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RETURN TO TRAINING AND COMPETITION AFTER INJURY

Joanna Kvist & Grethe Myklebust

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RETURN TO TRAINING AND COMPETITION AFTER INJURY

Joanna Kvist

Joanna Kvist is Associate Professor of physiotherapy at Linköping University. Her main research interests lies within the sports medicine and rehabilitation fields specializing in knee injuries.

Grethe Myklebust

Grethe Myklebust PT, PhD is an Associate Professor at the Oslo Sports Trauma Research Center. She is also authorized as Specialist in Sports Physiotherapy by the Norwegian Physiotherapy Federation and as Sports Medicine Physical Therapist (Idrettsfysioterapeut FFI) by the Norwegian Society of Sports Physiotherapy. Grethe has served as team PT for the female national teams in team handball, soccer and the national teams in beach volleyball for twenty years.

SUMMARY

Sports-related injuries are common and often result in periods when the sportswomen cannot participate in their sports. Rehabilitation during these periods aims to restore function, eliminate signs and symptoms, ensure a fast, safe return to sport and minimise the risk of re-injury. In this chapter, we describe some of the exercise modalities commonly used during rehabilitation. The decision about when and if the athlete can return to playing sport is complex; many factors such as tissue healing, physical performance, psychological status, and sports-related and social factors must be considered before the decision is made.

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TAKE-HOME MESSAGES:

- Rehabilitation after a sports-related injury takes the healing process of the injury into consideration. The rehabilitation is always individualised and the progression from simple to advanced exercises is regulated by specific criteria.
- A variety of factors can influence a safe return to sport: the type of injury, physical performance, psychological status, sports-related factors and social factors, amongst others.
- The criteria for return to sport are mostly based on the healing status of the injured tissue and on physical performance.
- The decision to return should be made by the medical team or others with medical expertise, in consultation with the athlete. In some cases, returning athletes should be advised to discontinue strenuous sports with pivoting manoeuvres to minimise the risk of re-injury and long-term consequences.

INTRODUCTION

Physical activity and sport are important for health. Physical activity is very beneficial for preventing and limiting the progression of chronic diseases and obesity. However, one unwanted but well-known consequence of physical activity is the occurrence of acute or overuse injuries to the musculoskeletal system. An injury to the musculoskeletal system reduces the likelihood of continuing physical activity. In many cases, such an injury is the reason that a young athlete stops participating in sport. Many young people (14–30 years) are injured when they participate in sport—at all levels. For instance, as many as 48–70% of elite female football players and 65–91% of elite male football players will sustain at least one injury during the season. This overall level of injury risk is about one thousand times higher than that of high-risk industrial occupations. A common and serious sports-related injury is rupture of the anterior cruciate ligament (ACL) in the knee. The incidence of this injury in elite female football and handball players is more than double that in their male counterparts. In addition, the women are injured at a significantly younger age than are the men.

The term 'injury' can be defined in different ways. Sports-related injury is a physical complaint sustained by an athlete that results from sports participation. If the injury results in a player are being unable to continue training for a period, the injury is referred to as a 'time-loss injury'. The severity of the injury is defined as the number of days that have elapsed from the date of injury to the date of the player's return to sports participation. Typically, the severity can be grouped according to the days of absence: slight (0 days); minimal (1–3 days); mild (4–7 days); moderate (8–28 days); severe (> 28 days); and career-ending. The definition of 'return to sport' can also vary, depending on the degree of participation (e.g. partial or full participation in training or competition (see *Safe and successful return to sport* later in the chapter).

Treatment of an injury can vary from a simple rest period to self-care, assistance from the coach, or medical attention that may include rehabilitation, medication and, sometimes, surgery. The rehabilitation process and the time until return to sports activity depends not only on the severity of the injury but also on other factors such as adherence to treatment and motivation to return to playing. Some studies have found differences in the return rates of women and men. Though both women and men similarly intended to return to sport, only 26% of the women, but as many as 37% of the men, successfully returned to their pre-injury level of sports participation after a reconstruction of the anterior cruciate ligament in the knee.

But why do sports injuries occur? Of course, the reasons can vary. For example, if an accident or a very stressful event occurs, it is difficult to prevent an acute injury. However, some preventive methods can be used (see text 5.3). Injuries can be classified as 'acute' if they are caused by acute overloading (e.g. from trauma) that results in tissue rupture (e.g. sprains and strains), or as 'overuse' injuries, which occur with excessive repetitive stress. All the musculoskeletal tissues need some load to maintain their mechanical properties and to stimulate strength. Too little load weakens the mechanical properties of the tissue and makes it more vulnerable to injury. Too big a load (e.g. in rate, magnitude or duration) leads to tissue failure.

REHABILITATION

The goal of rehabilitation is to restore function of the injured body part, eliminate signs and symptoms, and ensure a fast, safe return to sports. Rehabilitation programs focus mainly on the injured part of the body; however, rehabilitation of the entire body is of great importance. After an injury, a short time of immobilisation or adjusted or reduced activity is common. During that time, the entire body is affected by the inactivity. In some cases, the individual may compensate for the injury with altered body kinematics, resulting in overloading of the non-injured parts of the body.

Rehabilitation takes into consideration the *healing process* of the injury and adjusts the activity and the load according to the phases of healing. The healing process of an injured tissue is complex and involves several steps. The first step is the clotting phase after the tissue ruptures and swelling occurs at the wound site. The clotting phase normally occurs during the first few minutes after the injury, but can be prolonged for up to 48 hours if initial treatment is inadequate. The inflammation phase begins early after the injury and is necessary to begin the healing. The inflammatory response is a sophisticated process through which the wound is cleared of dead tissue. When the wound is free of dead tissue, repair of the damaged tissue and regeneration can occur. Repair and regeneration involve replacing the damaged tissue with new tissue with the same function. The next phase is the proliferation phase. This phase can last 4–6 weeks. The last phase of the healing process is maturation, when the tissue regains mechanical strength. Maturation can take more than a year. During that time, the tissue has not regained its original strength and is therefore vulnerable to new injury. Throughout the healing process, one phase does not abruptly change to another; rather, one phase tends to merge gradually into the next.

