Injury to muscle and tendon structures can substantially affect individual joint mobility and stability. Furthermore, muscle and tendon injuries can alter movement of the entire body and ultimately limit functional participation in life activities. The goal of this chapter is to aid the clinician in identifying and treating muscle and tendon injuries. Specifically, the objectives of this chapter are to (1) identify basic science components and healing parameters of the muscle-tendon unit, (2) differentially diagnose muscle and tendon pathologies, and (3) discuss evaluation considerations and rehabilitation principles for muscle and tendon injuries.

ANATOMIC COMPONENTS AND TISSUE RESPONSE TO INJURY

Muscles are composed of contractile tissue and are responsible for creating and dissipating force while enabling voluntary movement of the body. Movement of the skeletal system is made possible through the connection of muscle to bone via tendons. Together, muscles and tendons form a complex unit known as the muscle-tendon unit.

Muscle-Tendon Unit

The muscle-tendon unit is composed of a muscle with tendons at each end, and each tendon is attached to bone (Fig. 7–1). The point of connection between muscle and tendon is the myotendinous junction (MTJ), and the point of attachment of tendon to bone is the osseotendinous junction (OTJ). The entire muscle-tendon unit works to produce controlled movement, as well as to stabilize and protect joints. Therefore, when the musculotendinous unit sustains an injury, it often has an impact on joint stability and functional mobility. Injury to the muscle-tendon unit can occur within the body of the muscle or tendon or at their points of attachment. Frequently, the site of injury in the musculotendinous unit is at the MTJ. When injury occurs near the OTJ, an avulsion fracture may result, with the bony insertion separated from the bone (Fig. 7–2).

A commonly seen clinical pathology, Osgood-Schlatter disease, occurs when activation of the quadriceps muscle-tendon unit causes the infrapatellar tendon to pull excessively at the OTJ on the tibia. The OTJ becomes inflamed, and contraction of the quadriceps muscle-tendon unit, especially against resistance, causes pain. The pull of the quadriceps muscle-tendon unit causes a small separation at the tibial tubercle, which then results in additional bone growth. Osgood-Schlatter disease is often seen in children who participate in running and jumping activities in which the quadriceps muscle is repeatedly activated. This pathology is also commonly seen during periods of rapid growth when appropriate flexibility of the quadriceps musculotendinous unit is not maintained. The enlargement of the tibial tubercle that occurs with Osgood-Schlatter disease remains even after the symptoms subside.

CHAPTER OBJECTIVES

- Define the muscle-tendon unit.
- Describe the stages of tissue healing and the importance of application of this knowledge in rehabilitation.
- State the mechanism of injury for strains.
- Identify characteristics of the different grades of strains and application of this to rehabilitation.
- Describe the classifications of tendon pathology.
- State key aspects of the clinical evaluation.
- Identify rehabilitation principles for acute and chronic injuries and design appropriate rehabilitation interventions.
- Describe rehabilitation treatment techniques for common muscle-tendon pathologies.
Stages of Healing

It is important to have a fundamental understanding of healing time frames before discussing pathology and ultimately deciding on appropriate treatment because knowledge of tissue-healing phases will help guide the decision-making process during patient progression. The stages of soft tissue healing consist of the inflammatory response phase, the fibroblastic-repair phase, and the maturation-remodeling phase. Although the literature reports variations in the exact time frames for each phase, these phases of healing overlap and the time frames serve as general guidelines for the clinician since each soft tissue injury varies in severity and the individual’s response to injury.

The acute inflammatory phase begins immediately after tissue injury and is characterized by redness, swelling, increased temperature, and pain. The inflammatory phase involves capillary injury and vasodilation, which results in increased blood flow to the injured area. Neutrophils and macrophages are attracted to the site of injury to remove foreign debris and damaged tissue from the area and thereby improve the healing environment. The events in the inflammatory response phase last approximately 2 to 4 days. During the fibroblastic-repair phase, which typically begins 3 days after injury and lasts approximately 2 weeks, new blood vessels form and fibroblasts migrate to the area to synthesize new ground substance and collagen. The wound margins begin to contract in size and weaker type III collagen is deposited in an unorganized fashion to form scar tissue. Finally, during the maturation-remodeling phase, ongoing synthesis and reorganization of collagen fibers take place. The continued collagen deposition transitions to mainly type I collagen, and the collagen fibers in the scar tissue become parallel in alignment as a result of tensile forces applied to the injured soft tissue. The parallel alignment of collagen fibers is usually achieved by 2 months after injury and allows the tissue to endure higher tensile loads. However, this final healing phase is a long-term process that beginning approximately 3 weeks after injury and may last up to 1 year. While remodeling, the tensile strength of the wound continues to increase and at 3 months will have approximately 80% of normal tissue strength. When the remodeling phase is complete, the damaged tissue has often not achieved the same tensile strength as uninjured tissue. Luckily, the limitation in tensile strength does not typically affect function. The three phases of tissue healing overlap and represent a continuum of soft tissue healing (Fig. 7–3).

Injuries to muscles involve a similar process as just described, but unique to muscles are satellite cells, which are muscle-specific stem cells located on the border of muscle fibers. With injury to muscle, the ruptured myofibers contract and the gap is filled with edema and eventually scar tissue. On the ends of the retracted muscle fibers, satellite cells are activated to proliferate and cause muscle regeneration. The newly regenerated myofibers on the end of the torn muscle project into the forming connective tissue scar.

When compared with muscle, tendons have less vascularity and therefore less oxygen and nutrition after injury. As a result, tendons may be slower than muscles to recover after injury. With tendons it is thought that healing may occur through intrinsic and extrinsic pathways. The extrinsic mechanism involves inflammatory cells and fibroblasts from the surrounding area that enter to assist in tendon repair, whereas the intrinsic mechanism involves inflammatory cells and fibroblasts...
from within the tendon.\textsuperscript{16,17} Within the tendon the reparative cell is the tenocyte, which may be activated to produce collagen.\textsuperscript{8} Although collagen is needed to help repair the damaged tendon, fibrosis may develop and result in the formation of adhesions to surrounding tissue if excessive collagen synthesis occurs. Clinically, this is not ideal because limited mobility may occur as a consequence of the scar tissue adhesions.

