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Principles of Rehabilitation

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The number of adolescent athletes competing in organized sports has significantly increased over the past several years, thus causing a rise in sport-related injuries. Adolescents are specializing in sports at an earlier age and, in some cases, performing excessive and repetitive training that often leads to overuse injuries. Sport is the number one cause of injuries in 5–17-yr-old children (1). Many sports-related injuries do not receive proper rehabilitation. Adolescents may return to sports training and/or competition too quickly after an injury. This often causes a recurrence of the injury and/or the development of a new injury. Therefore, a comprehensive rehabilitation program to successfully manage an injury is extremely important to ensure the safe return to sport and/or competition. Appropriate rehabilitation and education of athletes, parents, and coaches are essential components in assisting the young athlete's recovery. In addition, the rehabilitation program should include the athlete's personal goals.

The evidence for rehabilitation practice in the field of adolescent sports medicine is often lacking proper research studies, particularly clinical trials. Many of the recommended rehabilitation programs are based on clinical experience, mainly with an adult population.

Before establishing a rehabilitation program, consideration must be given to the adolescent athlete's stage of maturation, which is more important than chronological age. Adolescence is a difficult period to define because of the wide variation in time of onset and termination. Age ranges of 8–19 yr in girls and 10–22 yr in boys are often listed as limits for the adolescent period. During this period, bodily systems become adult both structurally and functionally. Structurally, the rate of growth in stature marks the onset of the adolescent growth spurt. The rate of the statural growth reaches a peak, decelerates, and finally terminates with the attainment of adult stature (2).

Functionally, adolescence is defined by sexual maturation. Tanner and associates developed a sexual maturation scale that correlates with peak height velocity (*see* Table I.1 in the Introduction) (2). Tanner stage 1 is determined by growth hormone production, whereas stages 2–5 are related to sex hormones (3). Therefore, children are described as prepubertal

(Tanner stage 1), pubertal (Tanner stage 3), and postpubertal (Tanner stage 5). Postpubertal individuals are physically adults. Tanner staging is useful in determining the appropriate treatment and rehabilitative interventions. This chapter discusses the principles of rehabilitation, with emphasis on the evidence supporting these principles.

Principles of Rehabilitation

The major principle of rehabilitation is to safely maximize the athlete's abilities, despite an existing and/or a developing impairment. The goals of a rehabilitation program are to control inflammation and pain, promote healing, restore function, safely return to sports training and/or competition, and prevent future injury. In addition, maintaining the athlete's level of physical fitness while recovering from an injury is an essential component of the rehabilitation program.

The rehabilitation program includes assessments of posture, joint range of motion, muscle strength, endurance, balance, coordination, and function (4–8). Posture deviations and muscle weakness and/or tightness often lead to serious imbalances that can cause malalignment, an increase in pain, a decrease in function, and a predisposition to future injury.

Rehabilitation Program

A comprehensive rehabilitation program includes a detailed patient history, a review, an examination of all systems, and the establishment of a plan of care.

Patient History

Information is gathered from both the patient and parent (Table 1.1).

Table 1.1. Patient history.

Patient history
• Demographics and developmental history • Current medical diagnoses • Previous diagnoses • Past injuries with dates • Surgical history with dates and complications (if any) • Medications • Chronological age; bone age • Review of clinical tests (MRI, bone scan, radiograph) • Past and present activity level • Recreational versus competitive activity • Pain assessment at rest, night, with activity (age appropriate pain scale) patient's current concerns and goals[1]

Source: Cassella M, Richards K. Physical therapy/rehabilitation. In: The Pediatric and Adolescent Knee. Micheli L, Kocher, eds. 2006. By permission of Elsevier.

Table 1.2. Resting adolescent heart rate by sex and age.

Age	12	13	14	15	16	17
White males	76	76	74	73	70	73
White females	86	83	84	83	84	81
Afro-american males	75	71	73	71	69	66
Afro-american females	81	80	80	80	78	77

Source: Rabbia et al., 2002.

Systems Review

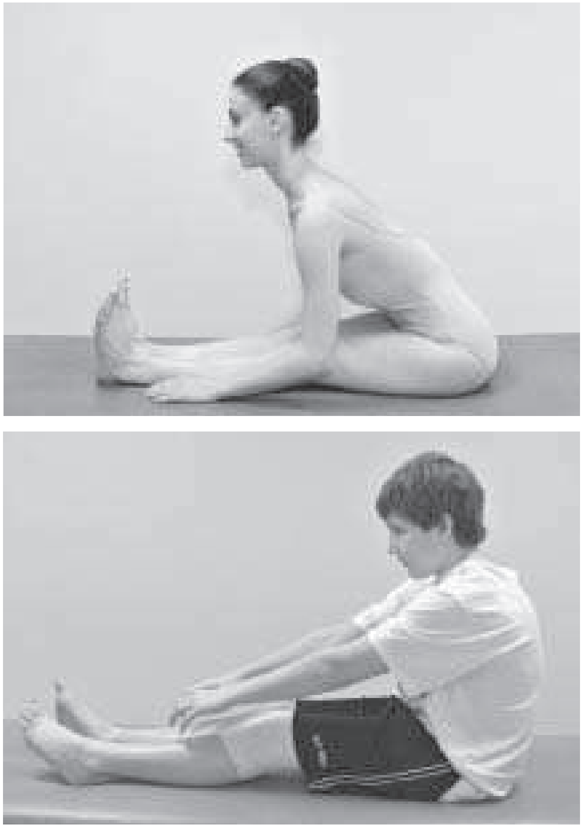
Gathering baseline information before treatment intervention is necessary to establish goals, monitor the effects of both therapeutic and conditioning exercises, and identify risks factors that may contribute to future injury. Systems to review include:

1. Cardiovascular/Pulmonary: Knowledge of normal respiratory rates, heart rates, and blood pressure for adolescents is necessary to monitor their response to treatment (Tables 1.2 and 1.3) (9,10).
2. Integumentary: Assessment of the integumentary system includes skin integrity, color, trophic changes, and scar formation. Blistering, skin temperature, scar tissue pliability, texture, and sensation should be observed. Activities or movements that aggravate the incisional site should be documented in adolescents who have had surgery. Scar types include contracture, hypertrophic, and keloid. A contracture scar is a tightening of surrounding tissues. These scars tend to cause impaired movement. Hypertrophic scar tissue can be caused by the overproduction of connective tissue. They are raised above the skin, thick, red, and itchy. Keloid formations are highly thickened areas of scar tissue. They are larger and more raised than the hypertrophic scars. This type of scarring is often genetic (11).
3. Musculoskeletal: Tightness in the muscle–tendon units seems to occur in the absence of injury as the athlete enters puberty. Adolescent athletes,

Table 1.3. Blood pressure for girls and boys by age and height percentile of 50%.

