Module 2. Muscle Injuries and Tendinopathies in Sport

Unit 2.1 Muscle Injuries in Sport

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Introduction

Muscle injuries, in particular those located in the thigh, frequently occur as a result of contusions and actions with repeated sprints and maximum accelerations/decelerations. Due to the fact that sport combines maximum sprints with frequent player-to-player contact, it is not surprising that up to 30% of all injuries are located in the thighs. In fact, results from elite competitions in Europe show that hamstring injuries are the most common type of injury in men's sport, representing 13% to 17% of all injuries. Other studies have shown that muscle contusion injuries in the thigh represent 16% of all injuries in elite teams. A clear example would be the following: on average, an elite men's football team consisting of 25 players can expect around 18 muscle injuries per season. Seven of them will affect the hamstrings and three the quadriceps (Hagglund, Walden & Ekstrand, 2013).

According to observations (FC Barcelona, unpublished data), the most common muscle injury in young players was the rupture of the rectus femoris, while in professional football players it was that located in the hamstrings. Due to the severity of the problem, the need for a better comprehension about muscle injuries and their prevention has become an emerging challenge in sports world. Deep knowledge of the muscle injury and all its implications will determine the success of the overall process of decision-making management.

Classification of Muscle Injuries

Knowing exactly the type of injury we are facing allows us to provide the players a much more effective individualized treatment and, therefore, a faster and safer return to sports activities.

Muscle injuries can be classified according to the following:

- their mechanism of injury;
- the anatomical area affected;
- the structure of each muscle.

According to its mechanism of injury:

Direct mechanism: contusions

Grade 1
- Maintained range of motion

Grade 2
- Limited range of motion <50%

Grade 3
- Range of motion >50%

Indirect mechanism: stretching-type

Grade 0
- History of the injury: non-specific
- Physical examination: unremarkable
- Image: no pathological findings

Grade 1
- Image: edema

Grade 2
- History of the injury: specific
- Physical examination: with specific findings
- Image: loss of muscle continuity

Grade 3
- History of injury: specific and severe
- Physical examination: delimited by pain
- Image: muscle tear or avulsion

Muscle pain after exertion

From delayed onset muscle soreness (DOMS) to rhabdomyolysis

Source: adapted from Balius & Pedret, 2019, 37-43.

According to the anatomical area affected:

Tedoperiosteal	Musculotendinous/ Musculoaponeurotic	Myofascial

Source: adapted from Balius & Pedret, 2019, 37-43.

Tenoperiosteal injuries have a worse prognosis, while the weakest area of the bone-tendon-muscle chain is the myotendinous junction, where most injuries occur.

Table 1: Common Injuries

Localization	*Mechanism of injury*
Triceps surae (Tennis Leg)	Change of pace or sprint
Rectus femoris	Kick Sprint
Hamstrings	Sprint, change of speed: • Dynamic eccentric contraction Overstretching
Adductors	Forced adduction Change of pace/sprint

Mechanism of Injury

Hamstring injuries occur most frequently during maximum sprints. It is believed that injuries to the biceps femoris are larger in the last swing phase, just before the heel strike. However, it has been suggested that the heel strike (stance phase) is also a position of risk. This injury mechanism is called “high speed running mechanism.” A second type of injury, known as "stretching-type” of injury, has been described. This occurs during movements that lead to extensive hamstring lengthening, such as high kicks and sliding actions. The muscle affected in these types of actions is the semimembranosus. Distinction is important, since the stretching-type of injury may demand a longer recovery period, in particular due to the proximity to the sciatic nerve (Askling, Malliaropoulos & Karlsson, 2012).

Rectus femoris injuries have not been extensively studied, but most of them are produced by kick the ball. However, they also occur after sudden accelerations and decelerations. In both situations, athletes will describe a sudden onset of significant and localized pain. The quadriceps are also a common area of contusions or contact injury.

While most thigh injuries are dealt with in a traditional way, one of the objectives of the history and examination is to spot the athletes who have severe injuries, since their performance will be affected and they will benefit from a surgical treatment. In this process, diagnosis is essential and it should start with a good anamnesis.

A good medical history must contain the following:

As regards the general history of the athlete:

Has the player suffered similar injuries before? (Some muscle injuries have a high recurrence rate.)

Is he prone to injuries?

Is the patient taking any medications?

As regards the mechanism of injury:

What was the mechanism of injury? (Was it a direct trauma? Was it a maximum sprint? Was it a maximum sprint? Did it happen by kicking the ball?)

Did it occur during training or during competition?

When did it start? Date and relation to the sports session (beginning, middle or end of the session.)

How did it start? (Suddenly, gradually, progressively.)

Any audible sound or pop with the onset of pain should be

As regards the initial progress:

Was the player able to continue or was he forced to stop?

How was the patient treated after the immediate injury?

How has the pain evolved over time?

Risk Factors

Several risk factors for muscle injury have been proposed. The most convincing risk factor is the existence of previous injuries. Particularly in football, players with a previous hamstring injury have a 7 times higher risk of injury than players with no history of injury (Arnason et al 2004). On average, reinjuries cause 30% longer absences (Ekstrand, Hagglund, & Walden, 2011a).

Age is also an important risk factor to be considered as regards injuries. Players younger than 22 years had a significantly lower incidence than players between 22 and 30 years and players older than 30 years old (Ekstrand, Hagglund & Walden, 2011b). In athletes who are in development, we should consider the differences between chronological and biological age. The latter is the most appropriate to plan and adapt training loads in order to prevent injuries, especially overuse injuries—such as apophysitis—and muscle tears.

In the literature, several risk factors have been identified and published. These include lack of strength, an imbalance between hamstring/quadriceps muscles, poor flexibility (Stojanovic & Ostojic, 2011), fatigue, intense training periods, mechanical and anthropometric aspects and even competing against rivals with a better level (Freckleton & Pizzari, 2013.)

The detailed study of all the risk factors together with the rise of technology has led us to a paradigm shift. Today, knowledge is oriented towards the personalization and individualization of the injured athlete and thus genetic markers that may play a role in muscle injuries have been identified. Some people are more likely to experience injuries and to need a longer recovery than others. Players with specific polymorphisms, insulin-like growth factor 2 (IGF2) and C-C Motif Chemokine Ligand 2 (CCL2) (specifically its dominant allelic form (GG)), may be more vulnerable to severe injuries (Pruna, Artells & Ribas et al., 2013.) In the future, it is possible that genetic tests will be used to identify individuals at risk of injury and to concentrate on specific prevention programs.

Clinical Examination

Clinical examination provides diagnostic information and makes an important prognosis about the injury. It is essential to compare the findings of the examination of the injured area with the uninjured area.

Important considerations include the following:

- Inspection in order to find ecchymosis or deformities in the muscle belly profile. Palpation so as to identify the specific area or injured muscle, as well as the presence or absence of a palpable defect.
- Evaluation of strength through manual resistance that is applied distally to the area of the injury.
- It is important to consider that inflicting pain with this evaluation is as relevant as the alteration of the functionality.
- Range of motion.
- Pain and discomfort during the examination are key considerations when evaluating.

The following is an example of how a clinical examination of an athlete should be done:

If an athlete has a quadriceps contusion, more than 90° of flexion at the knee joint indicates the presence of a minor injury which has shorter readaptation period; a flexion between 45-90° indicates a moderate injury; and a flexion of less than 90° indicates a severe injury which will demand a long recovery period.

Complementary Tests

Even though the diagnosis can be clear in clinical terms, ultrasounds and MRI can help confirm the diagnosis. Generally, plain radiographs (X-rays) are not useful unless bone avulsion or apophyseal fracture is suspected in a skeletally immature individual.

Musculoskeletal ultrasound is significantly less expensive than MRI, but it depends a lot on the technician. Even though it is a more expensive study, MRI visualizes deeper muscles more accurately and is more sensitive (Harmon, 2010.)

The ultrasound will take place immediately after the injury, depending on the experience of the medical team. However, it is recommended to wait 48 hours in order to get a clear diagnosis of the injury. Performing the ultrasound immediately after the injury is not the best time to obtain a detailed image, although we truly believe that MRI can be performed at any time, as it gives us, due to the current improvement in technology, important data for the diagnosis.

MRI findings that should be assessed are the following:

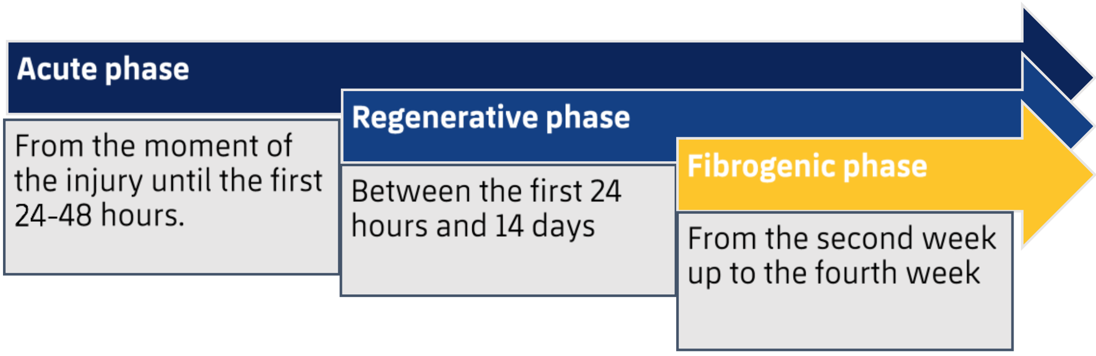
- affected connective tissue;
- the anatomical location of the injury;
- the distance between the origin (ischial tuberosity in the case of the hamstring or the anterior inferior iliac spine (AIIS)/edge of the acetabulum in the case of the rectus femoris) and the distal end of the muscle tear;
- transversal area of the affected muscle (Rogan, Wust, Schwitter & Schmidtbleicher, 2013.)

In general, a larger (or longer) injury is related to a prolonged return to competition, although a key prognostic factor is the affected connective tissue.

Treatment

In order to offer an efficient treatment, it is necessary to know the principles of muscle recovery and adjust our therapeutic plan to them. Biological and physiological knowledge shows that there are three phases: acute phase, regenerative phase and fibrogenic phase.

Figure 1: Phases of muscle recovery



The objectives of the treatment and readaptation are the following:

- first, to eliminate bleeding and bruises, restoring the range of motion without pain;
- second, to reach a level of functionality that gives place to the third phase, which involves a readaptation program on the playing field that reproduces the typical movements and actions of the sport.

1) Acute phase

The main objective here is to restore movement without pain. This is achieved through rest, compression bandage—if necessary—and physiotherapy. The main initial objective is to initiate optimal range of motion (ROM) training and isometric exercises. Massage is contraindicated during this period. In the case of minor injuries, readaptation should start two or three days after the injury, as this gives us the possibility of working on the athlete's cognitive skills, which will have an impact on the final process of performance adequacy.

There are also other treatments commonly used in the early stages of injury. These include:

- Nonsteroidal anti-inflammatory drugs (NSAIDs): in this phase, NSAIDs are an issue of debate due to their association with suboptimal regeneration of myofibrils and due to the fact that they increase scar tissue deposits. As a general rule, simple analgesics (acetaminophen or paracetamol) are a better choice in the acute phase.
- Corticosteroid injections: they are contraindicated in the acute phase. Although they may provide some advantages in the short term by reducing pain, they may make the player more prone to suffer an injury again in the

long term. Intramuscular steroid injections are prohibited on the World Anti-Doping Agency (WADA) list.

- Platelet-rich plasma (PRP): the use of PRP for muscle injuries in elite athletes appears to be gaining ground. The argument behind this treatment is that it facilitates growth factors, fostering muscle regeneration. However, there is still no convincing data to show that this improves recovery times (Petersen, Thorborg, Nielsen, Budtz-Jorgensen, & Holmich, 2011; Mendiguchi, Garrues, & Cronin, 2013).

2) Subacute phase

In this phase, exercises can be useful to remove the waste of the bleeding and to prevent the formation of scar tissue on the injured area. Massage and various types of electrotherapy may be indicated. The program should include various stretching, strength, core stability or CORE, neuromuscular and functional exercises on the competition field as soon as possible. Progression is individual and determined by pain and function. In general, numerous repetitions and low loads are targeted early in this phase Then, the load gradually increases while the number of repetitions decreases. Using a stationary bike or doing exercises in a swimming pool are delicate and effective methods to increase mobility. Soft training, with a shorter stride length, can begin as soon as permits it.

3) Functional phase

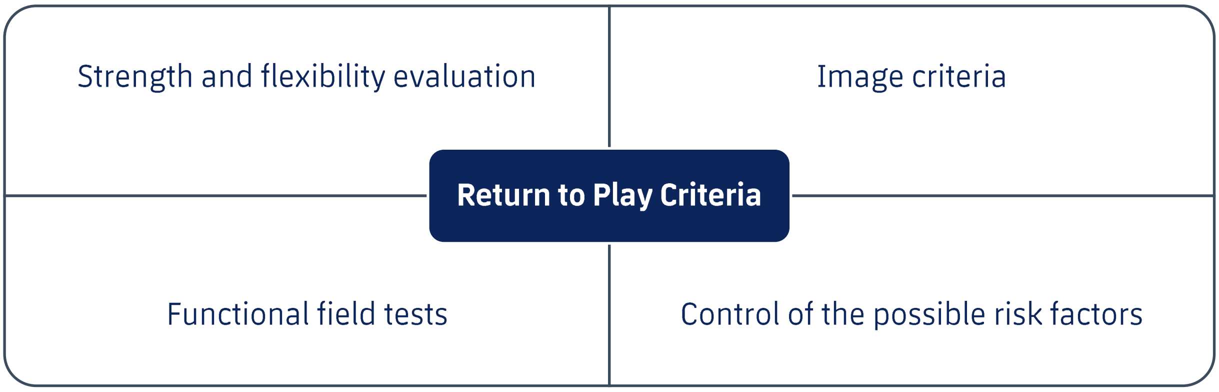
In this third phase, the development of strength programs, the increase of core stability exercises, and sport-specific tasks on the field are essential. The relationship with the coach or the conditioning coach is very important, as it is the step prior to team training.

