

Challenging Running Injuries: Be Knowledgeable, Be Prepared

Here's the current evolution in thought, literature, and treatment of these conditions.



Objectives

After reading this continuing education article, the podiatric physician should be able to:

- 1) Understand and list the possible causes of hallux rigidus.
- 2) Describe the major staging systems for hallux rigidus.
- 3) Describe surgical and conservative treatment for hallux rigidus by stage of deformity.
- 4) Define and classify turf toe.
- 5) List predisposing factors for the turf toe injury.
- 6) Describe conservative treatment of turf toe.
- 7) Discuss differential diagnoses for sesamoidopathy and describe causes of pain in the region of the sesamoid bones.
- 8) Describe the features healthy tendon and tendon affected by tendinopathy.
- 9) Be able to discern structures injured in what this article terms the "zone of confusion." In particular clinically distinguish between plantar fasciopathy, peroneus longus tendinopathy and flexor hallucis longus tendinopathy.
- 10) Be able to describe treatment plans for the midfoot tendon injuries described in this article including peroneus longus tendinopathy and flexor hallucis longus tendinopathy.

Welcome to Podiatry Management's CME Instructional program. Our journal has been approved as a sponsor of Continuing Medical Education by the Council on Podiatric Medical Education.

You may enroll: 1) on a per issue basis (at \$20.00 per topic) or 2) per year, for the special introductory rate of \$139 (you save \$61). You may submit the answer sheet, along with the other information requested, via mail, fax, or phone. In the near future, you may be able to submit via the Internet.

If you correctly answer seventy (70%) of the questions correctly, you will receive a certificate attesting to your earned credits. You will also receive a record of any incorrectly answered questions. If you score less than 70%, you can retake the test at no additional cost. A list of states currently honoring CPME approved credits is listed on pg. 168. Other than those entities currently accepting CPME-approved credit, Podiatry Management cannot guarantee that these CME credits will be acceptable by any state licensing agency, hospital, managed care organization or other entity. PM will, however, use its best efforts to ensure the widest acceptance of this program possible.

This instructional CME program is designed to supplement, NOT replace, existing CME seminars. The goal of this program is to advance the knowledge of practicing podiatrists. We will endeavor to publish high quality manuscripts by noted authors and researchers. If you have any questions or comments about this program, you can write or call us at: **Podiatry Management, P.O. Box 490, East Islip, NY 11730, (631) 563-1604 or e-mail us at bblock@podiatrym.com.**

Following this article, an answer sheet and full set of instructions are provided (p. 168).—**Editor**

By Stephen Pribut, DPM

A revolution is in the making for the prediction of and therapy for sports injuries. The next advances will come through genetics and genomic analysis. Functional genomics has led to a surge in research on the ge-

netic characteristics of basic and clinical phenomena that can predict and alter the mechanisms of health and disease. Progress is being made on linking the genome with the metabolic characteristics of tissues and cells.³ Recent studies have hinted at the relationship between tendinopathy and genetics.

Genetics has been found to play a role in motivation to exercise¹ and can be responsible for a lack of response to exercise training. Specific genes have been associated with leisure time activity.² Prediction is critical for groups as diverse as professional sports teams to the mili-

Continued on page 158

Injuries...

tary. Susceptibility to injuries such as stress fractures and Achilles tendinopathy will alter training regimens as risk assessment and prevention strategies improve.

Genetics and Athletic Injuries

Genetics may play a specific role in the pathogenesis of many athletic injuries. Studies of Achilles tendinopathy suggest a genetic component. This was first hypothesized when a study revealed an apparent association of the O blood group and Achilles tendon injuries in the Hungarian and Finnish populations. Chromosome 9 was then thought to be the locus of a change to this gene or a closely linked gene. Other studies did not demonstrate this association.

More recently, genomic studies have shown that individuals with variants of the tenascin-C gene⁴ or alterations in the COL5A1 gene,⁵ especially a BstUI restriction fragment length polymorphism, are more prone to develop Achilles tendinopathy. Future genomic research is likely to yield much more information about susceptibility to injury.

In this article, we'll be taking a practical approach as we wait for the new research to blossom. Our topics include injuries that are frequently encountered, those that are not common, those difficult to treat, and some not readily identified. We'll begin with the first metatarsophalangeal joint and then move to the plantar surface of the foot.

Hallux Rigidus, Turf Toe, Sesamoid Injury

Anatomy

A properly functioning first metatarsophalangeal joint is critical for running. In evolution, the abduction of the first ray, disappearance of an opposable hallux, and realignment of the first metatarsophalangeal joint and first metatarsocuneiform joint marked a

came obligate bipeds and were able to run.

The first metatarsophalangeal joint includes four bones. The most readily apparent portion of the joint is the articulation between the concave-shaped base of the proximal phalanx and the convex, rounded head of the first metatarsal. The plantar surface includes the two sesamoid bones (fibular or lateral, and tibial or medial) and the joint capsule. The joint capsule is reinforced on its plantar aspect by both a fibrocartilagenous plate and the plantar accessory ligament. The flexor hallucis longus and flexor hallucis brevis attach on the plantar aspect, along with the abductor hallucis muscle and the adductor hallucis muscle. Dorsally, the tendons of the extensor hallucis longus and the extensor hallucis brevis muscles insert.

Turf toe, sesamoiditis, and hallux rigidus are a functionally interconnected set of injuries. These problems can impair the ability to run. In severe cases, a runner may consider giving up the sport permanently. We'll examine these entities individually and review treatment.

Hallux Rigidus

Description and Definition

Hallux rigidus refers to an absence of dorsiflexion at the first metatarsophalangeal joint. The term hallux limitus has been used

to describe the condition in which the dorsiflexion is not absolutely limited. Functional hallux limitus, first described by Laird,⁷ refers to biomechanical features of the joint which limit dorsiflexion. Functional hallux limitus is a condition in which no degenerative changes are

Continued on page 159

TABLE 1 Modified Hybrid Grading System for Hallux Rigidus

Stage I: Functional limitus

Metatarsus primus elevatus
Hallux equinus or flexus
Plantar subluxation of the hallucal proximal phalanx
Periarticular subchondral sclerosis
Minimal dorsal exostosis (first metatarsal head and base of proximal phalanx)
Minimal flattening of first metatarsal head

Stage II: Early joint adaptation

Moderate dorsal exostosis (first metatarsal head and base of proximal phalanx)
Moderate flattening of first metatarsal head
Minimal joint space narrowing
Subchondral joint sclerosis
Lateral first metatarsal head erosion, and/or joint flare/exostosis
Sesamoid hypertrophy ± Subchondral cyst formation/loose body formation

Stage III: Established Arthrosis

Severe dorsal exostosis (first metatarsal head and base of proximal phalanx)
Irregular joint space narrowing
Traction enthesiopathic sesamoid hypertrophy with immobilization induced osteopenia
Definite subchondral cyst formation and presence of loose bodies

Stage IV: Ankylosis

Exuberant exostosis proliferation, trumpeting of the first metatarsal head, base of the proximal phalanx, and sesamoid apparatus
Minimal/absent joint space
Sesamoid fusion
Hallucal interphalangeal and/or first metatarsal-medial cuneiform osteoarthritic changes

complete change from arboreal living to obligate bipedalism. *Ardipithecus ramidus*, the oldest known hominid, had an adducted first metatarsal, opposable hallux, and was able to walk in a bipedal manner.⁶ When *Australopithecus* evolved with a more modern alignment of the great toe, hominids be-

Injuries...

present. It is thought to be one of many possible etiological causes of hallux rigidus.