Age	Girls systolic/diastolic	Boys systolic/diastolic
11	103/61	104/61
12	105/62	106/62
13	107/63	108/62
14	109/64	111/63
15	110/65	113/64
16	111/66	116/65
17	111/66	118/67

Source: Staley and Richard, 2001.



A

B

Figure 1.1. Hamstring length. **(A)** Normal and better than normal hamstring length. The dancer is able to exceed a 90-degree hip angle keeping her knee straight. **(B)** Tightness in the hamstring. The athlete has had an increase in linear growth; therefore, he is unable to attain a 90-degree hip angle with his knees straight.

particularly males, demonstrate a generalized loss of flexibility, especially in larger muscle groups, such as the hip flexors, hamstring, quadriceps, and triceps surae. Linear growth in the long bones and spine exceeds the rate of growth of the muscle–tendon unit. Therefore, during the adolescent growth spurt, a loss of both strength and flexibility can often occur (Figure 1.1) (12). The loss of strength and flexibility not only impacts the athlete's athletic ability, but also often leads to serious injuries. Therefore, detailed posture, joint range, muscle strength, and functional assessments should be performed at regular intervals to determine the athlete's fitness for sports activities. Specific tests and measurements will enable the professional to establish a baseline for appropriate treatment interventions for an existing injury and to prevent future injuries.

4. Posture: A detailed posture assessment helps the examiner identify deviations and/or malalignment (Table 1.4). Both can have a serious, nega-

Table 1.4. Posture assessment.

Posture Evaluation Form

Name: ________________________ Medical Record
NO. ________ D.O.B. _______ Sex ____
Diagnosis ___________________ Surgical Procedure/Date _______________________
Precautions ____

Posterior view			Left	Right
Head	Centered	Tilt		
Shoulders	Level	Elevated		
Scapulae	Level	Elevated		
Spine	Aligned	Shifted		
Waist folds	Symmetrical	Increased		
Pelvis	Level	Elevated		
Knees	Aligned	Varus		
		Valgus		
Heels	Aligned	Varus		
		Valgus		
Anterior view			**Left**	**Right**
Head	Centered	Tilt		
Neck folds	Symmetrical	Increased		
Breasts	Symmetrical	Prominent		
Arm length	Equal	Longer		
Pelvis	Level	Elevated		
Knees	Aligned	Varus		
		Valgus		
Forefoot	Aligned			
	Pronated			
	Supinated			
Lateral view			**Left**	**Right**
Head	Aligned		Forward	Backward
Cervical (anterior) curve	Normal		Increased	Decreased
Shoulders	Level		Forward	Backward
Scapulae	Aligned		Protracted	Retracted
Thoracic (posterior) curve	Normal		Increased	Decreased
Lumbar (anterior) curve	Normal		Increased	Decreased
Pelvis	Aligned		Anterior Tilt	Posterior Tilt
Adams forward bend test			**Left**	**Right**
Thoracic	Negative		Rib hump	Rib hump
Lumbar	Negative		Increased m. bulk	Increased m. bulk
Knees	Aligned		Hyperextension	Hyperextension
Ankles	Aligned		Increased DF	Increased DF
			Increased PF	Increased PF

Source: Cassella M, Richards K. Physical therapy/rehabilitation. In: The Pediatric and Adolescent Knee. Micheli L, Kocher, eds. 2006. By permission of Elsevier.

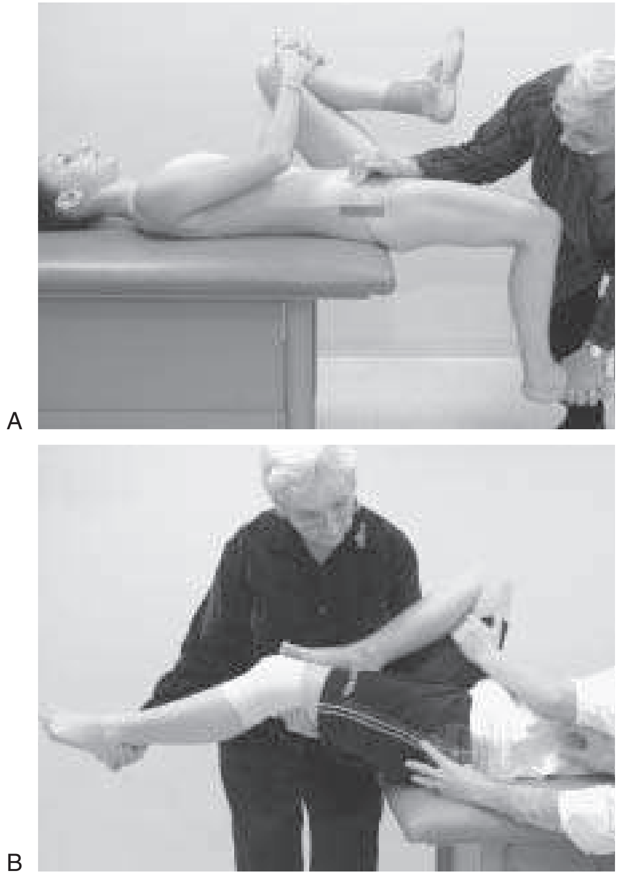


FIGURE 1.2. Thomas test. **(A) Negative** Thomas test. The lumbar spine remains flat on the table, the pelvis is in a neutral position, and the thigh is in contact with the table, indicating appropriate length of the iliopsoas muscle. **(B) Positive** Thomas test. The lumbar spine loses contact with the table, and the pelvis moves anteriorly at 30 degrees of hip flexion, indicating tightness in the iliopsoas muscle.

tive impact on body mechanics and sport-specific techniques. In addition, identifying postural deviations leads the examiner to further investigate specific joint and/or muscle impairments.

