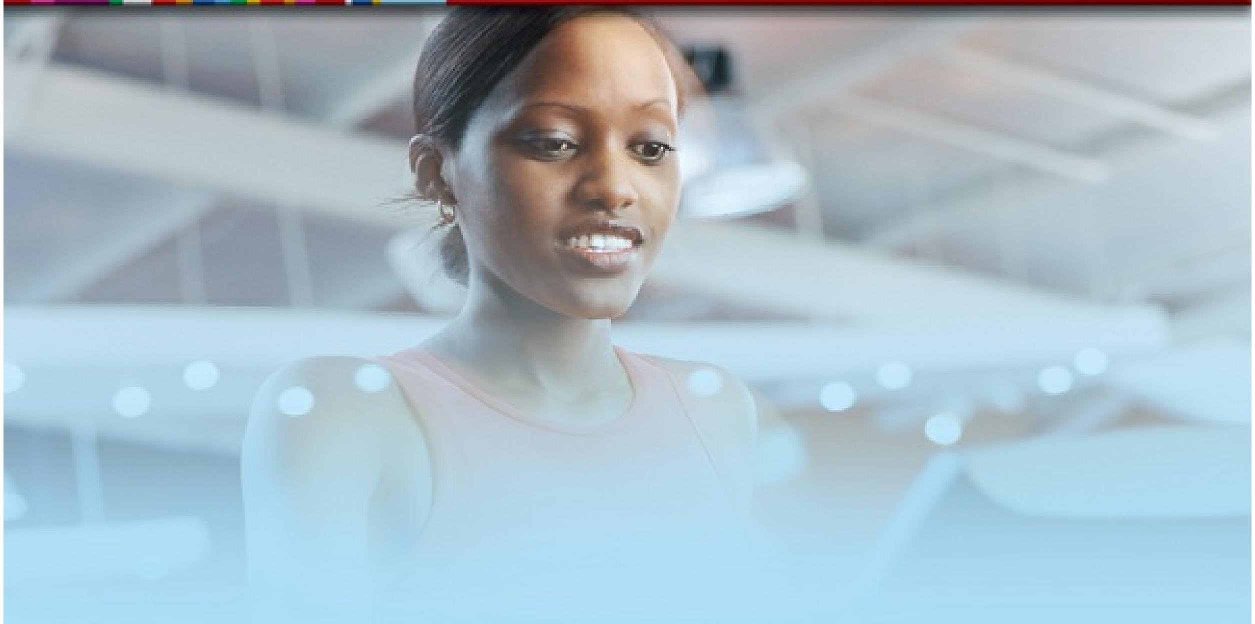
Basic Athletic Training
Course Pack B

For use in PES 385, Basic Athletic Training, SUNY Brockport.

CHAPTER

13

Therapeutic Exercise Program



STUDENT OUTCOMES

1. Explain the principles of the cognitive model used to describe an individual's adjustment to injury.
2. Identify various psychological influences that can affect an injured individual, and describe strategies or intervention techniques used to overcome these influences.
3. Explain the importance of dealing with the psychological concerns that an individual may develop during a therapeutic exercise program.
4. Identify key factors in the development of a therapeutic exercise program.

5. Describe the four phases of a therapeutic exercise program, including the goals of these phases and the methodology of implementation.
6. Utilize limb symmetry measures and patient outcomes in return to play decisions.
7. List the criteria used to clear an individual to return to full participation in sports and physical activities.

INTRODUCTION

The ultimate goal of therapeutic exercise is to return the injured participant to pain-free and full return to activity. To accomplish this, attention must focus on modulating pain and restoring normal joint range of motion (ROM), kinematics, flexibility, muscular strength, endurance, coordination, and power. Furthermore, cardiovascular endurance and strength in the entire body must be maintained. An understanding of each component is necessary within a well-organized, individualized therapeutic exercise program.

In this chapter, a therapeutic exercise program will be explained following the SOAP (Subjective evaluation, Objective evaluation, Assessment, and Plan) note format. Phases of a therapeutic exercise program are presented, including criteria used to determine when an individual is ready to progress in the program and, ultimately, to participate in sports or physical activities. Practical application of the material for the various body segments is included in Chapters 14 through 22

DEVELOPING A THERAPEUTIC EXERCISE PROGRAM

? A female distance runner diagnosed with plantar fasciitis complains of pain with weight bearing that radiates up the medial side of the heel as well as across the lateral side of the foot. In addition, passive extension of the great toe and dorsiflexion of the ankle increase pain and discomfort. What short- and long-term goals could the athletic trainer and the athlete establish for a therapeutic exercise program? How should progress be measured?

In designing an individualized therapeutic exercise program, several sequential steps help to identify the needs of the patient:

1. Assess the present level of function and dysfunction from girth measurements, goniometric assessment, strength tests, neurological assessment, stress tests, functional tests, and patient outcomes.
2. Organize and interpret the assessment to identify compensatory factors that have contributed to the injury. Establish short- and long-term goals to return the individual safely to participation.
3. Develop and supervise the treatment plan, incorporating therapeutic exercise, therapeutic modalities, and medication as well as activity modification.
4. Reassess the progress of the plan and adjust as needed.

The process is dependent on the patient's progress and adaptation to the therapeutic exercise program.

Assess the Patient

The subjective evaluation (i.e., history of the injury) is recorded in the **subjective**, or **S**, portion of the SOAP note. This information should include the primary complaint, mechanism of injury, characteristics of the symptoms, functional impairments, previous injuries to the area, and family and medical history. The objective evaluation (i.e., observation and inspection, palpation, and physical examination tests) establishes a baseline of measurable information and is recorded in the **objective**, or **O**, portion of the SOAP note. This information documents the visual analysis of the injury site, symmetry, and appearance; determines the presence of a possible fracture; identifies abnormal clinical findings in the bony and soft-tissue structures; and measures

ROM and strength (i.e., active, passive, and resisted ROM); stress tests for ligamentous and capsular integrity, neurological, and vascular testing; and sport-specific functional testing. In paired body segments, the dysfunction of the injured body part is always compared with the noninjured body part to establish standards for bilateral functional status.

Interpret the Assessment

When an assessment is completed, the data must be interpreted to identify factors outside the normal limits for an individual of the same age and fitness level. Specifically, primary deficits or weaknesses must be defined. These deficits, along with secondary problems resulting from prolonged immobilization, extended inactivity, or lack of intervention, are organized into a priority list of concerns. Examples of major concerns may include decreased ROM, muscle weakness or stiffness, joint contractures, sensory changes, inability to walk without a limp, or increased pain with activity. Physical limitations are then identified to determine the individual's present functional status. For example, normal gait and bilateral equal ROM should be documented. Specific problems are then recorded in a section called the problem list, which is a part of the **assessment**, or **A**, portion of the SOAP note.

Establish Goals

Next, long-term goals are established for the individual's expected level of performance at the conclusion of the exercise program. These goals typically focus on deficits in performing activities of daily living (ADLs) and might include bilateral equal ROM, flexibility, muscular strength, endurance, and power; relaxation training; and restoration of coordination and cardiovascular endurance. Then, short-term goals are developed to address the specific component skills needed to reach the long-term goals. The athletic trainer and patient should discuss and develop the goals. The individual must feel like a part of the process, because this may educate and motivate the individual to work harder to attain the stated goals. Many sport-specific factors, such as the demands of the sport; position played; time remaining in the season; regular season versus postseason or tournament play; game rules and regulations regarding prosthetic braces or safety equipment; location, nature, and severity of injury; and the mental state of the individual, may affect goal development.

The short-term goals are developed in a graduated sequence to address the list of problems identified during the assessment. For example, a high-priority short-term goal is the control of pain, inflammation, and spasms. Each short-term goal should be moderately difficult yet realistic. Specific subgoals should include an estimated timetable for attaining each one. These subgoals are time-dependent but are not fixed, because it is important to consider individual differences in preinjury fitness and participation status, severity of injury, motivation to complete the goals, and subsequent improvement. Constant reinforcement from the athletic trainer to achieve the subgoals can be an incentive to continually progress toward the long-term goals. Long- and short-term goals may be recorded in the **assessment**, or **A**, portion of the SOAP note; however, many athletic trainers choose to begin the **treatment plan**, or **P**, portion of the SOAP note with the objectives.

An example of **short-term goals** can be seen on the companion Web site at thePoint.

Develop and Supervise the Treatment Plan

Any therapeutic exercise and modality used to achieve the goals is recorded in the plan section of the SOAP note along with any medications prescribed by the physician. To return the individual safely to participation, the therapeutic exercise program is divided into four phases. The termination of one phase and the initiation of the next may overlap; however, each phase has a specific role. In phase 1, the inflammatory response, pain, swelling, and ecchymosis are controlled. Phase 2 focuses on regaining any deficits in ROM at the affected joint and restoring proprioception. Phase 3 involves restoring muscle strength, endurance, and power in the affected limb. Phase 4 prepares the individual to return to activity and includes sport-specific skill training, regaining coordination, and improving cardiovascular conditioning. These phases and their expected outcomes are discussed in more detail later in this chapter, and Box 13.1 lists the various phases of a therapeutic exercise program.

BOX 13.1 Phases of the Therapeutic Exercise Program

Phase 1: Control Inflammation

- Control the inflammatory stage and minimize scar tissue with cryotherapy using **PRICE** principles (**p**rotect, **r**estrict activity, **i**ce, **c**ompression, and **e**levation).
- Instruct the patient on relaxation and coping techniques.
- Maintain ROM, joint flexibility, strength, endurance, and power in the unaffected body parts.
- Maintain cardiovascular endurance.

