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Rehabilitation of Tendon Injuries in Sport

Ron El Hawary,[1] *William D. Stanish*[1,2] and *Sandra L. Curwin*[3]

1 Dalhousie University, Faculty of Medicine, Halifax, Nova Scotia, Canada
2 Orthopaedic and Sport Medicine Clinic of Nova Scotia, Halifax, Nova Scotia, Canada
3 Physical Therapy Program, Husson College, Bangor, Maine, USA

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Summary

Clinicians are faced with a growing number of athletes with injured tendons. Treatment of both acute and chronic injuries has proven to be quite complex. It is difficult to maintain the balance between resting the injured tendon and preventing atrophy of the surrounding muscles and joints. Questions also arise as to when the tendon should be strengthened and when the athlete is ready to return to full activity in sport. Through an awareness of the structural and mechanical properties of the tendon, an exercise programme for the rehabilitation of tendon injuries has been developed. It is recommended that this programme be used in combination with ice and other physical modalities. This approach will resolve most tendon injuries within 6 weeks of its implementation. The use of anti-inflammatory medications and surgery can only be recommended in select situations where more conservative measures are inadequate.

As a greater emphasis has been placed on physical activity and sports performance, tendon injuries have become much more common.[1] It has been determined that 75% of all tendon ruptures are sports-related.[2,3] Overuse tendon injuries have become quite prevalent because athletes have increased both the amount of time spent training and the intensity of their training.[1] This type of injury accounts for 30 to 50% of all sports-related injuries in the US.[1,4]

There has been substantial controversy over the treatment and rehabilitation of these injuries. However, by observing the following general principles, these injuries can be successfully managed:[5]

- identify and remove all negative external forces and factors
- estimate the phase of healing
- determine the appropriate focus for initial treatment
- institute an appropriate tensile loading programme
- control pain and inflammation.

1. The Tendon

1.1 Structure

Tendons are the strongest component of the musculotendinous unit. By linking muscle to bone, they transfer contractile forces across joints.[6] Tendons are composed primarily of collagen, glycosaminoglycans, elastin, glycolipids, cells and water.[5] The collagen is distributed throughout an extracellular matrix composed chiefly of water and glycosaminoglycan.[5-7] The roles of the two most functionally active complexes, collagen and elastin, differ significantly. While collagen acts to oppose tensile forces, elastin acts to increase tendon flexibility.[6] The extracellular matrix, which encompasses collagen, supplies it with both structural support and with a medium for the transport of essential nutrients.[6]

The complex structure of the tendon has best been described as the 'hierarchical organisation of the tendon'[8] (fig. 1). The smallest unit in the tendon is tropocollagen, which is a protein composed of type 1 collagen and created by fibroblasts.[6-8] Electrostatic bonds are responsible for the intrinsic stability of these molecules, while cross-links between tropocollagen molecules allow these units to combine and form fibrils[6,7] (fig. 2). When these fibrils lie parallel to one another within the extracellular matrix, they are capable of resisting loads. Groups of parallel fibrils form fibres, and groups of fibres constitute fascicles, which are the smallest functional unit in the tendon.[6] Enveloping fascicles is a sheath of connective tissue called the en-

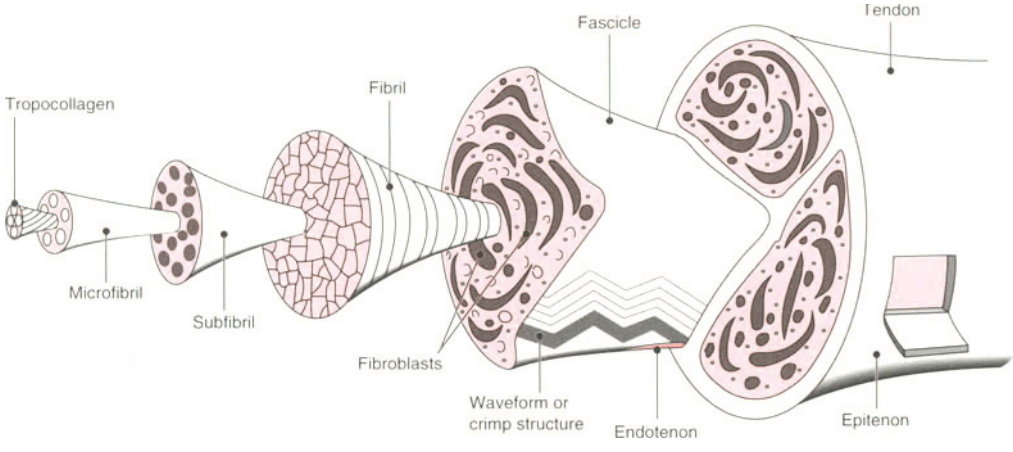

Fig. 1. The hierarchial organisation of the tendon, showing the various stages from tropocollagen to tendon (reproduced from Curwin and Stanish,[8] with permission).