Generally, rehabilitation is divided into four phases (Figure 1).

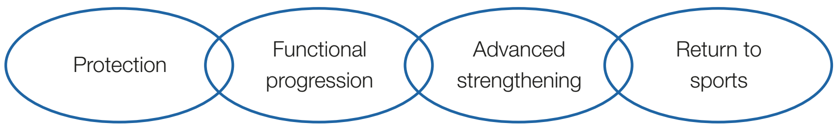

Figure 1. The four phases of the healing process. The phases do not end abruptly and each phase merges into the next.

The early phase (protection phase)

Initial healing of the injured tissue is the focus during this first phase. Immediately after the injury, the 'PRICE treatment' can accelerate the clotting phase (see also text 5.3). PRICE stands for Protection and Rest of the injured tissue; Ice, which is most often used to inhibit pain; and Compression and Elevation, in order to minimise the swelling (Figure 2).

PRICE	
P	Protection
R	Rest
I	Ice
C	Compression
E	Elevation

Figure 2. The mnemonic PRICE is useful for remembering the stages of treatment after acute musculoskeletal injury.

During the inflammation phase of the healing process, some immobilisation may be needed; however, some controlled loading and mobilisation will improve the healing response, with less scar tissue formation, better structural organisation and improved blood supply to the tissue. It also helps to minimise muscle weakness and atrophy. Prolonged immobilisation has many detrimental effects, including on the cardiovascular, respiratory and musculoskeletal systems, and should therefore be avoided. Alternatively, high mobility and excessive loading can potentially damage the healing tissue. During the protection phase, controlled isometric exercises (i.e. muscle contractions without joint movement), exercises with a controlled range of motion, progressive weight bearing, and re-education in movements and motor control are included in the rehabilitation program. It is also important to maintain strength, mobility and endurance in the entire body and to avoid stretching the healing tissue.

The intermediate phase (functional progression)

The aim of the second phase is to achieve a full, pain-free range of motion and to gain initial neuromuscular control. More aggressive exercises to increase the range of motion are introduced, which, together with controlled muscle activation, aim to normalise joint mobility. Dynamic strength exercises are used to increase muscle strength and gain neuromuscular control. Next, the complexity and specificity of the exercises are increased. Functional progression is determined by neuromuscular control and postural stability.

Advanced and dynamic strengthening

In the third phase, the load and number of repetitions of the exercises are progressively increased to improve muscle strength, power and endurance. Both specific endurance in the healing tissue and increased aerobic capacity of the cardiopulmonary system are required. More complex and challenging exercises further improve neuromuscular control and postural stability. Sport-specific exercises are also included for training in particular techniques.

The return to sport

When the athlete has attained a high standard in the exercises used in the previous phases and has no sign of, for example, lameness, pain or swelling, specific simulation of sports activities with progressively increasing load is introduced. We will describe the factors that influence the return to sport and the specific criteria used to determine the timing of return later in the chapter.

As mentioned above, clear borders do not always exist between the phases of rehabilitation. However, the criteria used to determine when an athlete should advance to the next phase are generally similar: no increase in pain, no swelling, the ability to perform the exercises with appropriate motor control, and the ability to maintain postural stability during the exercises. A number of techniques can be used to assess readiness to progress. Pain can be assessed with the Visual Analogue Scale (VAS), where 0 represents *no pain* and 10 is the *worst pain imaginable*. Often, however, some pain is allowed during the exercises. In this case, pain is assessed through the Pain Monitoring Model: the athlete grades the pain during and after training and the training is adjusted accordingly (Figure 3).

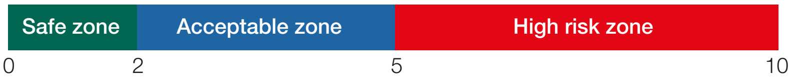

Figure 3. The Pain Monitoring Model. The scale is used to assess whether the level of pain experienced by the athlete is acceptable: pain up to level 2 during and after training is safe; pain up to level 5 during a specific exercise is acceptable if the pain decreases immediately after stopping the exercise; pain up to level 5 after completing the whole exercise program is acceptable, providing it has disappeared by the next morning.

Swelling is often assessed by palpation over the joint or the injured tissue. Muscle strength can be assessed by manual resistance: the athlete is instructed to gradually increase muscle contraction against the resistance provided by the therapist. Another way to assess muscle strength is using the one repetition maximum (1 RM) method. One RM is the maximum resistance that can be produced during one complete repetition of the exercise. Muscle strength can also be assessed by using various machines (e.g. isokinetic testing). Motor control and postural stability are often assessed by visual qualitative evaluation of the athlete performing a range of exercises.

TRAINING METHODS FOR REHABILITATION

Rehabilitation programs usually include exercises to improve muscle function, motor control and postural stability. The rehabilitation is always individualised because each athlete will progress at a different rate, depending on the pre-injury condition, the quality of tissue healing and the speed of the healing response. Pain, swelling and range-of-motion deficits can delay the progress of rehabilitation. In such cases, specific treatment modalities may be needed for these problems.

The skeletal muscles of the body contract to produce movement, stabilise the joints and maintain postural control during movement. Muscles must be structurally capable of producing power. In addition, they must also have appropriate innervation (nervous control) for correct activation in terms of amplitude and timing of the contraction. A variety of methods is used to improve muscle function by improving neuromuscular adaptations, which include both morphological (structural) changes of the muscle and neural (nerve) adaptations. The methods used to stimulate the adaptations can be generally divided into strength training and neuromuscular training. Strength training specifically aims to increase the strength and power of a muscle. Neuromuscular training specifically aims to increase neural adaptation to achieve better coordination of movements and better motor and postural control. However, both types of adaptation are interrelated and do not occur in isolation; thus strength training will also improve neural adaptation and neuromuscular training will increase muscle strength.