The term hallux limitus has been useful to describe limited range of dorsiflexion, but the current trend is to use only the term hallux rigidus. Hallux rigidus was first described in 1887 by Davies-Colley, who used the term hallux flexus in referring to a plantar-flexed posture of the phalanx relative to the metatarsal head.⁸ The term hallux rigidus was first used by Cotterill in 1888.⁹

Grading systems which delineate the biomechanical features and x-ray criteria are helpful to stage hallux rigidus. The most useful classification system for hallux rigidus was suggested by Roukis¹⁰ and combines criteria from the systems of Drago,¹¹ Hanft,¹² and Kravitz.¹³ Table 1 describes a modification of these approaches.

Hallux rigidus is a progressive

disorder of the first metatarsophalangeal joint. Starting with a mild limitation of dorsiflexion and little to no discomfort, it can progress to a condition that causes marked limitation of motion at the joint, pain

during athletic participation, and ultimately pain while walking. Shoes can impinge on the dorsal aspect of the joint and cause pain. Open-back shoes and sandals can create discomfort because of the increased motion required to walk in such shoes. Pain associated with hallux rigidus is caused by the degenerative arthrosis of the joint. Proliferation of bone and cartilage at the dorsal aspect of the joint contribute to

Steroid injections at the joint will not offer a long-term benefit for athletes. If a steroid injection is used, the athlete should not participate in sports for 48 hours.

the limitation of movement. Cartilage degeneration and osteophyte formation are caused by abnormal, repetitive contact of the joint surfaces.

Clinical Presentation

Patients usually first complain of pain at the dorsal aspect of the joint. The limited motion is not often noticed at this stage. Later,

the head of the metatarsal enlarges dorsally, flattens, and dorsal osteophytes develop. At this stage, the available dorsiflexion decreases. Compensatory gait changes follow, which include increased dorsiflexion at the ankle and increased knee flexion. Athletes change their running gait so that they run more toward

the outside of their foot. These compensatory gait changes can lead to other injuries. Central metatarsalgia is often found as weight-bearing forces shift laterally. A large dorsal exostosis can cause pain from the pressure of rubbing against footwear. Pain and occasionally hyperkeratoses sometimes develop at the interphalangeal joint in association with compensatory dorsiflexion.

Etiology

Metatarsus primus elevatus is believed to be a prime cause of hallux rigidus (Table 2). Restriction of plantar flexion of the first

Continued on page 160

TABLE 2 Possible Hallux Rigidus Etiologies

Biomechanical

Functional hallux limitus
Functional hypermobility of first ray
Gastrocnemius-soleus equinus
Compensated forefoot valgus
Excessive rearfoot pronation

Post-traumatic

Osteochondral first MTP joint injury
Intra-articular fracture at first MTP
Hallucal sesamoid fracture with resulting sesamoid dysfunction

Structural

Metatarsus primus elevatus
Long first metatarsal
Long proximal phalanx of hallux

Iatrogenic

Post-surgical excessive elevation of the first metatarsal
Post-surgical excessive lengthening of the first metatarsal
Post-surgical malalignment of the first metatarsophalangeal joint
Excessive fibrosis
Hallucal sesamoid dysfunction
Prolonged immobilization

Other

Gouty arthritis
Septic arthritis
Neuromuscular derived muscle imbalance affecting first ray

TABLE 3 Functional Orthoses Modifications for Hallux Rigidus

Inverted cast correction
Medial heel skive
Deep heel cup
Minimal arch fill on cast

Forefoot modifications:

Reverse Morton's padding
Sesamoid Accommodation
Kinetic wedge®
Other techniques to off-load the first ray.

Injuries...

metatarsal could also play a role. If the first metatarsal head does not functionally contact the supporting surface, the first ray will become elevated or dorsiflex during gait. Conditions which may contribute to metatarsus primus elevatus include gastrocnemius-soleus equinus, functional hypermobility of the first ray, compensated forefoot valgus, and an excessively long first metatarsal. Sesamoid dyscrasias, flexor plate injury or immobility, intrinsic muscle contracture, altered metatarsal head

shape, short first metatarsal, long proximal phalanx, or a tight medial slip of the plantar fascia could each contribute to a limitation of plantar flexion of the first metatarsal.^{10,14}

Turf toe refers to a condition that is commonly termed a "sprain" of the first metatarsophalangeal (MTP) joint.

The patient doesn't usually report "stiffness", but the range of motion will usually be limited. Further examination will often find tender-

Treatment (See Flow Chart)

Stage 1, 2—Functional Orthotics

Most patients with early stage hallux rigidus complain of pain in and around the first MTP. Dorsal pain at the joint is often the primary complaint.



Figure 1: X-ray demonstrating stage-3 hallux rigidus.

ness in one or both hallucal sesamoids. X-ray changes are minimal. Patients with severe symptoms should try a brief course of immobilization, followed with off-loading the joint using functional orthotics with forefoot modification.

NSAIDs can be useful in the initial stages. Ice is a useful adjunctive therapy. Activity level should be decreased as needed. Steroid injections at the joint will not offer a long-term benefit for athletes. If a steroid injection is used, the athlete should not participate in sports for 48 hours.