5. Joint range of motion: Standardized testing includes measuring each joint, especially those that impact the athlete's performance. A few examples of tests that measure tightness in muscle groups that are generally affected during the adolescent growth spurt are as follows:

a. Thomas test: The Thomas test measures tightness in the iliopsoas muscle (Figure 1.2). Restricted flexibility in this muscle can cause increased lumbar hyperlordosis, decreased hip extension, and an increase in knee hyperextension. The test is performed passively. The patient is positioned supine with both hips and knees flexed to the chest, with the lower back flat on the table. The patient holds one leg flexed to the chest. The examiner cradles the other leg and has one hand around the pelvis. The examiner's thumb is positioned on the anterior superior iliac spine (ASIS) to determine when the pelvis begins to move anteriorly. The examiner passively lowers the leg. When the ASIS begins to move anteriorly, the test is stopped and the angle of hip flexion is measured (13).

b. Straight leg raise: The straight leg raise measures hamstring tightness (Figure 1.3). Restricted flexibility in the hamstrings will negatively affect

A

B

FIGURE 1.3. Straight leg raise test. **(A) Negative** straight leg raise test. The pelvis remains in a neutral position as the straight leg is passively flexed to 90 degrees, indicating appropriate length of the hamstrings muscles. **(B) Positive** straight leg raise test. The pelvis begins to move anteriorly at 40 degrees of hip flexion, indicating tightness in the hamstrings muscles.

A

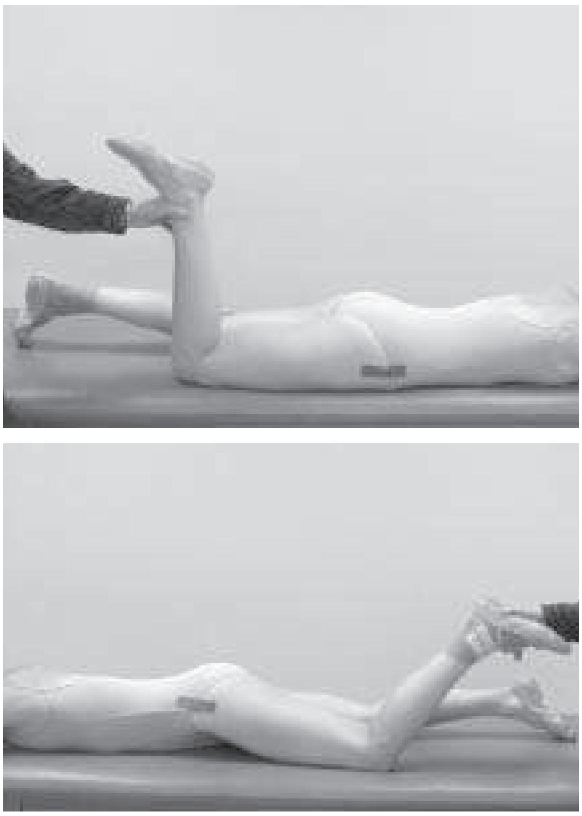
B

FIGURE 1.4. Ober test. **(A) Negative** Ober test. The thigh and knee are horizontal in relation to the hip joint, indicating normal length of the ITB. **(B) Positive** Ober test. The thigh and knee are above the horizontal in relation to the hip joint indicating a tight ITB.

low back, pelvis, hip, and knee alignment. The straight leg raise test focuses on proximal hamstring tightness. The test is performed passively. The patient is positioned supine with hips and knees extended and the pelvis in a neutral position. The examiner cradles the leg with one arm and has the other hand around the pelvis. The examiner's thumb is positioned on the ASIS. The examiner passively raises the leg, keeping the knee straight. As soon as the ASIS begins to move posteriorly, the test is stopped and the angle of hip flexion is measured (14,15).

c. Ober test: The Ober test measures tightness in the iliotibial band (ITB) (Figure 1.4). Restricted flexibility of the ITB often promotes lateral tracking of the patella. This malalignment of the patella can disrupt knee joint mechanics. Tightness of the ITB not only contributes to knee pain but can also interfere with function. The test is performed passively. The patient is positioned sidelying, with the lumbar spine in flexion. The hips and knees are flexed to the chest. The patient's neck and trunk are also flexed. The patient holds the bottom leg to the chest while the examiner cradles the top leg, keeping the knee flexed. The examiner flexes the hip and then widely abducts and extends the hip to allow the tensor fasciae latae muscle to move over the greater trochanter. The examiner attempts to passively lower the leg to the horizontal position (14).

d. Ely Test: The Ely test measures tightness in the rectus femoris muscle (Figure 1.5). Restricted flexibility in this muscle can also have a negative



A

B

Figure 1.5. Ely test. **(A) Negative** Ely test. The anterior hip remains in contact with the table when the knee is flexed to 90 degrees, indicating appropriate length of the rectus femoris muscle. **(B) Positive** Ely test. The anterior hip loses contact with the table and the buttock begins to rise when the knee is flexed to 60 degrees, indicating tightness in the rectus femoris muscle.

effect on patellar alignment. The test is performed passively. The patient is positioned prone, with the hips and knees extended. The examiner grasps the lower leg and slowly flexes the knee. The test is stopped when the hip begins to flex and the buttock begins to rise. The angle of knee flexion is measured (14).