We will now briefly describe the most common exercise modalities for improving muscle function, motor control and postural stability.

Strength training

The effects of strength training are twofold: morphological changes in the muscle that result in an increased cross-sectional size (i.e. hypertrophy), and neural adaptations that result in more refined muscle activation and more efficient and effective muscular contractions. To achieve the desired effects, progressive overload—an increase in the load to increase the training stimulus—can be used. The overload principle can be applied in two ways. The first is to increase the load intensity by either increasing the weights being lifted or the resistance used. The second is to increase the exercise volume via a combination of the number of sets, repetitions and load. The training frequency (i.e. how often the athlete is training), the duration (i.e. the time for which the athlete is training), as well as the rest intervals and recovery time between repetitions, sets and exercises are also important in determining the effectiveness of the strength training.

The speed at which the exercise is performed also influences the muscular adaptations to training. In addition, 'periodisation' of the training, that is, changing the exercise intensity and volume throughout the year, has a beneficial effect. Specificity refers to the fact that the muscles will specifically adapt to the demands placed on them. Therefore, training programs can be tailored to the requirements of the athlete. For example, an exercise program of heavy weights and few repetitions should be used to develop maximal force, and a program with light weights and many repetitions should be used for muscle endurance.

Some specific strength training techniques are described below.

Resistance training with external weights or machines

These exercises can be performed with isometric muscle contractions, that is, tension is developed in the muscle but no movement occurs in the joint, or in a dynamic way if joint movement occurs. Dynamic exercises involve concentric (muscle shortening) and eccentric (muscle lengthening) exercises.

Plyometric exercises

Fast, powerful movements are characteristic of plyometric training. The exercises use the stretch–shortening cycle of the muscle–tendon complex to generate more power during a concentric contraction. For example, jumping exercises where the athlete first bends the legs so that the calf muscles stretch and then quickly extends the legs and performs a jump. The exercises train for sudden changes in direction and improve muscle power. The difficulty can be increased by performing them on only one leg or by increasing load and velocity (Figure 4).

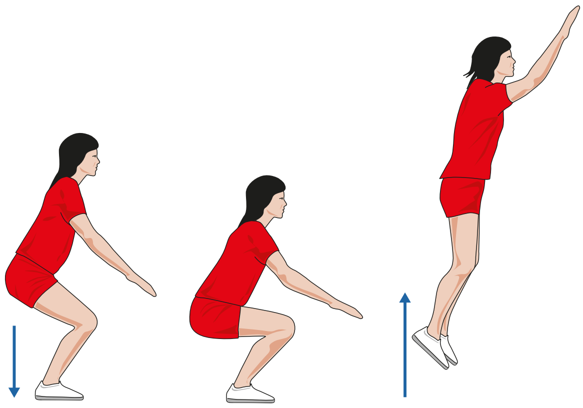

Figure 4. An example of a plyometric exercise using the vertical jump.

Closed and open kinetic chain exercises

Kinetic chain exercises imply that one or more joints are engaged in the exercise. An open kinetic chain involves only one joint and the activation of specific muscle groups, often with a low co-contraction of agonists and antagonists.[1] Closed kinetic chain exercises involve more than one joint, usually with axial compression in the joints. These exercises improve joint stability through the compressive forces and facilitate co-contraction of agonists and antagonists. An example of a closed kinetic chain exercise is a squat, which flexes the ankle, knee and hip. Often, the whole body is involved in the exercise, and during a squat, the back is inclined forward. For shoulder training, the legs and trunk can be integrated into the rehabilitation, which challenges the core stability. Diagonal movement patterns are used to involve more body parts in the kinetic chain and to increase the complexity of the exercises. (Figure 5).

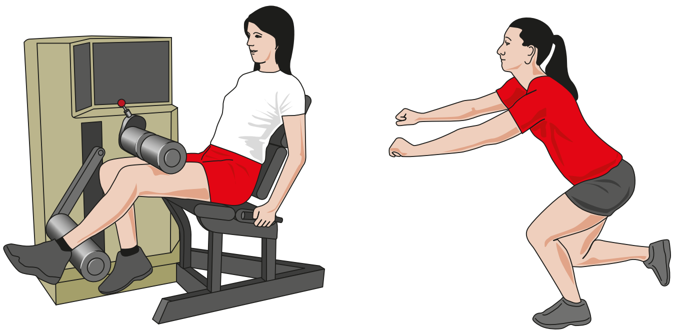

Figure 5. Examples of open (left) and closed (right) kinetic chain exercises.

Strength training of specific muscle groups

Selective activation and training of 'weaker' muscles (or parts of muscles) and local stabilisers must be completed before—or separated from—the training of global stabilisers and 'hyperactive' muscles. For example, athletes with shoulder pain may have muscle imbalance between the internal and external rotators of the joint. In this case, training of local muscle control to improve the balance between the internal and external rotator muscles, as well as the muscles that stabilise and re-track the scapula, should be done before training the larger global muscles. In addition, if the goal is to strengthen the external shoulder rotators because of a muscle imbalance with the internal rotators, the exercise should specifically activate only the external rotators. Hence, the relative strength of one muscle in relation to another is of importance. When balanced activation of the local muscles has been achieved, more complex kinetic chain exercises, first involving near joints and then the whole body, can be performed. The training can progress from exercises for muscle control in a limited range of motion to exercises with increasing load, speed and range of motion.

Neuromuscular training

Neuromuscular training aims to improve the ability of the nervous system to generate optimal and coordinated muscle contraction when external forces are applied to the body. The muscle contraction has to occur with the right timing and amplitude to improve coordination, joint stability and postural control. The training also attempts to improve motor control and to relearn movement patterns and skills.

1 Agonists and antagonists are the terms used to describe muscles, or groups of muscles, that act in opposition to each other. For example, when we flex the elbow, the biceps, which flexes the elbow, is an agonist, and the triceps, which extends the elbow, is the antagonist.