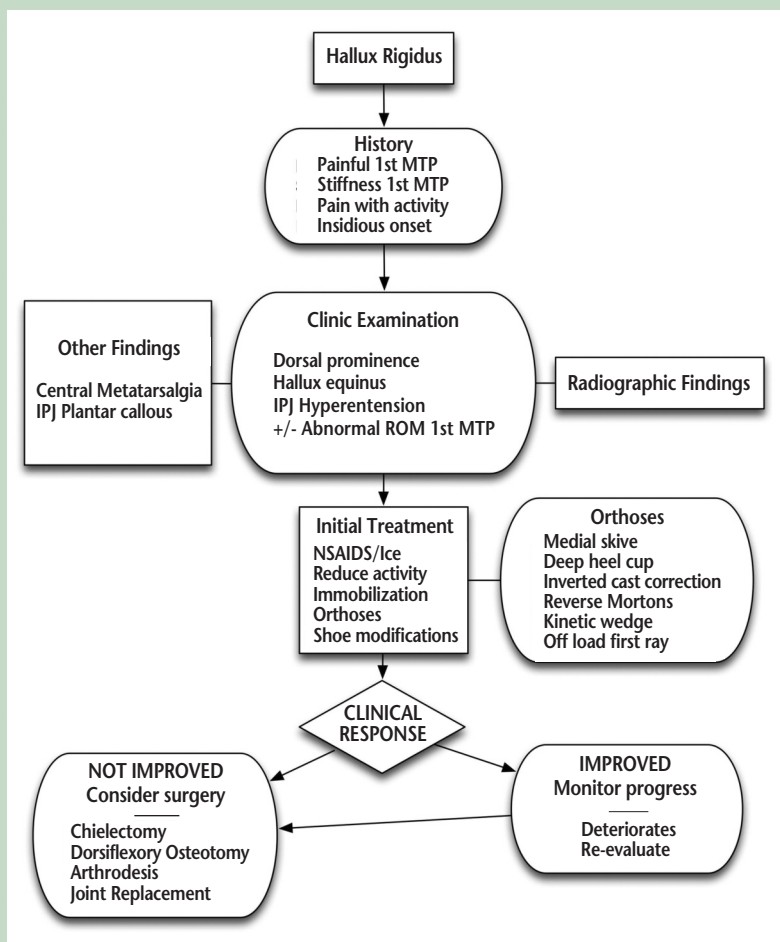
Stages 1 and 2 can often be successfully treated with functional orthotic therapy (Table 3). The goal of the functional orthotic is to improve first ray function by enhancing stability and limiting dorsiflexion of the ray. The design of the orthotic should allow the first metatarsal to maximally plantarflex. This allows the first MTP to be in a more relative dorsiflexed position towards the latter stages of stance. Less abnormal motion will take place at the first metatarsophalangeal joint and there will be a less sudden abutment at the dorsal aspect of the joint.

Stages 3, 4—Surgical Intervention

Surgical solutions may be needed at Stages 3 (Figure 1) and 4 if conservative care fails to relieve

Continued on page 161

CHART 1



Injuries...

pain. The most popular surgical solution for Stage 3 is chielectomy. In stage 4, arthrodesis of the joint or joint replacement may be required (Chart 1).

Turf Toe: From the Ground Up

Turf toe refers to a condition that is commonly termed a "sprain" of the first metatarsophalangeal (MTP) joint. Initially, it was applied only to injuries incurred by those participating in American-style football, and it occurred on artificial turf. In reality, it occurs in many other sports including soccer, basketball, volleyball, among dancers and occasionally runners. While this injury can range in severity from a mild soft tissue sprain to complete dislocation of the first MTP joint, in runners it does not often extend to the more serious grade injury (Table 4).

Turf toe is a complex injury (Table 5). It is caused by a sudden dorsiflexion (bending upwards) of the great toe on the first metatarsal head. Pain is often found at the

TABLE 4 Turf Toe Grading System

Classification systems for 1st MTP Sprains/Turf Toe

A. Jahas in 1980 classified sprains of the 1st MTP joint as follows:

Type I

Inter-sesamoid ligament and sesamoids remain intact.

Type II

Sprain disruption of the intersesamoid ligament and an associated transverse fracture of the sesamoids.

B. Clanton and Ford¹⁵ devised a useful classification system for 1st MTP sprains or Turf Toe in 1993:

Grade 1

Stretch injury or slight tearing of the capsule and ligaments of the first MPJ. Findings include local plantar or plantar medial tenderness, mild swelling, minimal loss of range of motion, ability to bear weight with only mild symptoms some pain on continuation of play.

Grade 2

Partial tear of the capsule and ligaments of the first MP Joint. Findings include moderate swelling, bruising, and moderate restriction of first MPJ range of motion. Limp noted.

Grade 3

Complete tear of the capsule and ligaments. Possible tear of the plantar plate.

dorsal aspect of the first metatarsal. There is usually an injury to the cartilage on the dorsum of the first metatarsal head, and almost always a limitation of motion in dorsiflexion after the injury.

Much of the injury occurs below the

first metatarsophalangeal joint (MTP). On examination, carefully assess the sesamoid bones. As the toe moves up, the sesamoids are forced into the first metatarsal bone. They are then subject to severe and sudden forces which injure the cartilage of the sesamoids and the plantar surface of the metatarsal head. Sometimes, the sesamoids may fracture from these forces. Often the soft tissue attachments are also injured. The flexor hallucis brevis, abductor hallucis and adductor hallucis muscles all have an intimate attachment with the sesamoid bones.

If the plantar portion of the joint is injured (which in reality, it always seems to be) there will be a limitation of motion. Attempts to increase the range of motion while the plantar structures are injured, and the dorsal structures are not in much

better condition, are not recommended. Instead, support, stabilize, and limit motion while the problem is in an acute stage.

Treatment of Turf Toe/1st MTP Joint Sprain (Table 6)

Do not force the injured toe to move, since it is going to cause

Continued on page 162

TABLE 5 Turf Toe Predisposing Factors

- Artificial turf and playing surfaces
- Athlete's experience and years of sports participation
- Flattened 1st MTP Joint
- Cavus foot type
- Football players (defensive and offensive running backs, wide receivers, linemen)
- Foot pronation
- Hallux degenerative joint disease
- Increased ankle dorsiflexion
- Increased friction between athletic shoe and turf
- Excessive toe box flexibility
- Prior 1st MTP joint injury
- Sesamoiditis

TABLE 6 Turf Toe Treatment Summary

Careful assessment followed by the appropriate treatment:

Acute Care:

PRICE: Protection, Rest, Ice, Compression, Elevation.
Off-loading shoe
Rocker sole
Pneumatic walker

Long Term:

Off-loading orthotic with sesamoid accommodation

Injuries...

pain and reinjure the damaged area. Rather, immobilize a high grade, painful injury that causes an antalgic gait. A CAM walker or pneumatic walker works well for this purpose. Immobilization will prevent or limit the loading of the forefoot and will also limit the dorsiflexion of the great toe at this early stage of healing. These devices limit the movement far better than a "post-operative shoe." By limiting the forward motion of the tibia over the foot and stopping the relative dorsiflexion of the foot, forces at the first metatarsophalangeal joint and concomitantly, the sesamoid bones, will be lessened.

For long-term follow-up, treat turf toe primarily as an injury to the sesamoid apparatus and struc-

tures attached to the sesamoid bones. Off-load it with a sesamoid accommodation pad (or a "dancers" pad) designed to shift weight and forces proximally and laterally. If this is successful, use an orthotic of a semi-rigid or somewhat softer material with an accommodation pad. On occasion,

For long-term follow-up, treat turf toe primarily as an injury to the sesamoid apparatus and structures attached to the sesamoid bones.

the injury needs to be evaluated for sesamoid fracture and avascular necrosis. Long-term x-rays on fractured sesamoids do not usually demonstrate healing as they do in the long bones. It just stays split, but fibrous connective tissue can make a firm union of the parts. An accom-

modation built into an orthotic usually helps, if well designed.