### MUSCLE-TENDON PATHOLOGIES

**Muscle Strain**

A muscle strain refers to pathology that involves some extent of disruption in the continuity and function of the muscle-tendon unit.\textsuperscript{1,3,18} The mechanism of injury of muscle strains may be related to passive overstretching, excessive active loading, or repetitive loading of fatigued musculature.\textsuperscript{1,18-21} In other words, the strain occurs when the amount of stretch exceeds the limits of flexibility, the amount of force exceeds the level of activation, or the duration of force exceeds the level of endurance of the involved muscle-tendon unit. In particular, eccentric repetitive loading is often a cause of muscle strain because muscle forces can be higher during the lengthening activation and lead to microscopic damage to the contractile element of the muscle.\textsuperscript{21-23} A muscle strain can also be the result of an acute impact (direct blow) to the involved musculature, known as a contusion.

Clinically, strains are frequently seen in certain muscle groups. Strains commonly involve muscles that have a large percentage of type II fast-twitch muscle fibers and muscles that cross two joints, such as the hamstrings, gastrocnemius, and rectus femoris.\textsuperscript{24,25} Muscles that span two joints are placed at risk through loading at both joints simultaneously and mixed demands during function. In sports medicine, muscle strains commonly occur in “speed athletes,” such as sprinters and football, basketball, and soccer players.\textsuperscript{26} Muscle strains also tend to occur during strenuous exercise, particularly during eccentric muscle activation or when the muscle is fatigued. At the end of practice or a training session, the musculature is more likely to be fatigued and the athlete is at an increased risk for an acute strain, especially if proper conditioning is not maintained.

Muscle strains should be differentiated from the exercise-induced muscle soreness that occurs after eccentric exercise or physical activity in naïve/unaccustomed individuals. Although both strains and exercise-induced muscle soreness occur with eccentric exercise and both produce pain with passive stretching or muscle activation (or both), a muscle strain is a painful event that is acute in nature and identified at the time of injury. In other words, the patient will report knowledge of the moment when the muscle strain was felt. In contrast, delayed-onset muscle soreness (or DOMS) typically peaks 24 to 72 hours after exercise. Importantly, DOMS occurs after bouts of eccentric exercise, especially in untrained muscle, but it typically resolves without intervention within a few days to a week.\textsuperscript{16,26,27}

#### Grading of Strains

Strains range from damage to a limited number of muscle fibers or connective tissue to a complete muscle tear or tendon avulsion. Typically, strains are categorized as grade 1, grade 2, or grade 3 (Table 7–1). Determining the appropriate grade of strain will help guide the clinician through the rehabilitation process. A grade 1 strain may leave the athlete with slight discomfort and minimal swelling but full range of motion (ROM) and little functional deficit. A grade 2 strain is characterized by a small to moderate palpable area of involvement along with increased pain and swelling. An athlete with a grade 2 muscle strain will often demonstrate restricted ROM and impaired gait if the lower extremity musculature is involved. A grade 3 muscle strain is typified by a moderate to severe palpable area of involvement and sometimes a defect at the site of injury. The athlete will demonstrate significant deficits in ROM, and functional mobility will be severely impaired.

A grade 3 strain with a complete muscle or tendon rupture may require surgical repair, so correct assessment of an avulsion injury is critical. For example, a grade 3 muscle strain of the Achilles tendon is best evaluated with the Thompson test (Fig. 7–4). To perform this test, the patient should lie prone with the feet extended off the end of a treatment table while the clinician passively squeezes the belly of the gastrocnemius muscle. When the Achilles tendon is intact, the foot should move into plantar flexion. However, if the Achilles tendon is ruptured, the foot will not plantar-flex. A patient with an Achilles tendon rupture will often report the feeling of a “pop” or being kicked in the calf. Rupture of the Achilles tendon often occurs around 2 to 6 cm from its insertion site on the calcaneus, where the gastrocnemius and soleus tendons meet and which it is thought to be the area with the poorest blood supply.\textsuperscript{6,24} Early diagnosis and treatment of this pathology is important. Treatment approaches can include either conservative or surgical management; however,
### Table 7-1 Grading of Muscle Strains

<table>
<thead>
<tr>
<th>Grade</th>
<th>Structural Fiber Damage/Deformation</th>
<th>Pain</th>
<th>Range of Motion</th>
<th>Strength</th>
<th>Swelling</th>
<th>Limitations in Ambulation (for Lower Extremity Strains)</th>
<th>Limitations in Participation in Sporting Activities (for Lower Extremity Strains)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Some fibers stretched or actually torn, no gross disruption of the muscle-tendon unit</td>
<td>Pain or tenderness with AROM or stretching</td>
<td>No loss, full ROM possible</td>
<td>No loss, full strength</td>
<td>Minimal, localized edema</td>
<td>Minimal to no limitation in ambulation</td>
<td>Minimal limitations, may be able to participate by using equipment (wraps, bracing, taping)</td>
</tr>
<tr>
<td>2</td>
<td>Torn muscle/tendon fibers, palpable depression in the area of injury; some degree of disruption of the muscle-tendon unit</td>
<td>Pain with active contraction of the muscle-tendon unit</td>
<td>Loss of ROM because of swelling and bleeding, limitation in AROM</td>
<td>Some loss of strength</td>
<td>Moderate edema</td>
<td>Ambulation with a limp, may need crutches</td>
<td>Unable to participate but should be able to return to play during the same season with appropriate rehabilitation</td>
</tr>
<tr>
<td>3</td>
<td>Complete rupture of the muscle belly, MTJ, or OTJ; noticeable defect in the muscle belly or evidence of a torn tendon</td>
<td>Intense pain that diminishes with damage and separation of nerve fibers</td>
<td>Severely limited ROM or total loss of ROM</td>
<td>Moderate to major loss of strength, unable to endure resisted motion</td>
<td>Moderate to major edema</td>
<td>Significant limitation in ambulation, likely to require crutches</td>
<td>Unable to participate; consider sitting out the season for conservative or operative treatment</td>
</tr>
</tbody>
</table>