Some studies have shown that neuromuscular control—the ability to produce controlled movement through coordinated muscle activity—differs between women and men. Neuromuscular control can be evaluated by measuring the time it takes for a muscle group to be activated after a specific external loading, or the time it takes to generate maximum muscle torque. Studies have shown that the activation time of women is longer than that of men in the muscles important for maintaining good knee stability, which may increase women's risk of injury. In addition, women utilised different motor control strategies during challenging exercises such as landing after a jump: they had greater lateral trunk displacement, altered flexion angles in the trunk, hip and knee, and increased hip adduction and internal rotation, all of which potentially increase injury risk.

Some specific neuromuscular training techniques are described below. These techniques are not clearly differentiated from each other. In many instances, the same exercise can be used for different purposes. In addition, the definitions of the techniques in the literature are not always clear for clinicians or researchers.

Balance training

Balance training focuses on postural stability, that is, the ability to control the body in relationship to the support base. In order to maintain postural stability and perform a coordinated movement, the nervous system receives information from three sources: somatosensory feedback from peripheral receptors (i.e. the mechanoreceptors in the muscles, tendons, joints and skin), the visual system and the vestibular system.[2] Each of these sources makes a unique contribution and gives information about the position and movement of the body. The information is processed in the central nervous system and generates a motor (muscle) response.

Exercises included in balance training programs are designed to challenge postural stability. The exercises can be progressed from performing on two legs to performing on one leg, and from performing on a stable, flat surface to performing on more challenging surfaces such as uneven ground, soft ground (mats), wobble boards or trampolines. The sensory feedback can also be challenged by excluding vision (performing with closed eyes) or by using different kinds of distractions (Figure 6).

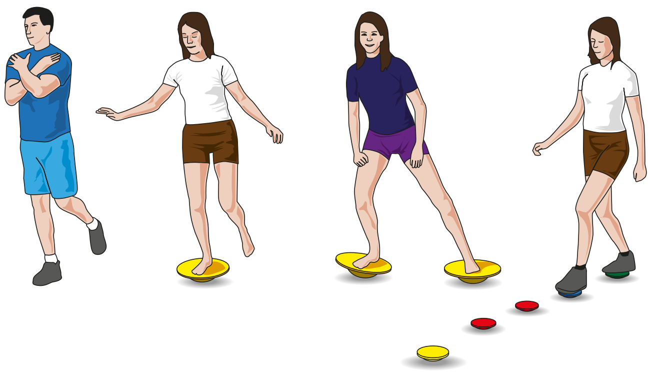

Figure 6. Examples of exercises used for balance training.

Proprioceptive training

Proprioception is the ability to recognise the position of the body parts in relation to one another and to the surroundings. Proprioceptive information is provided by the

2 The vestibular system of the inner ear, including the semicircular canals, is involved in maintaining the body's equilibrium.

somatosensory system mentioned above. Proprioceptive training can be regarded as part of balance training. A musculoskeletal injury, specially a ligament injury, leads to disturbances in proprioception due to injury of the mechanoreceptors. Specific training can improve proprioception and some studies indicate that recovery of proprioception may be one of the most important factors for good functional outcomes. The training includes exercises to improve the sensing of joint position, that is, the ability to recognise and reproduce the position (angle) of a joint, and to improve kinaesthesia (the ability to detect motion).

Perturbation training

Perturbation training is a specific kind of neuromuscular training in which the muscles have to react to a sudden movement (perturbation) in order to keep postural control and stop the person from falling. In the beginning of a training program, the perturbations are quite slow and predictable. The exercises then progress by applying perturbations from random directions and perturbations of increased force, magnitude and speed. Decreasing the verbal cues also raises the level of difficulty (Figure 7).

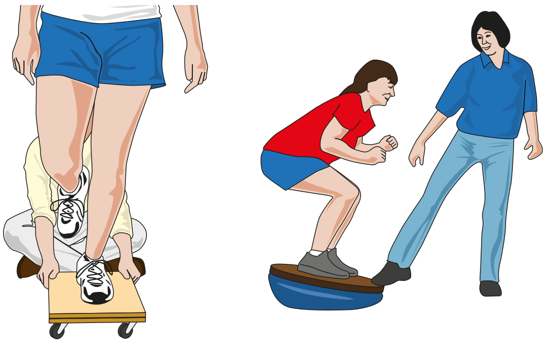

Figure 7. Perturbation training. The person stands on a board with wheels (left) or (right) on an unstable surface (e.g. a Bosu® as shown here) and must react when the therapist suddenly moves the surface or disrupts the balance in other ways.

Specific techniques to improve neuromuscular control

Specific neuromuscular control techniques can be used when practising various exercises and activities, for example, when landing after jumping. The person should focus on maintaining control of a particular joint, and on general control of a kinetic chain, during the activities. After injury, the goals are to restore muscular balance and muscular endurance with correct biomechanics, and to gradually restore proprioception, dynamic joint stability, neuromuscular control and postural stability. The exercises must be performed in various planes to challenge different muscle groups (Figure 8).

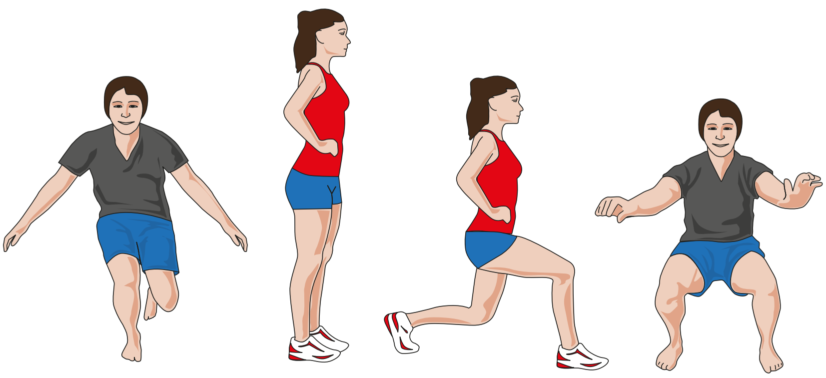

Figure 8. Examples of exercises for improving neuromuscular control.