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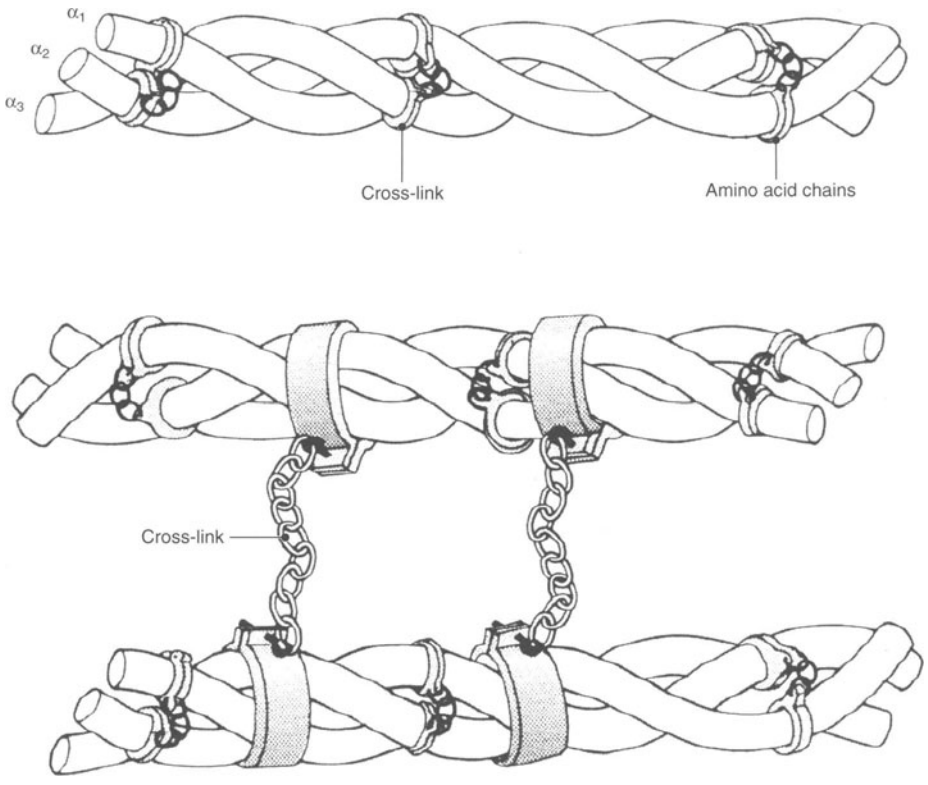

Fig. 2. Intramolecular (**top**) and intermolecular (**bottom**) cross-links are responsible for the tensile strength of the tendon (reproduced from Curwin and Stanish,[8] with permission).

dotenon. This sheath contains the vital nervous, vascular and lymphatic structures for the tendon.[5,6] Completing the hierarchial structure are the epitenon and the peritenon, both of which surround the endotenon.

1.2 Biomechanics

The efficacious structure of the tendon is primarily responsible for its mechanical properties. Tendons have the ability to deform under high tensile stresses and to then return to their original length once they are unloaded.[6] Collagen and elastin are both responsible for these favourable characteristics. Through intramolecular and intermolecular cross-links, collagen contributes greatly to the tensile strength of tendons. It has the unique quality of having an ultimate strength similar to that of steel.[6] It is the type, quantity, cross-sectional area and structural organisation of collagen that determines the tensile stress that the tendon can accommodate without failure.[6,8,9] In the case of the Achilles, the largest tendon in the body, it can receive up to 8 times the body's weight during running when a force of 7000N is applied.[10,11] On the other hand, by being able to elongate up to 70% of its original length before rupture, elastin is largely responsible for tendon flexibility.[6]

These biomechanical features are easily described by the stress-strain curve (fig. 3). This curve is comprised of 4 regions: toe, linear, microscopic failure and macroscopic failure. When the tendon is unloaded, it has a crimped appearance. As the tendon is progressively loaded, the collagen fibres begin to straighten until 2% strain when the