AROM, Active range of motion; MTJ, myotendinous junction; OTJ, osseotendinous junction; ROM, range of motion.
surgical repair of an Achilles tendon rupture produces a lower rerupture rate and provides the patient with a quicker and more optimal return to function. One of the evolving rules in the treatment of these injuries is allowing ROM in the postoperative period or even with conservative care because ROM appears to be vital to long-term success.24,28

Contusions

A contusion injury may be caused by a direct hit or acute blow to the muscle belly. This impact results in muscle cell damage and bleeding into the muscle. Immediately following the injury, an acute inflammatory reaction takes place. Satellite cells on the membrane of muscle cells become new muscle cells, and connective tissue is formed in the damaged area.14,15 The damaged tissue continues to progress through the stages of soft tissue healing as described earlier. The extent of muscle tissue damage with a contusion injury will determine the degree to which ROM, strength, and functional activity are impaired.

Contusion injuries are commonly seen in individuals engaging in athletic activities such as football, where an athlete’s helmet or shoulder pad may forcefully impact an opponent’s quadriceps muscle, for example. Contusions can be classified as mild, moderate, or severe based on the amount of ROM allowed by the involved muscle in the adjacent joints (Table 7–2).28,30 A mild contusion may cause a loss of one third of normal ROM, whereas a severe contusion may limit motion to less than one third of normal mobility.29 Like strains, contusions may also lead to deficits in strength and functional limitations. A severe contusion is characterized by significant bleeding and a large palpable area of involvement, and the muscle may herniate through the fascia. Clinically, muscle strains and contusions are some of the most common injuries seen in sports participation.24

The clinician should also be aware of a condition known as myositis ossificans (also called heterotopic bone) that can develop after a severe muscle contusion (Fig. 7–5). It commonly occurs in the thigh musculature after a direct blow to the muscle causes tissue disruption and excessive bleeding that leads to ectopic bone formation in the area of the injured soft tissue. Initial radiographs are negative, but after 4 to 6 weeks bone formation can be identified radiographically. Even though myositis ossificans can restrict mobility, it is not always treated surgically because the ectopic bone may not impair function and the body may eventually absorb the ossification. However, if surgical resection is indicated, it is performed only after the bone has fully matured because early surgery can exacerbate the condition.

Clinical Pearl #2

Proper treatment of a contusion can help decrease risk for the development of myositis ossificans. Immediately after a quadriceps contusion injury, the knee should be immobilized in flexion.24,31,32 During this initial rest period, the knee is kept flexed to provide tension on the quadriceps muscle and inhibit blood pooling and muscle contraction.24 While the leg is wrapped, ice is applied to the area of injury to limit excessive blood flow to the injured area, and nonsteroidal antiinflammatory medication may help in addressing the inflammation as well.33 Typically, the leg is initially wrapped in flexion for the first 24 hours. Afterward, the patient can proceed through the rehabilitation process by beginning with isometric quadriceps-strengthening exercises and progressing to gentle, pain-free ROM and stretching. Reinjury, especially shortly after the initial injury, increases risk for the development of myositis ossificans. Therefore, it is important to avoid activities that may reinjure the muscle tissue, including aggressive overstretching, early aggressive massage, or trying to continue typical athletic activity with a grade 2 or 3 contusion. Heat or thermal modalities that increase blood flow to the area should also be avoided initially after injury.33

Tendinopathy

The terminology involved in tendon injury is evolving and requires further clarification. In the past, tendinitis has been used as a catch-all term to describe all tendon pathologies. However, what is now known about the histologic differences in tendon pathologies requires further clarification of the language used when discussing tendon injuries. Several terms are used to describe various tendon pathologies. For example, tenosynovitis refers to inflammation of the synovial sheath that lines some tendons, and enthesis or bony attachment. Therefore, new classification systems have been proposed to subgroup tendon pathologies.23,34–36

For clarity, tendinopathy is used in this chapter as a broad term that refers to any pathology involving tendons and, as a result, is inclusive of several different tendon pathologies.

In this chapter, tendinopathies will be classified as tendinitis, paratenonitis, and tendinosis (Table 7–3). Tendinitis and paratenonitis are the earliest signs of tendon pathology and trigger an acute inflammatory response. However, if tendon damage continues, tendinosis, partial tears, or even tendon rupture may occur. Tendinitis, paratenonitis, and tendinosis may occur separately, or these pathologies may occur simultaneously, as is the case with paratenonitis and tendinosis.29

FIGURE 7-4 Thompson test. The Thompson test is a clinical test used to assess the integrity of the Achilles tendon. As the clinician squeezes the patient’s calf musculature, an intact tendon will cause the foot to plantar-flex, whereas a ruptured tendon will not produce any movement of the foot.
Table 7-2 Classification of Contusions with Emphasis on the Commonly Seen Quadriceps Contusion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Impairments in Body Structure/Function</th>
<th>Limitations in Ambulation (for Quadriceps Contusions)</th>
<th>Limitations in Function and Participation in Sporting Activities (for Quadriceps Contusions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>Muscle fiber damage, vascular hemorrhage, and hematoma formation</td>
<td>Localized tenderness</td>
<td>Minimal to no loss of strength</td>
</tr>
<tr>
<td>Moderate</td>
<td>Muscle fiber damage, vascular hemorrhage, and hematoma formation</td>
<td>Tender muscle mass</td>
<td>Knee ROM less than 90°</td>
</tr>
<tr>
<td>Severe</td>
<td>Muscle fiber damage, vascular hemorrhage, and hematoma formation; muscle may herniate through fascia</td>
<td>Marked tenderness</td>
<td>Knee ROM less than 45°</td>
</tr>
</tbody>
</table>

ROM, Range of motion. 