The exercises progress by variation of the loading, range of motion, speed and visual feedback. Initially, the exercises can be used for re-education in motor control. For this purpose, the athlete begins with controlled isometric contractions and progresses to exercises with a dynamic range of motion, first without resistance. More load can be applied when acceptable coordination and confidence in performance are achieved, and when the tissue can tolerate the loading. The exercises should be performed in a variety of positions (e.g. standing, lying prone or kneeling) that place different mechanical loads on the joints and present different proprioceptive challenges to the neuromuscular system. Of most importance are developing good motor control and performing the exercises safely without risking loss of control or subluxation.

Functional training

This form of training includes a wide range of exercises performed without mechanical assistance. As the name suggests, the exercises mimic functional activities and often involve many joints (i.e. closed kinetic chain exercises). The exercises are performed in many planes and are dynamic, including accelerations and decelerations.

Agility drills and sport-specific exercises

These drills and exercises are a natural progression from functional training and involve more complex activities that prepare an athlete to return to sport. The agility drills include adaptation to rapid changes in direction, acceleration and deceleration, cutting activities, and stopping manoeuvres. Some examples are lateral running, backward running, figure-of-eight running, and cutting at 45 and 90 degrees. Progression is from drills in straight lines to activities involving cutting and pivoting. Exercises can also be made more sport-specific by, for example, adding kicking of a ball with the contralateral leg while standing on one leg, or passing a basketball during training perturbations—the drills depend on the athlete's particular sport.

SAFE AND SUCCESSFUL RETURN TO SPORT

A return to sport often occurs in a step-wise manner. That is, the athlete may not return to full training and practice immediately. Initially, they may start training at an adjusted level, which is often referred to as 'return to practice' or a 'partial return'. A partial return may mean the athlete participates in only some of the training exercises. For example, they may not do any turning or pivoting moves (fast changes in direction) or any contact drills. Gradually, the athlete can participate in more sport-specific drills and complete most of the training program. Finally, it must be decided if the athlete is ready to return to competitive situations with unrestricted participation and play. For a full return to sport, the athlete must participate for some time at the same level as that before the injury occurred.

Studies have shown a sex difference in the rate of successful return to sport after an ACL reconstruction. One study found that a much higher proportion of men than women (37% vs 26%) who wanted to return to sport before their surgery successfully returned to their pre-injury level of participation.

A full return to sport must be safe, in that the risk of a new injury is minimised. Unfortunately, re-injuries are very common. For example, during one season in Australian Rules football, muscle strains had a cumulative injury recurrence rate of up to 30%. Many factors can influence a safe return to sport and specific criteria should be fulfilled before the decision to return is taken.

Factors influencing the safe return to sport

Many factors must be considered before an athlete can safely return to sport. Healed tissue is not sufficient—muscle strength must also be restored; or perhaps the athlete is not psychologically prepared to return.

The injury

The magnitude of the injury and possible associated injuries affect the timing of a safe return. Pain and effusion (the accumulation of fluid due to inflammatory processes) can inhibit muscle activation and coordination, making the body vulnerable to new injuries. If the injury resulted in joint instability (e.g. following a ligament sprain), dynamic joint stability—the ability to stabilise the joint during activity—must be achieved. Biological healing of the tissue must be secured. If the athlete has undergone surgery, the recommended postsurgical timeline, taking the biomechanical properties of the healing tissue into consideration, must be followed. The ability to complete at least several training sessions with full participation and without pain or lameness should be a prerequisite for competition. Sometimes, a return to sport, or at least not a return to competitive sport, is advisable because of the risk of new injury or long-term consequences such as osteoarthritis. It is vital that all athletes are correctly informed about the risks of long-term consequences from their specific injury before they decide whether to return to the same sport or to their previous competitive level.

Physical performance

Muscle function and flexibility, range of motion, functional performance, endurance (aerobic capacity), postural control, acceptable sport-specific skills, and full speed, agility and sport-specific performance must be achieved before a safe return (see also the specific criteria described below).

Psychological status

High motivation to return and confidence in athletic performance facilitate a safe return, whereas anxiety and fear of re-injury hinder a successful return. Although some level of fear may be protective because the most common injury is a re-injury, fear itself is a risk factor for a new injury. Therefore, an athlete must be able to control this fear. To reduce the fear, the athlete may need to practice for a long time before taking part in a competition. Generally, low psychological mood has a negative effect on performance.

Sports-related factors

Different sports put different stresses on the injured tissue. High-intensity sports will delay safe return. Examples include sports in which many activities require fast acceleration and deceleration and those in which the athletes perform pivoting movements or contact teammates or opponents. The athlete’s playing position is also important. For example, risk exposure may differ between a goalkeeper and a defender. A high level of competition is also associated with a higher risk of a new injury. In addition, the timing of the injury and the planned return must be taken into consideration. For instance, during playoffs in the final weeks of the season, play may be more aggressive and the risk of injury higher. However, it may be important to have the athlete return during that period. In the offseason, when there are no competitions, return to team training may be easier for the athlete. Good knowledge of the sport-specific demands on strength and physical function is also important.

Social factors

Social factors such as pregnancy, finishing college, scholarships, financial situation, and pressure from others and the media all affect the timing of a return to sport.

In light of all these factors, it is crucial that any return to sport must be individualised—for the athlete, the specific injury and the sport in question.

Criteria for the safe return to sport

Definitive criteria for a safe return to sport are generally unknown. However, specific assessment should give us information about important factors influencing return, such as the status of the healing tissue, physical performance and psychological status.