6. Neuromuscular system: The neuromuscular system includes assessment of strength, coordination, balance, proprioception, agility, and gait. Coordination and agility are the ability to perform movements with appropriate speed, distance, direction, rhythm, and muscle tension. When assessing adolescents, normal development of skill acquisition must be taken into consideration so that testing is age appropriate. By age five, the child can hop 10 hops, but a skillful hop that requires flight and distance continues to develop into early adolescence (15). Neuromuscular training describes a progressive exercise regimen that restores synergy and synchrony of the muscle-firing patterns that are necessary for dynamic stability and fine motor control. This is accomplished by enhancing the dynamic muscular stabilization of the joint and by increasing the athlete's cognitive awareness of both joint position and motion.

Establishment of A Plan of Care

A successful rehabilitation program depends not only on physiological factors but also on the emotional and psychosocial attitudes of the adolescent athlete (16). These factors have a significant influence on compliance, performance, and the expectations of both the athlete and the health professional.

Positive communication is the key to a successful rehabilitation program. Communication between health professionals, team members managing the athlete's condition, and the parents is necessary to achieve a positive outcome. The adolescent understands the consequences of compliance, but often focuses on the here and now (17). Education and detailed explanations with the rationale for each activity will help to promote the athlete's compliance.

The rehabilitation program is based on the diagnosis, the goals of treatment, the athlete's expectations, and the anticipated course of healing (Table 1.5). Acute injuries require early medical attention, especially if the injury affects mechanics and performance. An accurate diagnosis is necessary so that the appropriate management can be planned. The goals of rehabilitation are to control inflammation and pain, promote healing, and restore function. Once the athlete has recovered sufficiently, return to sports and/or competition can be considered. Maintaining the athlete's physical fitness during recovery, education on preventing future injuries, and specialized training to increase performance are essential components of the rehabilitation program.

TABLE 1.5. Guidelines for a rehabilitation program based on the stages of healing.

Time	Stages of Healing	Rehabilitation program	Therapeutic goals
Phase 1 Days 1–3	Acute Inflammation	Modified activities, Ice, Compression, Elevation (MICE); crutches, braces, supportive devices PRN	**1. Control Inflammation and Pain** Acute care management Protect affected area (protective weight bearing in lower extremity injuries) Reduce swelling and inflammation Minimize hypoxic damage to tissue
Days 4–7	Repair/Substrate/ Inflammation	Isometric exercises Gentle "pain free" active range of motion	Limit further tissue damage Gradually increase "pain free" range of motion
Phase 2 Days 7–21	Proliferation	Restore active full range of motion Gentle progressive resistive exercises	**2. Promote Healing** Decrease protected status if indicated (i.e partial weight bearing status) Reduce muscle atrophy Improve: range of motion, flexibility, strength
Phase 3 Week 3 to 6	Healing and Maturation	Functional activities as tolerated More complex movements Progress loading (i.e. cycling, light weights)	**3. Restore Function** Continue to restore range of motion and strength Restore proper muscle activation and biomechanics Improve: proprioception, endurance
Phase 4 Week 6–6 mo	Tissue Remodeling	Sport specific training Simulate the demands of the sport/activity Coordination and balance exercises Eccentric loading exercises	**4. Return to Activities and Sports** Restore anatomic form, physiologic function Improve conditioning Return to play/sport Consider training modifications and return to play/sports
plans			
			5. Prevent Future Injury Protective equipment Injury prevention exercises/ programs

Source: Jarvinen TAH, Jarvinen TLN, Kaariainen M, et al. Muscle injuries: biology and treatment. Am J Sports Med, 2005;33(5);745–764. Reprinted by permission of Sage Publications, Inc.

Rehabilitation Plan of Care

The aims of a rehabilitation plan of care are to:

- provide immediate injury care (RICE)
- promote healing
- restore function
- return to sports and/or competition
- prevent future injury.

Immediate Care

The acronym **RICE** (**R**est/modified activity depending on the severity of the injury, **I**ce, **C**ompression, and **E**levation) is applied in acute injuries. Self-treatment or treatment by the coach or trainer on the field should begin immediately after an injury (18,19). A recent article by Bleakley et al. reviewed the evidence for cryotherapy in the acute management of soft tissue injuries and noted the following:

- Applying ice immediately after an acute injury reduced tissue temperature by 10–15°C.
- Ice applied intermittently at 10-min intervals was shown to be more effective at cooling in animal and human tissues.
- Simultaneous ice and compression did not prove to be any more efficient than compression alone. However, the studies did not look at the thickness of the various dressings that may have impeded the cooling effect.
- Cryotherapy or ice application may be most effective when combined with exercises. The cooling effect reduces pain, spasm, and neural inhibition, which allows exercises to begin earlier.

According to Bleakely et al., because of the variables of the studies reviewed, future studies are required to evaluate the effects of cryotherapy at each phase of an injury (20).

Promote Healing

Controlling pain and reducing inflammation facilitates the healing process.

Currently, there are reliable and valid tools to assess pain in neonates, infants, toddlers, school age children, adolescents, and adults. Adolescents are able to accurately report their pain level because they have developed a more complex pain vocabulary. The Visual Analog Scales can be used with the adolescent athlete. It consists of a horizontal or a vertical line exactly 10 cm long, with anchors (0 no pain, 10 extreme pain) at either end. The athlete marks a point through the line that best describes the pain level, which can be read as a percentage or a number (21).

The athlete needs to be able to differentiate between the pain associated with an injury and the discomfort that can be expected from therapeutic exercise. The athlete also needs to understand that pain is the body's sign that there is a problem. However, the athlete should also be informed that delayed muscle soreness might be expected after stretching or strengthening exercises. If recurrent swelling, increased stiffness, loss of motion or severe discomfort occurs at any time during the rehabilitation program, the exercise should be discontinued and the athlete's physician notified. Treatment is only resumed with physician approval.

The application of the following treatment modalities may not only reduce pain and inflammation but may also enhance the healing process (Table 1.6):

Medications are sometimes prescribed in addition to RICE. However, medications should be used judiciously because the athlete's natural healing potential is good. The most commonly prescribed medications for sports-related injuries are nonsteroidal antiinflammatory drugs (NSAIDs). These medications are sometimes used to control inflammation and pain. However, studies in animal models have suggested that some of these medications may interfere with the normal tissue healing process. This issue requires further study in humans. Long-term use of NSAIDs is not indicated for children or adolescents. Pain should not be masked with the use of NSAIDs, or any other type of medication, to allow the athlete to compete. Most NSAIDs, other than ibuprofen and Naprosyn, are not approved for use in children.