<table>
<thead>
<tr>
<th>Structural Fiber Damage/Deformation</th>
<th>Pain</th>
<th>Range of Motion (for Quadriceps Contusions)</th>
<th>Strength</th>
<th>Swelling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0
Tendinopathies are often caused by repetitive tendon trauma, overuse, excessive loading, or preexisting tendon degeneration. Tendon overload is believed to be central to the pathologic process and may result in weakening and eventual failure of the tendon if it is unable to respond to the applied load. However, tendons are able to withstand some extent of tensile loading before injury (Fig. 7–6). At rest, the collagen fibers of the tendon are in a wavy, crimped formation. With slight elongation, the crimped fiber configuration straightens. As the tensile load increases, the collagen fibers continue to deform linearly.

**Table 7–3 Classification of Tendon Injury**

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Description</th>
<th>Nature of Onset</th>
<th>Inflammatory Process Present</th>
<th>Cause</th>
<th>Clinical Signs and Symptoms</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendinitis</td>
<td>Injury to the tendon itself involving partial or complete tearing, vascular disruption, acute inflammatory/repair response; can involve symptomatic degeneration of the tendon when chronic</td>
<td>Acute</td>
<td>Yes (in tendon)</td>
<td>Macrotraumatic, strain or tear, repetitive loading/overuse</td>
<td>Swelling, pain, tenderness, warmth, (depending on the duration/severity of the pathology)</td>
<td>Ice, antiinflammatories, rest, modified activities, progressive ROM and strength exercises</td>
</tr>
<tr>
<td>Paratenonitis</td>
<td>Inflammation of only the paratenon, regardless of whether the paratenon is lined by synovium</td>
<td>Acute</td>
<td>Yes (in paratenon tissue)</td>
<td>Repetitive loading/overuse, irritation because of limited space</td>
<td>Swelling, pain, tenderness, warmth, crepitus (depending on the duration/severity of the pathology)</td>
<td>Ice, antiinflammatories, rest, modified activities, progressive ROM and strength exercises</td>
</tr>
<tr>
<td>Tendinosis</td>
<td>Intratendinous degeneration, noninflammatory in nature</td>
<td>Chronic</td>
<td>No</td>
<td>Repetitive loading/overuse, “failed” healing response, vascular compromise, aging</td>
<td>No swelling of the tendon sheath, often palpable nodule that may or may not be tender, can occur asymptomatically</td>
<td>Eccentric exercises, stretching</td>
</tr>
</tbody>
</table>

**FIGURE 7–5** Myositis ossificans. A radiographic image shows ectopic bone formation in the thigh musculature.

**FIGURE 7–6** Stress-strain curve for tendon injury. The stress-strain curve represents the relationship for progressive loading of the tendon. The curve is divided into five different regions: toe region (A), linear region (B), progressive failure region (C), major failure region (D), and complete rupture region (E). The toe region represents a minimal amount of tissue elongation in which the crimped formation of collagen fibers straightens. In the linear region, the collagen fibers continue to deform linearly with increasing load but are able to return to their original configuration when the tension is removed. In the progressive failure and major failure regions (beyond 4% strain), increasing tendon damage occurs. At 8% elongation, the tendon ruptures.
With tensile loading causing up to 4% elongation, the collagen fibers are able to return to their original configuration when the tension is released. However, tensile loading beyond 4% of its length will cause the collagen cross-links to fail, and the collagen fibers will slide past one another and cause injury to the tendon. The repetitive strain that occurs in tendon overuse injuries implies a repeated strain of 4% to 8% of its original length, and the tendon cannot endure further tension. At 8% elongation, the tendon ruptures.\(^5\),\(^6\),\(^7\),\(^8\)

Tendinitis, paratenonitis, and tendinosis are frequently seen pathologies in the clinical setting. Specifically, these tendinopathies tend to commonly occur in the rotator cuff tendons at the shoulder, the forearm tendons at the medial and lateral aspects of elbow, the quadriceps tendon at the knee, and the Achilles tendon at the ankle. An understanding of tendinitis, paratenonitis, and tendinosis can assist the clinician in deciding appropriate treatment principles. However, a true diagnosis of which specific tissue is involved and the histopathologic factors present can be confirmed only with tissue biopsy, which is often performed only in the late stages of tendon injury when conservative treatment has failed.

**Tendinitis**

As mentioned previously, the term *tendinitis* has been used in the past to refer to any tendon pathology. However, clarification must be made that tendinitis refers to the presence of inflammation within the tendon tissue.\(^5\),\(^6\),\(^9\),\(^10\),\(^11\),\(^12\) When initial overuse or a strain of the tendon occurs, microscopic tearing of the tendon results in inflammation, localized swelling, and complaints of pain.\(^5\),\(^6\) As a result of the injury, the tendon will begin the healing process. In tendinitis, the initial inflammation occurs within the tendon itself, without inflammation of the surrounding paratenon.

Tendinitis is frequently caused by repetitive demands placed on the tendon during a period of overuse or during excessive acute strain, such as a recent increase in activity level. Applying a tensile load to the tendon will produce pain, and the inflamed tendon is often tender when palpated. Frequently, tendinitis occurs in individuals whose occupation requires repetitive motion or in sports-related repetitive loading of the muscle-tendon unit.