Orthotics must be used for at least 12 months. The orthotic functions by directly removing pressure from the sesamoidal apparatus, placing the great toe in a good



Figure 2: Orthotic with tapered sesamoid accommodation.

functional position, and eliminating the early, rapid change in position of the great toe that takes place as the gait cycle passes through heel-off. Shoes with a stiff forefoot or a rocker forefoot sole can be adjunctive therapy when used with orthotics.

Bone stimulators may be effective. Splints have been suggested and are placed below the first metatarsophalangeal joint.

Sesamoidopathy

The hallucal sesamoid bones are associated as a portion of the first metatarsophalangeal joint complex, along with the big toe and the first metatarsophalangeal joint. They function as a fulcrum, although some describe the function as being more like a pulley. The primary effect of the sesamoids is to increase the mechanical advantage of the muscles that plantarflex the big toe.

Continued on page 163

TABLE 7 Differential Diagnosis of Sesamoidopathy and Causes of Pain

Differential Diagnosis

Stress Fracture
AVN
Diastasis
Overt Fx
Chondral injury
Osteomyelitis
Neoplasm

Causes of Pain in Sesamoid Region

Intra-articular:
Chondral injury
Plica
Cyst
Capsulitis

Extra-articular:
Tendinopathy
Neural trauma
Bursitis

TABLE 8 Differential Diagnosis of FHL Tendinopathy

- Symptomatic os trigonum
- Posterior impingement syndrome
- Steida's process fracture (Shepherd's fracture)
- Posteromedial talar osteochondral injury
- Subtalar joint coalition
- Posterior tibial tendinopathy
- Flexor digitorum longus tendinopathy
- Peroneus longus tendinopathy
- Partial tear of the plantar fascia
- Plantar fasciopathy
- Hypertrophy of the FHL muscle and compression within the fibro-osseous tunnel
- Sesamoiditis
- Neoplasm

Injuries...

Sesamoid pathology is more complex than the term “sesamoiditis” would imply (Table 7). Methodical analysis will allow one to distinguish among the myriad entities that may occur in this location. Richard Bouché, DPM has lectured often on the “sick sesamoid”, and has coined the term sesamoidopathy. That is the term we will use to apply to sesamoid injuries in which the diagnosis has not been further refined.

Treatment of Sesamoidopathy

Treatment of sesamoidopathy may include padding, orthotics (Figure 2), or surgery. Immobilization is used in severe cases. In the long term, orthotics with a sesamoid accommodation are often helpful. Surgical procedures that have been used include relocation, complete or partial excision, sesamoidal planing, metatarsophalangeal joint fusion.

The Rise of Tendinopathy

Healthy tendons are white, firm, have a fibroelastic texture, and are able to handle heavy loads. Shapes of tendons vary from short and broad, such as the quadriceps tendon, to long and rounded, such as the peroneal tendons. Tendons transfer the forces generated by muscles to bone. This force transfer results in movement. The elasticity of tendons allow for improved muscle function through the force-length-tension relationship.

This improved function also results from the ability of the tendon to store mechanical potential strain energy. The storage and recovery of energy is a passive process that does not need to be turned on and off. In fact, the mechanical properties

of tendon are not dependent upon metabolic activity.

The tensile strength of tendon at 5.0 kN/cm² to 10 kN/cm² is higher than that of bone. With the strength of tendons at times exceeding the strength of bone, injuries such as fifth metatarsal styloid process avulsion fractures may occur. Tendons may become injured when repeated loads exceed their strength capacity. The elastic modulus of an injured tendon is lessened while its stiffness is increased.

The structures which surround tendons consist of five types of tissue¹⁶:

1) Fibrous sheaths—These are channels through which usually longer tendons glide. Friction is reduced through their course. The grooves and notches through which tendons must pass are almost always lined with fibrocartilage just below the fibrous sheath. Overlying the notches and channels, above the tendons, are often retinacula such as the superior and inferior extensor retinacula at the ankle and the superior and inferior peroneal retinacula.

2) Reflection pulleys—The cuboid groove is an example of a reflection pulley. Reflection pulleys are areas in which the tendon must make a dramatic change in direction.

3) Synovial sheaths—Where friction may occur, tendons are often covered with synovial sheaths which usually secrete a friction-reducing peritendinous fluid.

4) Peritendinous sheaths—Ten-

dons such as the Achilles tendon, which do not have a true synovial sheath, may be covered with tissue that serves a similar function.

5) Tendon bursa—The tendon bursae reduce friction. The retrocalcaneal bursa and pes anserinus bursa are well known examples.

In this article we'll be looking at tendons that are often injured but not considered in the diagnostic process. Here, we will pay special attention to the peroneus longus tendon and the flexor hallucis longus

tendon, which along with the insertion of the posterior tibial tendon and the mid-portion of the plantar fascia, sit in what I call the “zone of confusion.” In this zone, too many injuries are often called “plantar fasciitis.” A high level of suspicion and careful examination should lead to the proper diagnosis. Treatment failure often follows a failure to make the correct diagnosis. Diligence in creating a reasonable set of differential diagnoses should be done for each patient. Careful examination, consideration, and imaging (when necessary) will minimize diagnostic errors.

Tendinopathy is now the term of choice for the clinical condition following overuse injury. The terms tendinosis and tendinitis are histopathological descriptions and should not be used without microscopic confirmation. Overuse tendon injuries cause pain, reduce strength and function, and decrease tolerance and length of exercise. The Achilles tendon and posterior tibial tendon are among the most common areas affected by tendinopathy in runners.

Surgical specimens, taken from patients with well-established tendinopathy, show little to no signs of inflammation. Instead, the specimens show hypercellularity, an increase in proteoglycan content, vascularization, and a loss of

Continued on page 164

Repetitive overload and microtrauma can occur in conjunction with non-uniform stress within a tendon.

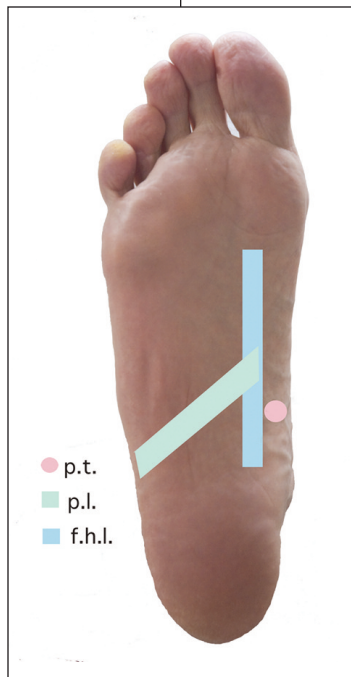


Figure 3: Zone of confusion key structures P.T.—Insertion of posterior tibial tendon. P.L.—peroneus longus tendon. F.H.L.—flexor hallucis longus tendon).