Superficial heat and cold increases or decreases tissue temperature at a depth up to 5 cm, depending on the method of delivery (22). The physiological response to heat causes vasodilatation and erythema, whereas the application of cold causes vasoconstriction followed by vasodilatation. Ice can help reduce metabolism and secondary hypoxic injury (20). Both heat and cold can reduce fast and slow nerve fiber sensation (23). The initial goal is to decrease pain and promote relaxation of the tissues. In addition, applying pressure with cold reduces posttraumatic swelling. It is essential to have a

Table 1.6. Treatment modalities.

Rice	Massage
Medication	Orthotics and assistive devices
Superficial heat and cold	Therapeutic Ultrasound (deep heat)
Hydrotherapy	Neuromuscular Electrical Nerve Stimulation (NMES)
Acupuncture	Iontophoresis
Transcutaneous Electrical Nerve Stimulation (TENS)	

Source: Rennie and Michlovitz, 1996; Cassella M, Richards K. Physical therapy/rehabilitation. In: Micheli L, Kocher, eds. The Pediatric and Adolescent Knee. Elsevier; 2006. By permission of Elsevier.

proper barrier between the skin and the hot or cold pack to prevent skin irritation and/or damage. There is no clear evidence to demonstrate the effectiveness, indications, duration, and optimal mode of cryotherapy for closed soft-tissue injuries, particularly in children (20). There is no clear evidence that heat has a long-term effect on pain (24).

Hydrotherapy is the immersion of body segments in water, for example in a whirlpool. Water immersion promotes an increase or decrease in superficial tissue temperature in a large body part. The main goal of hydrotherapy is to decrease swelling, relieve joint pain and stiffness, and promote relaxation (25).

Acupuncture describes a family of procedures involving stimulation of anatomical points on the body by a variety of techniques. Acupuncture originated in China over 2,000 yrs ago, and it has been used in the treatment of many health problems, including musculoskeletal injuries, headaches, gastrointestinal problems, and pain (26). An example is the insertion of fine needles into selected acupuncture points to bring the body's systems into "balance."

Transcutaneous electrical nerve stimulation (TENS) is the procedure of applying controlled, low-voltage electrical impulses to the nervous system by passing electricity through the skin. It is effective for the symptomatic treatment of acute and chronic pain. TENS is based on the theory that the peripheral stimulation of large-diameter cutaneous afferent nerve fibers blocks sensation at the spinal cord through the gate control mechanisms (27).

Massage is the manipulation of soft tissues by the hands. Pressure and stretching compresses soft tissue, causing an increase in arterial blood and lymphatic circulation, thus promoting better muscle nutrition and relaxation (28). Massage before performing a series of exercises can promote better mobility, pain reduction, and cardiovascular and neuromuscular relaxation, and it also has psychological benefits (29).

Orthotic and assistive devices are prescribed to support or immobilize a body part, correct or prevent deformity, and/or to assist function. Devices include braces, foot orthotics, shoulder slings, splints, prosthetics, crutches, and many others. Devices such as braces restrict, control, or eliminate joint movement, whereas others, such as prosthetics, assist movement (30). Some orthotic devices can help to reduce pain, decrease swelling, control and enhance movement, and improve proprioception. Proper selection, evaluation, and fit of the orthoses are critical to ensure both safety and patient compliance. Instruction in proper orthotic application and care is a key component to a successful outcome. External supports have been shown to reduce ankle sprains in high-risk recreational activities in adolescents with previous ankle sprains (31).

Therapeutic ultrasound is produced by a transducer, which converts electrical energy into sound energy. Ultrasound produces a thermal effect by increasing tissue temperature 1–2°C at a depth of 5 cm. Nonthermal effects include cavitation and mechanical and chemical alterations (32). The main goal is to increase tissue extensibility and decrease inflammation, swelling, pain, and muscle spasm. In addition, ultrasound can help to reduce joint contractures and scar tissue. Ultrasound should never be applied over open epiphyses (33,34). Although ultrasound is widely used, there is minimal evidence that ultrasound has long-term effects on the outcome of musculoskeletal injuries (35).

Neuromuscular electrical nerve stimulation (NMES) is electrical current applied to the skin that activates motor units, causing an involuntary skeletal muscle contraction (36). The main goal is to provide biofeedback and muscle reeducation to the involved muscles. Neuromuscular electrical nerve stimulation has been shown to enhance muscle function postoperatively (37,38).

Iontophoresis is the transfer of topical medications in the form of applied active ions into the epidermis and mucous membranes of the body by direct current (39). Topical steroids are commonly administered using iontophoresis. The goals of iontophoresis include the reduction of inflammation and edema and the softening of scar tissue.

Restore Function

The goal of restoring function is to achieve independence in all activities with maximum efficiency and effectiveness. Exercises to increase and maintain flexibility, muscle strength, proprioception, speed, power, neuromuscular training, and cardiovascular endurance are the major components for full restoration of function. The rate of exercise progression is based on the athlete's abilities and the nature of the injury. An experienced therapist is helpful in determining the appropriate program.

Early mobilization may be limited because of pain, swelling, internal joint derangement, scar tissue formation, and prolonged immobilization. Prolonged immobilization can often lead to muscle shortening, loss of sarcomeres, atrophy, and weakening of the muscle. After some injuries, tightening of surrounding tissues from scarring may cause impaired movement. The period of muscle–tendon immobilization should be short, usually less than 1 wk, to limit the extent of connective tissue proliferation at the site of injury (40).

Muscle Length (Flexibility)

Limited muscle flexibility can have a detrimental effect on the overall rehabilitation program. Stretching exercises may have to be discontinued while the athlete is recovering from a specific injury. The injured area must be fully healed before resuming a stretching program. However, maintaining the athlete's overall flexibility is essential to ensure fitness when the athlete is ready to return to sports and/or competition. A safe stretching program before activities is best done after a series of "warm-up" exercises. Warm-up exercises increase tissue elasticity, thus protecting the muscle–tendon units from further stretch injury (41). A suggestion for warming-up is to start with global, gentle movements ranging in time from 3–5 min. This will help to increase the muscle and body core temperature (42).

The optimal length of time, frequency, and the type of exercises to improve long-term flexibility needs to be clearly established. Static stretching when the muscle is elongated to tolerance and sustained for a length of time appears to be the safest and most effective method (43). Static hamstring stretches performed once a day, holding each stretch for 30 s, resulted in a significant improvement over a 6-wk period (44). Teaching the athlete how and when to safely stretch is the key to a successful outcome.

Joint Range of Motion

After an injury, restoring joint range of motion may need to begin very slowly with active, assistive exercises done with gravity eliminated. For example, the athlete with an acute knee injury is positioned side lying on his involved side, with the uninvolved leg over a pillow. The side-lying position not only eliminates gravity, but also helps to facilitate active, assistive knee flexion and extension (Figure 1.6). Non–weight-bearing active or passive exercises in the side-lying position can be very comfortable and is less painful. Gentle "contract/relax" exercise techniques can help to quickly regain full, pain-free range of motion (45).

FIGURE 1.6. Active-assisted knee flexion and extension. Side lying on the involved side to facilitate pain-free knee flexion and extension with gravity eliminated.

Joint range of motion can also be increased with manual therapies, including both manipulation and mobilizations. Manipulation is defined as a small-amplitude, high-velocity thrust technique involving a rapid movement beyond a joint's available range of motion. Mobilizations are low-velocity techniques that can be performed in various parts of the available joint range based on the desired effect (46). Mobilization techniques have been shown to produce concurrent effects on pain, sympathetic nervous system activity, and motor activity. Joint mobilizations are considered far safer than manipulations because the patient participates in the technique.

Restore and Improve Strength

Regaining neuromuscular strength and the control to perform functional activities requires a safe, well-designed, age-appropriate, resistive exercise program. Optimal loading of the muscles during strength training exercises includes varying the amount of resistance, repetitions, frequency, speed, and rest intervals (Table 1.7) (47). Appropriate exercise programs are designed to apply controlled, sufficient, but not excessive, stress to healing structures. After an injury, there can often be persistent weakness, muscle atrophy, and painful inhibition. A well-designed exercise program helps to alleviate the sequelae of an injury.

Eccentric loading involves the development of tension while the muscle is contracting and being lengthened, e.g., the downward movement (eccentric) of a biceps curl using a dumbbell. The high forces produced in muscles eccentrically can cause damage and/or injury, particularly in muscle and tendon tears, as well as in overuse injuries (48). However, if the eccentric contractions are applied progressively and repeatedly, the muscle–tendon unit is capable of adapting to these high forces. Eccentric loading exercises have been demonstrated to help in rehabilitation of chronic tendinopathies, such as Achilles and patellar tendinosis, using incline drop squats (49,50).

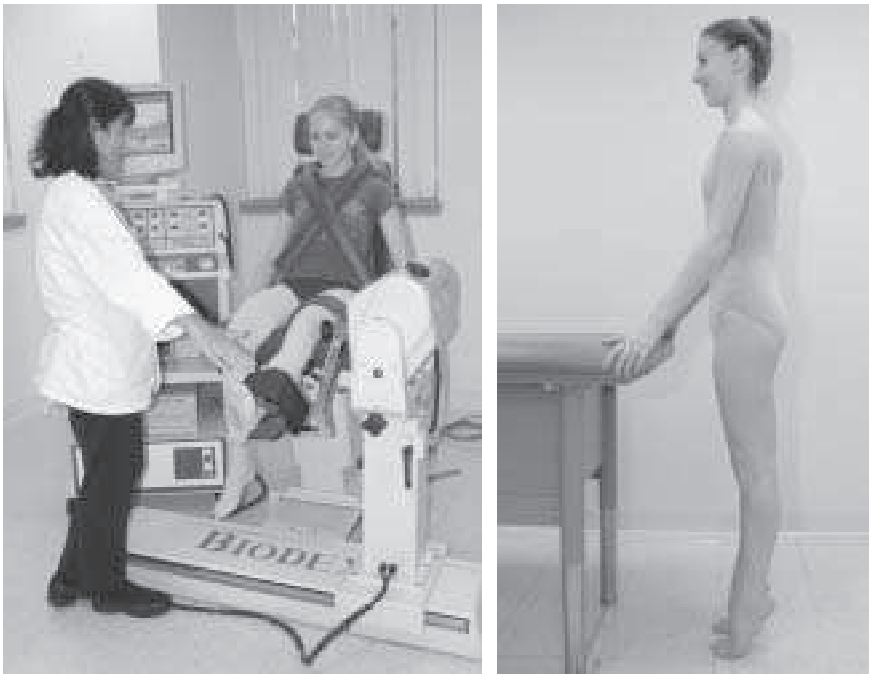
Table 1.7. Guide to strength training in the young athlete.

Number of Exercises	8–12 address all major muscle groups
Frequency	2 nonconsecutive strength training sessions per week
Resistance	60–75% maximal weight load
Repetitions	10–15 repetitions of each exercise
Sets	1 challenging set
Speed	Controlled 3–5 s each rep
Range	Full range of pain-free motion
Technique	Proper posture, biomechanics, and smooth movement
Progression	Increase resistance 5–10% when 15 reps can be completed

Source: Adapted by permission from Faigenbaum and Westcott, 2004.

The term "kinetic chain" refers to the coordinated activities of body segments and the forces generated from proximal to distal. Open kinetic chain (OKC) exercises are performed with the distal lower extremity segment free (Figure 1.7 A). A short arc knee extension, quadriceps-strengthening exercise is an example of an OKC. Closed kinetic chain (CKC) exercises are performed with the distal segment fixed (Figure 1.7 B) (51). An example of a CKC exercise is a leg press. CKC exercises tend to be more functional and safer.

Core stability is the recruitment of the trunk musculature while controlling the position of the lumbar spine during dynamic movements. The stabilization of the central core (trunk) in sports has benefits for preventing injuries, as well as improving performance. The core muscles include the abdominals, extensors, and rotators of the spine. The core muscles act as a bridge between the upper and lower extremities providing stability to the limbs. The strength of the abdominal muscles is critical in maintaining optimal alignment of the trunk and pelvis (7). Figure 1.8 illustrates normal abdominal muscle strength.



A B

FIGURE 1.7. OKC and CKC. **(A) OKC** exercise using BIODEX equipment. The distal segment is free as the athlete performs a long-arc quadriceps strengthening exercise. **(B) CKC** exercise. The distal segment is fixed as the dancer performs a gastrocnemius-strengthening exercise.

FIGURE 1.8. Core stability. The dancer is able to the keep lumbar spine in contact with the table, while strengthening both the upper and lower abdominal muscles.

Proprioception allows the body to maintain stability and orientation during static and dynamic activities at both the conscious and unconscious level. Mechanoreceptors are the neurosensory cells that are responsible for monitoring joint position and movement. After an injury, proprioception can be diminished from damage of the mechanoreceptors. In addition, loss of tensile properties of static structures such as ligaments or the joint capsule, and the latent response of muscles to provide reflex stabilization of a joint, can also have a negative effect on proprioception (52). A rehabilitation program designed to improve proprioception stimulates the mechanoreceptors that encourage joint stabilization, balance, and postural activities at both the conscious and unconscious level.

Neuromuscular training describes a progressive exercise program that restores synergy and synchrony of the muscle firing patterns required for dynamic stability and fine motor control. This is accomplished by enhancing the dynamic muscular stabilization of the joint and by increasing the cognitive awareness of both joint position and motion. Activities are designed to restore both functional stability around the joint and enhance motor control skills. Use of balance equipment, such as a wobble board and therapeutic exercise balls, can challenge the proprioceptive and balance systems (Figure 1.9). This helps to restore dynamic stability and allow the control of abnormal joint translation during functional activities (53).

FIGURE 1.9. Dynamic stability (proprioception training). The dancer is catching a medicine ball (weighted), while maintaining her balance on a wobble disc.

Safe Return to Sport/Competition

Athletes are able to safely return to their sport/competition when their injuries are healed and their physical attributes are sufficient to withstand the demands of their activity. A comprehensive rehabilitation program must include progressive exercises to ensure the athlete's readiness for these demands. A program designed for sport-specific activities is implemented when the athlete has achieved full, pain-free, passive and active joint range of motion. In addition, adequate muscle strength and cardiovascular and muscle endurance are essential components in restoring normal movement patterns.

The athlete must have medical clearance before returning to full activity. Functional testing helps to determine the athlete's readiness to return to a specific sport (Table 1.8). Functional tests emphasize skill-related activities and often include assessments of agility, balance, coordination, speed, power, and reaction time (Figure 1.10).

Plyometrics is a natural event that occurs in jumping, hopping, skipping, and even walking. Sport-specific plyometric exercises can be incorporated

Table 1.8. Example of functional test for lower extremity.

Test	Goal	Directions	Measure	Normative data (NV)
SLS for Distance	To hop as far forward as possible on one leg	Stand on test leg heel on zero mark. Hop as far forward as possible, landing on test leg.	Horizontal distance hopped from heel at start position to heel on landing position.	Age 14.5 NV = 119.9–155.1 cm
SLS Triple Jump for Distance	To hop as far forward 3 consecutive times	Start position as above. Hops 3 consecutive times on the test leg. On the final hop, hop for maximal distance. Hold landing foot stationary for 1 s.	Horizontal distance hopped from heel at starting positon to heel on landing position.	Unknown
SLS Vertical Jump	To jump as high as possible and land on one leg	Record standing reach. Jump on test leg touching wall with chalked hand. Landing on same leg. Record reach.	Maximal height jumped minus patient's standing reach height.	Age 14.3–15.8 NV = 46.9–49.0 cm
SLS 6 m Hop for Distance	To hop 6 m as quickly as possible	Stand on test leg. Hop forward for 6 m as quickly as possible.	Time to nearest 0.01 s.	Unknown

Source: Manske R, Smith B, Wyatt F. Test-retest reliability of lower extremity functional tests after a closed kinetic chain isokinetic testing bout. J Sport Rehab 2003;12(2):119–132. Reprinted with permission from Human Kinetics.

into the athlete's functional programs (Figure 1.11). The principle of plyometric training is the stretch-shortening cycle, which is when the muscle is stretched eccentrically and immediately contracted, leading to an increase in the force of the contraction. Plyometric training increases the athlete's power and speed. An example of a plyometric program consists of 1 set of 5–10 repetitions of low-intensity drills, such as squat jumps and medicine ball chest passes, performed 2 times per week. Depending on the athlete's ability, the program may progress to multiple hops, jumps, and throws (54). A recent study demonstrated that jumping power and running velocities were improved in prepubescent boys that performed plyometric exercises; the improvements were maintained after a brief period of reduced training compared with matched controls (55). Another study of female athletes ages 15.3 ± 0.9 yr who underwent 6 wk of training, which included

FIGURE 1.10. Agility and balance. The athlete is instructed to jump within the rungs of a ladder to promote agility, balance, and coordination.

plyometric training, core strengthening, and balance and speed training, showed improved measures of performance and movement biomechanics (56).

Prevention of Future Injuries

Prevention is the ideal management for all sports injuries. However, because the nature of sport activities involves risk-taking and, in some cases, pushing individuals to the limits of performance, injuries are bound to occur. The risk factor that is associated most with future injury is a previous history of a similar injury (57).

Preseason conditioning and "warm-up" exercises can often help to reduce injuries. Preseason conditioning, such as treadmill running on a 40-degree incline twice a week and plyometric sessions, reduced injuries in adolescent competitive female soccer players (58). A structured program of "warm-up" exercises was shown to prevent knee and ankle injuries in young female handball players by approximately 50% (59).