Status of the healing tissue

The injured tissue must have healed before return. Often, pain and other symptoms may disappear before the tissue has completely healed. Knowledge about the biological process of tissue healing is important to minimise the risk of a new injury. Incompletely healed tissue has weaker mechanical properties and is therefore more vulnerable to injury. Laboratory tests or imaging techniques, for example magnetic resonance imaging (MRI) or ultrasonography, may be needed to determine the status of the healing tissue. For instance, MRI can be very helpful after muscle strains to visualise the magnitude of the injury, signs of local tissue inflammation and oedema, and then the progress of the healing. In addition, a detailed clinical examination will add information about the tissue's response to load during controlled clinical unloaded and loaded tests. Pain, stiffness, increased laxity, or decreased range of motion and flexibility may be indicative of incomplete healing. Information must also be gathered through discussion with the athlete about possible pain or swelling, both during and after activity, as these signs can be indicative of low load tolerance.

Physical performance

Different aspects of physical performance must be evaluated. Restored muscle function is important and is often a prerequisite for normal overall functional ability and for lowering the risk of re-injury. Muscle function can be assessed as both maximal strength and maximal performance in functional activities.

Muscle strength

Muscle strength is often evaluated by maximal or sub-maximal tests. The tests are either specific for one muscle (open kinetic chain) or for a whole (closed) kinetic chain. Muscle strength can be evaluated by measuring peak torque in an isokinetic machine that measures torque throughout a predefined range of motion with the limb moving at a constant speed. Muscle strength can also be evaluated during functional exercises, for example, a squat with weights. The one repetition maximum (1 RM)—the heaviest resistance that can be lifted for one complete repetition of the exercise—is measured. Isokinetic testing has a safety advantage without risk of injury, whereas 1 RM tests require caution because of the need to apply maximal external weights (Figure 9).

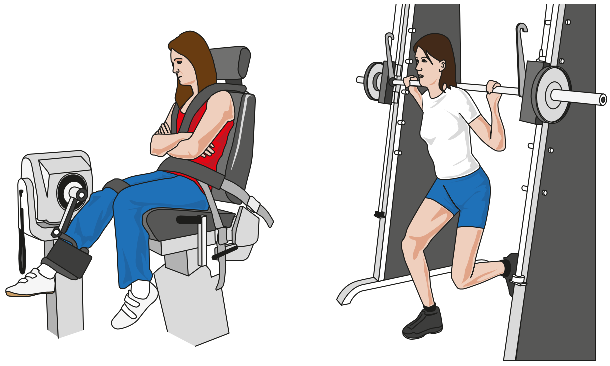

Figure 9. Testing muscle strength in open (left) and closed (right) kinetic chain exercises.

Muscle function tests

Tests for muscle function test the ability to perform activities, often sport-specific activities such as hop tests. These tests provide information about the integration of muscle strength and coordination, range of motion, endurance, postural control, and psychological factors such as fear and confidence. In addition, functional tests can either map the progress of the rehabilitation process (low-demand tests) or the readiness to return to sport (high-demand tests). In the latter case, the load and stress should be similar to the demands of the athlete's sport.

Using a battery of tests is recommended. For example, use of three hop tests evaluates different qualities of muscle function. A single-leg hop test for maximum distance is a clear, straightforward test in which factors like muscle strength, postural control, range of motion and psychological factors influence the result. A triple jump test or a multiple jump test will also evaluate endurance. A side hop test (single or multiple, standing or moving forward, or running with pivoting movements) is more complex and challenges different characteristics that can affect the results. A battery of tests that includes a single-leg hop for distance, a single-leg vertical jump and a side hop test has been shown to discriminate well between the involved and non-involved knee in patients after an ACL injury (Figure 10).

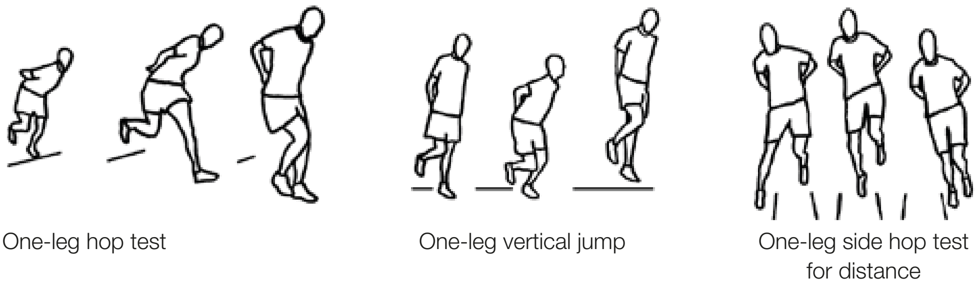

Figure 10. A battery of three hop tests used to evaluate physical performance. *Single-leg hop for distance*: the athlete stands on the test leg and hops as far as possible, landing on the same leg with a controlled landing. The distance is measured (cm). *Single-leg vertical jump*: the athlete stands on the test leg, quickly bends the test knee as much as desired and jumps upwards, attempting to maximise the height. The flight time is measured using a 'contact mat'. *Side hop test:* the athlete stands on one leg and jumps from side to side between two parallel strips of tape, placed 40 cm apart on the floor. The athlete jumps as many times as possible during 30 seconds. The number of successful jumps performed without touching the tape is recorded. All jumps are performed on one leg (both starting and landing), with the hands behind the back. These tests were devised by Gustavsson and colleagues (2006).

Another battery of jump tests described by Noyes and colleagues (1991) has been used to screen patients with ACL injuries to determine who will potentially function well or badly after non-operative treatment. The tests are performed on one leg: a distance hop test, a straight triple hop test for distance, a triple-crossover hop test and a 6-metre timed hop test (Figure 11).