Surgical Management of Muscle Injuries

Surgical procedures are rarely taken into account for the treatment of muscle injuries. However, there are very specific situations in which surgical intervention could be beneficial for severe muscle injuries, even though there is not an evidence-based treatment protocol.

Some surgeons believe that surgical treatments with postoperative readaptation protocols should be considered if a patient complains about chronic pain (a duration of 4-6 months) of a previously injured muscle, especially if the pain comes with a clear extension deficit. In these chronic instances, scar tissue formation and adhesions that limit motion should be suspected and a surgery release of these may be considered. In addition, and in general terms, all significant proximal hamstring tendon avulsions should be treated with surgical reintegration.

Figure 2: Return to Play Criteria



Source: adapted from Orchard, 2005.

Return to play (RTP) is defined as the multidisciplinary decision-making process that allows an athlete who has been injured or ill to return to play.

To assist and corroborate this decision making, high-tech tools are increasingly used to monitor the loads applied at each moment of the readaptation process and to provide the basic principles until the athlete is asymptomatic, i.e., to be able to apply increasing loads in a progressive manner until the injury has healed completely.

Factors that should be consider when making decisions regarding the RTP:

- The hamstrings are a heterogeneous group of muscles. Therefore, it is necessary to divide injured muscles into subgroups that result in different "rest" and recovery times.
- In order to provide an accurate diagnosis, we consider the clinical diagnosis and, then, the information provided by the MRI and the ultrasound.
- RTP can be individualized, based not only on the type and location of the injury but also on the player's position on the field and his individual anatomical characteristics.

We suggest the following criteria to guide the process of return to play.

1) Regarding the type and anatomical area of the injury, it is compulsory to follow the biological time of evolution.
2) To return to football, there should be no clinical symptoms and there must be a static and dynamic ultrasound examination that shows a good tissue healing.
3) Explosive eccentric strength should be demonstrated in a sport-specific and injury-relevant way. For instance, it is suggested that the Askling H-Test 18 is

appropriate for a stretching-type of injury (semimembranosus), while comfort during high speed running without symptoms is appropriate for a sprint-type of injury, usually located in the biceps femoris.

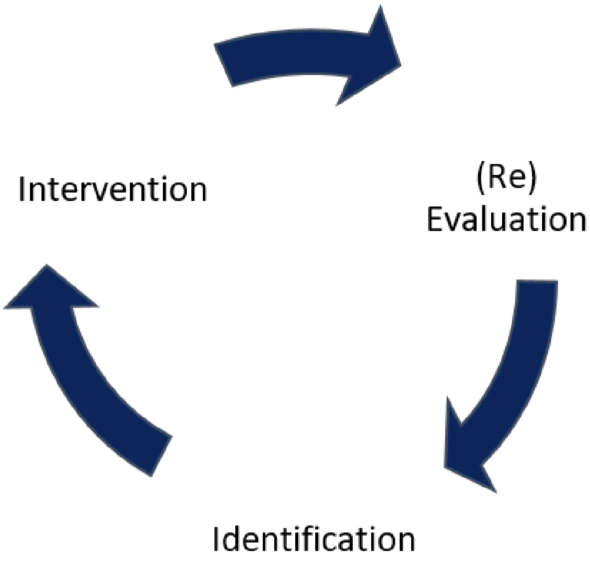
4) CORE and proprioception exercises should be carried out during recovery until relevant objective skills are achieved. Usually, this is at least up to 70% of the time of the readaptation program.

5) Commonly, a GPS (global positioning system that targets values such as maximum sprint speed, accelerations, decelerations and step balance) evaluation is performed. This should show sport-specific parameters appropriate to the athlete's previous performance profile and should be accompanied by the absence of symptoms. For example, an athlete should be able to run more than 21 km/h without any symptoms, to accelerate at 3-4 m/s and to have full tolerance to braking/deceleration.

Prevention

An increasing level of evidence suggests that it is possible to reduce the risk of hamstring muscle injury. Although there is less data related to the risk of rectus femoris injury, it is possible that similar principles are applied to prevent such injuries. The strategies proposed include different types of stretching activities, eccentric strength training, CORE stability and multi-intervention combinations of these.

Figure 3: Muscle Injury Treatment Cycle



Source: *The Team Sport Injury Prevention (TIP) Cycle from FCB Muscle Injury Guide*

Evaluation:
- Which is the current status of the injuries?
- Which is the current status of the prevention strategies?

Identification:
- Which are the risk factors and mechanisms of injury?
- Which are the barriers and facilities for the prevention programs?

Intervention:
- Introducing prevention strategies.
- Planning the content of prevention strategies.

Stretching

Even though most coaches and athletes generally believe that stretching is effective, it is unclear whether it prevents injuries or not (McHugh MP, Cosgrave CH., 2010; Rogan S, Wust D, Schwitter T, Schmidtbleicher D., 2013). There are no adequate studies that address this issue as regards elite athletes. While it is possible that stretching has a role in injury prevention, it is likely to be substantially less effective than eccentric training.

Eccentric Strength

Several studies show that eccentric training reduces the incidence of hamstring injuries in different athlete populations, for example, through exercises such as Nordic Hamstring (NH; figure 4). The best evidence for the preventive effect of eccentric strengthening is a randomized controlled trial conducted in Denmark comparing the effect of NH exercise with the hamstring injury rate in acute phase among male football players This study showed that the injury rate was 71% lower in NH exercise for players with a history of hamstring injury. The effect was even greater with an 86% reduction in injury rates (Petersen, Thorborg, Nielsen, Budtz-Jorgensen, & Holmich, 2011).

The intensity and the repetitions are classified according to the recovery phase of sports injury:

- Beginner: 1 set (3-5 repetitions).
- Intermediate: 1 set (7-10 repetitions).
- Advanced: 1 set (minimum 12-15 repetitions).

In addition, similar types of eccentric protocols have also been proposed to prevent quadriceps injuries (reverse Nordic). These are associated with a gradual increase in the training volume of kicks in athletes at critical periods to help reduce the injury rate. The optimal intensity of eccentric training programs is still unclear.

Figure 4: Nordic Hamstring Exercise

Source: Untitled image about the Nordic hamstring exercise, retrieved from goo.gl/uT2AP4

CORE

Many of the hamstring injuries occurred in trunk flexion during sprint, in the typical position taken during it and acceleration. Motor control of the lumbar spine and pelvis is essential in the preparation and execution of different sports movements. The inclusion of CORE exercises in training sessions can also decrease the risk of quadriceps rectus femoris injuries (Mendiguchia, Garrues, Cronin et al., 2013).

Multi-intervention

Injury prevention training programs with the execution of several components (proprioception, CORE, stretching and strength) have been effective in reducing the number of muscle injuries. The FIFA 11+ program is a good example of the combination of preventive strategies. Completing the FIFA 11+ injury prevention warm-up (fig. 5) regularly has been proven to reduce the risk of hamstring and quadriceps injuries in athletes by 30-50% (Soligard, Myklebust, Steffen et al., 2008).

Currently, these strategies are used as a basis for complementary work to training or even incorporated within this to reduce the number of injuries. In addition, these strategies increase ROM, muscle strength levels and proprioception, all of which are key aspects of the athlete's performance.

Nevertheless, with the individualization and personalization of programs and actions, there is an increasing tendency to replace the concept of prevention with that of adaptation. Therefore, technology offers us tools to monitor the loads and obtain optimal profiles of each athlete to specifically guide their adaptation to effort, trying to avoid injuries.

Figure 5: FIFA 11+ Warm-Up Protocol

Source: Fifa 11+, 2010, retrieved from goo.gl/nr9wGK

Conclusions

Thigh muscle injuries occur frequently in sports as a result of contusions and as a result of repeated maximum sprints and accelerations/decelerations.

Examination of the injured muscle should consider inspection, palpation, evaluation of strength and range of motion. Although the diagnosis is clear in clinical terms, ultrasound and MRI examinations can help confirm it.

Most muscle injuries can be healed with traditional methods: first, restoring the range of motion without pain (acute phase); second, reaching a level of performance (subacute phase) that gives place to the third phase, a functional readaptation program (functional phase). However, there are very specific situations in which surgeries could be beneficial for severe muscle injuries

reventive strategies have been proposed in muscle injuries to decrease their incidence. The most important primary prevention is the correct planning of the training of volume and intensity, so that the athlete is in physically good conditions to compete. Secondary prevention should be individualized so as to modify risk factors in the athlete with a previous injury. Injury prevention training programs with the execution of several components (with proprioception and eccentric strength) have been effective in reducing the number of muscle injuries. The FIFA 11+ program is a good example of the combination of preventive strategies.

Unit 2.2 Tendinopathy in Sports

Javier Yanguas Leyes

1. Definition

For years, the word tendinitis was used to encompass all pathological entities located in the tendon, believing that there was an inflammation that justified the use of this term. Later on, histological and biochemical studies ruled out the existence of inflammatory markers significant enough to cause symptomatology. However, they did reveal a marked disorganization and degeneration of the tendon collagen fibers with a yellowish color (a macroscopic appearance known as myxoid or mucoid degeneration), variable fibrosis and the presence of new blood vessels and nerve fibers that could justify the painful clinic. Therefore, the term tendinosis is preferred (Fu, Rolf, Cheuk, Lui & Chan, 2010; Maffuli, Khan & Puddu, 1998). According to the anatomical location of the discomfort, we will classify them as *insertional tendinopathies or enthesopathies* when it is affected at the insertion of the tendon with the bone and as tendinopathies, as a general term, when the discomfort is located in the tendon itself.

This clinical situation may involve complications because of the inflammation of the paratenon, which is the outer sheath of the tendon. This inflammation can occur in isolation (peritendinitis) or in association with tendinosis (tendinosis with peritendinitis) (Brukner & Khan, 2007). Nowadays, there is unanimous consensus to use the term tendinopathy to define any clinical entity affecting a tendon.

2. Epidemiology

The increasing number of recreational athletes and the high demands of professional sports result the prevalence of tendinopathies in all groups of athletes. In professional football, for example, patellar tendinopathy accounts for 1.5% of all injuries, showing an injury incidence of 0.12 injuries per 1000 hours and a relapse rate up to 20% (Hägglund, Zwerver, & Ekstrand, 2011). Achilles tendinopathy accounts for 2.5% of injuries, with an injury incidence of 0.18/1000 hours and up to 27% of relapses (Gajhede-Knudsen, Ekstrand, Magnusson, & Maffulli, 2013). These two tendinopathies have a much higher level of incidence and prevalence in sports such as basketball and volleyball; therefore, patellar tendinopathy is referred to as jumper's knee (de Vries, van der Worp, Diercks, van den Akker-Scheek, & Zwerver, 2015; van der Worp, van Ark, Zwerver, & van den Akker-Scheek, 2012). Distal iliotibial band syndrom is common in long-distance runners (runner's knee). Rotator cuff tendinitis is more common in overhead throwing sports such as handball, water polo and baseball, among others (Lewis, 2009). Therefore, it is possible to state that the vast majority of tendinopathies is linked to specific movements and some are more common than others, depending on the sport practiced (technopathies).

3. Pathophysiology

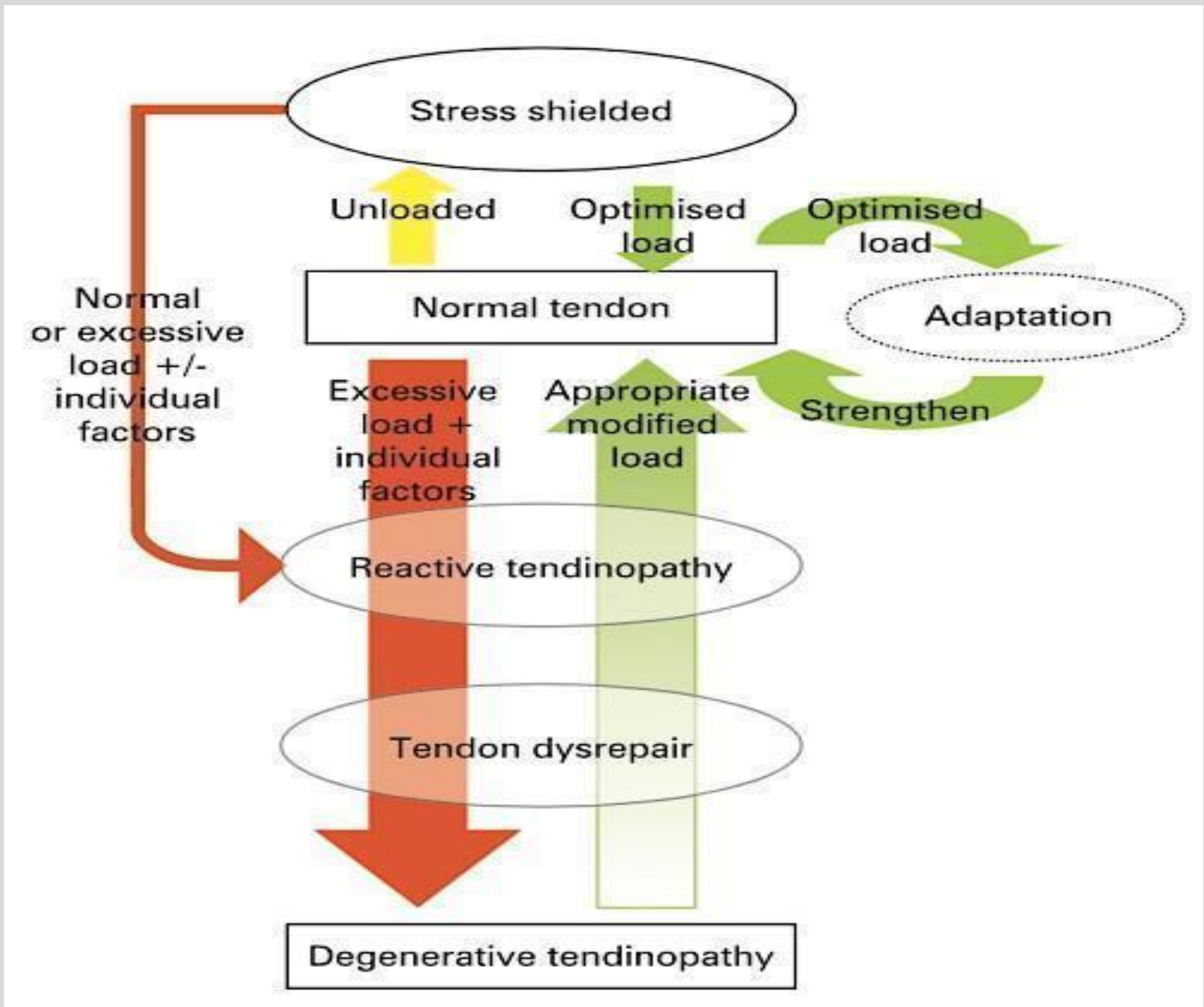
Although different theories have been proposed to explain the pathophysiology of tendinopathologies, we accept as valid the continuum tendinopathy model, described by Cook & Purdam (2009). This model includes three pathological stages regarding the tendon: a reactive tendinopathy, a tendinopathy in which the repair mechanisms fail and a degenerative tendinopathy (figure 6). Although three different stages are described, there is a continuity and overlap between them.

a) Reactive tendinopathy: it is characterized by a cellular and extracellular matrix proliferative response—which is non-inflammatory—due to mechanical forces of compression and distraction on the tendon, which results in a relative thickening of a part of the tendon. This phase is reversible if the mechanical load on the tendon disappears.

b) Tendinopathy of repair failure: it involves the increase of proliferation and the number of cells (chondrocytes and myofibroblasts) together with an increase in the production of proteins (proteoglycans and collagen), which leads to the disorganization of collagen fibers. This, in turn, results in an increase in type III collagen fibers and in the extracellular matrix together with a blood vessel neoformation and nerve endings. This neovascularization seems to be involved in the generation of pain, but it is still a matter of debate within the medical community (Dean, Gwilym, & Carr, 2013). This stage is reversible if physical loads are controlled and appropriate exercises are performed, which will be discussed later.

c) Degenerative tendinopathy: Progression of the disorganization of collagen fibers, the disruption of the extracellular matrix progress and cellular change: apoptosis of cellular islets, degeneration of tenocytes and areas of acellularity and neovessels. It is quite difficult to reverse this stage. Chronic pain is common and it is caused by cytokines, pain mediators, hypoxia phenomena and pH changes.

Figure 6: Model of the "continuum tendinopathy" described by Cook & Purdam



Source: Cook & Purdam, 2009.

Model of the "continuum tendinopathy" described by Cook & Purdam (2009), which includes three stages: reactive tendinopathy, tendinopathy in which the repair mechanisms fail and degenerative tendinopathy.

4. Etiology and Risk Factors

Tendinopathy has a multifactorial etiology and risk factors are often divided into intrinsic—those acting from within the body—and extrinsic—those acting on the body (Cook & Purdam, 2014; Malliaras, & O'Neill, 2017).

Within the *extrinsic factors*, it is important to be aware of the errors in training planning. Increasing the intensity of training sessions or increasing the total training volume leads to poor tendon adaptability to the imposed training loads and can result in an injury (tendinopathy). The repetition of intense training loads (known as compressive and tensile loads) without enough recovery time (i.e., without the necessary recovery between the training sessions) can be a risk factor in tendon pathology. In insertional tendinopathies, it has been suggested that the reduction of enthesis pressure is a key aspect of prevention and treatment. For instance, in the case of the Achilles tendon, this reduction can be achieved by using a supination heel wedge (Malliaras and O'neill, 2017).

Multiple *intrinsic factors* have been proposed. Systemic factors such as overweight, insulin resistance, type 2 diabetes, and hypercholesterolemia for Achilles tendinopathy. Genetic predisposition and the existence of previous tendon injuries have been proposed too.

In any case, there seems to be a direct relationship as regards mechanical factors. The reception of the horizontal jump is associated with a greater force of the patellar tendon than the vertical landing. Posture and foot function (dynamic pronation) have been proposed as risk factors for lower limb tendinopathy. The increase and decrease of the ankle dorsiflexion range of motion have been associated with the development of Achilles tendinopathy in prospective studies. Patellar tendinopathy has been associated with both increased and decreased hamstring flexibility (Malliaras & O'neill, 2017).

5. Clinic and diagnosis

The symptomatology of tendinopathies can be directly related to one of the stages proposed by Blazina, Kerlan, Jobe, Carter and Carlson in 1973. According to how much the tendon is affected and the symptoms, tendinopathy is classified as follows:

GRADE 1

Pain:

It only appears after physical activity, as a painful response to the training load.

It subsides later with rest.

GRADE 2

Pain:

It appears at the beginning of the training session.

It disappears during the training session.

It reappears after the training session.

GRADE 3

3a:

Pain:

It is continuous and it interferes with the development of the exercise.

It clearly causes a decrease in performance.

3b:

Pain:

It is constant.

It is present even in daily activities

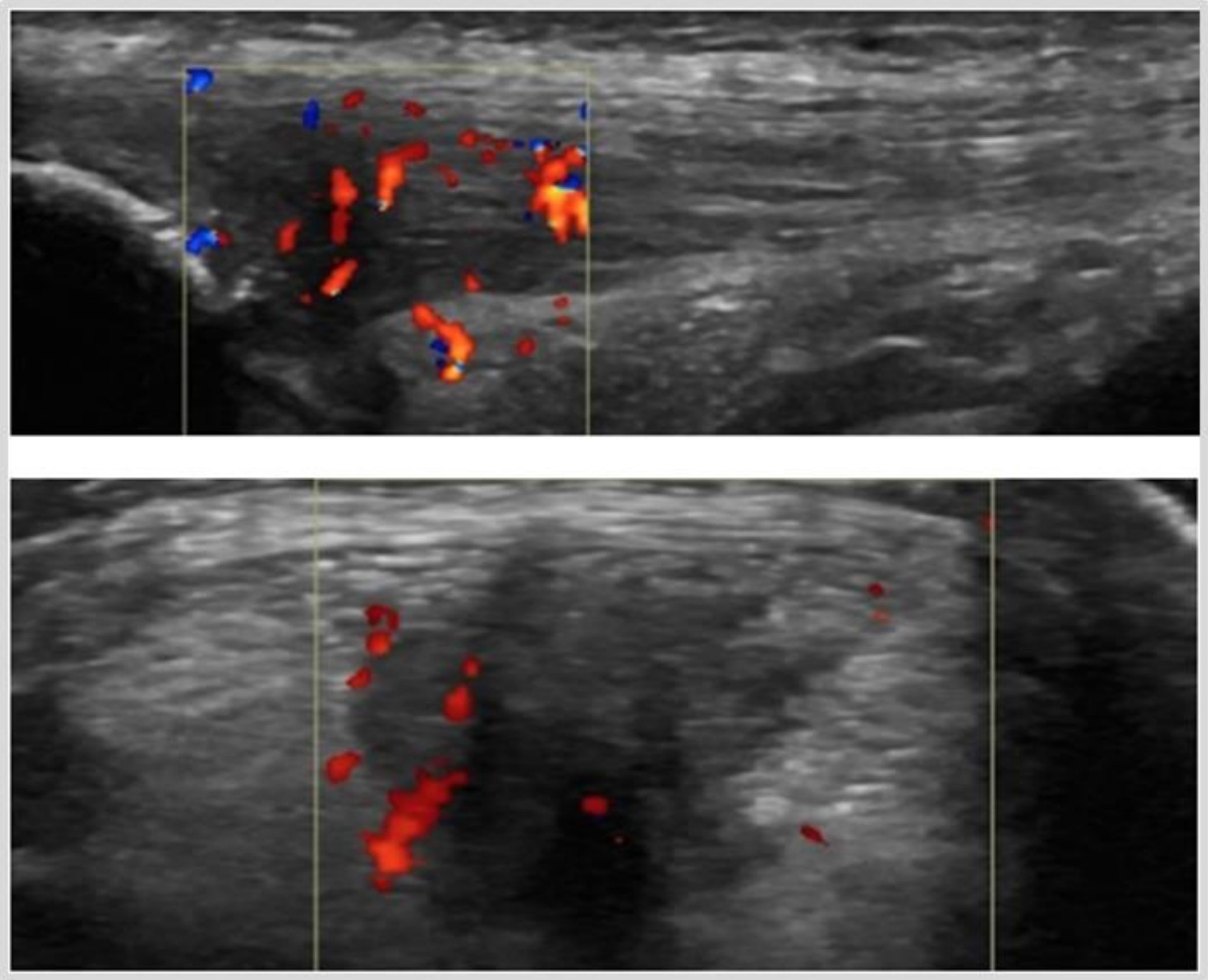
The physical examination of the athlete will include evaluating if the range of motion of the knee is painful, if the palpation and mobilization of the tendon cause pain, if the tendon presents thickening, if there is pain associated with the stretching of the tendon, or if there is pain with active or contraction against resistance or not. In addition, the quadriceps may present a greater or a lesser degree of atrophy but only in highly chronic cases.

The complementary imaging tests are basically two: ultrasound and magnetic resonance imaging (MRI).

Ultrasound (Balius, Sala, Álvarez, & Jiménez, 2007) is a harmless and non-invasive method which does not emit ionizing radiation. It is economical (given its low cost compared to other diagnostic tests) and allows an evaluation of the injured structure both statically and dynamically. It requests the collaboration of the athlete when asking him to contract or to relax the muscle. On the other hand, it depends on a technician and his interpretation demands prior training in this field of diagnosis. Ultrasound can be accompanied by color Doppler to reveal the presence or absence of neovascularization.

Under normal conditions, a tendon has a clear fibrillar structure that represents the bunches of collagen fiber bundles that are successively packed together. There are tendons that are covered by a sheath of elastic connective tissue and between the sheath (paratenon) and the tendon itself some fluids can be found under normal circumstances. Ultrasound allows us to obtain images in the long axis of the transducer (longitudinal slices) and in the short axis (transverse slices). Figure 7 shows the characteristics of a pathological tendon ultrasound.

Figure 7: Longitudinal (top) and transverse (bottom) ultrasound of a pathological patellar tendon.

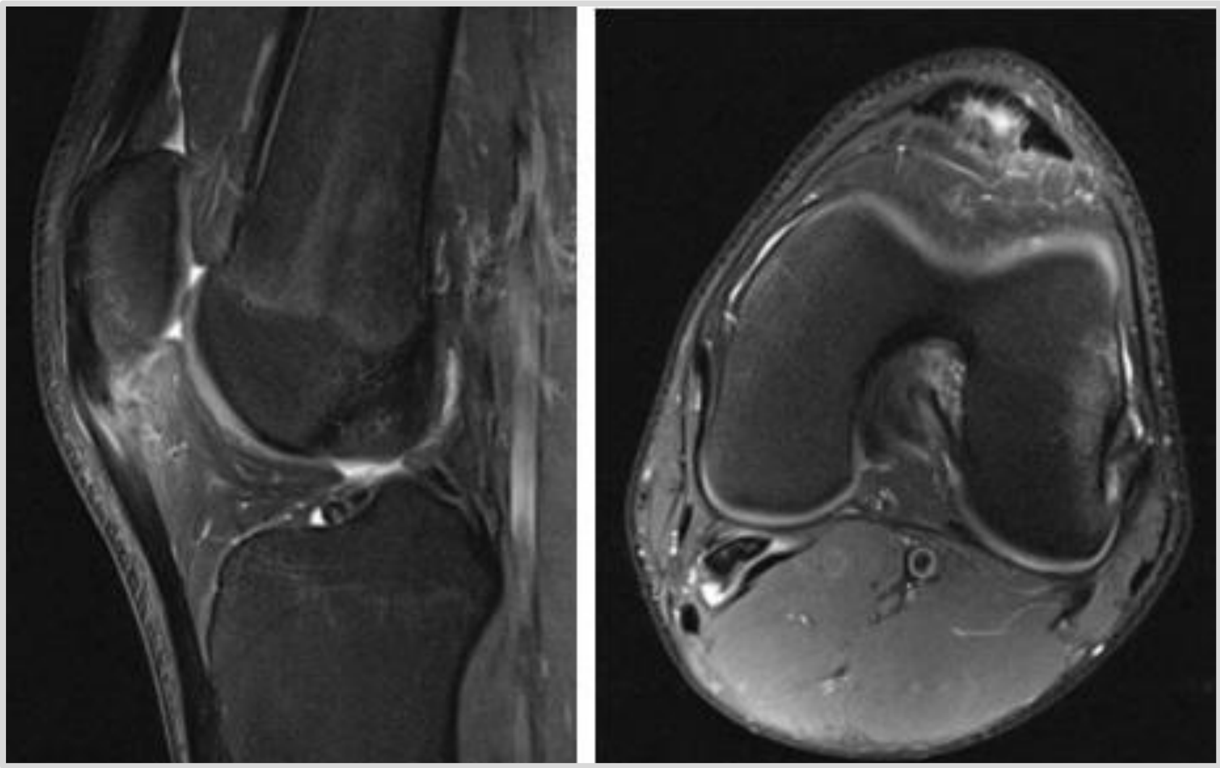


Source: own elaboration.

Longitudinal (top) and transverse (bottom) ultrasound of a pathological patellar tendon. The image above shows a thickening of the tendon in its most proximal part (inferior pole of the patella) with disorganization of the fibrillar pattern of its fibersand and with positive color Doppler activity indicating the presence of new blood vessels. These vessels, accompanied by new nerve endings, are said to be responsible for the pain in tendinopathies. The image below, in transverse view, shows the same fibrillar disorganization and color Doppler activity.

Magnetic resonance imaging (MRI) is a more expensive diagnostic examination, but it allows greater detail of the soft tissues. Moreover, an MRI examination takes longer. The images are static and are displayed in three planes: axial, coronal and sagittal. It is considered an examination that does not require an observer and that is useful to evaluate injuries associated with the tendon. Figure 8 shows the characteristics of an MRI for the study of a tendinopathy.

Figure 8: T2 fat sat image of a sagittal (left) and axial (right) slice in a knee with



patellar tendinopathy.

Source: own elaboration.

In both images an intratendinous signal change (white hypersignal) can be observed. It shows the disorganization of the collagen fibers of the patellar tendon.

6. Control and Treatment

In a tendinopathy, it will be important to differentiate between the (medical or physiotherapy) treatment of its acute phase (basically based on physiotherapy and gym training) and a chronic tendinopathy.

Finally, in the case of tendinopathies that do not respond to traditional treatments, surgery is the last option.

6.1 Acute Tendinopathy

- *Nonsteroidal anti-inflammatory drugs (NSAIDs)*: although there is not much evidence as regards the existence of inflammatory response in tendinopathies, a short period (7 to 14 days) of NSAIDs in reactive tendinopathy may be effective as a first-line treatment in terms of initial pain control. NSAIDs have shown less efficacy in cases of chronic tendinopathies.

- *Analgesics and local anesthetics*: few analgesics are potent enough to cope with pain. The use of local anesthetics injected into the affected tendon is not recommended.

- *Corticosteroids*: local injection of corticosteroids appears to show some short-term effectiveness when it comes to reducing pain, but their effectiveness in chronic tendinopathies is still unclear. Furthermore, local infiltrations have bad reputation not only due to their use in inappropriate phases (degenerative stage) but also due to intratendinous injections which may lead to tear.

- *Sclerosing agents (polidocanol) and injection of large volumes of saline*: these have been used with the aim of reducing pain through neurovascular disruption (neuron that appear in chronic tendinopathies), but there is still not enough evidence to justify their use as a first-line treatment.

- *Platelet-rich plasma (PRP)* is a biological therapy that has promising experimental results just like biological therapies with regenerative purposes such as *stem-cell therapy*.

- Local injections of *aprotinin*—an inhibitor of the extracellular matrix metalloprotease activity—or of *prolotherapy*—injections of various substances that cause irritation (phenol), osmotic agents (dextrose) or sclerosants (sodium morrhuate)—have shown subtle and inconclusive results.

- *Extracorporeal shock wave therapy (ESWT)*: it is not an option recommended as a first- line treatment and its use is reserved for chronic tendinopathies that show great resistance to conventional treatments. Good results have been reported in up to 74% of patients without having to interrupt their sports activity (van Leeuwen, Zwerver, & van den Akker-Scheek, 2009). The mechanism of action proposed is to cause a disruption of the new nerves and existent blood vessels in chronic tendinopathies, as well as to induce the proliferation of tenocytes.

6.2 Chronic Tendinopathy

As discussed, tendinopathy is not understood as a transient inflammatory process of the tendon but as a chronic pathology that evolves according to the stages proposed above. It requires constant management of painful flare-ups by means of therapeutic tools mentioned. However, what it really requires is an adequate management of the various physical training loads and an adequate management of the series of exercises to perform in the gym. From a biochemical point of view, the aim would be to reduce the activation or sensitization of tenocytes.

While storing elastic energy increases cell signalling, very high physical loads generate cell death. Reducing cellular activity may result in decreased cytokine and neuropeptide release and in the deposition of proteoglycan in the extracellular matrix, preventing a future disruption of the matrix and increasing the progressive tolerance to training loads.

The reduction of physical loads (both compressive and tensile) is particularly important since, if it is not done, a reactive response would be triggered (stage 1 of the three-stage model, Cook, & Purdam, 2014). Eccentric training, which has been strongly recommended as a key aspect in the prevention and treatment of tendinopathies, becomes a dangerous weapon if it is added to training sessions without first reducing the overall physical load of the session. Moreover, a direct contusion on the tendon itself also induces a reactive response. Likewise, stretching appears to be counterproductive in adductor, Achilles and hamstring insertional tendinopathies (Cook, & Purdam, 2012).

Therefore, it is clear that the high loads that cause pain in the tendon must be eliminated. Nevertheless, these loads, at a lower intensity, must be introduced as soon as possible while maintaining a certain load stimulus, since a tendon that does not receive any physical load goes into a process of catabolism and degeneration (Arnoczky, Lavagnino, & Egerbacher, 2007; Kubo et al., 2004). So, it has been studied which would be the most adequate training and there is scientific evidence that allows us to affirm that isometric exercise, when there is pain, is useful to generate a situation of analgesia. In patellar tendinopathy, it has been studied the effect of five sets of isometric training of the quadriceps (60° of knee flexion at 70% of the maximum voluntary isometric contraction) of 45 seconds duration and it has been observed that, within the next 45 minutes, an analgesia is produced by cortical inhibition mechanisms (Rio et al., 2015). It is recommended to do this training every day during the season in athletes with patellar tendinopathy. Such training in tandem with the individualization of training loads will allow the athletes to train and compete normally. Although this exercise was initially described to be performed on a knee extension machine, an accepted alternative is the bipedal squat at 70-90° of knee flexion wearing a Russian belt (figure 10). A useful, quick and objective way for the athletes to monitor the clinical evolution of their tendinopathies is by means of provocative clinical tests, as proposed by Cook and Purdam (2014), which are shown in figure 9.

Figure 9: Pain provocation test for clinical monitoring of tendinopathy, retrieved from Cook & Purdam (2014).

Table 2 Provocative clinical tests useful to monitor tendon pain

Tendon	Low-load clinical test	High-load clinical test
Achilles	Single leg heel raise	Hop
Patellar tendon	Decline squat	High single leg jump, landing from a height
Hamstring tendon	Single leg bent knee bridge	Single leg dead lift
Gluteal tendon	Single leg stance	Hop

Source: Cook & Purdam (2014).

According to Malliaras, Cook, Purdam and Rio (2015), in the case of athletes who have been absent from training and competition due to an incapacitating tendinopathy, once the "protocol" of isometric training has been performed and when they report a maximum pain of 3/10, it is convenient to start carrying out isotonic exercises that will seek to increase muscle mass and strength through the performance of the full range of joint movement. At the beginning, it is recommended to limit the range of motion between 10 and 60° of flexion and then increase it to 90° (figure 10). The proposal is the following: three to four series with loads that allow the athlete to perform about 15 repetitions till he has reached the fatigue limit. This will allow the athlete to make progress. The workout should be carried out every two days, increasing the load to six repetitions before reaching the fatigue limit (figure 10). Finally, and moving on to a phase in which the aim will be to seek the storage of elastic energy in the tendon, exercises such as one leg squat (four sets of eight repetitions with 150% of body weight) will be performed. These exercises should always be carried out with a pain perception of less than or equal to 3/10 (figure 10).

Figure 10: Model of training progression in patellar tendinopathy. Retrieved from Malliaras et al. (2015).

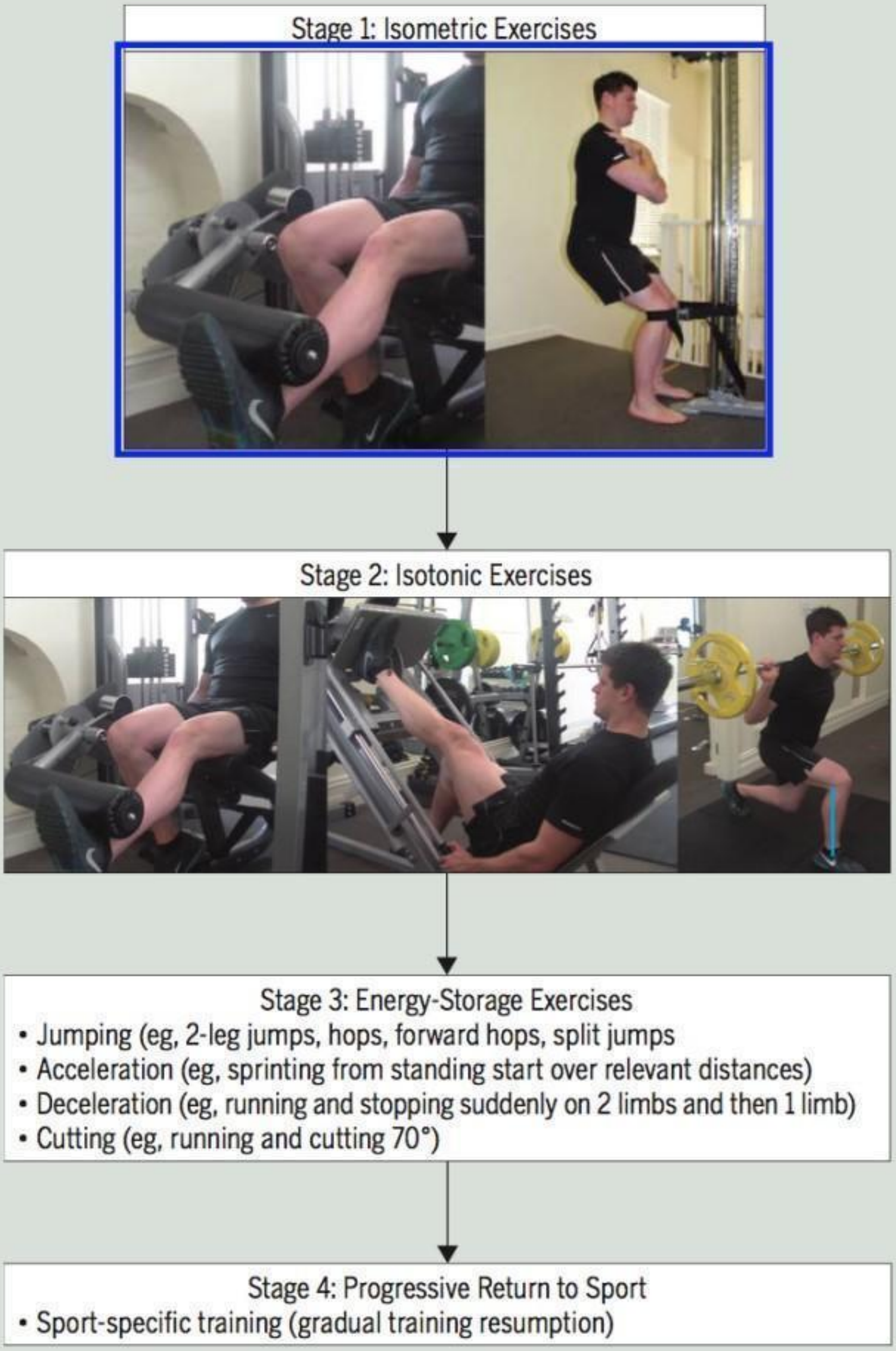


FIGURE 2. Progression of patellar tendinopathy rehabilitation. Stage 1: (A) isometric knee extension performed between 30° and 60° of knee flexion, (B) Spanish squat at 70° to 90° of knee flexion. Stage 2: (A) isotonic knee extension, (B) leg press, (C) split squat. All exercises performed between 10° and 60° of knee flexion, progressing to 90° as pain permits. Maintain the tibia perpendicular to the ground in the split squat, with the knee not going forward beyond the foot, so knee flexion is less than 90°, as indicated by the blue vertical line.

Source: retrieved from Malliaras et al (2015).

Figure 11: Model of training progression in patellar tendinopathy, retrieved from Malliaras et al. (2015).

TABLE — REHABILITATION STAGES AND PROGRESSION CRITERIA

Stage	Indication to Initiate	Dosage
1. Isometric loading	More than minimal pain during isotonic exercise*	5 repetitions of 45 seconds, 2 to 3 times per day; progress to 70% maximal voluntary contraction as pain allows
2. Isotonic loading	Minimal pain during isotonic exercise*	3 to 4 sets at a load of 15RM, progressing to a load of 6RM, every second day; fatiguing load
3. Energy-storage loading	A. Adequate strength† and consistent with other side B. Load tolerance with initial-level energy-storage exercise (ie, minimal pain during exercise and pain on load tests returning to baseline within 24 h)*	Progressively develop volume and then intensity of relevant energy-storage exercise to replicate demands of sport
4. Return to sport	Load tolerance to energy-storage exercise progression that replicates demands of training	Progressively add training drills, then competition, when tolerant to full training

Abbreviation: RM, repetition maximum.
**Minimal pain defined as 3/10 or less.*
†For example, around 150% body weight (4 × 8) for most jumping athletes.

Source: retrieved from Malliaras et al (2015).

6.3 Surgical Treatment

In cases of chronic tendinopathies (basically in Achilles and patellar tendon), surgery is recommended only as the last therapeutic option when traditional methods have not produced satisfactory results after a minimum of six months. In any case, it is unpredictable to know if the intervention will solve the clinical problems of the athlete even after the intervention. Therefore, it is essential to insist that surgery should be the last option.

The basic objective of the tendon surgery is to release the tendon from fibrous adhesions and to remove degenerative nodules inside the tendon, restoring vascularization and stimulating immature tenocytes to start a synthesis of new tendon material and thus regenerate the injured tendon. Traditional surgeries require six to nine months of post-surgical rehabilitation.

Likewise, in the last years, different surgical approaches that are minimally invasive (percutaneous tenotomies, including some with ultrasound guidance) have been proposed with the aim of reducing surgical aggression, offering less painful postoperative recovery and reincorporating the athlete to training sessions and competition in less time than traditional surgeries.

In cases of insertional tendinopathies, there is no consensus about the best surgical option. Besides, there is a debate about whether to use surgical techniques similar to those used for tendinopathies of the tendon itself or whether to involve the bone where the tendon fibers are inserted (osteotomies) (Marcheggiani et al., 2013).

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