Proprioception and neuromuscular training continue to be areas of injury-prevention research. A recent study showed that a 6-mo home-based weekly balance-training program using a wobble board improved static and dynamic balance (60). Balance training has been particularly important in the reduction of anterior cruciate ligament (ACL) injuries, especially for female athletes (61). Another study (PEP: Preventative Injury and Enhance-

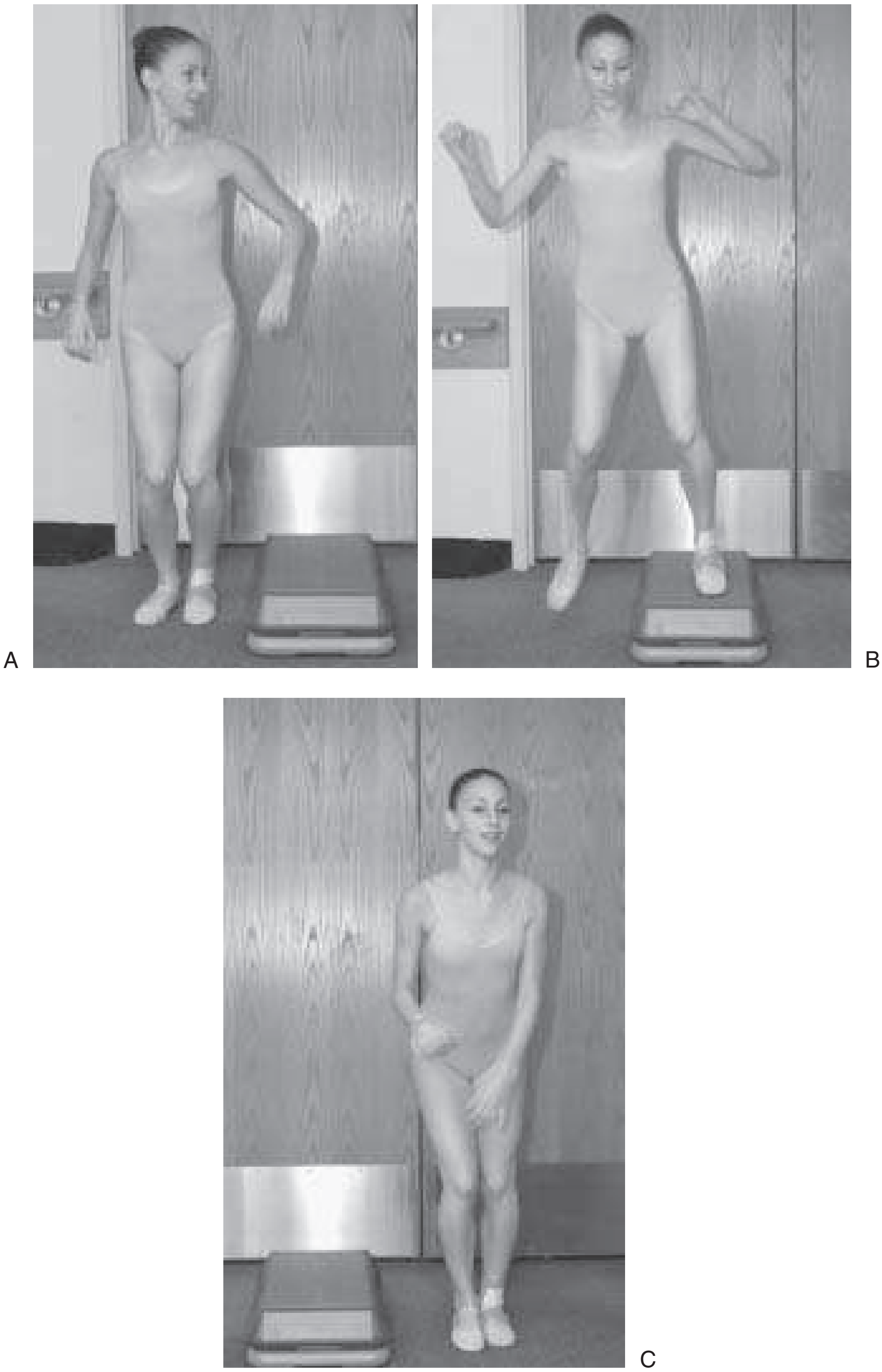


FIGURE 1.11. Plyometrics. The jump sequence is an example of a plyometric exercise. The dancer (A) jumps up to (B) a high step and (C) back down to the floor.

ment Program) of female soccer players aged 14–18 participating in a neuromuscular training program consisting of basic "warm-up" activities, stretching techniques for the trunk and lower extremity, strengthening exercises, plyometric activities, and specific agility drills, had 88% less ACL injuries in the first year and 74% less in the second year (62).

To reduce the risk of reinjury when returning to an intensive training schedule, the athlete must maintain a high level of fitness during the rehabilitation phase. Selection of an appropriate aerobic conditioning program must take into account the athlete's injury, physical ability, and condition. The athlete should begin slowly and not be overexerted with the aerobic activity. Activities such as swimming, low impact exercises, and strengthening of the uninjured area will help to maintain this high level of fitness. Suggested increases for frequency, intensity, and duration are approximately 5–10 % per week, depending on the athlete's level of fitness (64). Adequate periods of recovery should be planned between training sessions.

Summary

An athlete can often lose confidence after a serious injury, even if the injury is healed. A well-designed rehabilitation program that not only focuses on the injured area but also maintains the athlete's fitness level and incorporates sport-specific functional exercises, will help to alleviate the athlete's fear. The skill and movement of the sport are broken down into individual parts and are progressed slowly to build the athlete's confidence. Placing appropriate demands on the recovered injured area will not only help the athlete safely return to sports but also to decrease fear and apprehension.

A successful rehabilitation program includes a comprehensive team approach. Communication between the physician, physiotherapist, athletic trainer, coach, and athlete is essential to determine the athlete's readiness to return to sport. A successful program returns the athlete to his or her preinjury level without putting the athlete or others at risk for injury.

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