Phase 2: Restore Motion

- Restore ROM to within 80% of normal in the unaffected limb.
- Restore joint flexibility to that observed in the unaffected limb.
- Begin proprioceptive stimulation through closed isotonic chain exercises.
- Begin pain-free, isometric strengthening exercises on the affected limb.
- Begin unresisted, pain-free functional patterns of sport/activity-specific motion.
- Maintain muscular strength, endurance, and power in the unaffected muscles.
- Maintain cardiovascular endurance.

Phase 3: Develop Muscular Strength, Power, and Endurance

- Restore full ROM and proprioception in the affected limb.
- Restore muscular strength, endurance, and power using progressive resisted exercise.

- Maintain cardiovascular endurance.
- Initiate minimal-to-moderate resistance in sport/activity-specific functional patterns.

Phase 4: Return to Sport/Physical Activity

- Analyze skill performance and correct biomechanical inefficiencies in motion.
- Improve muscular strength, endurance, and power.
- Restore coordination and balance.
- Improve cardiovascular endurance.
- Increase sport/activity-specific functional patterns and return to protected activity as tolerated.

Each phase of the exercise program must be supervised and documented. In addition, progress notes should be completed on a weekly or biweekly basis or updated any time there is a change made to the rehabilitation plan. In many health care settings, these records also are used for third-party reimbursement of services rendered and, should litigation occur, provide documentation of services rendered.

Reassess the Progress of the Program

Short-term goals should be flexible enough to accommodate the progress of the individual. For example, if therapeutic modalities or medications are used and the individual attains a short-term goal sooner than expected, a new short-term goal should be written. Some conditions, however, such as edema, hemorrhage, muscle spasm, atrophy, or infection, may impede the healing process and delay the attainment of a short-term goal. Periodic measurement of girth, ROM, muscle strength, endurance, power, and cardiovascular fitness determine whether progress occurs. If progress is not seen, the individual should be reevaluated. The athletic trainer must determine if the delay is caused by physical problems, noncompliance, or psychological influences, necessitating referral to the appropriate specialist (e.g., physician or clinical psychologist). The individual should continue to progress through the short-term goals until the long-term goals are attained and the individual is cleared for full activity.

> Long-term goals for the distance runner might include pain-free ROM, flexibility, muscle strength, endurance, and power; maintenance of cardiovascular endurance; restoration of normal joint biomechanics; increased proprioception and coordination; restoration of bilateral function of adls; and pain-free, unlimited motion in sport-specific skills.

PHASE 1: CONTROLLING INFLAMMATION

> ? Given the acute nature of the distance runner's plantar fasciitis, the acute care protocol was followed, including submersion of the foot in an ice bath. Would it be appropriate to begin any rehabilitation exercises during this initial phase of injury management?

Phase 1 of the exercise program begins immediately after injury assessment. The primary goal is to control inflammation by limiting hemorrhage, edema, effusion, muscle spasm, and pain. The individual can move into phase 2 when the following criteria have been attained:

- Control of inflammation with minimal edema, swelling, muscle spasm, and pain
- ROM, joint flexibility, muscular strength, endurance, and power are maintained in the unaffected/uninjured areas of the body.
- Cardiovascular fitness is maintained at the preinjury level.

Collagenous scar formation, a natural component of the repair and regeneration of injured soft tissue, is less efficient and tolerant of tensile forces compared with the original mature tissue. The length of the inflammatory response is a key factor influencing the ultimate stability and function of scar tissue: The longer the inflammatory process progresses, the more likely the resulting scar tissue will be less dense and weaker in yielding to applied stress. Furthermore, immobilization for more than 2 or 3 weeks may lead to joint adhesions that inhibit the regeneration of muscle fiber. Therefore, all inflammatory symptoms need to be controlled as soon as possible. **PRICE**, a well-known acronym for protect, restrict activity, ice, **c**ompression, and **e**levation, is used to reduce acute symptoms at an injury site.

Control of Inflammation

Following trauma, hemorrhage and edema at the site of injury lead to a pooling of tissue fluids and blood products that increases pain and muscle spasm. The increased pressure decreases the flow of blood to the injury site, leading to hypoxia (a deficiency of oxygen). As pain continues, the threshold for pain is lowered. These events lead to the cyclical pattern of pain-spasm-hypoxia-pain. For this reason, cryotherapy (i.e., ice, compression, and elevation) is preferred during the acute inflammation stage to decrease circulation, cellular metabolism, the need for oxygen, and conduction velocity of nerve impulses to break the pain–spasm cycle. An elastic compression wrap can decrease hemorrhage and hematoma formation yet still expand in cases of extreme swelling. Elevation and active ROM uses gravity to reduce the pooling of fluids and pressure inside the venous and lymphatic vessels and thereby prevent fluid from filtering into the surrounding tissue spaces. The result is less tissue necrosis and local waste, leading to a shorter inflammatory phase. Application Strategy 13.1 explains acute care of soft-tissue injuries using the PRICE principle.

APPLICATION STRATEGY 13.1

Acute Care of Soft-Tissue Injuries

Ice Application

- Apply crushed ice for 30 minutes directly to the skin (40 minutes for a large muscle mass, such as the quadriceps).
- Ice applications should be repeated every 2 hours when awake (every hour if the athlete is active) and may extend to more than 72 hours postinjury.
- Skin temperature can indicate when acute swelling has subsided. For example, if the area (compared bilaterally) feels warm to the touch, swelling continues. If in doubt, extend the time of a cold application.

Compression

- On an extremity, apply the wrap in a distal-to-proximal direction to avoid forcing extracellular fluid into the distal digits.
- Take a distal pulse after applying the wrap to ensure that the wrap is not overly tight.
- Felt horseshoe pads placed around the malleolus may be combined with an elastic wrap or tape to limit ankle swelling.
- Maintain compression continuously on the injury for the first 24 hours.

Elevation

- Elevate the body part 6–10 in above the level of the heart.
- While sleeping, place a hard suitcase between the mattress and box spring, or place the extremity on a series of pillows.

Restrict Activity and Protect the Area

- If the individual is unable to walk without a limp, fit the person for crutches and apply an appropriate protective device to limit unnecessary movement of the injured joint.
- If the individual has an upper extremity injury and is unable to move the limb without pain, fit the person with an appropriate sling or brace.

Cryotherapy, intermittent compression, and therapeutic exercise may be used to control hemorrhage and eliminate edema. Electrical muscle stimulation (EMS) is not currently recommended as a means to improve function, reduce edema, or decrease pain in the treatment of acute lateral ankle sprains.[1]

Electrical therapy also has been shown to decrease pain and muscle spasm, strengthen weakened muscles, improve blood flow to an area, and enhance the healing rate of injured tendons. Transcutaneous electrical nerve stimulation (TENS) also may be used to limit pain (see Chapter 12). The modality of choice is determined by the size and location of the injured area, the availability of the modality, and the preference of the supervising health care provider. A decision to discontinue treatment and move to another modality should be based on the cessation of inflammation. Increased tissue temperature may indicate that inflammation is still present as well as swelling and redness in the involved body part.

Effects of Immobilization

The effects of immobilization on various tissues of the body have been extensively covered in the literature. It is well accepted that muscle tension, muscle and ligament atrophy, decreased circulation, and loss of motion prolong the repair and regeneration of damaged tissues. As determined by the physician, it is indicated to maintain partial to full weight bearing in the lower extremity in order to maintain strength.

Muscle

Immobilization can lead to a loss of muscle strength within 24 hours. This is manifested by decreases in muscle fiber size, total muscle weight, size and number of mitochondria (the energy source of the cell), muscle tension produced, and resting levels of glycogen and adenosine triphosphate, which reduces muscle endurance. Motor nerves become less efficient in recruiting and stimulating muscle fibers. Immobilization also increases muscle fatigability as a result of decreased oxidative capacity. The rate of loss appears to be more rapid during the initial days of immobilization; however, after 5 to 7 days, the loss of muscle mass diminishes.[2] Although both slow-twitch (type I) and fast-twitch (type II) muscle fibers atrophy, it generally is accepted that greater degeneration occurs in slow-twitch fibers with immobilization and that muscles immobilized in a lengthened or neutral position maintain muscle weight and the fiber cross-sectional area better than muscles immobilized in a shortened position. When shortened, the length of the fibers decreases, leading to increased connective tissue and reduced muscle extensibility. Muscles immobilized in a shortened position atrophy faster and have a greater loss of contractile function.

Articular Cartilage

The greatest impact of immobilization occurs in the articular cartilage, where adverse changes appear within 1 week of immobilization. The specific effects depend on the length of immobilization, the position of the joint, and joint loading. Intermittent loading and unloading of synovial joints is necessary to ensure the proper metabolic exchange necessary for normal function. Constant contact with opposing bone ends can lead to pressure necrosis and cartilage cell (chondrocyte) death. In contrast, noncontact between two surfaces promotes the growth of connective tissue into the joint. Diminished weight bearing, as well as loading and unloading, also can increase bone resorption. In general, articular cartilage softens and decreases in thickness. Immobilization for longer than 30 days can lead to progressive osteoarthritis.

Ligaments

Similar to bone, ligaments adapt to normal stress by remodeling in response to the mechanical demands that are placed on them. Stress leads to a stiffer, stronger ligament, whereas immobilization leads to a weaker, more compliant structure. This causes a decrease in the tensile strength, thus reducing the ability of ligaments to provide joint stability.

Bone

Mechanical strain on a bone affects the osteoblastic (bone cell formation) and osteoclastic (bone cell resorption) activity on the bone surface. Accordingly, the effects of immobilization on bone are similar to those on other connective tissues. Limited weight-bearing and muscle activity lead to bone loss, which can be detected as early as 2 weeks after immobilization.[2] As immobilization time increases, bone resorption occurs, resulting in the bones becoming more brittle and highly susceptible to fracture. Disuse atrophy appears to increase bone loss at a rate 5- to 20-fold greater than that resulting from metabolic disorders affecting bone.[3] Therefore, non–weight-bearing immobilization should be limited to as short a time as possible.