The initial response to acute microtrauma or strain takes place during the inflammatory phase, and the tendon continues to the fibroelastic-repair and maturation-remodeling phases of soft tissue healing. However, the typical healing process occasionally goes awry and chronic tendinitis persists. The exact mechanism that converts acute tendinitis to chronic tendinitis is unknown, but histologically, chronic tendinitis is characterized by increased collagen formation and fibrosis. Other characteristic signs similar to tendinosis and symptomatic degeneration of the tendon are also present.\(^9\)

**Paratenonitis**

Tendons are covered by loose areolar connective tissue called the paratenon, which serves as an elastic sleeve to assist the tendon as it moves against surrounding tissue. Therefore, the term *paratenonitis* describes inflammation of the outer layer of the tendon only, regardless of whether the paratenon is lined by synovium.\(^4\),\(^9\),\(^13\),\(^14\),\(^15\) Collectively, paratenonitis includes the separate pathologies of paratendinitis, tenosynovitis, and tenovaginitis. Paratenonitis commonly occurs during repetitive motion when the tendon rubs over a bony prominence, is in a tight anatomic location, or is subjected to an external compressive force. For example, during a repetitive jumping motion, if the Achilles tendon repeatedly slides against poor-fitting footwear as the gastrocnemius and soleus muscles contract, inflammation and irritation of the paratenon may occur. The limited space for the tendon to function during muscle contraction can result in friction as the tendon slides, and then it becomes inflamed. Paratenonitis is manifested as pain, swelling, warmth, and possibility crepitation over the inflamed paratenon. The crepitation is caused by the inflammatory products that accumulate on the irritated tendon and then cause adherence of the paratenon to surrounding structures as it slides back and forth during muscle activation.\(^9\),\(^17\),\(^37\)

**Clinical Pearl #3**

In some tendons, the outermost lining is a synovial sheath that serves to decrease irritation in areas of high friction. Tenosynovitis, which is inflammation of this outer sheath, can be classified as paratenonitis and has symptoms similar to tendinitis: pain on movement, tenderness, and swelling. Crepitus may also occur with tenosynovitis because adhesions form to surrounding structures. Since the adhesions may restrict the gliding motion of the tendon and the space itself for the tendon to move may be diminished, the patient may also have greater limitation in ROM. Successful treatment of tenosynovitis is similar to treatment of tendinitis. Initial treatment focuses on addressing the inflammation and resting the injured tissue. Intrinsic and extrinsic factors that may be causing the inflammation should also be assessed. For example, intrinsic factors include structural malalignment, muscle weakness, and decreased flexibility, whereas extrinsic factors include poor equipment and training errors.\(^37\)

**Tendinosis**

Tendinosis describes degenerative changes within the tendon without histologic signs of an inflammatory response.\(^15\),\(^34\),\(^36\),\(^38\) Whereas acute injuries are typified by inflammation, tendinosis has a slow, insidious onset because of chronic microtrauma and structural damage. With tendinosis, the tendon degeneration consists of loss of normal collagen structure and cell abnormality, but no inflammatory cellular response.\(^15\),\(^34\),\(^36\),\(^38\) The histologic appearance of a normal tendon and one with tendinosis is shown in Figure 7–7. The degenerative tendon loses the parallel alignment of its collagen fibers and is therefore weaker and may be more vulnerable to injury.\(^9\) Paratenonitis, as described earlier, can also occur with tendinosis. In this clinical scenario, inflammation of the outer paratenon with intratendinous degeneration is observed.

Tendinosis causes pain that often has a gradual onset and is commonly preceded by repetitive overloading of the tendon. The pain in the tendon results in a limitation in functional activity. However, tendinosis is not always symptomatic.\(^5\) For example, the Achilles tendon can rupture without previous symptoms of injury or pain but still demonstrate histologic signs consistent with tendinosis degeneration. Since tendinosis may develop asymptomatically, it is unclear whether the acute inflammatory response always occurs before chronic degenerative changes. Regardless, the chronic degeneration seen with tendinosis has been associated with aging, vascular compromise, repetitive loading causing microtrauma to the tendon, and preexisting tendon injury.\(^35\),\(^39\)
CHAPTER 7 | Principles of Rehabilitation for Muscle and Tendon Injuries

CLINICAL EXAMINATION AND EVALUATION

Understanding of musculoskeletal anatomy and the mechanism of injury will provide the clinician with valuable knowledge during the clinical examination. In particular, a thorough and detailed history will help in discerning whether the injury is acute or chronic. Acute injuries occur as a result of a recent overstretch, recent overuse, or a single direct impact causing tissue damage. Conversely, chronic injuries are due to the accumulation of repeated small stresses over time, which ultimately results in tissue irritation and damage. For example, when assessing acute tendinitis, the patient may describe a recent activity involving repetitive motion or recent excessive stretching of the involved muscle-tendon unit. A "weekend warrior" often describes an acute injury with a history of a suddenly increasing activity level and overexertion when proper training and conditioning have not been maintained.

After taking the patient’s history, the clinician should supplement the history by asking questions that include those in Box 7–1. These questions will help provide further insight into the current injury for which the patent is seeking treatment.

In addition to eliciting a complete subjective history, palpation of the injured area will also provide the clinician with valuable information. For example, since most tendons are superficial and can be relatively easily palpated, the clinician can often accurately identify the specific location of the pain. When assessing acute muscle strains, the patient may report diffuse muscle pain or pain with muscle activation. Depending on the degree of strain, the clinician may be able to palpate the area of involvement or a defect in the muscle itself.

The next step in a comprehensive examination and evaluation includes performing static and dynamic assessments. The clinician should consider standard static measurements, including ROM, muscle girth for symmetry, strength testing, posture and alignment assessment, and balance and neuromuscular testing. If possible, it is also beneficial to assess dynamic tasks. This may be more realistic for an individual with a chronic versus acute injury, especially if evaluation of the acute injury takes place relatively soon after onset. Evaluation of dynamic mobility can include balance, gait, and a functional movement assessment. When assessing dynamic movement, it is important to identify faulty technique or other exacerbating factors for the particular movement pattern because they may play a causative role in the musculotendinous pathology.

CLINICAL PEARL #4

When assessing an individual’s dynamic movement pattern, it is important to evaluate the entire kinetic chain. Weakness or dysfunction at any point throughout the kinetic chain may help determine one of the underlying causes of the individual’s pathology. It is also beneficial to make the dynamic assessment as activity specific as possible. When evaluating athletes, it is important to consider any equipment that they may use. Likewise, when evaluating an individual with an occupation-related problem, it is wise to observe movement pattern techniques for repetitive tasks, as well as long-duration static positioning.