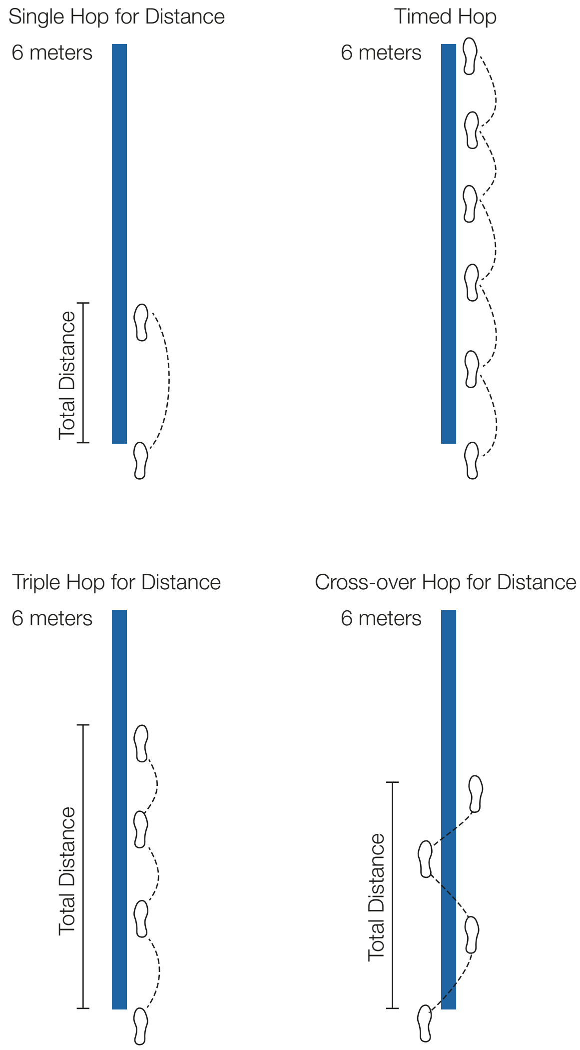

Figure 11. An alternative battery of jump tests to evaluate physical performance. *One-leg hop for distance*: the athlete stands on the test leg and hops as far as possible, landing on the same leg with a controlled landing. *Straight triple hop test for distance*: the athlete stands on one leg and jumps as far forward as possible during three consecutive hops on the same leg. *Triple-crossover hop test*: the athlete stands on one leg and jumps as far forward as possible, crossing over a tape 15 cm wide for each consecutive hop. The distances covered in these three tests are measured (cm). *6-metre timed hop test*: the athlete stands on one leg and is timed jumping as rapidly as possible for a distance of 6 metres. All jumps are performed on one leg (both starting and landing), with the hands behind the back. These tests were devised by Noyes and colleagues (1991).

Sport-specific functional field tests

Functional tests must be demanding enough to test abilities beyond those normally expected of players in training. For example, extra running and cutting manoeuvres, simulated play situations with team players, testing when fatigued, full sprints, bending, acceleration, deceleration, and landing from the hop. For this purpose, sport-specific functional field tests have been developed. One example is the zigzag running test used in football, which is performed with or without a ball (Figure 12).

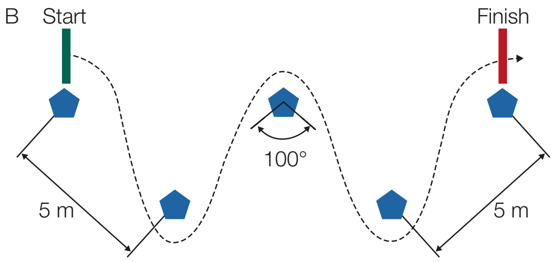

Figure 12. The zigzag test. Five cones are placed 5 m apart, forming a path with three 100-degree turns. The athlete is timed running the path as fast as possible.

Often, the Limb Symmetry Index (LSI) is used to reports the results. LSI is the ratio of the involved limb score expressed as a percentage of the uninvolved limb score (involved/uninvolved x 100). The rationale is to ensure that the involved limb reaches the same or a similar level of performance and function as the uninvolved limb, which minimises the risk of new injuries. The current recommendation from the European Board of Sports Rehabilitation is that the LSI must be 100% for strength tests and 90% for functional tests (hop performance) before returning to sports that involve pivoting movements, and contact and competitive sports. For return to sports without pivoting movements, and noncontact and recreational sports, the LSI should be 90% for strength tests and 90% for functional tests (hop performance).

Many injuries occur during the last minutes of a competition, which indicates the importance of good aerobic capacity and muscle endurance. Therefore, aerobic capacity and muscle endurance, as well as muscle strength in fatigued conditions, are also important to test. Because psychological factors can affect a successful return, questionnaires evaluating psychological readiness for return to sport may also be of importance. For example, high motivation and a positive psychological response towards resuming sports participation have been shown to discriminate between athletes who return and athletes who do not return to sport after ACL reconstructive surgery. The questionnaire ACL-Return to Sports Index (ACL-RSI) has been designed to measure athletes' emotions, confidence in performance and risk appraisal in relation to return to sport after an ACL injury (Figure 13).

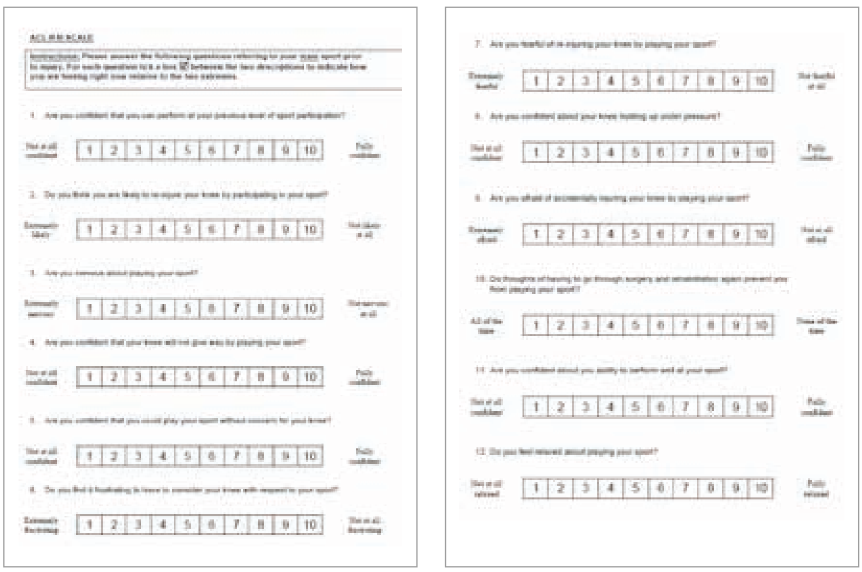

Figure 13. The questionnaire used to calulate the ACL-Return to Sports Index (ACL-RSI). The questionnaire evaluates the psychological impact of returning to sport after an anterior cruciate ligament (ACL) injury.