Effects of Remobilization

Early controlled mobilization can speed the healing process. Bone and soft tissue respond to the physical demands that are placed on them, causing the formation of collagen to remodel or realign along the lines of stress, and thereby promoting healthy joint biomechanics (**Wolff law**). Continuous passive motion can prevent joint adhesions and stiffness and can decrease joint hemarthrosis (blood in the joint) and pain. Early motion, as well as loading and unloading of joints, through partial weight-bearing exercise, maintain joint lubrication to nourish articular cartilage, menisci, and ligaments. This leads to an optimal environment for proper collagen fibril formation. Tissues recover at different rates with mobilization: Muscle recovers more quickly, and articular cartilage and bone respond least favorably.

Muscle

Muscle regeneration begins within 3 to 5 days after mobilization. Both fast-twitch and slow-twitch muscle fibers can completely recover after 6 weeks. Muscle contractile activity rapidly increases protein synthesis; however, maximal isometric tension may not return to normal until 4 months after mobilized activity. The use of electrotherapy (i.e., EMS) may be helpful in reeducating muscles, limiting pain and spasms, and decreasing effusion through the pumping action of the contracting muscle. Unfortunately, neither EMS nor isometric exercise has been shown to prevent disuse atrophy.

Articular Cartilage

The effects of immobilization, whether with contact or with a loss of contact between joint surfaces, can adversely interfere with cartilage nutrition. Articular cartilage generally responds favorably to mechanical stimuli, with structural modifications noted after exercise. Soft-tissue changes are reversible if immobilization does not exceed 30 days; these structural changes may not be reversible if immobilization exceeds 30 days.

Ligaments

The bone–ligament junction recovers more slowly than the mechanical properties in the midportion of the ligament. In addition, other nontraumatized ligaments weaken with disuse. Recovery depends on the duration of immobilization. Studies have shown that following 12 weeks of immobilization, a recovery of 50% of normal strength in a healing ligament is found after 6 months, 80% after 1 year, and 100% after 1 to 3 years, depending on the type of stresses placed on the ligament and on the prevention of repeated injury.[4] Although the properties of ligaments return to normal with remobilization, the bone–ligament junction takes longer to return to normal. This factor must be considered when planning a rehabilitation program.

Bone

Although bone lost during immobilization may be regained, the period of recovery can be several-fold greater than the period of immobilization. In disuse osteoporosis, a condition involving reduced quantity of bone tissue, bone loss may not be reversible on remobilization of the limb. Isotonic and isometric exercises during the immobilization period can decrease some bone loss and hasten recovery after returning to a normal loading environment.

Protection After Injury

The type of protection selected and the length of activity modification depend on the severity of the injury, the structures damaged, and the philosophy of the supervising health care provider. Several materials, including elastic wraps, tape, pads, slings, hinged braces, splints, walking boots, and crutches, can be used to protect the area; many of these items were discussed and illustrated in Chapter 4. If an individual cannot walk without pain or walks with a limp, crutches should be recommended (**Application Strategy 13.2**).

APPLICATION STRATEGY 13.2

Fitting and Using Crutches and Canes

Fitting Crutches

1. Have the individual stand erect in flat shoes with the feet close together.
2. Place the crutch tip 2 in in front and 6 in from the outer sole of the shoe.
3. Adjust crutch height to allow a space of about two finger widths between the crutch pad and the axillary skinfold to avoid undue pressure on neurovascular structures.
4. Adjust the hand grip so the elbow is flexed 25°–30° and is at the level of the hip joint (greater trochanter).

Fitting for a Cane

1. Place the individual in the same position as previous. Adjust the hand grip so the elbow is flexed at 25°–30° and is at the level of the hip joint (greater trochanter).

Swing Through Gait (Non–Weight-Bearing)

1. Stand on the uninvolved leg. Lean forward and place both crutches and the involved leg approximately 12–24 in in front of the body.
2. Body weight should rest on the hands, not the axillary pads.
3. With the good leg, step through the crutches as if taking a normal step. Repeat the process.
4. If possible, the involved leg should be extended while swinging forward to prevent atrophy of the quadriceps muscles.

Three-Point Gait (Partial Weight Bearing)

1. This is indicated when one extremity can support the body weight, and the injured extremity is to be touched down or to bear weight partially.
2. As tolerated, place as much body weight as possible onto the involved leg, taking the rest of the weight on the hands.
3. Make sure a good heel-to-toe technique is used, whereby the heel

strikes first, then the weight is shifted to the ball of the foot.

4. Increase the amount of weight bearing by decreasing the force transferred through the arms; mimic a normal gait.

Going Up and Down Stairs

1. Place both crutches under the arm opposite the handrail.
2. To go **up** the stairs, step **up with the uninvolved leg** while leaning on the rail.
3. To go **down** the stairs, place the crutches down on the next step and step **down with the involved leg**.

Using One Crutch or Cane

1. Place one crutch or cane on the uninvolved side and move it forward with the involved leg.
2. Do not lean heavily on the crutch or cane.

See **Daily Adjusted Progressive Resistance Exercise Program** on the companion Web site at thePoint.

Restricted activity does not imply cessation of activity but rather means relative rest—that is, decreasing activity to a level below that required in sport but tolerated by the recently injured tissue or joint. **Detraining**, or a loss of the benefits gained in physical training, can occur after only 1 to 2 weeks of nonactivity, with significant decreases measured in both metabolic and working capacities.[5] Strengthening exercises in a weight-lifting program can be alternated with cardiovascular exercises, such as jogging on an antigravity treadmill, swimming or water running, or use of a stationary bike or upper body ergometer. These exercises can prevent the individual from experiencing depression as a result of inactivity and can be done simultaneously with phase 1 exercises as long as the injured area is not irritated or inflamed.

In addition to cold treatments for the control of inflammation, it would be appropriate to initiate gentle stretching exercises during this phase.

The particular areas that should be stretched include the Achilles tendon and the toe flexor tendons. In addition, general body strength and cardiovascular endurance exercise can be performed as long as the injured area is not irritated.

PHASE 2: RESTORATION OF MOTION

? The acute inflammatory symptoms associated with the plantar fasciitis have subsided. In the ongoing treatment of the plantar fasciitis, what type of exercises should be encouraged at this point during the rehabilitation process? Are there any modalities that could be used to supplement the exercise program?

Phase 2 begins immediately after the inflammation is controlled. This phase focuses on restoring ROM and flexibility at the injured site as well as on continuing to maintain general body strength and cardiovascular endurance. This phase may begin as early as 4 days after the injury, when swelling has stopped, or may have to wait until several weeks after the injury. The injured site may still be tender to the touch, but it is not as painful as in the earlier phase. Also, pain is much less evident on passive and active ROM (AROM). If the patient is in an immobilizer or splint, the splint should be removed for treatment and exercise. The splint then can be replaced to support and protect the injured site. The individual can move into phase 3 when the following criteria have been completed:

- Inflammation and pain are under control.
- ROM is within 80% of normal in the unaffected limb.
- Bilateral joint flexibility is restored, and proprioception is regained.
- Cardiovascular endurance and general body strength are maintained at the preinjury level.

An assessment of normal ROM should be done with a goniometer on the paired, uninjured joint (see Chapter 5). Cryotherapy or EMS may be used before exercise to decrease perceived pain, or thermotherapy may be used to warm the tissues and increase circulation to the region. When the tissue is warmed, friction massage, instrument-assisted soft-tissue mobilization, or joint mobilization may be helpful to break up scar tissue to regain normal motion.

Progression in this phase begins gradually, with the restoration of ROM, proprioception, and total joint flexibility. Factors that limit joint motion include bony block; joint adhesions; muscle tightness; tight skin or inelastic, dense scar tissue; swelling; pain; and fat or other soft tissues that block normal motion. Prolonged immobilization can lead to muscles losing their flexibility and assuming a shortened position, which is referred to as a **contracture**. Similar to muscle tissue, however, connective tissue adaptively shortens if immobilized. Connective tissue and muscles may be lengthened through passive and active stretching as well as proprioceptive neuromuscular facilitation exercises. However, fascial tissue forms a whole-body, continuous three-dimensional viscoelastic matrix of structural support that surrounds and penetrates skeletal muscle, joints, organs, nerves, and vascular beds. The classical concept of its mere passive role in force transmission has recently been disproven with evidence suggesting contractile elements enabling a modulating role in force generation and also mechanosensory fine-tuning.[6]

Passive Range of Motion

Two types of movement must be present for normal motion to occur around a joint. Physiological motion, measured by a goniometer, occurs in the cardinal movement planes of flexion–extension, abduction–adduction, and rotation. Accessory motion, also referred to as **arthrokinematics**, is an involuntary joint motion that occurs simultaneously with physiological motion, but it cannot be measured precisely. Accessory movements involve the spinning, rolling, or gliding of one articular surface relative to another. Normal accessory movement must be present for full physiological ROM to occur. If any accessory motion component is limited, normal physiological motion will not occur.

Limited passive ROM (PROM) is called **hypomobility**. These discrete limitations of motion prevent a pain-free return to competition and predispose an individual to microtraumatic injuries that reinflame the original injury or create compensations in other parts of the body. Restoring PROM prevents degenerative joint changes and promotes healing.

Joint Mobilization

Joint mobilization uses various oscillating forces, applied in the open-packed position, to "free up" stiff or "fixed" joints. The oscillations produce several key benefits in the healing process:

- Breaking up adhesions and relieving capsular restrictions
- Distracting impacted tissues
- Increasing lubrication for normal articular cartilage
- Reducing pain and muscle tension
- Restoring full ROM and facilitating healing

Joint mobilization is contraindicated in several instances (**Box 13.2**). Maitland[7] described five grades of mobilization:

BOX 13.2 13.2 Contraindications to Joint Mobilization

- Acute inflammation
- Hypermobility
- Osteoporosis
- Advanced osteoarthritis
- Infections
- Premature stressing of surgical structures
- Congenital bone deformities
- Malignancy
- Rheumatoid arthritis

- Fractures
- Neurological signs
- Vascular disease

- **Grade I:** a small-amplitude movement at the beginning of the available ROM; used when pain and spasms limit movement early in the ROM
- **Grade II:** a large-amplitude movement within the available ROM; used when spasms limit movement sooner with a quick oscillation than with a slow one or when slowly increasing pain restricts movement halfway into the range
- **Grade III:** a large-amplitude movement up to the pathological limit in the ROM; used when pain and resistance from spasms, inert tissue tension, or tissue compression limit movement near the end of the ROM
- **Grade IV:** a small-amplitude movement at the very end of the ROM used when resistance limits movement in the absence of pain and spasm.
- **Grade V:** a small-amplitude, quick thrust delivered at the end of the ROM, usually accompanied by a popping sound called a manipulation used when minimal resistance limits the end of the ROM. Manipulation is most effectively accomplished by the velocity rather than the force of the thrust.

Grading is based on the amplitude of the movement and where within the available ROM that the force is applied. Grades I and IV are small-amplitude movements performed at the beginning and end of the ROM, respectively. Grades II and III are large-amplitude movements. Grade II tends to be applied in the midrange of movement, whereas grade III is performed up to the pathological limit of the available ROM. Grade V is the manipulation grade and is a small-amplitude thrust beyond the end range of a joint's restricted motion. Grades I and II joint mobilizations are used primarily to decrease joint pain, and grades III and IV joint mobilizations are used to increase joint ROM and reduce joint stiffness. Proper training is necessary prior to performing grade V mobilizations.

In performing joint mobilization, the individual is placed in a comfortable position, with the joint placed in an open-packed position. This allows the surrounding tissues to be as lax as possible and the intracapsular space to be at its largest. The direction of force is dependent on the contour of the joint surface of the structure being mobilized. The concave–convex rule states that when the concave surface is stationary and the convex surface is mobilized, a glide of the convex segment should be in the direction opposite to the restriction of joint movement. If the convex articular surface is stationary and the concave surface is mobilized, however, gliding of the concave segment should be in the same direction as the restriction of joint movement (Fig. 13.1). Typical treatment involves a series of three to six mobilizations lasting from 30 to 60 seconds, with one to three oscillations per second.[7] Figure 13.2 demonstrates joint mobilization techniques.

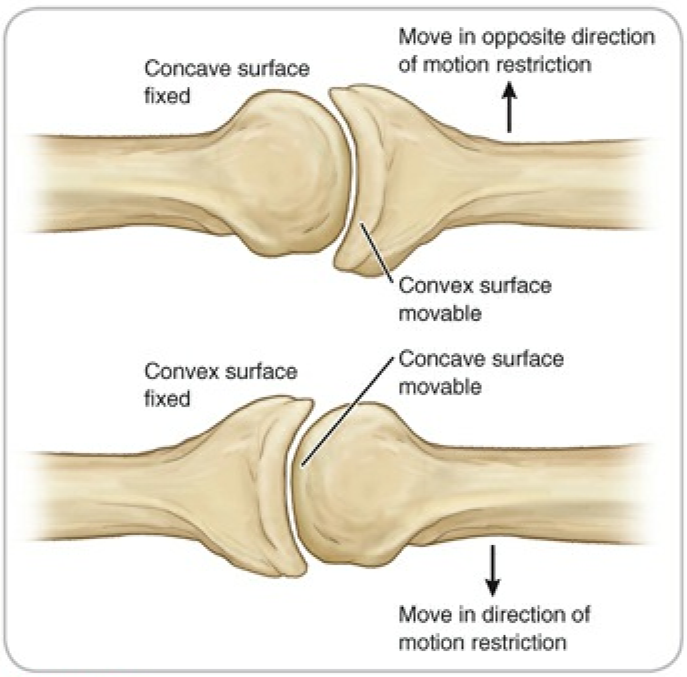


Figure 13.1. Concave–convex rule. If the joint surface to be moved is convex, it should be mobilized in the direction opposite that of the motion restriction. If the joint surface of the body segment being moved is concave, it should be moved in the direction of the motion restriction.

Figure 13.2. Joint mobilization technique. Posterior humeral glide uses one hand to stabilize the humerus at the elbow while the other hand glides the humeral head in a posterior direction to increase flexion and medial rotation at the joint.

Flexibility

Flexibility is the total ROM at a joint that occurs pain-free in each of the planes of motion. Joint flexibility is a combination of normal joint mechanics, mobility of soft tissues, and muscle extensibility. For example, the hip joint may have full PROM, but when doing active hip flexion from a seated position, as in touching one's toes, resistance from tight hamstrings may limit full hip flexion. This type of resistance may be generated from tension in muscle fibers or connective tissue.

Muscles contain two primary proprioceptors that can be stimulated during stretching—namely, the muscle spindles and the Golgi tendon organs. Because muscle spindles lie parallel to muscle fibers, they stretch with the muscle. When stimulated, the spindle sensory fibers discharge and, through reflex action in the spinal cord, initiate impulses to cause the muscle to contract reflexively, thus inhibiting the stretch. Muscles that perform the desired movement are called **agonists**. Unlike muscle spindles, Golgi tendon organs are connected in a series of fibers located in tendons and joint ligaments, and they respond to muscle tension rather than to muscle length. If the stretch continues for an extended time (i.e., longer than 6 to 8 seconds), the Golgi tendons are stimulated. This stimulus, unlike the stimulus from muscle spindles, causes a reflex inhibition in the **antagonist** muscles, and this sensory mechanism protects the musculotendinous unit from excessive tensile forces that could damage muscle fibers.

Flexibility can be increased through active stretching, passive stretching, or a combination of the two. **Active stretching** includes flexibility exercises performed by the patient without outside assistance from another individual. For example, a **static stretch** produces movement that is slow and deliberate and has been found to increase hamstring flexibility.[8,9] Golgi tendon organs are able to override impulses from the muscle spindles, leading to a safer, more effective muscle stretch. When the muscle is stretched to the point at which a mild burn is felt, the joint position is maintained statically for approximately 15 seconds and then is repeated several times. Box 13.3 outlines guidelines for static stretching to improve flexibility.

BOX 13.3 Guidelines for Static Stretching to Improve Flexibility

1. Stretching is facilitated by warm body tissues; therefore, a brief warm-up is recommended. If unable to jog lightly, stretching may be performed after a superficial heat treatment.
2. In the designated stretch position, the individual should move to a position in which a sensation of tension is felt.
3. No bouncing should be associated with the stretch. The stretch position should be held for 10–30 seconds, until a sense of relaxation occurs. The individual should be aware of the feeling of relaxation or "letting go." Repeat the stretch six to eight times.
4. Breathing should be performed rhythmically and slowly. The individual should exhale during the actual stretch.
5. It is important to avoid being overly aggressive in stretching. Increased flexibility may not be noticed for 4–6 weeks.
6. If an area is particularly resistant to stretching, then partner stretching or proprioceptive neuromuscular facilitation may be used.
7. Vigorous stretching of tissues should be avoided in the following

conditions:

- After a recent fracture
- After prolonged immobilization
- With acute inflammation or infection in or around the joint
- With a bony block that limits motion
- With muscle contractures or when joint adhesions limit motion
- With acute pain during stretching

Passive stretching includes several short- and long-term stretches with the use of equipment or another person to assist in the stretch activity. An example of this occurs when the clinician stabilizes the proximal segment of a joint and then moves the patient's limb through the available ROM, applying a slight stretch at the end of the motion. The patient should feel a stretch or tension but no pain. In a long-term stretch, a static stretch is applied from 20 to 30 minutes; however, little research exists on a definitive time.

Proprioceptive neuromuscular facilitation uses both active and passive stretching to promote and hasten the response of the neuromuscular system through the stimulation of the proprioceptors (Fig. 13.3). The patient should be taught how to perform the exercise through cutaneous and auditory input. Often, the individual looks at the moving limb while the clinician moves the limb from the starting to terminal position. Verbal cues are used to coordinate voluntary effort with reflex responses. Words such as "push" or "pull" commonly are used to ask for an isotonic contraction. "Hold" may be used for an isometric or stabilizing contraction, followed by "relax." Manual (cutaneous contact) helps to influence the direction of motion and to facilitate a maximal response, because reflex responses are greatly affected by pressure receptors. Current research indicates that static stretching had a negative effect on explosive performances up to 24 hours poststretching on muscles in the lower extremity. Conversely, the dynamic stretching of the same muscle groups is highly recommended 24 hours before performing sprint and long jump performances. In conclusion, the positive effects of dynamic stretching on explosive performances seem to persist for 24 hours.[10] Once the injury has healed and the participant has return to activity, dynamic stretching is preferred prior to participation in activity.

Figure 13.3. Proprioceptive neuromuscular facilitation. In performing proprioceptive neuromuscular facilitation stretching techniques, the athletic trainer passively stretches a muscle group. In this picture, the hip flexors are being stretched. When slight tension is felt, the individual isometrically contracts the muscle group against resistance for 3, 6, or 10 seconds. The muscle is then passively stretched. This process is repeated four or five times.

These exercises increase flexibility in one muscle group (i.e., agonist) and simultaneously improve strength in another muscle group (i.e., antagonist). Furthermore, if instituted early in the exercise program, proprioceptive neuromuscular facilitation stretches can aid in elongating scar tissue. As scar tissue matures and increases in density, it becomes less receptive to short-term stretches and may require prolonged stretching to achieve deformational changes in the tissue.

The proprioceptive neuromuscular facilitation techniques recruit muscle contractions in a coordinated pattern as agonists and antagonists move through an ROM. One technique uses active **inhibition**, whereby the muscle group reflexively relaxes before the stretching maneuver. Common methods include contract–relax, hold–relax, and slow reversal–hold–relax (Box 13.4). The clinician stabilizes the limb to be exercised. Alternating contractions and passive stretching of a group of muscles are then performed. Contractions may be held for 3, 6, or 10 seconds, with similar results obtained.[11]

BOX 13.4 Active Inhibition Technique

To stretch the hamstring group on a single leg using the three separate proprioceptive neuromuscular facilitation techniques, the following guidelines should be followed:

Contract–Relax

1. The thigh is stabilized and the hip passively flexed into the agonist pattern until limitation is felt in the hamstrings.
2. The individual performs an isotonic contraction with the hamstrings through the antagonist pattern.
3. A passive stretch is applied into the agonist pattern until limitation is felt, and the sequence is repeated.

Hold–Relax

1. The leg is passively moved into the agonist pattern until resistance is felt in the hamstrings.
2. The individual performs an isometric contraction to “hold” the position for approximately 10 seconds.
3. The individual should relax for approximately 5 seconds.
4. A passive stretch is applied into the agonist pattern until limitation is felt, and the sequence is repeated.

Slow Reversal–Hold–Relax

1. The individual consciously relaxes the hamstring muscles while doing a concentric contraction of the quadriceps muscles into the agonist pattern.
2. The individual performs an isometric contraction, against resistance, into the antagonist pattern for 10 seconds.

3. The individual should relax for approximately 10 seconds.
4. The individual actively moves the body part further into the agonist pattern, and the sequence is repeated.

A second technique, known as **reciprocal inhibition**, uses active agonist contractions to relax a tight antagonist muscle. In this technique, the individual contracts, against resistance, the muscle opposite the tight muscle. This causes a reciprocal inhibition of the tight muscle, leading to muscle lengthening. An advantage to proprioceptive neuromuscular facilitation exercise is the ability to stretch a tight muscle that may be painful or in the early stages of healing. In addition, movement can occur in a single plane or in a diagonal pattern that mimics actual skill performance.

Active Assisted Range of Motion

Frequently, PROM at the injured joint may be greater than active motion, perhaps because of muscle weakness. A person may be able to sit on top of a table and slide the leg across the tabletop away from the body to fully extend the knee. If, however, the individual sits at the edge of the table with the legs hanging over the edge and then attempts to straighten the knee, the individual may be unable to move the limb voluntarily into full extension. In this situation, normal joint mechanics exist and full PROM is present. To attain full AROM, however, the individual may require some assistance from an athletic trainer, a mechanical device, or the opposite limb (active assisted ROM). Working the limb through available pain-free motion with assistance restores normal AROM more quickly than working the limb within limited voluntary motion.

Active Range of Motion

AROM exercises performed by the individual enhance circulation through a pumping action during muscular contraction and relaxation. Full, pain-free AROM need not be achieved before strength exercises are initiated; however, performance of skills and drills, such as throwing or full squats, which require full pain-free ROM or certain agility drills, must be delayed until proper joint mechanics are restored. AROM exercises should be relatively painless and may be facilitated during certain stages of the program by completing the exercises in a whirlpool to provide an analgesic effect and to relieve the stress of gravity on sensitive structures. Examples of AROM exercises include spelling out the letters of the alphabet with the ankle and using a wand or cane with the upper extremity to improve active assisted ROM.

Resisted Range of Motion

Resisted ROM may be either static or dynamic. Static movement is measured with an isometric muscle contraction and can be used during phases 1 and 2 of the exercise program in a pain-free arc of motion. Dynamic resisted motion (dynamic strengthening) is discussed in the next section.

Isometric training measures a muscle's maximum potential to produce static force. The muscle is at a constant tension, whereas muscle length and the joint angle remain the same. For example, standing in a doorway and pushing outward against the door frame produces a maximal muscle contraction, but joints of the upper extremity do not appear to move. In performing an isometric contraction, a maximal force is generated against an object, such as the clinician's hand, for approximately 10 seconds and is repeated 10 times per set. Contractions, performed every 20° throughout the available ROM, are called multiangle isometric exercises.

Isometric exercise is useful when

1. Motion is contraindicated by pathology or bracing.
2. Motion is limited because of muscle weakness at a particular angle, called a sticking point.
3. A painful arc is present.
4. Prescribed postsurgical.

Isometric strength exercises are the least effective training method, because although circumference and strength increase, strength gains are limited to a range of 10° on either side of the joint angle. In addition, during isometric exercise, an adverse, rapid increase in blood pressure can occur when the breath is held against a closed glottis. This occurrence, referred to as the **Valsalva effect**, can be avoided with proper breathing.

Proprioception

Proprioception is a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (**kinesthesia**) and joint position. Sensory receptors located in the skin, muscles, tendons, ligaments, and joints provide input into the central nervous system relative to tissue deformation. Visual and vestibular centers also contribute afferent information to the central nervous system regarding body position and balance. The ability to sense body position is mediated by cutaneous, muscle, and joint mechanoreceptors.

Joint Mechanoreceptors

Joint mechanoreceptors are found in the joint capsule, ligaments, menisci, labra, and fat pads, and they include four types of nerve endings: Ruffini corpuscles, Golgi receptors, Pacinian corpuscles, and free nerve endings. Ruffini corpuscles are sensitive to intra-articular pressure and stretching of the joint capsule. Golgi receptors are intraligamentous and become active when the ligaments are stressed at the end ranges of joint movement. Pacinian corpuscles are sensitive to high-frequency vibration and pressure. Free nerve endings are sensitive to mechanical stress and the deformation and loading of soft tissues that comprise the joint.

Muscle Mechanoreceptors

As mentioned, the receptors found in muscle and tendons are the muscle spindles and the Golgi tendon organs. Muscle spindles are innervated by both afferent and efferent fibers and can detect not only muscle length but also, and more importantly, the rate of change in muscle length. Golgi tendon organs respond to both contraction and stretching of the musculotendinous junction. If the stretch continues for an extended time (i.e., longer than 6 to 8 seconds), the Golgi tendons are stimulated, causing a reflex inhibition in the antagonist muscles. This sensory mechanism protects the musculotendinous unit from excessive tensile forces that could damage muscle fibers.

Regaining Proprioception

Balance involves positioning the body's center of gravity over a base of support through the integration of information received from the various proprioceptors within the body. Even when the body appears motionless, a constant postural sway is caused by a series of muscle contractions that correct and maintain a dynamic equilibrium in an upright position. When balance is disrupted, as in falling forward or stumbling, the response is primarily automatic and reflexive. An injury or illness can interrupt the neuromuscular feedback mechanisms. Restoration of the proprioceptive feedback is necessary for promoting dynamic joints and functional stability to prevent reinjury.

Proprioceptive exercises must be specific to the type of activity that the individual will encounter during participation in a sport and physical activity. In general, the progression of activities to develop dynamic, reactive neuromuscular control is achieved through a progression that moves from slow speed to high speed, low force to high force, and controlled to uncontrolled activities. A single-leg stance test (e.g., stork stand) requires the individual to maintain balance while standing on one leg for a specified time with the eyes closed. The clinician looks for any tendency to sway or fall to one side. In the next stage, with the eyes open, the patient can progress to playing catch with a ball. This exercise can be made more difficult by having the patient balance on a trampoline while playing catch with a ball. Use of an Airex pad might begin with bilateral balancing and progress to one-legged balancing, dribbling a basketball, or playing catch with a ball. Many of these exercises can be adapted to the upper extremity. An individual can begin in a push-up position and shift his or her weight from one hand to another or perform isometric or isotonic press-ups, balance on one hand, balance on a BOSU ball or ball, or walk on the hands over material of different densities or heights.

Open Versus Closed Kinetic Chain Exercises

A common error in developing an exercise program is failure to assess the proximal and distal segments of the entire extremity, or kinetic chain. A **kinematic chain** is a series of interrelated joints that constitute a complex motor unit, constructed so that motion at one joint will produce motion at the other joints in a predictable manner. Whereas kinematics describe the appearance of motion, **kinetics** involves the forces, whether internal (e.g., muscle contractions or connective tissue restraints) or external (e.g., gravity, inertia, or segmental masses) that affect motion. Initially, a closed kinetic chain (CKC) was characterized as the distal segment of the extremity in an erect, weight-bearing position, such as the lower extremity when a person is weight bearing. Subsequently, when the distal segment of the extremity is free to move without causing motion at another joint, such as when non–weight-bearing, the system was referred to as an open kinetic chain (OKC). When force is applied, the distal segment may function independently or in unison with the other joints. Movements of the more proximal joints are affected by OKC and CKC positions. For example, the rotational components of the ankle, knee, and hip reverse direction when moving from an OKC to CKC position.

Because of incongruities between the lower and upper extremity, particularly in the shoulder region, several authors have challenged the traditional definition of OKC and CKC positions.[12–14] Stabilizing muscles in the scapulothoracic region produces a joint compression force that stabilizes the glenohumeral joint in much the same manner as a CKC in the lower extremity. Although debate continues on defining CKC and OKC relative to the upper extremity, there remains a general agreement that both CKC and OKC exercises should be incorporated into an upper and lower extremity rehabilitation program.

Injury and subsequent immobilization can affect the proprioceptors in the skeletal muscles, tendons, and joints. In rehabilitation, it is critical that CKC activities be used to retrain joints and muscle proprioceptors to respond to sensory input. CKC exercises are recommended because they

- Stimulate and reeducate the proprioceptors
- Increase joint stability and congruity

- Provide greater joint compressive forces
- Exercise multiple joints through weight bearing and muscular contractions
- Better control velocity and torque
- Reduce shear forces
- Increase muscle coactivation
- Allow better use of the specific adaptations to imposed demands (SAID) principle
- Permit more functional patterns of movement (including spiral and diagonal) and greater specificity for athletic activities
- Facilitate postural and dynamic stabilization mechanics

In contrast, OKC exercises can isolate a specific muscle group for intense strength and endurance exercises. In addition, they can develop strength in very weak muscles that may not function properly in a CKC system because of muscle substitution. Although OKC exercises may produce great gains in peak force production, these exercises usually are limited to one joint in a single plane (uniplanar) and have greater potential for joint shear, limited functional application, and limited eccentric and proprioceptive retraining. OKC exercises, however, can assist in developing a patient–athletic trainer rapport through uniplanar and multiplanar manual therapeutic techniques. **Figure 13.4** illustrates OKC and CKC chain exercises for the lower extremity.

Figure 13.4. Open and closed kinetic chain exercises for the lower extremity. A, Open kinetic chain exercise for the hamstrings. **B,** Closed kinetic chain exercise for the hip and knee extensors.

When ROM has been achieved, repetition of motion through actual skill movements can improve coordination and joint mechanics as the individual progresses into phase 3 of the program. For example, a pitcher may begin throwing without resistance or force application in front of a mirror to visualize the action. This also can motivate the individual to continue to progress in the therapeutic exercise program.

> During phase 2, passive stretching and AROM exercises should be conducted. In particular, stretching and strengthening of both the intrinsic and extrinsic muscles of the foot and ankle should be major parts of the rehabilitation plan. Cryotherapy, thermotherapy, EMS, joint mobilization, or massage can complement the exercise program as needed.

PHASE 3: DEVELOPING MUSCULAR STRENGTH, ENDURANCE, AND POWER

> ? The distance runner has full, pain-free ROM. She wants to resume her

running workouts. Is it advisable for her to do so at this time? What is the likelihood that reinjury will occur?

Phase 3 focuses on developing muscular strength, endurance, and power in the injured extremity as compared with the uninjured extremity. The individual can move into phase 4 when the following criteria have been completed:

- Bilateral ROM and joint flexibility are restored.
- Muscular strength, endurance, and power in the affected limb are equal or near equal to those in the unaffected limb.
- Cardiovascular endurance and general body strength are equal to or better than the preinjury levels.
- Score on Y balance test ≤4 cm and four hop testing scores at 80% to 90%.
- Sport-specific functional patterns are completed using mild to moderate resistance.
- The individual is psychologically ready to return to protected activity.

Muscular Strength

Strength is the ability of a muscle or a group of muscles to produce force in one maximal effort. Although static strength (isometric strengthening) is used during phases 1 and 2 in a pain-free arc of motion, dynamic strengthening is preferred during phase 3 of the program. Two types of contractions occur in dynamic strength: **concentric**, in which a shortening of muscle fibers decreases the angle of the associated joint, and **eccentric**, in which the muscle resists its own lengthening so that the joint angle increases during the contraction. Concentric and eccentric contractions also may be referred to as positive and negative work, respectively. Concentric contractions work to accelerate a limb; for example, the gluteus maximus and quadriceps muscles concentrically contract to accelerate the body upward from a crouched position. In contrast, eccentric contractions work to decelerate a limb and provide shock absorption, especially during high-velocity dynamic activities. For example, the shoulder external rotators decelerate the shoulder during the follow-through phase of the overhead throw, and hamstrings act to decelerate the body when running.

Eccentric contractions generate greater force than isometric contractions, and isometric contractions generate greater force than concentric contractions. In addition, less tension is required in an eccentric contraction. One major disadvantage of eccentric training, however, is delayed-onset muscle soreness, which is defined as muscular pain or discomfort 1 to 5 days following unusual muscular exertion. Delayed-onset muscle soreness is associated with joint swelling and weakness, which may last after the cessation of pain. This differs from acute-onset muscle soreness, in which pain during exercise ceases after the exercise bout is completed. To prevent the onset of delayed-onset muscle soreness, eccentric exercises should progress gradually. Remember to train specific muscles based on how they primarily function producing positive or negative work. Dynamic muscle strength is gained through isotonic or isokinetic exercise (Fig. 13.5).

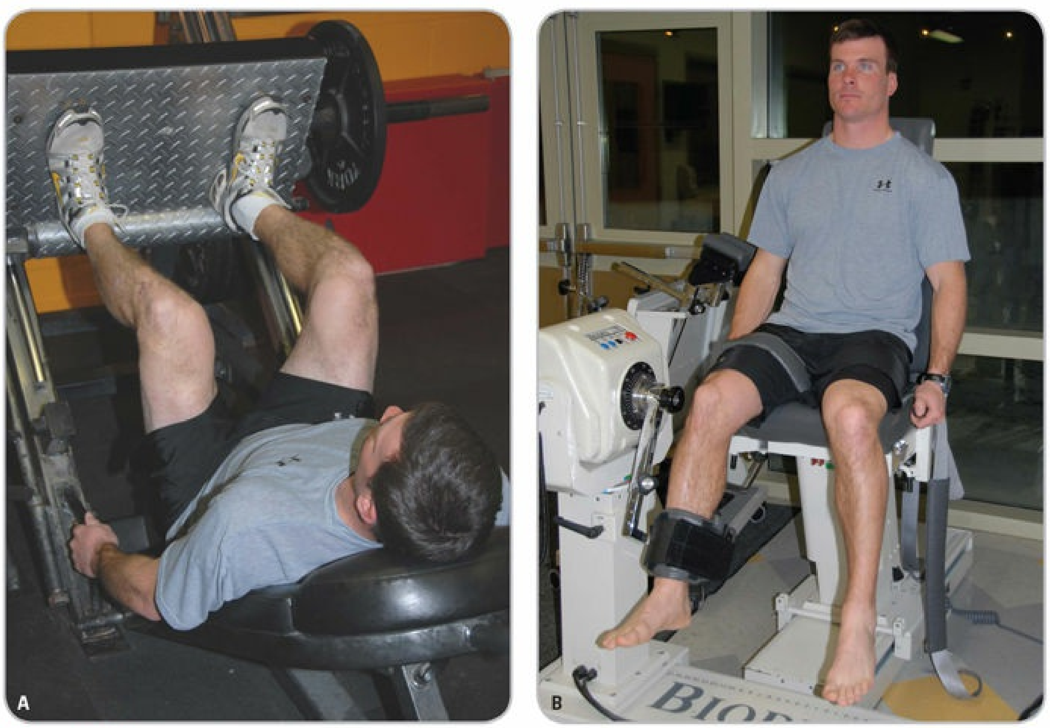


Figure 13.5. **Dynamic muscle strengthening.** Dynamic strength may be gained through **(A)** isotonic exercise or **(B)** isokinetic exercise.

Isotonic Training (Variable Speed/Fixed Resistance)

A more common method of strength training is isotonic exercise or, as it sometimes is called, **progressive resistive exercise**. In this technique, a maximal muscle contraction generates a force to move a constant load throughout the ROM at a variable speed. Both concentric and eccentric contractions are possible with free weights, elastic or rubber tubing, body weight exercises, and weight machines. Free weights are inexpensive and can be used in diagonal patterns for sport- or activity-specific skills, but adding or removing weights from the bars can be troublesome. In addition, a spotter may be required for safety purposes to avoid heavy weights being dropped. Thera-Band, or surgical tubing, is inexpensive and easy to set up, can be used in diagonal patterns for sport- or activity-specific skills, and can be adjusted to the patient's level of strength using bands of different tension. Weights on commercial machines can be changed quickly and easily. Using several stations of free weights and commercial machines, an individual can perform circuit training to strengthen multiple muscle groups in a single exercise session. Typically, however, the machines are large and expensive, work in only a single plane of motion, and may not match the biomechanical makeup or body size of the individual.

Isotonic training permits the exercise of multiple joints simultaneously, both eccentric and concentric contractions, and weight-bearing CKC exercises. A disadvantage is that when a load is applied, the muscle can only move that load through the ROM with as much force as the muscle provides at its weakest point. Variable resistance machines provide minimal resistance where the ability to produce force is comparatively lower (i.e., early and late in the ROM) and greatest resistance where the muscle is at its optimal length tension and mechanical advantage (i.e., usually the midrange). The axis of rotation generates an isokinetic-like effect, but angular velocity cannot be controlled.

Isokinetic Training (Fixed Speed/Variable Resistance)

Isokinetic training, or accommodating resistance, allows an individual to provide muscular overload and angular movement to rotate a lever arm at a controlled velocity or fixed speed. Theoretically, isokinetic training should activate the maximum number of motor units, which consistently overloads muscles and achieves maximum tension-developing or force-output capacity at every point in the ROM, even at the relatively "weaker" joint angles. Cybex, Biodex, and Kin Com are examples of equipment that use this strength training method. Coupled with a computer and appropriate software, torque-motion curves, total work, average power, and measures of torque to body weight can be instantaneously calculated to provide immediate, objective measurements to the individual and clinician.

Two advantages of isokinetic training are that a muscle group can be exercised to its maximum potential throughout the full ROM and that the dynamometer's resistance mechanism essentially disengages if pain is experienced by the patient. As the muscles fatigue, however, isokinetic resistance decreases. In contrast, with an isotonic contraction, because the resistance is constant as the muscle fatigues, the muscle must either recruit additional motor units, thus increasing muscle force, or fail to perform the complete repetition. It is hypothesized that during rehabilitation, isotonic training is more effective than isokinetic training in achieving rapid gains in strength during training using the daily adjusted progressive resistance exercise (DAPRE) technique.[15] Two other disadvantages are the cost of the machine, computer, and software package (ranging from $25,000 to $60,000) and the fact that most available machines permit only OKC exercises. For this reason, isokinetic training should be used in conjunction with other modes of resistance training.

Muscular Endurance

Muscular endurance is the ability of muscle tissue to exert repetitive tension over an extended period of time. The rate of muscle fatigue is related to the endurance level of the muscle (i.e., the more rapidly the muscle fatigues, the lower the muscle endurance). A direct relationship exists between muscle strength and muscle endurance. As muscle endurance is developed, density in the capillary beds increases, providing a greater blood supply, and thus, a greater oxygen supply to the working muscle. Increases in muscle endurance may influence gains in strength; however, the development of strength has not been shown to increase muscle endurance. Muscular endurance is gained by lifting low weights at a faster contractile velocity with more repetitions in the exercise session or with the use of stationary bikes or aquatic therapy, an elliptical, a StairMaster, or a slide board.

Muscular Power

Muscular power is the ability of muscle to produce force in a given time. Power training is started after the injured limb has regained at least 80% of the muscle strength in the unaffected limb. Regaining power involves weight training at higher contractile velocities or using plyometric exercises.

Plyometric training employs the inherent stretch–recoil characteristics of skeletal muscle through an initial, rapid eccentric (loading) prestretching of a muscle, thereby activating the stretch reflex to produce tension before initiating an explosive concentric contraction of the muscle. This stretch produces a strong stimulus at the level of the spinal cord, which causes an explosive reflex concentric contraction. The greater the stretch from the muscle's resting length immediately before the concentric contraction, the greater the load the muscle can lift or overcome. Injury can result if the individual does not have full ROM, flexibility, and near normal strength before beginning these exercises. Many of the anterior cruciate ligament (ACL) injury prevention programs use plyometric exercises in order to develop explosive power and correct improper jumping mechanics. Examples of plyometric exercises include a standing jump, multiple jumps, box jumps or drop jumping from a height, single- or double-leg hops, bounding, leaps, and skips. In the upper extremity, a medicine ball, surgical tubing, plyoback, and boxes can be used. Performing jumping and skipping exercises on grass or mats reduces the impact on the lower extremity during landing by reducing ground reaction force. These exercises should be performed every 3 days to allow the muscles to recover from fatigue.

Functional Application of Exercise

Strength, endurance, and power can only be increased by using the **overload principle**, which states that physiological improvements occur only when an individual physically demands more than normally is required of the muscles. This philosophy is based on the SAID principle, which states that the body responds to a given demand with a specific and predictable adaptation. Overload is achieved by manipulating the intensity, duration, frequency, specificity, speed, and progression in the exercise program.

Intensity

Intensity reflects both the caloric cost of the work and the specific energy systems that are activated. Strength gains depend primarily on the intensity of the overload, not on the specific training method used to improve strength. The DAPRE of Knight[16] is an objective method of increasing resistance as the individual's strength increases or decreases. A fixed percentage of the maximum weight for a single repetition is lifted during the first and second sets. Maximum repetitions of the resistance maximum are lifted during the third set. Adaptations to the amount of weight lifted are then increased or decreased accordingly during the fourth set and during the first set of the next session. The DAPRE guidelines are based on the concept that if the working weight is ideal, the individual can perform six repetitions when told to perform as many as possible. If the individual can perform more than six repetitions, the weight is too light. Conversely, if the individual cannot lift six repetitions, the weight is too heavy.

For individuals with chronic injuries or early postoperative rehabilitation, the DAPRE method may not be appropriate. Instead, a high-repetition, low-weight exercise may be more productive, particularly during the early phases. High weights potentially can cause a breakdown of the supporting soft-tissue structures and exacerbate the condition. Use of smaller weights and submaximal intensities can stimulate blood flow and limit tissue damage. To gain strength and endurance, higher repetitions are required. The individual begins with two or three sets of 10 repetitions, progressing to five sets of 10 repetitions as tolerated. When the individual can perform 50 repetitions, 1 lb may be added and the repetitions can be reduced to three sets of 10 repetitions.

All exercises should be performed slowly, concentrating on proper technique. As strength increases, the DAPRE method or other type of progressive resistance exercise schedule may be used.

Duration

Duration refers to the estimated time that it will take to return the individual to full (100%) activity; more commonly, however, duration refers to the length of a single exercise session. The time can shorten if pain, swelling, or muscle soreness occurs. In general, the individual must participate in at least 20 minutes of continuous activity, with the heart rate (HR) elevated to at least 70% of maximal. This is particularly important when increasing cardiovascular endurance, which will be explained later in this chapter.

Frequency

Frequency refers to the number of exercise sessions per day or week. Although exercise performed twice daily yields greater improvement than exercise performed once daily, in most cases, the exercise program should be conducted three to four times per week. It is critical not to work the same muscle groups on successive days to allow recovery from fatigue and muscle soreness. If daily bouts are planned, strength and power exercises may be alternated with cardiovascular conditioning, or exercises for the lower extremity may alternate with exercises for the upper extremity.

Specificity

An exercise program must address the specific needs of the patient. For example, exercises that mimic the throwing action will benefit a baseball pitcher but are not applicable to a football lineman. If exercises simulate actual skills used in the individual’s sport or activity, the patient is more likely to be motivated and compliant with the exercise program. The type of exercise (e.g., isometric, isotonic, or isokinetic) also is important. Individuals who rely on eccentric loading also must include eccentric training in their rehabilitation program. Rhythm, or velocity, also has been shown to be specific to that required for the sport skill, with the greatest gains in strength consistently occurring at training speeds.[17]

Speed

Speed refers to the rate at which the exercise is performed. Initially, exercises should be performed in a slow, deliberate manner, at a rate of approximately 60° per second, with emphasis placed on concentric and eccentric contractions. The individual should exercise throughout the full ROM, pausing at the end of the exercise. Large muscle groups should be exercised first, followed by the smaller groups. In addition, the exercise speed should be varied. As strength, endurance, and power increase, functional movements should increase in speed. Surgical tubing can be used to develop a high-speed regimen to produce concentric and eccentric synergistic patterns, and isokinetic units also may be used at the highest speeds.

Progression

In an effort to maintain motivation and compliance, an objective improvement should occur each day, whether this is an increase in repetitions or intensity. Muscular strength is improved with a minimum of 3 days per week of training that includes 12 to 15 repetitions per bout of 8 to 10 exercises for the major muscle groups.[5] If the individual complains of pain, swelling, or residual muscle soreness, the program may need to be decreased or varied in intensity. An orderly progression should move from ROM exercises to isometric, isotonic, isokinetic, and functional activities however, progressing from low to high intensity with ever increasing demands on the patient as the healing process allows.

> Before permitting the distance runner to resume running workouts, her muscle strength, endurance, and power in the affected limb, in addition to full and pain-free ROM, must be at or near the levels of the unaffected limb to prevent reinjury.

PHASE 4: RETURN TO SPORT/PHYSICAL

ACTIVITY

> ? The distance runner has full ROM and near normal strength in the affected limb. She has maintained cardiovascular endurance by swimming and using an upper body ergometer. What additional factors need to be considered to prepare this patient for a return to full activity?

The individual can return to the sport activity as soon as muscle strength, endurance, and power are restored. During phase 4, the individual also should correct any biomechanical inefficiency in motion and movement dysfunction; restore coordination and muscle strength, endurance, and power in sport-specific skills; and improve cardiovascular endurance. The individual may be returned to activity if the following goals are attained:

- Coordination and balance are normal.
- Sport-specific functional patterns are restored in the injured extremity.
- Muscle strength, endurance, and power in the affected limb are equal to those in the unaffected limb.
- Cardiovascular endurance is equal to or greater than the preinjury level.
- Quantitative testing should be completed: Examples include four hop test for the lower extremity, isometric strength tests measurements, Y balance test, and patient outcome scales specific to the injured body part.[18]
- The individual receives clearance to return to participation by the supervising physician.

Coordination

Coordination refers to the body's ability to execute smooth, fluid, accurate, and controlled movements. Simple movement, such as combing hair, involves a complex muscular interaction using the appropriate speed, distance, direction, rhythm, and muscle tension to execute the task. Coordination may be divided into two categories: gross motor movements involving large muscle groups and fine motor movements using small groups. Gross motor movements involve activities such as standing, walking, skipping, and running. Fine motor movements are seen in precise actions, particularly with the fingers, such as picking up a coin off a table, clutching an opponent's jersey, or picking up a ground ball with a glove. Coordination and proprioception are directly linked. When an injury occurs and the limb is immobilized, sensory input from proprioceptors and motor commands are disrupted, resulting in an alteration of coordination.

Performing CKC activities during phase 2 of the exercise program can help to restore proprioceptive input and improve coordination. Constant repetition of motor activities using sensory cues (i.e., tactile, visual, or proprioceptive) or increasing the speed of the activity over time can help a patient continue to develop coordination during phases 3 and 4. A wobble board, teeter board, Pro Fitter, or Biomechanical Ankle Platform System (BAPS) board often is used to improve sensory cues and balance in the lower extremity. Proprioceptive neuromuscular facilitation patterns and the Pro Fitter also may be used to improve sensory cues in the upper and lower extremities. Although the resistance-band protocol is common in rehabilitation, the proprioceptive neuromuscular facilitation strength protocol is also an effective treatment to improve strength in individuals with chronic ankle instability. Both protocols showed clinical benefits in strength and perceived instability. To improve functional outcomes, clinicians should consider using additional multiplanar and multijoint exercises.[18]

Sport/Activity-Specific Skill Conditioning

Because different sports require different skills, therapeutic exercise should progress to the load and speed that are expected for the individual's sport or physical activity. For example, a baseball player performs skills at different speeds and intensities than a football lineman. Therefore, exercises must be coupled with functional training or with specificity of training related to the physical demands of the sport.

As ROM, muscular strength, and coordination are restored, the individual should work the affected extremity through functional diagonal and sport-specific patterns. For example, during phase 3, a baseball pitcher may have been moving the injured arm through the throwing pattern with mild-to-moderate resistance. During phase 4, the individual should increase resistance and speed of motion. Working with a ball attached to surgical tubing, the individual can develop a kinesthetic awareness in a functional pattern. When controlled motion is done without pain, actual throwing can begin. Initially, short throws with low intensity can be used, progressing to longer throws with low intensity. As the player feels more comfortable and is pain-free with the action, the number of throws and their intensity are increased. Similar programs can be developed for other sports or physical activities. Other sport/activity-specific skills that can be performed at this level include sprint work, agility runs, figure eights, side stepping, shuttle runs, and interval training (i.e., alternating periods of intense work and active recovery).

Cardiovascular Endurance

Cardiovascular endurance, commonly called aerobic capacity, is the body's ability to sustain submaximal exercise over an extended period and depends on the efficiency of the pulmonary and cardiovascular systems. When an injured individual is unable to continue or chooses to stop aerobic training, detraining occurs within 1 to 2 weeks.[5] If the individual returns to activity without a high cardiovascular endurance level, fatigue sets in quickly, placing the individual at risk for reinjury.

Similar to strength training, maintaining and improving cardiovascular endurance is influenced by an interaction of frequency, duration, and intensity. The American College of Sports Medicine (ACSM) recommends that aerobic training be moderate-intensity aerobic physical activity for a minimum of 30 minutes per exercise session on 5 or more days per week or vigorous-intensity aerobic activity for a minimum of 20 minutes on 3 or more days.[5,19] If added consideration is needed to preserve bone health during adulthood, the ACSM recommends 30 to 60 minutes of weight-bearing cardiovascular exercises three to five times per week in addition to resistance exercises two or three times per week.[20] The targeted HR can be calculated in two manners:

1. An estimated HRmax for both men and women is approximately 220 bpm. HR is related to age, with HRmax decreasing as an individual ages. A relatively simple calculation is

$$\text{HRmax} = 220 - \text{Age}$$

With a 20-year-old individual working at 80% of maximum, the calculation is $0.8 \times (220 - 20)$, or 160 bpm.

2. Another commonly used formula (Karvonen formula) assumes that the targeted range of the HR is between 60% and 90% of HRmax. This calculation is

$$\text{Target HR range} = [(\text{HRmax} - \text{HRrest}) \times 0.60 \text{ and } 0.90] + \text{HRrest}$$

where HRrest is the individual's resting HR. If an individual's HRmax is 180 bpm and the HRrest is 60 bpm, this method yields a target HR range between 132 and 168 bpm.

Non–weight-bearing exercises, such as swimming, rowing, biking, or use of the upper body ergometer, can be helpful early during the therapeutic program, particularly if the individual has a lower extremity injury. Walking, cross-country skiing, jumping rope, or running can be performed as the condition improves.

> In preparing the distance runner for a return to her sport, modifications in running workouts must be addressed because it would not be appropriate for the athlete to continue at her previous level of training. Ongoing management of the condition should be addressed as well. In particular, the athlete should be informed about signs and symptoms that would warrant a decrease in activity and a return to more intensive rehabilitation. Finally, the documentation needed to clear the distance runner for return to activity, including a doctor's medical clearance, should be completed. It is important to remember that all

written documentation of the exercise program and written medical clearance should be placed in the patient's file and stored in a safe, secure location for a minimum of 3 to 5 years. With changes in insurance reimbursement, proper documentation is critical for all athletic trainers.

SUMMARY

1. Rehabilitation begins immediately after the injury assessment and includes the following actions:
   - The level of function and dysfunction is assessed.
   - Results are organized and interpreted.
   - A list of patient problems is formulated.
   - Long- and short-term goals are established.
   - A treatment plan is developed, including therapeutic exercises, modalities, and medications.
   - The program is then supervised and periodically reassessed with appropriate changes made.
2. Phase 1 of the therapeutic exercise program should focus on patient education and control of inflammation, muscle spasm, and pain.
3. Phase 2 should regain any deficits in ROM and proprioception at the affected joint as compared with the unaffected joint.
4. Phase 3 should regain muscular strength, endurance, and power in the affected limb.
5. Phase 4 prepares the individual to return to activity and includes an analysis of motion, sport/activity-specific skill training, regaining coordination, and cardiovascular conditioning.
6. At the conclusion of the rehabilitation program, the supervising physician

determines if the individual is ready to return to full activity. This decision should be based on a review of the individual's ROM and flexibility; muscular strength, endurance, and power; biomechanical skill; proprioception and coordination; and cardiovascular endurance.

7. If additional protective bracing, padding, or taping is necessary to enable the individual to return safely to activity, this should be documented in the individual's file. In addition, it should be stressed that use of any protective device should not replace a maintenance program of conditioning exercises.
8. The athletic trainer should keep a watchful eye on the individual as he or she returns to activity. If the individual begins to show signs of pain, swelling, or discomfort or if skill performance deteriorates, the individual should be reevaluated to determine whether activity should continue or the therapeutic exercise program needs to be reinstituted.

APPLICATION QUESTIONS

1. A football running back had knee surgery to repair a menisci injury. The supervising physician has suggested the inclusion of CKC exercises in the rehabilitation process. What are the advantages of CKC exercises?
2. A 21-year-old male hurdler has tight hamstrings. How can proprioceptive neuromuscular facilitation exercises be used to decrease the tightness of the hamstrings? What exercises might you consider using?
3. You are a high school athletic trainer with a limited budget. What type of rehabilitative equipment can you purchase to increase muscle strength, endurance, and power without overextending the budget?
4. An 18-year-old field hockey player has been diagnosed with Achilles tendinitis. Her current symptoms include increased pain with active plantar flexion and accompanying muscle weakness in plantar flexion. What short- and long-term goals might you suggest for her therapeutic

exercise program?

5. A collegiate basketball player sustained a grade 2 inversion ankle sprain. What specific exercises would you suggest to improve the individual's proprioception?
6. A 32-year-old professional golfer sustained a lumbar strain, which resulted in an inability to practice or play competitively for 3 weeks. He has now completed phase 4 of the therapeutic exercise program for the injury. How will you determine his readiness to return to full activity and competition?

REFERENCES

1. Feger MA, Goetschius J, Love H, et al. Electrical stimulation as a treatment intervention to improve function, edema or pain following acute lateral ankle sprains: a systematic review. *Phys Ther Sport*. 2015;16(4):361–369.
2. Mangine B, Nuzzo G, Harrelson GL. Physiologic factors of rehabilitation. In: Andrews JR, Harrelson GL, Wilk KE , eds. *Physical Rehabilitation of the Injured Athlete*. 3rd ed. Philadelphia: WB Saunders; 2004:13–33.
3. Mazess RB, Whedon GD. Immobilization and bone. *Calcif Tissue Int*. 1983;35(3):265–267.
4. Konin JG, Harrelson GL, Leaver-Dunn D. Range of motion and flexibility. In: Andrews JR, Harrelson GL, Wilk KE , eds. *Physical Rehabilitation of the Injured Athlete*. 3rd ed. Philadelphia, PA: WB Saunders; 2004:136–156.
5. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition, and Human Performance*. 6th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2007.
6. Klingler W, Velders M, Hoppe K, et al. Clinical relevance of fascial tissue and dysfunctions. *Curr Pain Headache Rep*. 2014;18(8):439.
7. Maitland GD. *Extremity Manipulation*. London, United Kingdom: Butterworth; 1977.
8. O'Sullivan K, Murray E, Sainsbury D. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. *BMC Musculoskelet Disord*. 2009;10:37.
9. Davis DS, Ashby PE, McCale KL, et al. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. *J Strength Cond Res*. 2005;19(1):27–32.
10. Haddad M, Dridi A, Chtara M, et al. Static stretching can impair explosive performance for at least 24 hours. *J Strength Cond Res*. 2014;28(1):140–146.
11. Nelson KC, Cornelius WL. The relationship between isometric contraction durations and improvement in shoulder joint range of motion. *J Sports Med Phys Fitness*. 1991;31(3):385–388.
12. Wilk KE, Arrigo CA, Andrews JR. Closed and open kinetic chain exercise for the upper extremity. *J Sport Rehabil*. 1996;5(1):88–102.
13. Lephart SM, Henry TJ. Functional rehabilitation for the upper and lower extremity. *Orthop Clin North Am*. 1995;26(3):579–592.

14. Dillman CJ, Murray TA, Hintermeister RA. Biomechanical differences of open and closed chain exercises with respect to the shoulder. *J Sport Rehabil*. 1994;3(3):228–238.
15. Knight KL, Ingersoll CD, Bartholomew JB. Isotonic contractions might be more effective than isokinetic contractions in developing muscle strength. *J Sport Rehabil*. 2001;10(2):124–131.
16. Knight KL. Rehabilitating chondromalacia patellae. *Phys Sportsmed*. 1979;7(10):147–148.
17. Dale RB, Harrelson GL, Leaver-Dunn D. Principles of rehabilitation. In: Andrews JR, Harrelson GL, Wilk KE , eds. *Physical Rehabilitation of the Injured Athlete*. 3rd ed. Philadelphia:WB Saunders; 2004:157–188.
18. Hall EA, Docherty CL, Simon J, et al. Strength-training protocols to improve deficits in participants with chronic ankle instability: a randomized controlled trial. *J Athl Train*. 2015;50(1):36–44.
19. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081–1093.
20. Kohrt WM, Bloomfield SA, Little KD, et al. American College of Sports Medicine position stand: physical activity and bone health. *Med Sci Sports Exerc*. 2004;36(11):1985–1996.