**Box 7–1**

**Questions That Should Be Included in a Patient’s History**

- “What is the location, duration, and intensity of your pain?”
- “What factors make the pain worse, and what factors make the pain better?”
- “Has the pain progressively gotten better or worse over time?”
- “Have you had any treatment for the current medical issue?”
- “Have you had a similar injury in the past?”
- “Are you currently taking any medications for the problem?”
- “What are your functional limitations?”

**FIGURE 7–7** Histologic image of normal and pathologic tendon. 
A, Normal, healthy tendon with parallel alignment of collagen fibers. 
B, Pathologic tendinosis with disorganized structure.
Diagnostic testing can also aid the clinician in further identifying and understanding the extent of tissue pathology. Common diagnostic tests for individuals with muscle or tendon pathology include magnetic resonance imaging (MRI) and sonography. Although MRI and sonography can assist in evaluating soft tissue injuries, radiographic imaging is also useful for assessing the attachment site of the tendon to bone. On MRI, first-degree strains are manifested as focal signal abnormalities without a tear, second-degree strains are seen as a partial tear, and third-degree strains are characterized by full-thickness tears with hemorrhage and muscle or tendon retraction. However, because of the cost associated with MRI, it is often not used for the diagnosis of acute grade 1 or 2 muscle strains or for acute tendinitis pathologies. Clinically, grade 1 or 2 strains can frequently be diagnosed by applying stretch to the injured muscle or by activating the muscle group against resistance. When a grade 3 strain is suspected or for chronic tendon pathologies that have failed conservative rehabilitation, MRI will probably be considered. In cases in which disruption of the tendon occurs at the bony attachment, radiographic images may be helpful in identifying an avulsion fracture but will provide limited information on the extent of soft tissue injury. Finally, ultrasound has been widely used for evaluation of tendon attachments and muscle tears. In addition to being less costly than MRI, ultrasound is done in real time and allows dynamic assessment of the musculotendinous unit during muscle contraction.

**REHABILITATION PRINCIPLES**

As rehabilitation specialists, it is important to apply knowledge of anatomy and understanding of healing time frames to each unique muscle and tendon pathology. Additionally, each patient’s personal characteristics, level of training, motivation, and other personal and external factors for the given scenario will influence individual rehabilitation programs. The following discussion covers rehabilitation principles for the acute, inflammatory-mediated and chronic, degenerative pathologies covered in this chapter.

**Acute Inflammatory Injuries**

One of the overlying principles for management of an acute injury involves applying the healing time frames for soft tissue injuries. Immediately after an acute injury, the inflammatory response process begins in the damaged tissue. As discussed earlier, the initial inflammatory response includes pain, heat, swelling, and redness. During this phase, the clinician should control pain and edema by using the principles of PRICE (rest, ice, compression, elevation). We like to use the principle PRICE because protection may play a larger role in an athletic population. Application of ice or cryotherapy is performed several times a day for a minimum of 48 hours to help limit the amount of bleeding from surrounding tissue. Compression wraps or bandages may also be used to help minimize the swelling.

Although the inflammatory phase of the healing response is important, rest and immobilization of the injured tissue should be limited and not last longer than 1 to 2 days. This is based on another principle of rehabilitation for acute injuries that involves early mobilization to restore tensile strength of the injured tissue. Soft tissue will respond to the physical demands placed on it; it will remodel or realign along the lines of tensile force, and early motion that applies stress serves as a physical stimulus to aid in the formation and maintenance of collagen. Prolonged immobilization and deprivation of stress lead to actual loss of collagen fibers. In other words, controlled mobilization is better than immobilization to restore the tensile properties of the tissue. Additionally, immobilization may cause contractures, muscle atrophy, and disorganization of collagen fibers. The exception to this principle is complete muscle or tendon rupture, for which longer immobilization is necessary. In this case, conservative treatment involves immobilization with only controlled passive ROM for several weeks to allow the tissue to heal in proper alignment.

Early mobilization after injury is implemented through pain-free ROM exercises and should be initiated shortly after the initial inflammatory response phase. Both passive and active exercises that apply a longitudinal strain to the injured structure will help the tissue accommodate to the new stress. When rehabilitating an acute injury, it is also important to prescribe exercises initially at a low load to stress the collagen fibers without overloading them and progressively increase the demands placed on the tissue. As the pain and swelling subside and the healing process continues, the patient can progress through ROM, flexibility, and strengthening exercises in a controlled fashion. The patient should begin with active ROM in the pain-free range. If mobility remains limited in the subacute stages of healing, heat modalities may be considered in combination with manual techniques to increase ROM and soft tissue mobility. Otherwise, isometric exercises can be prescribed for initial strengthening and should progress to isotonic strengthening. Balance activities can also be incorporated into the rehabilitation program since loss of proprioception often occurs with injury. Throughout the rehabilitation process, general conditioning exercises that do not aggravate the condition may be performed to maintain cardiovascular endurance, flexibility, and strength of the surrounding joints. While increasing tensile loading throughout the rehabilitation program, the clinician should continuously monitor for pain with progression of activity. Pain may indicate excessive loading and alert the clinician to alter the rehabilitation program.

The final phase of rehabilitation is return to functional participation in occupational, recreational, or athletic activities. This phase should include a gradual progression of functional or sport-specific training activities over a period of several weeks. As the level of functional activity progresses in difficulty, the clinician continues to monitor for pain or weakness as a sign to return to an easier level of physical activity. This is important because returning the patient to functional or athletic activity too soon may predispose the athlete to reinjury.

The acute pathologies covered in this chapter include muscle strains, contusions, tendinitis, and paratenonitis. When addressing an acute muscle strain or contusion, one must first assess the severity of the injury. Although first- and second-degree strains are treated nonoperatively, a third-degree strain may require surgery. Likewise, contusions typically do not require surgery unless significant bleeding causes an acute compartment syndrome, which requires immediate surgical care involving a fasciotomy. After an acute strain and contusion, the initial treatment goals are to stop interstitial bleeding and prevent further injury to the muscle fibers. After the initial inflammatory response, the patient should begin early mobilization with gentle passive, pain-free stretching to improve ROM and flexibility. However,
care must be taken, especially after a contusion injury, to avoid reinjury of the muscle to limit risk for the development of further complications. Muscle strength and endurance are also important as the patient continues to progress through the rehabilitation program. Care must be taken to progress slowly and avoid reinjury to the tissue. Even though it is not recommended that a “cookbook approach” be taken when treating these pathologies, a general guideline for the management of grade 1 and 2 strains and mild to moderate contusions is provided in Table 7–4.

Initial treatment of acute tendonitis and paratenonitis involves rest, avoidance of repetitive motion, and removal of the external irritant that may be pressing or rubbing on tissue and causing inflammation. This means that patients need to avoid the irritant and modify their activity. Early treatment also includes ice or antiinflammatory medication to limit the amount of local inflammation in the tissue. ROM and strengthening exercises can then be introduced as the pain and swelling subside.

The process of rehabilitation for acute injuries involves several principles, including application of the soft tissue healing stages, early mobilization after injury with caution to avoid reinjury, and progressive strengthening for return to function. Specifically, the goals after an acute injury are to (1) control pain and edema; (2) restore normal ROM and flexibility; (3) reestablish normal strength, endurance, and neuromuscular control; and (4) achieve preinjury function and activity. Successful completion of the rehabilitation process is important because inappropriate management of injury may lead to worsening of the pathology or may place the individual at risk for future injury.

Chronic Degenerative Injuries

The chronic pathology addressed in this chapter is tendinosis, which lacks the histologic inflammation seen with acute injuries. Therefore, different treatment principles apply when treating tendinosis. The overarching principle of management of tendinosis involves reducing tendon pain because it is the limiting factor for functional activity.

The most promising treatment of tendinosis is eccentric exercise, or active lengthening of the muscle-tendon unit. Eccentric exercise has been shown to decrease pain and increase function in patients with tendinosis.\(^5\) The basis of an eccentric exercise program is to place progressively increased stress on the tendon to ultimately improve its ability to withstand tensile loads. The eccentric loading may also lead to a more normalized tendon structure.\(^5\) However, the specific mechanism that makes eccentric exercises effective has yet to be clearly described.

In addition to eccentric loading, stretching has also been shown to decrease pain and increase function in individuals with tendinosis.\(^5\) Stretching works to lengthen the muscle-tendon unit, which improves flexibility and ROM. Moreover, if the resting length of the muscle-tendon unit increases, less joint strain may occur during loading. In other words, a regular stretching program will help decrease tension on the muscle-tendon unit.\(^5\)

Finally, several other factors can be addressed to help decrease tendon pain. For example, rest periods or training modifications can be implemented. Additionally, external aids such as braces, orthotics, or taping can help alleviate the strain placed on the tendon. Antiinflammatory cortisone injections may also help relieve some of the pain with tendinosis; however, use of corticosteroids is controversial. Caution should be taken when working with a patient shortly after an injection because corticosteroids have also been associated with tissue damage and short-term decreased tensile strength of collagen.\(^5\)

Prevention

Although the intent of this chapter is to focus on principles governing rehabilitation after muscle and tendon injuries, it is important to acknowledge the ability to educate patients on injury prevention principles as well. Important factors for preventing muscle strains include maintaining flexibility and proper conditioning, which is achieved through stretching and strengthening, respectively. First, the viscoelastic property of muscle is affected by warmth and can contribute greatly to changes in muscle length. Therefore, warm-up should facilitate stretching and thus prepare the muscle-tendon units for exercise.\(^5,20,42\) Specifically, since strains are common in muscles that cross two joints, perhaps extra emphasis should be placed on stretching the hamstrings, rectus femoris, and gastrocnemius musculature in the lower extremities. In addition to stretching, proper conditioning and strengthening can aid in prevention of injuries.\(^5,56\) Finally, fatigue may also play a role in injury; so proper training and conditioning are important for prevention of injuries. Unfortunately, in our experience prevention is more helpful in those who have not had a previous injury. It appears that once injured, individuals remain at a higher risk for reinjury than their not previously injured cohort.

| Table 7–4 Management of First/Second-Degree Strains and Mild to Moderate Contusions |
|-----------------|-----------------|-----------------|-----------------|
| Phase | Goals | Treatment | Time Frame |
| I | Reduction of pain and edema | Immobilization, ice, rest, elevation | Days 1-2 |
| II | ROM | Ice, modalities, pain-free ROM, isometric strength | Days 3-7 |
| III | Strengthening, endurance | Progressive strengthening, isometrics to isotonics | Days 7-21 |
| IV | Neuromuscular coordination, return to function/sport | Running, functional progression, sport-specific exercises | Days 21+ |

ROM, Range of motion.
Hamstring Strain

History
A 16-year-old soccer player came to the clinic after sustaining a hamstring injury over the weekend. He reported that he was sprinting down the field and went to kick the ball when he felt an immediate "pull" in his hamstrings. He stopped playing and came out of the game to put ice on his injury.

Impairments/Functional Limitations
The patient complained of diffuse pain (4/10 rating) and was tender when palpated near his distal lateral (biceps femoris) hamstring. No palpable depression was noted in the area of injury and minimal localized edema. He had full knee flexion and extension, but limited hamstring flexibility. He was able to walk into the clinic without crutches but felt unable to take a full stride with gait and would not consider higher-demand activity. Fortunately for this athlete, he appeared to have what we call a low hamstring strain, which typically does better than more proximal injuries (closer to the hip).

Rehabilitation Program
Initial rehabilitation addressed the inflammatory factors of pain and edema. Treatment included cryotherapy to decrease the pain and reduce the swelling. The patient was also prescribed a thigh compression sleeve to help decrease the swelling and provide support. Gentle, pain-free stretching exercises for the hamstring were initiated. One week later, the patient returned for follow-up care. He continued with the stretching exercises and started hamstring-strengthening exercises (isometric and isotonic). Typically, a progression of concentric to eccentric strengthening exercises is followed. Examples of exercises after a hamstring strain, including strengthening exercises (lunges, bridges on a stability ball, and hamstring curls on a stability ball) are shown in Figure 7–8. Two weeks after his injury, the patient reported no pain and demonstrated improved flexibility and good strength. He had also been performing endurance training on a bike with no restrictions. Therefore, he began functional exercises such as agility drills and soccer-specific maneuvers. We also added kneeling assisted forward curls (also known Russian hamstrings) as shown in Figure 7–9. He moved forward while keeping his trunk erect, which required the hamstrings to eccentrically control his forward motion. Typically a sport cord is attached around the trunk to enable control and assistance by the clinician. By 3 weeks after his grade 1 strain, he returned to running and was ready to play.

Achilles Tendinosis

History
A 55-year-old competitive runner complained of pain in the midportion of her Achilles tendon that was affecting her ability to run. She reported a gradual onset of dull pain that began...
3 months ago after her long runs. Despite the pain, she continued with her competitive training. Now she reports pain during running and therefore decided to seek medical treatment at this time.

**Impairments/Functional Limitations**

Clinical evaluation revealed tenderness and local thickening of the Achilles tendon. Palpation revealed mild nodules and crepitus with active dorsiflexion and plantar flexion movement. Dorsiflexion ROM was limited, and the heel-raise motion was painful. The patient also had significant pes planus.

**Rehabilitation Program**

Treatment began with stretching of the Achilles tendon complex. Specifically, gastrocnemius (knee straight) and soleus (knee flexed) stretching was initiated. The patient was advised to hold the stretch for 20 to 30 seconds and repeat for three to five repetitions. The knee flexed stretching was accomplished by using a chair–foot flat–knee flexed–lean into the chair sequence. Eccentric strengthening exercises for the Achilles tendon were also started (Fig. 7–10). The eccentric exercises were repeated for three sets of 15 repetitions and were performed with the knee straight and again with the knee in a semiflexed position.

**FIGURE 7–9** A to C, Russian hamstring curl. The patient starts in a kneeling position on a Bosi ball while the clinician braces the patient’s feet and provides resistance by holding the piece of Thera-Band from behind the patient. The patient then begins to lean forward to about 45° of knee flexion. The patient is instructed to maintain the trunk erect and to let the forward motion come from the knees. The patient then slowly returns to the starting position.
Progressive loading of the eccentric exercises was continued for several weeks by slowly adding weight or use of a weighted vest. Finally, the patient was fitted with foot orthotics to correct the pes planus and improve alignment of the Achilles tendon. Because she had access to a leg press device, she was instructed in bilateral toe press with involved return via the single leg. She resumed a more competitive running sequence in 10 to 12 weeks, consistent with our experience and others.

CONCLUSION

Anatomic Components and Response of Tissue to Injury

- The muscle-tendon unit is composed of the muscle, tendon, their attachment sites to each other (MTJ), and the tendon attachment site to bone (OTJ).
- Injury to the muscle-tendon unit can occur at any point in the musculotendinous unit, but it most commonly involves the MTJ.
- Injured muscle and tendon structures progress through the stages of soft tissue healing, which include the inflammatory response, fibroblastic-repair, and maturation-remodeling phases.
- The tensile strength of the damaged tissue increases with time as the collagen fibers remodel and become organized in a parallel alignment with the applied tensile force.
- Satellite cells are specific to muscles and aid in muscle fiber regeneration after injury, whereas tenocytes assist in tendon healing.

Muscle-Tendon Pathologies

- Muscle strains occur as a result of excessive passive stretching or during active eccentric loading. Muscles that cross two joints and muscles that are fatigued are at a higher risk for strain injury.
- Muscle strains can be categorized as grade 1, grade 2, or grade 3 based on the severity of the injury. Contusions can be categorized as mild, moderate, or severe based on the amount of ROM at the adjacent joint.
- Tendinitis and paratenonitis refer to an inflammatory process taking place within either the tendon or paratenon, respectively. Tendinosis refers to a chronic degenerative non-inflammatory process occurring within the tendon.
- Repetitive loading of the tendon is often the cause of tendon pathology. Tendons are able to withstand tensile loads causing up to 4% elongation, but tensile loads causing between 4% and 8% elongation result in tendon injuries.

Clinical Examination and Evaluation

- A thorough clinical examination consists of a detailed history, in-depth palpation, and static and dynamic clinical assessments.
- Diagnostic imaging of musculotendinous pathologies is often not indicated unless significant tissue damage is suspected or the patient has failed conservative treatment and is considering surgical measures. MRI and ultrasound can be used to identify soft tissue pathologies, whereas radiographic images can be used identify the extent of bony involvement if pathology at the OTJ is suspected.

Rehabilitation Principles

- The principles of rehabilitation for acute injuries include application of the soft tissue healing stages, early mobilization after injury, and progressive loading of the tissue for return to function.
- Goals after an acute injury are to (1) control pain and edema; (2) restore normal ROM and flexibility; (3) reestablish normal strength, endurance, and neuromuscular control; and (4) achieve preinjury function and activity.
Management of tendinosis includes eccentric exercises and stretching. Other factors such as modifications in training routines and the use of tape, braces, or orthotics may also decrease pain and improve function.

Strategies to prevent muscle-tendon injuries include flexibility and proper strength conditioning.

Case Studies

Appropriate treatment of muscle and tendon pathologies involves application of the previously described principles of rehabilitation for acute and chronic pathologies.

REFERENCES