Many tests and questionnaires are reliable (low measurement error) and give very similar results if repeated in one or two days. However, these tests have often not been specifically validated for assessing safe return to sport. Such scientific evaluation is difficult and requires large numbers of athletes to test for correlation between test results and risk of injury. Nevertheless, we know that physical performance and psychological status are only two of many factors involved in injuries. Other factors include body composition, age, skill level, external risk factors (environment, sports equipment and human factors), playing situation, and the behaviour of the player and opponents. Therefore, the decision whether to return to sport must often be based on expert opinion with little scientific support, and the components of the criteria used are based on theoretical models and empirical (observational) evidence.

A coach-based model for return to sport

Hägglund et al. (2007) described a 10-step rehabilitation program controlled by the team coach to decide when footballers should return to play after an injury. A randomised controlled study—a study design that produces high-quality evidence—was used to test this program; the coaches also received information about re-injury risk and rehabilitation principles. The results showed that the rehabilitation program could prevent re-injuries in amateur male football players. Though not confirmed by a research trial, we could expect similar results for female football players.

This program can be used as a guide to assist coaches in making the decision about whether an athlete should return to sport. The program is usually begun after a doctor or physiotherapist has cleared the athlete to return to training. For minor injuries that required no treatment by medical personnel, the criteria to begin the program are walking without limping and without pain. The first step in the program is forward jogging. Then turning and cutting manoeuvres that are more challenging for motor control and postural stability are introduced. Increasing the speed of exercises also raises the level of difficulty. In step 7, more football-specific skills such as individual ball drills are introduced. In step 8, more match-like components are introduced and the athlete starts to train with her teammates, but without contact. In step 9, full team training is allowed. To finally return to play requires completion of a specific number of team training sessions based on the severity of the injury.

The athlete can progress from step to step provided they do not experience any pain or swelling during the training or the day after (Figure 14).

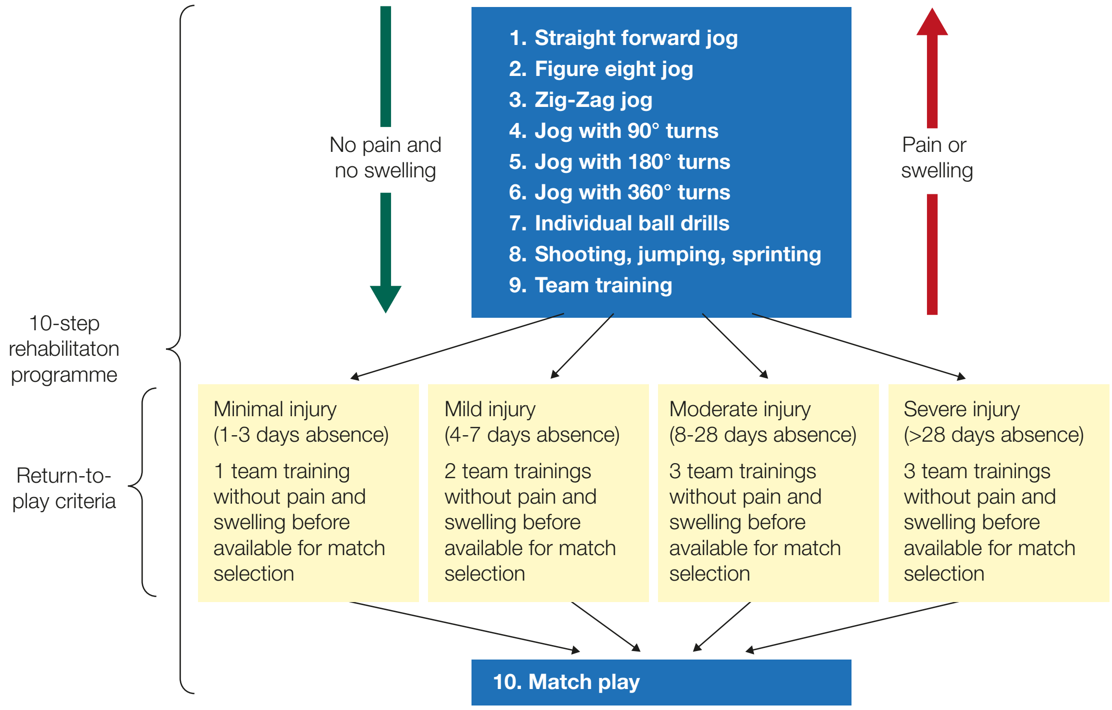

Figure 14. A coach-based model for return to sport (from Hägglund et al. [2007]).

WHO SHOULD DECIDE WHEN THE ATHLETE IS READY FOR RETURN TO SPORT?

The medical team or others with medical expertise should be responsible for the decision to let an athlete return to sport. The decision must secure the best outcome for the athlete in terms of avoiding re-injury and new injuries, and the ability to perform her best. No other conflict of interest should influence the decision, for example, disagreement between the medical team and the sports team or coaches about the time for return.

In addition, the athlete must agree that she is ready to return. Sometimes, the athlete may want to return earlier because of financial benefits or job security in the case of professional athletes, or because of pressure from others (e.g. parents, coaches, teammates, fans or the media). However, returning too early and sustaining a new injury may end an athlete's career, and the athlete may be unaware of this risk. Also, the athlete's perceived functional status, as documented by subjective, patient-reported scores, does not always correlate with objective scores on functional and strength tests. Hence, the medical team must make the final decision.

We have discussed the well-known facts that sports injuries increase the risk of new injuries and that re-injuries are the most common injuries. Therefore, it is vital that an athlete planning to return to sport is informed about the risk of new injuries and, sometimes, the increased risk of long-term consequences such as chronic pain or osteoarthritis.

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