Injuries...

the usual tightly bundled collagen appearance. Tendinopathic tissue is usually grey or brown in color. Physically, the tissue is soft and fragile. Animal preparations do not demonstrate inflammation as a component of long-standing tendon injury. Inflammation is only seen in cases of acute and extreme tendon loading. The microscopic pathology of both mid-tendon and enthesitis injuries is histologically similar.

Repetitive overload and micro-trauma can occur in conjunction with non-uniform stress within a tendon. The result is local fiber degeneration. A single abnormal loading cycle (e.g., a misstep) could be enough to create isolated fibril damage. The patient would not likely recall a specific injury. Neer believed impingement could be a cause of tendinopathy in the supraspinatus tendon below the anterior margin of the acromium.¹⁷ An analogous process may contribute to peroneus longus tendinopathy adjacent to the cuboid bone.

Tendon overload creates matrix changes in the collagen structure. There is an increase in proteoglycans and cellular protein, and enzyme production is altered. Production of prostaglandin E2 and leukotriene B4 are increased. These compounds likely contribute to the development of tendinopathy. Apoptosis may also play a role. An increase in cytochrome-c related caspase activation is a potential inductive pathway for apoptosis. Heat shock protein (HSP-25) is also found in animal models of tendinopathy with apoptosis.¹⁸

Theories of Tendon Pathology

We need to look at other possible mechanisms for overuse tendinopathy, as inflammation is no longer believed to be the major cause. The features described above

are all compatible with the current major theories of tendinopathy. The theory of incomplete healing views the injured tendon as being in a healing phase, with active cellular activity and increased protein production occurring in the midst of a disorganized matrix and neovascularization. This has also been termed "failed healing."¹⁹

Overuse tendon injuries have also been viewed as degenerative processes. The terms hypoxic degeneration, mucoid degeneration or hyaline degeneration are often applied. This suggests an end stage and difficult-to-reverse process.²⁰ It is possible that a continuum may exist with incomplete healing leading ultimately to a degenerative process. Cook and Purdam have described this hypothesis.²¹

Diagnostic Approaches

Magnetic resonance imaging (MRI) and diagnostic ultrasound (US) are the most frequently employed diagnostic procedures. In contrast to tenography, both of these procedures are non-invasive and cause no further damage to the tissues. US is a fast and inexpensive technique which can be performed in an office setting. Tendon thickening, echogenic changes around the tendon, and adhesions are readily seen. Tendons affected by tendinosis, on US examination, show low reflectivity peripherally.

In chronic tendinosis, peritendinous adhesions are seen as a hypochoic paratenon with poorly defined borders. MRI, using relatively small spaced images, provides greater detail, but takes longer to perform and is considerably more expensive.

Clinical examination is still an

important component of the evaluative process. Bains and Porter (2006) state that "clinical evaluation remains the main criterion measure" for evaluation of potential areas of tendinopathy.²²

Zone of Confusion: Re-evaluating Intractable Plantar Fasciitis

The plantar mid-foot can be an area of consternation. Classically, the mid-foot includes the navicular, cuboid, and the three cuneiform bones. It lies anterior to Choparts joint which includes the calcaneocuboid and talonavicular joints. Our zone of confusion extends within the soft tissue a bit

Longitudinal tears of the peroneus longus tendon at or proximal to the cuboid tunnel can often be treated with immobilization.

distal to this (Figure 3). Many times, pain in this area is mistakenly ascribed to plantar fasciitis or plantar fasciopathy.

Perform a painstakingly careful evaluation of this area while keeping in mind the structures you are palpating (Figure 3). Specifically, trace and palpate the peroneus longus tendon, flexor hallucis longus tendon, and the insertion point of the posterior tibial tendon. Any of these tendons could cause symptoms that mimic plantar fasciopathy.

We'll focus on these clinical entities, but you should keep in mind more dorsal structures that could contribute to pain in this area, including: Lisfranc ligament or joint injury, metatarsal stress fracture, cuboid stress fracture, navicular stress fracture, and plantar fascia tear.

Structures Affected in the Zone of Confusion

Posterior Tibial Tendon/ Spring Ligament

The posterior tibial tendon (PTT) runs behind the medial malleolus in a fibro-osseous groove and inserts primarily into the navicular tuberosity, but also into the

Continued on page 165

The accessory navicular bone is reported to occur in up to 21% of the population.

Injuries...

cuneiform bones. In the athletic population, overtraining and excessive pronation of the foot are risk factors. MRI can be an adjunct to diagnosis and to recognition of tears in the tendon.

The spring ligament (plantar calcaneonavicular ligament) is a static structure, but functions in tandem with the posterior tibial tendon. An injury to the spring ligament would usually be found only in conjunction with an injury to the PTT. The MRI would show the ligament to be abnormally thickened and would demonstrate increased signal intensity. Previous articles have discussed posterior tibial tendon dysfunction in detail.

Accessory Navicular Bone

The accessory navicular bone is reported to occur in up to 21% of the population. This bone may slightly increase the risk for PTT pathology. Type-I accessory navicular bones are small, round, and can be located considerably proximally. They have the appearance of a sesamoid bone and are not likely to create any dysfunction in the PTT.

Type-II accessory navicular is larger and sits immediately adjacent to the main body of the navicular bone. Type-II accessory navicular bones are what most clinicians readily observe. Type-III navicular bone is cornuate shaped and incorporates the accessory navicular into the body of the navicular. An injured accessory navicular bone (Type-II) will show bone marrow edema and possibly cyst formation. PTT pathology can often be seen in conjunction with the injury to the accessory navicular bone.²³

Os Peroneum/Peroneus Longus Tendinopathy

The os peroneum is a sesamoid bone found within the peroneus longus tendon. It is usually located just proximal to the cuboid tunnel. This bone is thought to be present in the majority of people, and a corresponding facet is found in the cuboid 93% of the time. The os peroneum is often only partly ossified or fibrocartilagenous. It is visible on x-ray only 5% of the time.

In conjunction with an inversion injury and tenderness at the cuboid, the os peroneum is often a contributing factor in lateral foot pain. This bone can traumatically fracture. In the presence of a painful os peroneum, the MRI often shows signs of tendinopathy of the peroneus longus tendon, along with peritendinopathy, and bone marrow edema of the cuboid.²⁴ Sclerosis and fragmentation of the os peroneum after chronic pain have also been found.