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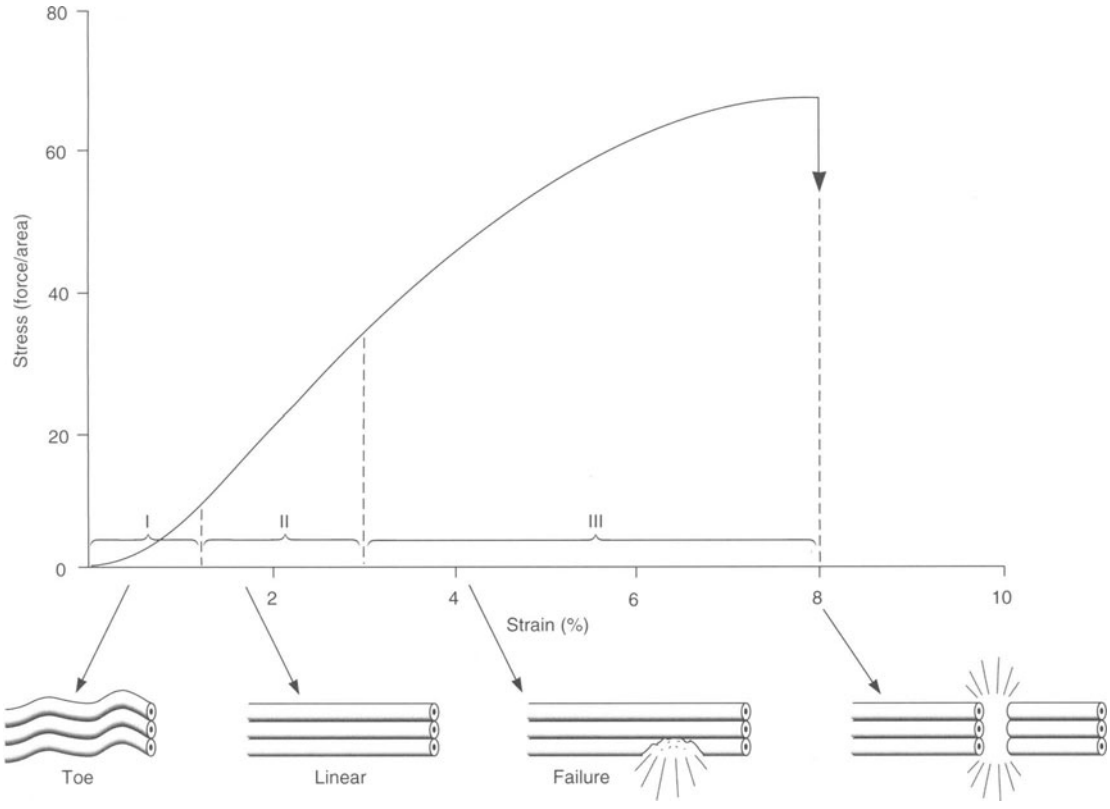

Fig. 3. The stress-strain curve for the tendon.

appearance is no longer undulating. This is represented in the first part of the stress-strain curve (the toe region) and is simply due to the elastic properties of collagen.[5,6] As collagen fibres respond linearly to applied load the linear region of the stress-strain curve is formed and it is the slope of this region that represents the stiffness of the tendon.

If strain does not exceed 4%, the tendon will return to its original length when unloaded. Since tendons rarely rupture under normal physiological loading, it has been assumed that, functionally, they are only exposed to the toe and linear regions of the stress-strain curve.[5,12] Therefore, the stiffness of the tendon is an important indicator of its mechanical behaviour.[5] The linear region ends as cross-links begin to fail and some fibrils rupture.[5,6] This microscopic failure of fibrils occurs from 4 to 8% strain when the fibres are loaded to greater than one-third of their ultimate strength.[6,7] The last region of the curve illustrates macroscopic tensile and shear failure of the collagen fibres.[6] This results in complete tendon rupture once the tendon is strained to 8 to 10% of its original length.[5]

2. Aetiology of Sports Tendon Injuries

A thorough understanding of the aetiology of sports tendon injuries is necessary for the clinician to effectively treat the injured athlete. Seven basic mechanisms of sports tendon injuries have been described:[4]

- contact
- impact
- overuse
- dynamic overload

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- structural vulnerability
- inflexibility
- rapid growth.

These mechanisms may occur independently, but most commonly occur together. Sports tendon injuries may be acute (contact, dynamic overload) or chronic (impact, overuse, structural vulnerability, inflexibility, rapid growth).[4] Overuse injuries account for 30 to 50% of sports tendon injuries and occur with the repetitive use of an anatomic part.[4] The overuse theory explains that when a healthy tendon is exposed to chronic loads that extend into the linear region of the stress-strain curve, microscopic failure of tendon fibrils occurs.[5,13] These loads, which are in the physiological range, are so frequently applied that tendon recovery is unable to occur between load applications and fatigue of the tendon results.[3,5,13] Since it has been established that tendon injuries rarely occur in previously healthy tendons,[5] the other mechanisms of tendon injury usually occur in combination with an underlying overuse injury.[5]

Rupture of the Achilles tendon is a frequently used example of the multifactorial nature of tendon injuries.[3,10,14,15] Most ruptures of this tendon occur at the relatively avascular region 2 to 6cm proximal to the tendon's calcaneal insertion.[1,3,14] This devitalised area of the Achilles tendon, in combination with overuse, results in chronic degenerative and inflammatory changes within the tendon.[10,14,15] As a result, a sudden increase in stress may lead to complete rupture of the tendon.[14] Other examples of tendon disorders can be found in figure 4.

Various classifications of sports tendon injuries have been proposed.[4,5,16] Tendinitis is a term which has commonly been used to describe symptoms of pain located on or near a tendon.[16] It may be either acute, subacute or chronic. Symptoms are experienced for less than 2 weeks in acute, for 2 to 6 weeks in subacute, and for greater than 6 weeks in chronic tendinitis.[17] An accepted classification system defines tendinitis as an injury of the tendon with a resultant inflammatory reaction of the paratenon.[16] It also provides definitions for paratenonitis, tendinosis and paratenonitis with tendinosis. Paratenonitis is an inflammation of only the paratenon, while tendinosis is a significant degeneration of the tendon but without an inflammatory response within either the tendon or paratenon.[16] Paratenonitis with tendinosis is a combination of tendon degeneration and paratenon inflammation.[16] Although this classification scheme is popular, it is based upon tendon pathology and is difficult to use in a clinical setting. Table I presents a more practical classification system for tendon disorders based on pain and function of the tendon.[5]

Table I. Classification of tendon disorders

Intensity	Level	Pain	Performance
Mild	1	None	Does not affect performance
	2	With extreme exertion only	Does not affect performance
		Not intense	
		Disappears immediately when activity stops	
Moderate	3	Starts with activity	Performance may be affected
		Lasts 1-2h after activity	
	4	With any athletic activity	Performance level significantly decreased
		Increases during activity	
		Lasts 4-6h afterwards	
Severe	5	Immediately upon any activity involving tendon	Performance markedly curtailed or prevented
		Sudden increase in pain if activity is continued	
		Lasts 12-24h afterwards	
	6	During daily activities	Unable to participate

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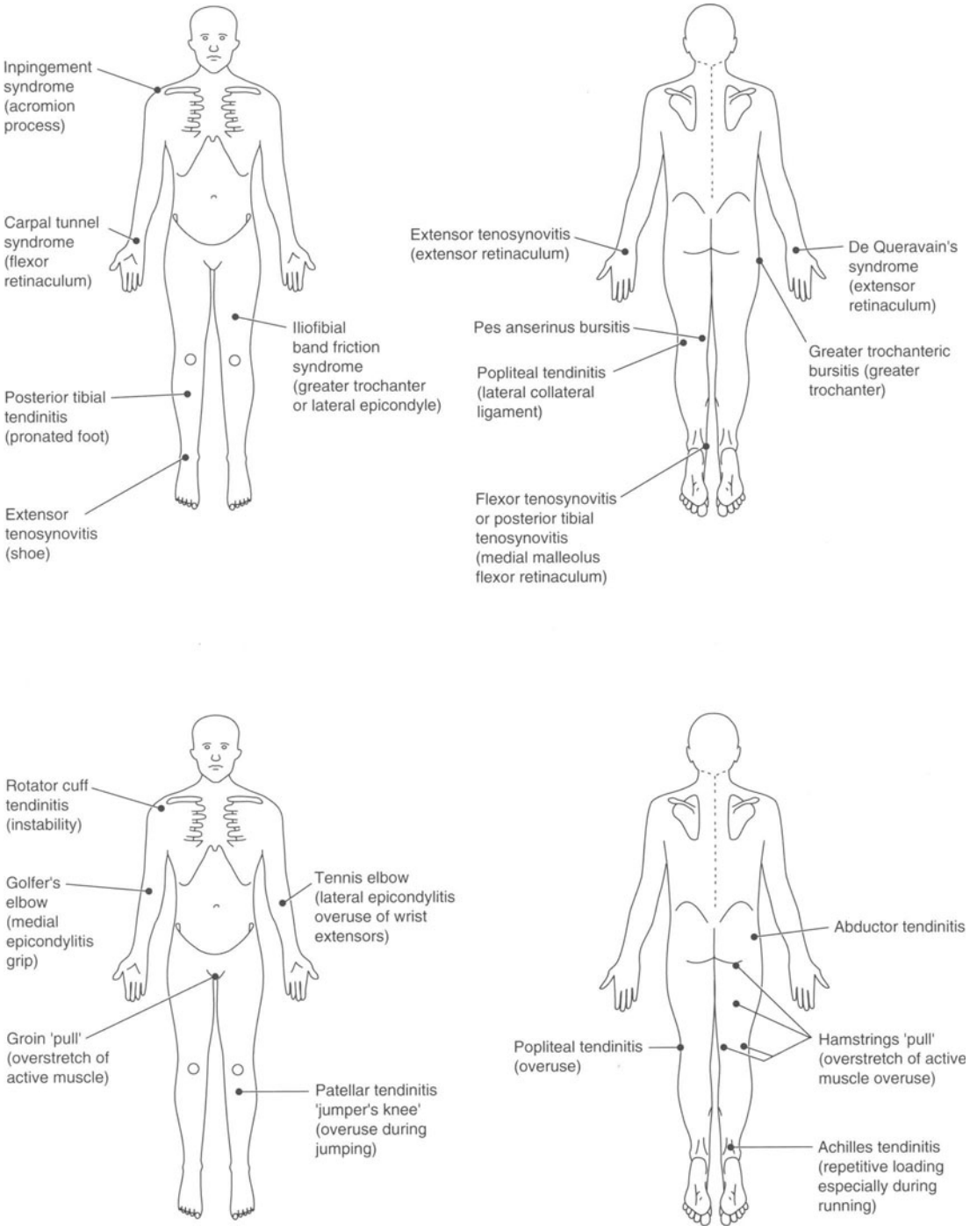

Fig. 4. Examples of tendon disorders.

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3. Tendon Healing

When a tendon has been acutely injured, its healing follows 3 overlapping stages:[5,18,19]

- the inflammatory stage occurs during the first 6 days
- the fibroblastic/proliferative stage occurs from days 5 to 21
- the remodelling/maturation stage begins on day 20.

Determining the stage of tendon healing is essential because each stage involves different events and therapy must be tailored to the specific mechanisms involved in the present stage of healing.[18]

The inflammatory process involves monocytes, eosinophils, neutrophils, lymphocytes, platelets and monocytes.[18] By the fifth day, fibroblasts are also active as they create tropocollagen molecules which do not have intermolecular cross-links.[6,18]

The second stage begins as these fibroblasts begin to proliferate and the acute inflammatory response begins to abate.[18] Between the sixth and fourteenth day, cross-links begin to develop between the tropocollagen molecules, but these fibrils are still distributed randomly throughout the tendon.[6] Therefore, these new fibres lack the tensile strength that the organisation in a mature tendon offers. During these early stages, the fibres are likely to rupture under tensile loads.[6]

The remodelling stage overlaps with the proliferative stage as the newly formed fibrils begin to become organised along the longitudinal axis of the tendon.[6,18] This organisation of collagen fibrils into bundles corresponds with a substantial increase in the mechanical strength of the healing tendon.[9,18]

The alignment of collagen during the remodelling stage is an important concept in the treatment of tendon injuries. By applying tensile stress during fibroplasia, the organisation of fibrils is facilitated.[18] This results in a tendon that is capable of withstanding a greater tensile stress.[18]

The healing process in tendinosis is significantly different than that seen in acutely injured tendons. The major difference in tendinosis is the lack of an inflammatory response within both the tendon and paratenon. Only tendon degeneration can be observed.[16] As a result, in tendinosis, tendon healing does not follow the 3 stages seen with acute injuries (inflammation, proliferation and remodelling). Tendinosis may represent only the late fibrotic stage of tendinitis.[5] It is, therefore, very difficult to estimate the stage of healing in the tendon of a patient with chronic tendinitis.

4. Treatment and Rehabilitation

4.1 General Principles

The major goals of treating the ruptured tendon are to avoid interfering with the healing process during the first few days and to then mobilise the joint as soon as possible.[5,20] There is a delicate balance between protecting the tendon from rerupture and immobilising it to the extent that surrounding muscles atrophy from disuse (see table II). Rehabilitating the chronically injured tendon is not as simple as it is for a ruptured tendon. The difficulty with treating chronic tendinitis is that the precise time of injury is unknown.[5] By not knowing when the injury occurred, it is difficult to know the stage of healing of the tendon. Therefore, treatment will not be as specific as for acute injuries.[5] To overcome this obstacle, the following assumptions about chronic tendinitis must be made[5]:

- All cases of tendinitis are in an acute stage if treatment is progressed accordingly.
- The chronically injured tendon will heal in much the same way as the severed (acute) tendon.
- Inflammation reflects the degree of damage to the tendon, and the signs of inflammation can be monitored to assess the progress of tendon damage or recovery.
- Effects of exercise and disuse will be the same for chronic tendinitis as for normal and severed tendons. Therefore, exercise will be beneficial in the treatment of chronic tendinitis.

The rehabilitation of tendon injuries should be divided into phases that are specific for the injured tendon's stage of healing.[18,20,21] Table II summarises these stages. The main goal in treating the inflammatory stage is to avoid disrupting the tissues

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Table II. Overview of principles governing clinical intervention during tendon healing

	Stage of healing		
	inflammatory	fibroblastic/proliferation	remodelling/maturation
Time (days)	0-6	5-21	20 days and onwards
			Progressive stress on tissue
Suggested therapy	Rest, ice, anti-inflammatory modalities, decreased tension	Gradual introduction of stress, modalities to increase collagen synthesis	
Physiological rationale	Prevent prolonged inflammation, prevent disruption of new blood vessels and collagen fibrils, promote ground substance synthesis	Increase collagen, increase collagen cross-linking, increase fibril size and alignment	Increase cross-linking (tendons and ligaments), decrease cross-linking (joint capsule), increase fibril size
Main aims	Avoid new tissue disruption	Prevent excessive muscle and joint atrophy	Optimise tissue healing

which are formed during these first few days. Treatment should include rest, ice, anti-inflammatory medications and decreased tension. Physiologically, this therapy prevents prolonged inflammation, prevents disruption of new blood vessels and collagen fibrils, and promotes ground substance synthesis.[5,20]

During the fibroblastic stage, care includes a gradual introduction of stress on the tendon and the continuation of modalities to increase collagen synthesis. These treatments act to increase collagen, collagen cross-linking and fibril size and alignment. The object of this therapy is to prevent the atrophy of surrounding muscle and joint.[5,20]

The remodelling stage should include a progression in the amount of stress placed upon the injured tendon. This facilitates cross-linking in the tendon and increases the size of fibrils. The end result of this stage is an optimisation of tissue healing.[5,20]

4.2 Physical Modalities

Numerous physical modalities have been used over the years to treat tendon injuries. The success of modalities has been quite subjective as the physiological effects are known, but the effects at the tissue and cellular levels are not very well understood.[22]

Ultrasound is a popular heat-based modality that can be delivered in the form of pulsed or continuous waves.[23] Like other modalities, the mechanism of action of ultrasound is poorly understood.[22-27] It has been reported that the use of ultrasound in the early stages of tendon healing stimulates collagen synthesis by fibroblasts and increases tensile strength, but it has not been proven to have any anti-inflammatory effects.[22-25,27]

Like ultrasound, laser has been found to stimulate cell metabolism and proliferation, but it also affects tissue inflammation.[28,29] Due to the wide variability in the timing, dose and penetration of laser therapy, significant research remains to be completed before lasers can be utilised to their maximum potential.[5,28]

Electrical stimulation has improved regeneration of injured tissues.[30-32] It has been proposed that pulsed electromagnetic fields are useful in the treatment of tendinitis which has not responded to other conservative measures.[30] Although the future of electrical stimulation remains encouraging, questions about the optimum dosage and timing remain.[5]

Since the 1950s, ice has remained one of the mainstays of the treatment of tendon injuries.[33] It is thought to decrease the metabolic rate of injured cells, and therefore to decrease their need for oxygen and to enable the cells to become more resistant to hypoxia. This results in decreased tissue damage and oedema.[33] Another advantage of ice is that its analgesic effect may allow the athlete to begin an exercise programme much sooner than they may otherwise.[5]

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4.3 Medications

Nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids and anabolic steroids have all been employed in the treatment of tendon injuries. NSAIDs have anti-inflammatory, analgesic and antipyretic qualities, but most research has demonstrated that they are of modest benefit in the treatment of tendon injuries.[34,35] Due to the well-known adverse effects of NSAIDs, clinicians must carefully evaluate the athlete's situation to correctly decide on their use.[35]

Oral corticosteroids are the most powerful drugs available for the treatment of inflammation, but also have the most potent adverse effects.[36] As a result, their use is not endorsed for treating tendon injuries.[36] Repeated local injection of steroids should also be avoided.[37-41] Numerous studies have reported rupture of tendons after local injection of steroids.[37,39,40] It is the deposition of steroids directly into the tendon that weakens the tendon to the extent that its rupture becomes more likely.[37,39] If injections of steroids are administered, stress on the tendon should be minimised for 2 weeks for the tendon to recuperate.[8,37,42]

4.4 Surgery

Almost all sports tendon injuries can be effectively treated with nonsurgical methods.[43-45] This type of therapy is considered more favourable than surgical treatment as there is less morbidity and no hospitalisation associated with conservative treatment.[46] Surgery becomes necessary in cases that do not respond to nonoperative interventions.

Surgery is useful in the treatment of chronic tendinitis that has been resistant to conservative measures for at least 6 months.[10,44,45,47] Also, surgery is essential for the successful recovery of ruptured tendons.[3,10,45] If surgery is employed, it is important that an acceptable exercise and retraining programme be assumed post-operatively.[3,44,47]

4.5 Eccentric Exercise Programmes

From our knowledge of the mechanisms of tendon injury and healing, it is known that these injuries result from tensile stresses that are greater than the tendon's own biomechanical strength and that healing allows tendons to adapt to increasing loads.[5] It has been determined that cyclic tensile loading offsets the negative mechanical changes that are observed in the immobilised tendon.[12] Motion assists tendon healing by facilitating the orientation of new collagen fibres along the direction of the applied tensile stress.[12,48] Exercise has also been found to increase the size of fibres and the ultimate strength of tendons.[48] It is therefore evident that exercise programmes are an effective way to take advantage of the natural healing properties of tendons.[49]

Three basic principles of exercise must be followed to ensure the success of an exercise programme:[5]

- specificity of training
- maximal loading
- progression of loading.

Specificity is accomplished by reproducing the movement that is associated with maximal tendon forces on the injured musculotendinous unit. Because the desired magnitude and speed of this loading is directly related to the stage of tendon healing, it is very important to first accurately evaluate the stage of healing. Using the example of an Achilles tendon injury, the tendon is specifically stressed by standing at the edge of a step and dropping the heels.[5]

Maximum load is crucial for facilitating the healing tendon's adaptation to increasing loads. It is determined by the amount of pain that the patient experiences during the exercise.[5] For maximal loading, pain should occur between the twentieth and thirtieth repetition of the exercise.[8,50]

The third basic principle of exercise, progression of loading, is also essential for aiding the healing tendon adapt to load. The tendon is increasingly stressed as it becomes stronger throughout the rehabilitation programme. This provides the tendon with a constant stimulus for healing.[5] Progression of loading is accomplished by increasing the speed of movement or by increasing the external resistance.[5] Like maximal loading, this prin-

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ciple is also defined by the amount of pain experienced by the athlete.

An eccentric exercise programme that includes these basic principles of exercise has been developed and successfully employed for rehabilitating sports tendon injuries.[8] Eccentric contraction is 1 of 3 types of musculotendinous contraction.[50] It occurs when a muscle resists an applied force, but the muscle-tendon unit lengthens.[50] Running downhill is an example of eccentric contraction of the Achilles tendon.[50]

Since eccentric force places the maximum load on the tendon, it is the logical choice for rehabilitation of a tendon injury.[50] The programme was developed for athletes with chronic tendinitis, but may be used in the treatment of any tendon injury. The plan has 5 steps:

- Warm-up: this is accomplished by general exercise such as cycling or jogging. It is useful for increasing the circulation and the body temperature. It is not designed to load the tendon.
- Flexibility: because inflexibility is a major cause of chronic tendinitis, a flexibility programme will relieve the athlete's symptoms. Stretching the injured musculotendinous unit and its antagonist should be performed for at least 2 sets of 30 seconds before the specific exercise is started.
- Specific exercise: 3 sets of 10 repetitions should be performed, with a short rest and stretch between repetitions. From the maximal loading principle, the athlete should feel pain between the twentieth and thirtieth repeat. If pain is felt outside of this range, then the speed or the load should be adjusted accordingly.
- Repeat flexibility exercises as in step 2.
- Ice: this should be applied to the affected area for 10 to 15 minutes. This helps to prevent inflammation caused by the exercise programme.

This programme must be followed daily and progressed continuously until symptoms are no longer experienced during activity[5] (fig. 5). During rehabilitation, athletes with chronic tendinitis commonly do not need to refrain from their sport.[5] These athletes are usually asymptomatic 6 to 8 weeks after beginning the eccentric exercise programme at home.

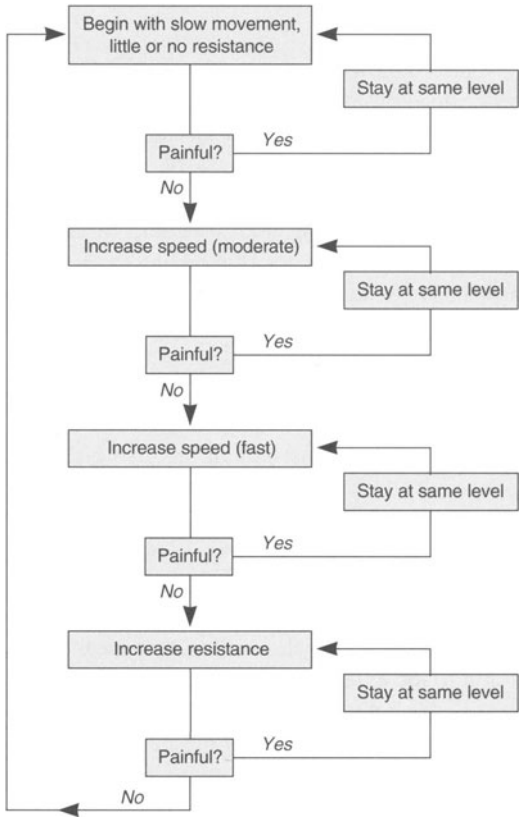

Fig. 5. The method of progression of the eccentric exercise programme.

Only if severe or constant pain is experienced is it necessary for the athlete to adjust their participation in sports.[5] In this case, athletic participation should be resumed cautiously. It should begin at 25% of the pre-injury level and should be performed on alternate days. If the athlete remains asymptomatic at this level, participation should be increased by 10% per week until pre-injury levels are reached. Therefore, athletes with a severe tendon disorder require 10 to 12 weeks of treatment.

If 2 weeks of patient-directed, or 1 week of clinician-directed, treatment elapse without signs of improved condition, the clinician must re-evaluate the athlete's condition. If on re-evaluation the clinician still feels that tensile loading is the root of

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the symptoms, the exercise programme should be modified. It may also be possible that the diagnosis of a tendon injury was not accurate. Outside factors that may have caused the symptoms should be explored and reversed if discovered.

Physical modalities and NSAIDs may be employed as adjuvants to the eccentric exercise programme. Physical modalities may be deemed necessary if the physiotherapist feels that synthetic activity within the tendon is inadequate. NSAIDs may be used if it is felt that the tendon is still in the inflammatory stage of healing.

5. Prevention

It is generally agreed that tendon injuries are, for the most part, highly preventable.[2,10,44] These injuries can be avoided through simple measures such as:

- pre-season strength training
- proper stretching and warming-up
- avoidance of hills and uneven running surfaces
- equipment modification
- technique adjustment.[2,10,44,51]

6. Conclusions

Regardless of the level of performance, prevention of tendon injury should always be a cornerstone in the development of the athletic training programme. In cases where prevention alone is insufficient for the avoidance of injury, appropriate treatment and rehabilitation should commence immediately. Treatment must be specific for the tendon's stage of healing to augment the body's own healing response and to take advantage of the structural and biomechanical properties of the tendon. It is advisable to carefully rehabilitate the injured tendon with a combination of exercise, ice and other physical modalities. The use of drugs and surgery should be administered judiciously only in select cases where their benefit would be indisputable.

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Correspondence and reprints: Dr *W.D. Stanish*, Fenwick Medical Centre, Suite 311, 5595 Fenwick Street, Halifax, Nova Scotia, B3H 4M2, Canada.

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