Clinically, always examine patients with lateral foot or plantar mid-foot pain for tenderness along the plantar course of the peroneus longus tendon. It appears to be a structure that is often injured. The first step in diagnosis of a distally injured peroneus longus tendon is suspicion of the injury. After deter-

***FHL tendinopathy
has been found
in conjunction with
plantar fasciitis.***

mining that there is a likely peroneus longus injury, direct your attention to the lateral ankle. Tenderness of the lateral ligaments is a confirmatory sign of inversion injury. Often, the inversion injury does not appear major and tenderness is only seen at the anterior talofibular ligament. An MRI can be of assistance and prevent a mistaken diagnosis of "cuboid syndrome".

Longitudinal tears of the peroneus longus tendon at or proximal to the cuboid tunnel can often be treated with immobilization. If these tears fail to heal, excision of non-viable tissue and suturing may be performed. An enlarged peroneal tubercle should also be removed. Look to see if a peroneus quartus inserts into the tubercle. Complete peroneus longus tendon tears occur most often at the cuboid tunnel, sometimes in conjunction with an os peroneum. The os peroneum can retract proximal to the calcaneocuboid joint when the distal tendon is torn. If an end-to-end re-

pair is not possible, one may either perform a tenodesis to the peroneus brevis or alternatively attach the longus to the cuboid.

Physical examination of the plantar aspect of the foot must be meticulous. Often an injury to the peroneus longus tendon in this location is missed. Avulsion from the tendon's insertion into the base of the first metatarsal or medial cuneiform is possible. Usually, surgical repair is not necessary for tears of the peroneus longus tendon in this region. Diagnosis, followed by immobilization and adequate time for healing, is vital. If pain and swelling persist, consider removing non-viable tissue and perform a tenodesis to the peroneus brevis.²⁵

Flexor Hallucis Longus Tendinopathy

The flexor hallucis longus is a multi-joint muscle which plantar-flexes the hallux, contributes to resisting pronatory forces, and is a weak plantar-flexor at the ankle, although in the ballet dancer, it is the important force transfer link in attaining the point position. Flexor hallucis longus (FHL) tendinopathy is known to be a frequently encountered injury among ballet dancers. In ballet dancers, FHL tendinopathy can be found in association with a symptomatic os trigonum. Scattered reports exist of injuries to this tendon in runners.²⁶ Olaff, in a study of non-athletes, noted that this is likely an under-reported injury.²⁷ Most authors have found that the majority of the injuries to this tendon take place proximally, with some tears occurring at the level of the hallucal sesamoid bones.

Our concern here is with tendinopathy within the "zone of confusion." Most clinicians do not have injuries to this tendon high on their list of suspected causes of plantar and medial foot pain. In addition to the widely described common areas of injury, be certain to examine the plantar mid-foot carefully and palpate this tendon. The term flexor hallucis longus dysfunction appears most appropriate and should be included in a

Continued on page 166

Injuries...

differential diagnosis for pain in the medial foot or plantar medial foot (Table 8). The symptoms may overlap with that of plantar fasciitis, tarsal tunnel syndrome, and insertional posterior tibial tendinopathy.²⁸

Tenography may be an accurate indicator of injury to this tendon, but is no longer widely used. Physical examination, MRI, and diagnostic ultrasound could be useful in the diagnosis of this clinical entity. Physical examination will reveal tenderness along the course of the FHL tendon. Limitation of dorsiflexion of the hallux may be found. Pain may be elicited by dorsiflexion of the hallux or dorsiflexion at the ankle.

FHL tendinopathy has been found in conjunction with plantar fasciitis.²⁹ Upon questioning, the patient will often reveal having performed vigorous dorsiflexion exercises of the toes and hallux in attempting to "stretch" the plantar fascia.

Treatment

Conservative treatment is often useful and yields excellent results in the plantar mid-foot. Dorsiflexion exercises of the great toe and vigorous over-stretching of the Achilles tendon should be discontinued. Short-term immobilization may be necessary. Eliminate over-cushioned and excessively flexible shoes. Following weaning from a CAM walker or pneumatic walker, begin soleus and gastrocnemius stretching and strengthening. Recommend a running shoe that is a good match for the patient's individual biomechanics.

The surgical treatment described includes debridement, tenolysis, decompression, and excision of a symptomatic os trigonum. The reported surgical results for proximal injuries have been excellent.^{29,30} The patient should be kept non-weight-bearing for two to three weeks. Begin gentle hallux range of motion exercises at seven days. Following the non-weight bearing time period, transition to a pneumatic walking boot for two weeks, then wean the patient from the pneumatic walking boot.

Summary

We have reviewed several troubling injuries. Diagnosis is the key to successful treatment of injuries. Careful assessment and review of differential diagnoses should lead to the proper diagnosis. Regular critical review of the available literature will keep your knowledge up-to-date. Successful diagnosis and treatment of your patients is the first step towards overall success. ■

References

- Eisenmann, J.C. and E.E. Wickel, The biological basis of physical activity in children: revisited. *Pediatr Exerc Sci*, 2009. 21(3): p. 257-72.
- De Moor, M., et al., Genome-Wide Association Study of Exercise Behavior in Dutch and American Adults. *Med Sci Sports Exerc*, 2009.
- Beloqui, A., Guazzaroni, M., Pazos, F., Vieites, J., Reactome Array: Forging a Link Between Metabolome and Genome. *Science*, 2009. 326(October 9): p. 252-257.
- Mokone, G.G., et al., The guanine-thymine dinucleotide repeat polymorphism within the tenascin-C gene is associated with achilles tendon injuries. *Am J Sports Med*, 2005. 33(7): p. 1016-21.
- Mokone, G.G., et al., The COL5A1 gene and Achilles tendon pathology. *Scand J Med Sci Sports*, 2006. 16(1): p. 19-26.
- Lovejoy, C.O., et al., Combining prehension and propulsion: the foot of *Ardipithecus ramidus*. *Science*, 2009. 326(5949): p. 72e1-8.
- Laird, P.O., Functional hallux limitus. *Illinois Podiatrists*, 1972. 9(4).
- Davies-Colley, M., Contraction of the metatarsophalangeal joint of the great toe. *Br Med J*, 1887. 1: p. 728.
- Cotterill, J., Stiffness of the great toe in adolescents. *Br Med J*, 1888. 1: p. 1158.
- Roukis, T.S., et al., A prospective comparison of clinical, radiographic, and intraoperative features of hallux rigidus. *J Foot Ankle Surg*, 2002. 41(2): p. 76-95.
- Drago, J.J., L. Oloff, and A.M. Jacobs, A comprehensive review of hallux limitus. *J Foot Surg*, 1984. 23(3): p. 213-20.
- Hanft, J.R., et al., A new radiographic classification for hallux limitus. *J Foot Ankle Surg*, 1993. 32(4): p. 397-404.
- Kravitz, S.R., LaPorta, G. A., Lawton, J., Progressive staging classification of hallux limitus and hallux rigidus. *Lower Extremity*, 1994. 1(1): p. 55-66.
- Vanore, J.V., et al., Diagnosis and treatment of first metatarsophalangeal joint disorders. Section 2: Hallux rigidus. *J Foot Ankle Surg*, 2003. 42(3): p. 124-36.
- Clanton, T.O. and J.J. Ford, Turf toe injury. *Clin Sports Med*, 1994. 13(4): p. 731-41.
- Jozsa, L., Kannus, P., Human Ten-

dons: Anatomy, Physiology, and Pathology. 1997: Human Kinetics.

¹⁷ Neer, C., Impingement lesions. *Clin Orthop Relat Res*, 1983. 173: p. 70-77.

¹⁸ Xu, Y. and G.A. Murrell, The basic science of tendinopathy. *Clin Orthop Relat Res*, 2008. 466(7): p. 1528-38.

¹⁹ Iglehart, J.K., The new era of medical imaging—progress and pitfalls. *N Engl J Med*, 2006. 354(26): p. 2822-8.

²⁰ Jozsa, L. and P. Kannus, Histopathological findings in spontaneous tendon ruptures. *Scand J Med Sci Sports*, 1997. 7(2): p. 113-8.

²¹ Cook, J.L. and C.R. Purdam, Is tendon pathology a continuum? A pathology model to explain the clinical presentation of load-induced tendinopathy. *Br J Sports Med*, 2009. 43(6): p. 409-16.

²² Bains, S., Porter, K, Lower limb tendinopathy in athletes. *Trauma*, 2006. 8: p. 213-224.

²³ Ting, A.Y., W.B. Morrison, and E.C. Kavanagh, MR imaging of midfoot injury. *Magn Reson Imaging Clin N Am*, 2008. 16(1): p. 105-15, vi.

²⁴ Sobel M, P.H., Geppert MJ, Thompson FM, DiCarlo EF, Davis WH, Painful os peroneum syndrome: a spectrum of conditions responsible for plantar lateral foot pain. *Foot Ankle Int*, 1994. 15((3) March): p. 112-24.

²⁵ Slater, H.K., Acute peroneal tendon tears. *Foot Ankle Clin*, 2007. 12(4): p. 659-74, vii.

²⁶ Coghlan, B.A. and N.M. Clarke, Traumatic rupture of the flexor hallucis longus tendon in a marathon runner. *Am J Sports Med*, 1993. 21(4): p. 617-8.

²⁷ Oloff, L.M. and S.D. Schulhofer, Flexor hallucis longus dysfunction. *J Foot Ankle Surg*, 1998. 37(2): p. 101-9.

²⁸ Schulhofer, S.D. and L.M. Oloff, Flexor hallucis longus dysfunction: an overview. *Clin Podiatr Med Surg*, 2002. 19(3): p. 411-8, vi.

²⁹ Michelson, J. and L. Dunn, Tenosynovitis of the flexor hallucis longus: a clinical study of the spectrum of presentation and treatment. *Foot Ankle Int*, 2005. 26(4): p. 291-303.

³⁰ Hamilton, W.G., Posterior ankle pain in dancers. *Clin Sports Med*, 2008. 27(2): p. 263-77.

Dr. Pribut is a Clinical Assistant Professor of Surgery at George Washington University Medical School. He is a past president of the American Academy of Podiatric Sports Medicine. He is in private practice in Washington, DC.



See answer sheet on page 169.

- 1) A painful stage 3 hallux rigidus is likely to be treated by all of the following, except:
- A) Orthotic therapy
 - B) Chielectomy
 - C) First metatarsophalangeal joint fusion
 - D) Achilles tendon lengthening
- 2) The most likely surgical procedure for a Stage 4 hallux rigidus is:
- A) First metatarsophalangeal joint fusion
 - B) Chielectomy
 - C) Achilles tendon lengthening
 - D) Lapidus procedure
- 3) The most likely etiology of hallux rigidus is which of the following?
- A) Tailor's bunion
 - B) Metatarsus primus varus
 - C) Metatarsus primus elevatus
 - D) Metatarsus adductus
- 4) Turf toe is caused by:
- A) Sudden stop or change of direction
 - B) Sudden dorsiflexion of the hallux
 - C) Tight shoes
 - D) Haglund's deformity
- 5) Risk factors that may contribute to turf toe include all of the following, except:
- A) Prior first metatarsophalangeal joint injury
 - B) Sesamoiditis
 - C) Playing football on artificial grass
 - D) Diabetic neuropathy
- 6) Grade-3 first metatarsophalangeal (MTP) joint sprains, also known as turf toe, include which of the following?
- A) Mild stretching of the capsule of the first MTP
 - B) Partial tear of the capsule of the first MTP
 - C) Complete tear of the capsule of the first MTP
 - D) Intact and uninjured capsule of the first MTP
- 7) The most important area of those listed below to evaluate in turf toe injury is:
- A) Base of the fifth metatarsal
 - B) The sesamoid bones
 - C) The medial cuneiform bone
 - D) The Achilles tendon
- 8) Useful initial treatment of turf toe does not include which of the following?
- A) Excision of both sesamoid bones
 - B) Pneumatic or CAM walker
 - C) PRICE (protection, rest, ice, gentle compression, elevation)
 - D) Off-loading shoe
- 9) The sesamoid bones function to:
- A) Increase the mechanical advantage of the flexor hallucis longus
 - B) Decrease the efficiency of the flexor hallucis longus
 - C) Increase the ability of the hallux to dorsiflex
 - D) Increase pronation of the midtarsal joint
- 10) Intra-articular causes of pain in the sesamoid region include which of the following?
- A) Tendinopathy
 - B) Bursitis
 - C) Injury to the regional nerves
 - D) Chondral injury
- 11) Treatment of painful sesamoidopathy is least likely to include:
- A) Cole procedure
 - B) Excision of the sesamoid bone
 - C) Orthotic with a sesamoidal accommodation
 - D) Immobilization
- 12) Tendons assist in making muscles more efficient, in part, by their ability to store:
- A) Kinetic energy
 - B) Potential strain energy
 - C) Chemical energy
 - D) Nuclear energy
- 13) The mechanical features and properties of tendon result from all of the following except:
- A) active metabolism of tendons
 - B) fibroelastic texture
 - C) their force-tension relationship
 - D) decreased friction and improved function from the surrounding tissues around tendon.
- 14) Plantar fasciopathy or partial tears of the fascia may be confused with which of the following?
- A) Extensor digitorum longus tendinopathy
 - B) Achilles tendinopathy
 - C) Peroneus longus tendinopathy
 - D) Peroneus brevis tendinopathy

Continued on page 168

PM's CPME Program

Welcome to the innovative Continuing Education Program brought to you by *Podiatry Management Magazine*. Our journal has been approved as a sponsor of Continuing Medical Education by the Council on Podiatric Medical Education.

Now it's even easier and more convenient to enroll in PM's CE program!

You can now enroll at any time during the year and submit eligible exams at any time during your enrollment period.

PM enrollees are entitled to submit ten exams published during their consecutive, twelve-month enrollment period. Your enrollment period begins with the month payment is received. For example, if your payment is received on September 1, 2006, your enrollment is valid through August 31, 2007.

If you're not enrolled, you may also submit any exam(s) published in PM magazine within the past twelve months. **CME articles and examination questions from past issues of *Podiatry Management* can be found on the Internet at <http://www.podiatrym.com/cme>.** Each lesson is approved for 1.5 hours continuing education contact hours. Please read the testing, grading and payment instructions to decide which method of participation is best for you.

Please call (631) 563-1604 if you have any questions. A personal operator will be happy to assist you.

Each of the 10 lessons will count as 1.5 credits; thus a maximum of 15 CME credits may be earned during any 12-month period. You may select any 10 in a 24-month period.

The Podiatry Management Magazine CME program is approved by the Council on Podiatric Education in all states where credits in instructional media are accepted. This article is approved for 1.5 Continuing Education Contact Hours (or 0.15 CEU's) for each examination successfully completed.

15) The structures which most frequently surround tendon include all of the following, except:

- A) Glial cells
- B) Synovial sheaths
- C) Peritendinous sheaths
- D) Reflection pulleys

16) Structures in the "zone of confusion" include all of the following, except:

- A) Peroneus longus tendon
- B) Flexor hallucis longus tendon
- C) Extensor hallucis longus tendon
- D) Insertion of the posterior tibial tendon

17) Injured tendon without histological examination is properly termed:

- A) Tendinitis
- B) Tendinopathy
- C) Tendinosis
- D) Stenosing tenovaginitis

18) The major theories of the causes of tendinopathy include all of the following, except:

- A) Incomplete healing
- B) Tendon degeneration
- C) Apoptosis, enzyme activation, and heat shock protein production
- D) Vitamin D deficiency

19) Useful procedures for the diagnosis of tendinopathy include all of the following, except:

- A) Tenography
- B) MRI
- C) Plain Film
- D) Ultrasonography

20) Likely causes of lateral foot pain within the "zone of confusion" include which of the following?

- A) Injury to os peroneum
- B) Injury to the proximal phalanx of the fifth toe
- C) Calcaneus
- D) Fracture of the neck of the fifth metatarsal

See answer sheet on page 169.

**Home Study CME credits now
accepted in Pennsylvania**

Enrollment/Testing Information and Answer Sheet

Note: If you are mailing your answer sheet, you must complete all info. on the front and back of this page and mail with your credit card information to: **Podiatry Management, P.O. Box 490, East Islip, NY 11730.**

TESTING, GRADING AND PAYMENT INSTRUCTIONS

(1) Each participant achieving a passing grade of 70% or higher on any examination will receive an official computer form stating the number of CE credits earned. This form should be safeguarded and may be used as documentation of credits earned.

(2) Participants receiving a failing grade on any exam will be notified and permitted to take one re-examination at no extra cost.

(3) All answers should be recorded on the answer form below. For each question, decide which choice is the best answer, and circle the letter representing your choice.

(4) Complete all other information on the front and back of this page.

(5) Choose one out of the 3 options for testgrading: mail-in, fax, or phone. To select the type of service that best suits your needs, please read the following section, "Test Grading Options".

TEST GRADING OPTIONS

Mail-In Grading

To receive your CME certificate, complete all information and mail with your credit card information to:

**Podiatry Management
P.O. Box 490, East Islip, NY 11730**

There is **no charge** for the mail-in service if you have already enrolled in the annual exam CPME program, and we receive this

exam during your current enrollment period. If you are not enrolled, please send \$20.00 per exam, or \$139 to cover all 10 exams (thus saving \$61* over the cost of 10 individual exam fees).

Facsimile Grading

To receive your CPME certificate, complete all information and fax 24 hours a day to 1-631-563-1907. Your CPME certificate will be dated and mailed within 48 hours. This service is available for \$2.50 per exam if you are currently enrolled in the annual 10-exam CPME program (and this exam falls within your enrollment period), and can be charged to your Visa, MasterCard, or American Express.

If you are *not* enrolled in the annual 10-exam CPME program, the fee is \$20 per exam.

Phone-In Grading

You may also complete your exam by using the toll-free service. Call 1-800-232-4422 from 10 a.m. to 5 p.m. EST, Monday through Friday. Your CPME certificate will be dated the same day you call and mailed within 48 hours. There is a \$2.50 charge for this service if you are currently enrolled in the annual 10-exam CPME program (and this exam falls within your enrollment period), and this fee can be charged to your Visa, Mastercard, American Express, or Discover. If you are not currently enrolled, the fee is \$20 per exam. When you call, please have ready:

1. Program number (Month and Year)
2. The answers to the test
3. Your social security number
4. Credit card information

In the event you require additional CPME information, please contact PMS, Inc., at **1-631-563-1604**.

ENROLLMENT FORM & ANSWER SHEET

Please print clearly...Certificate will be issued from information below.

Name _____ Soc. Sec. # _____
Please Print: FIRST MI LAST

Address _____

City _____ State _____ Zip _____

Charge to: Visa MasterCard American Express

Card # _____ Exp. Date _____

Note: Credit card is the only method of payment. Checks are no longer accepted.

Signature _____ Soc. Sec.# _____ Daytime Phone _____

State License(s) _____ Is this a new address? Yes _____ No _____

Check one: I am currently enrolled. (If faxing or phoning in your answer form please note that \$2.50 will be charged to your credit card.)

I am not enrolled. Enclosed is my credit card information. Please charge my credit card \$20.00 for each exam submitted. (plus \$2.50 for each exam if submitting by fax or phone).

I am not enrolled and I wish to enroll for 10 courses at \$139.00 (thus saving me \$61 over the cost of 10 individual exam fees). I understand there will be an additional fee of \$2.50 for any exam I wish to submit via fax or phone.

EXAM #1/10
Challenging Running Injuries:
Be Knowledgeable, Be Prepared
(Pribut)

Circle:

- | | |
|-------------|-------------|
| 1. A B C D | 11. A B C D |
| 2. A B C D | 12. A B C D |
| 3. A B C D | 13. A B C D |
| 4. A B C D | 14. A B C D |
| 5. A B C D | 15. A B C D |
| 6. A B C D | 16. A B C D |
| 7. A B C D | 17. A B C D |
| 8. A B C D | 18. A B C D |
| 9. A B C D | 19. A B C D |
| 10. A B C D | 20. A B C D |

LESSON EVALUATION

Please indicate the date you completed this exam

How much time did it take you to complete the lesson?
_____ hours _____ minutes

How well did this lesson achieve its educational objectives?
_____ Very well _____ Well
_____ Somewhat _____ Not at all

What overall grade would you assign this lesson?
A B C D
Degree _____

Additional comments and suggestions for future exams:

