Continuing Medical Education

The Top Five Running Injuries Seen in the Office

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

Objectives

1) Describe the features of the top running injuries.

2) Present recent concepts on muscle imbalance and the relationship of core muscles to clinical entities including PFPS and iliotibial band syndrome.

3) Review the significance of tendinopathy and fasciopathy in clinical practice.

4) Review the concept of enthesis and tendinopathy as they pertain to Achilles tendon injuries.

5) Review current theories of the cause of medial tibial stress syndrome.

6) Present current concepts of stress reactions and stress fractures of bone as repetitive stress injuries of bone.

7) Describe an outline of treatment recommendations for Achilles tendonitis, plantar fasciitis, iliotibial band syndrome, patellofemoral pain syndrome, medial tibial stress and stress reactions of bone.

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By Stephen Pribut, DPM

Long distance running is a uniquely human undertaking. No other primate runs long distances. Considering mammals in general, some cover shorter distances at a faster speed, but only a select few are able to maintain a rapid pace over a long distance. The development of bipedal locomotion and an upright posture has resulted in structural and functional differences in our musculoskeletal system and in the biomechanical function of our locomotor systems. It is thought that running may have been a significant evolutionary adaptation permitting easier survival by virtue of primitive hominids' enhanced ability to escape from predators and to catch prey.

Running is a vitally important part of the lives of many people. It is not only a sport, but an integral segment of the runners' lives that is often carried out with near religious fervor. Running yields health benefits ranging from those which

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impact our psychological well being to our physical health. Running has been found to have a positive impact on depression, cardiovascular health, muscular fitness, osteoporosis, diabetes, blood pressure, obesity, prevention of colon cancer, and a variety of other measures of health.[1,2]

What Makes Runners Different

For those who have made this sport a vital part of their lives, it may just be their favorite aspect of evolution. But along with this evolution, runners have developed their own special and unique outlook towards their bodies.

Emotional Aspects

Runners have high expectations that treatment of their injuries have both excellent results and that these results be quickly achieved. Most runners are highly motivated and are not patient. Exercise withdrawal can have a large impact on their mental health and may result in insomnia or depression. Most runners do not want to be told not to run! The concepts of relative rest, cross-training, and alternative forms of exercise must be carefully explained to the runner. It is therefore important to spell out clearly the modifications to training that must be made to assist runners in recovery from injury.

Runners often look for a physician who is a participant and shares their passion for running. While football coaches are not usually chosen for their ability to catch or throw passes, running docs are frequently sought out if they are runners.

Physical Aspects

Most runners are physically fit, with the exception of those who are recent converts to the sport. Recently, the ranks of marathoners have swollen with many new runners. Chorley, et al. studied runners joining a 25-week marathon training program and found that 52% had never run a marathon before and 16% had been sedentary in the three months prior to starting training.[3] Previous injuries were reported by 38% of runners and 35% of those injuries were still symptomatic at the inception of the training program. Desire may oftentimes be greater than readiness. No longer do the new runners slowly work up to a marathon by running for six months to a year before starting marathon training.

In looking at the biomechanics of running, it is important to remember that running is a one legged sport. Unlike the walking gait, the runner is only on one foot and leg at a time, and never on two. Significantly higher forces are encountered while running. The foot gear used for distance running is designed for straight ahead motion and is not suited for significant side-to-side motion or sudden changes in direction.

Risk Factors, Studies on Injury Prevention

Accurately predicting what factors are responsible for running injuries has not been readily achievable in studies thus far.[4] A general agreement exists, however, that most running injuries are injuries of overuse.[3-6] All aspects of a patient's exercise program must be evaluated. There may have been a change in the patient's shoes, with them becoming excessively worn, or the shoes may have been replaced by an inappropriate pair. A change in the training program may have triggered the problem. This can occur when what has been

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TABLE 1

Risk Factors

- Increased Q Angle
- Weak or ineffective Vastus Medialis (VMO)
- Patellar Dysplasia (e.g., small medial pole of patella)
- Trochlear Dysplasia (congenital flattening of the lateral femoral condyle)
- Patella Alta (Ward et. al. JBJS 2007 Patella Alta: Association with Patellofemoral Alignment....)
- Hypermobility of Patella
- Ligamentous Laxity
- Genu Varum/Valgum
- Female gender (possibly multifactoral, wider hips, higher Q angle, etc.)
- Malalignment of Extensor Mechanism
- Abnormal knee joint moments
- Abnormal pronation of the foot
- Other Lower Extremity Malaligment
- Weak Hip Abductors
- Canted Surface
- Overtraining

Abbreviations

MPFL	medial patellofemoral ligament
VMO	vastus medialis obliquus
PFPS	patellofemoral pain syndrome
ITB	iliotibial band
ITBS	iliotibial band syndrome
MRI	magnetic resonance imaging
RSI	repetitive stress injury
MTSS	medial tibial stress syndrome

termed the "terrible too's" occurs. These include "too much, too soon, too fast, too often, with too little rest."

The stress loads of exercise must be gradually increased. These loads should not outpace the body's physical ability to adapt to the new loads. While some studies have not been sufficiently designed to discern running-related injuries per hours run (RRI/1000 hours), other authors have posited the significance of the gradual build-up although not successfully demonstrated it in an epidemiological study.[7]

In the rush for fitness, many are injured. This article reviews the top five running-related injuries for which patients seek treatment, with a bonus injury or two. As we examine these injuries, we'll also note that there has been an evolution in the conceptualization of many of these injuries. This evolution has occurred slowly and in the face of imperfect knowledge. The concept of tendinopathy, as the appropriate term for tendon pathology, is an evolution of thought as is the conceptual and terminology changes suggested for problems such as plantar fasciitis. Is the iliotibial band syndrome a problem of friction or something else? Is the Vastus medialis the muscle that we need to have the patient strengthen to improve quadriceps function and treat patello-femoral pain syndrome? We'll consider these problems below.

Top Five Running Injuries

Knee Pain (PFPS, ITBS)
Achilles Tendon
Stress Fractures
Medial Tibial Stress Syndrome
Plantar Fasciitis

Knee Pain: Patellofemoral Pain Syndrome and ITB Syndrome

Called by a number of different terms over the years, patellofemoral pain is one of the top five running injuries. Chondromalacia patella, runner's knee, and anterior knee pain have all been applied to this condition. Since the site of origin of pain in this area includes several structures, the appellation "chondromalacia" is too limiting. Therefore, the nonspecific term patellofemoral pain syndrome (PFPS) is preferred by most authors. Pain here is thought to arise from any or all of the following structures: the subchondral bone, medial and lateral retinaculae, infrapatellar fat pad and the anterior synovium. Patellofemoral pain syndrome has been reported to affect up to 30% of all runners. While many features of this very common malady remain to be detailed, a number of risk factors have been cited over the years. The complex relationship of anatomical alignment of the limb, patellar shape, presence of patella alta, and even the functional aspects of the peripatellar retinaculum[8] have an impact on both the forces occurring within this system and the development and resolution of symptoms of this condition. A number of risk factors have been thought to contribute to PFPS. They are detailed in Table 1.

Changing Concepts in PFPS

We need to keep in mind the myriad factors that come into play with this disorder. The stability of the patellofemoral joint occurs via the interplay of soft tissue structures, bone and joint surfaces, and overall lower extremity biomechanics.[9] Clearly more than excessive pronation of the subtalar joint and a weak vastus medialis muscle contribute to this problem.

Senavongse and Amis view the stabilizers of the patellofemoral complex as 1) active stabilizers—the quadriceps muscles, 2) passive stabilizers—the retinaculum and ligamentous structures, and 3) static stabilizers—the joint surfaces.[9] Structures providing medial stability to the patella include the VMO, medial patellofemoral ligament and, to a small degree, the medial retinaculum.[8] The patella itself is found to have the lowest amount of medial stability at 20 degrees of flexion.[9] This is only part of the story but gives a larger picture than

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TABLE 2

Outline of Therapy for PFPS

Relative or Absolute Rest
Pain reduction with medication (NSAIDs)

For 8-12 Weeks the following exercises:
- Therapeutic Exercise Program Strengthening the Quadriceps
  - Straight leg lifts—Start with 3 sets of 10 reps each side, work up to 10 sets of 10 reps.

Hip and Core Muscle Strengthening (Gluteus Medius, Maximus)
Strengthen Calf Muscles—standing with knee straight
Strengthen Gluteal Muscles—standing, knee as straight as possible.

Posterior Stretching

Additional Therapy:
- Patellar Tendon and Peripatellar Massage and Manipulation
- Taping or Bracing

Upon return to running:
- Easy graded return.
- Avoid speed work
- Avoid down hills
- Proper shoes for biomechanical needs of lower extremity
- Orthotics, if indicated

Gradual return to speedwork
Continue to be wary of downhill running

we usually consider.

Quadriceps weakness is most often addressed in rehabilitative exercises. While the VMO is often mentioned as the weak link within the quadriceps, the VMO cannot be directly and independently strengthened using most exercise programs. The only method that has emphasized the VMO over the VL has been with the use of biofeedback. The concept that the VMO only comes into play in the end range of motion and exercises that emphasize motion at the end range of extension isolate the VMO has been found to be false. While the VMO[10,11] is known to be the primary muscular stabilizer of the knee, it functions throughout the range of flexion and extension of the knee.

Hip abductor weakness has recently been found to be associated with PFPS and may be another area for therapeutic intervention.[12,13] Confirmation of this suspicion was made by Cichanowski, who noted significant differences in hip abductor and external rotator strength between limbs suffering from PFPS and the normal limbs.

Abnormal pronation of the subtalar joint was first mentioned as a contributing factor to this condition in early lectures and books of George Sheehan, M.D.[14] More recent research has confirmed Sheehan's early feelings on this and reaffirmed his suggestion that foot orthoses were likely to be effective.[15]

Chondromalacia is a surgical observation, and no longer a term applied diagnostically to this clinical condition.

The pain of PFPS appears to be caused, in part, by overload of the richly-innervated subchondral bone, the extensor retinaculum, and the infrapatellar fat pad. Chondromalacia is a surgical observation, and no longer a term applied diagnostically to this clinical condition.

Treatment of PFPS (Table 2)

Treatment for this condition includes a decrease in running via relative or absolute rest. NSAIDs can be used to reduce pain. It is important to strengthen the quadriceps by a carefully instituted program. Straight leg lifts result in the least amount of force occurring at the patello-femoral joint while strengthening the quadriceps. Core body strengthening has also been recommended.

Lower extremity biomechanics and foot structure should be assessed. Recommendations for proper shoes, and orthotics, if deemed necessary, should be made. Orthotics have been found to be helpful in the treatment of PFPS.[16] Resumption of running should be gradual with incremental increases in at first distance, and later speed work.

Iliotibial Band Syndrome (ITBS)

Twenty years ago iliotibial band syndrome (ITBS) was an infrequent diagnosis. More recently it has become a substantial cause of pain in runners. The change in training and the characteristics of many of today's long distance runners, including the "sudden marathoner syndrome", is the most likely cause of the dramatic increase in this malady. It has become clear that ITBS is associated with weak hip abductor muscles. Weak hip abductor muscles result in the recruitment of the muscles which insert into the iliotibial band to assist with hip abduction. This causes an increase in tension developing within the ITB itself.

Keep in mind that running is a one-legged exercise and it is important to keep the pelvic bone level through the work of the gluteus medius. There is the possibility that what occurs within the ITB is a tendinopathy. Most of the historical literature refers to this syndrome as a "friction band syndrome" and inflammation was often mentioned as contributing to the pain.[17] In spite of this terminology, no studies documenting inflammation within the tendon turned up on a Medline search.

More recently further anatomical studies have suggested that pain in the iliotibial band area is not caused by friction.[18,19] Fairclough raises the question "Is the iliotibial band syndrome really a friction syndrome?"[18,19] He contends that the ITB is firmly attached to the femur and is not anatomically capable of moving forward and backwards over the lateral epicondyle of the femur. Recent cadaver studies and MRI studies have failed to document the expected evidence for friction or for a primary anatomical bursa. Instead an area of compres-

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TABLE 3

Treatment Outline for ITBS

Relative or absolute rest

Strengthening:
Hip Abductor Muscle Strengthening—Standing hip tilts on one leg to isolate hip abductors.

Stretching:
Side bends to stretch tight lateral structures, hip capsule and fibers inserting into the iliotibial band.

Ancillary stretches—adductors and rotators of hip.

Advanced stretches:
Stair dip
Stair Strides

Optional:
Ice
Foam roller

sion has been noted which seems to affect the richly vascularized and thoroughly innervated fat below the tendon. On MRI a zone of signal intensity abnormality was found in this area and felt to be associated with intermittent fat compression.[19,20]

Quadriceps weakness is most often addressed in rehabilitative exercises.

Tension within the iliotibial band was cited by Noehren et. al. as a contributing factor, with compression occurring rather than friction:

"The development of iliotibial band syndrome appears to be related to increased peak hip adduction and knee internal rotation. These combined motions may increase iliotibial band strain, causing it to compress against the lateral femoral condyle. These data suggest that treatment interventions should focus on controlling these secondary plane movements through strengthening, stretching and neuromuscular re-education."[21]

Muscular and neuromuscular fatigue and the resulting kinematic changes that occur during long distance running may also contribute to this and other overuse injuries. Impact shock, while more often studied, is not a factor. Instead, increased hip adduction, an increase in knee flexion at heel strike, and maximum knee internal rotation velocity were found to be higher at the end of a run in individuals with ITBS.[22] Miller's computer modeling system also indicated that tension would be greater in the ITB for patients throughout the stance phase of the running gait cycle.

Anatomical Considerations

The iliotibial band (ITB) is a continuation of the tensor fascia lata as a thickening of the lateral fascia of the upper leg. A significant portion of the gluteus maximus inserts into the ITB. Along the course of its descent down the leg there are connections to the linea aspera of the femur. The ITB fans out distally to insert on the lateral aspect of the patella, the lateral retinaculum and Gerdy's tibial tubercle. Functionally the tensor fascia lata, gluteus medius and gluteus minimus function as hip abductors.

Diagnosis of ITBS

Iliotibial band syndrome (ITBS) is a clinical diagnosis which is made in the presence of lateral knee pain in the general region of the lateral femoral epicondyle, with tenderness and pain upon compression of this area while the knee is flexed and extended. Tenderness in adjacent structures, including the lateral collateral ligament of the knee and at the lateral joint line, should not be present. In early stages, the pain might only manifest itself while running or following a run.

Evolution in Conceptualization of ITBS (Summary)

The ITBS seems to be primarily caused by overuse in the presence of muscular imbalance. Weak hip abductor muscles are the culprit. ITBS, in most cases, is not a friction syndrome with a "popping" of the tendon over the femoral epicondyle. Instead, there is a compression in this region that most often affects the fat tissue overlying the femoral epicondyle. Clinically, pain while walking and tenderness is not always found in the early stages. Tension does develop within the band and early stage tendinopathic changes may be present, but no research has demonstrated this yet.

Treatment of ITBS

Relative or absolute rest is an important component of the treatment plan for any of these running-related overuse syndromes. Directly addressing the cause of the ITB syndrome, in most cases, seems to give significant clinical success. Weak hip abductor muscles have been directly implicated in this condition. An additional factor may be tendon and capsular tightness. A treatment program should include hip abductor strengthening in conjunction with lateral hip capsule and soft tissue stretching.

NSAIDs or ice may be used to reduce discomfort. Foam rollers and

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TABLE 4

Classification of Injuries to the Achilles Tendon and Surrounding Structures

Zone 1: Non-insertional Achilles Injuries
- Achilles paratendinopathy
- Achilles tendinopathy
- Achilles tendinosis
- Achilles tendon rupture

Zone 2: Insertional Achilles Injuries
- Achilles insertional tendinopathy
- Haglund's Triad
- Achilles insertional calific tendinopathy
- Retrocalcaneal bursitis
- Pre-achilles tendon bursitis
- Avulsion fracture of calcaneus

Zone 3:
- Partial tears/tears of muscle-tendinous junction
- Strain of medial head of gastrocnemius muscle
- Plantaris strain/rupture

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tissue-mobilizing massage have been recommended. Abnormal biomechanical functioning of the foot and leg should be addressed, including limb length discrepancy, but there is no evidence that either motion-control shoes or excessively cushioned shoes contribute to this condition or help to alleviate it. Table 3 outlines a treatment program for ITBS.

Achilles Tendinopathy

Anatomy

The Achilles tendon is the continuation of the gastrosoleus complex of muscles and is at the terminal aspect of this multijoint system. The gastrocnemius begins above the knee joint, the soleus below. The joints on which they have a direct impact include the knee joint, the ankle joint, and the subtalar joint. The most distal aspect of the insertion becomes contiguous with the plantar fascia. The complex anatomy of the insertion is described below as an enthesis organ.

Pathology

For years, almost all tendon pain was lumped into the category of tendonitis. It was mistakenly believed that inflammation was the underlying process causing the pain and pathology in what was called Achilles Tendinitis. Recently, the term tendinopathy has become the lump-all category for tendon pathology. This term includes early stage tendinitis, paratendinitis, and later stage chronic tendinosis. Histological studies have demonstrated that those with chronic tendon pain do not have inflammatory changes in the affected tendon, but rather degenerative changes.[23]

The term tendinosis is used specifically to apply to tendons with known chronic degenerative changes. The term tendinopathy itself does not have this connotation and is well used to apply to overuse tendon pain and swelling in the absence of a histopathological diagnosis (Maffulli, Khan, Paddu). In long-standing tendinopathy, at surgery, the tissue demonstrates the appearance of mucoid degeneration. The tissue appears brown or yellow and shows disorganization, and an apparent lack of well-defined tightly bundled collagen fibers. Microscopic examination reveals degenerative changes and concomitant fibrosis.[24] Ultrasound examination has previously demonstrated neovascularization in the injured tissue.

Achilles tendon disorders are often divided into three zones: 1) Noninsertional—the tendon proper (and paratenon), 2) conditions affecting the tendon insertion, and 3) proximal—at the muscle tendon interface and more structures proximal.[25,26] An outline based on Puddu, et al., and Werd is seen in Table 4.

Evolution of Thought in Insertional Enthesopathy

Tendinopathy may occur at the insertion of the Achilles tendon or within the main body of the tendon itself. It is possible that these two differing areas may result from diverse predisposing factors. It has been suggested that repeated stresses that are well within a clinical and functional range may create the pathology in a manner similar to the manner in which bone stress reactions may occur.[27] The major contributing causes cited include overuse, abnormal biomechanical factors, fluoroquinolone antibiotics and corticosteroid use.

TABLE 5

Differential Diagnosis of Insertional Enthesopathy

- Seronegative spondyloarthropathy
- Gout
- Systemic steroid caused
- Fluoroquinolones
- Familial hyperlipidemia
- Sarcoidosis
- Diffuse idiopathic skeletal hyperostosis

At the insertion of the Achilles tendon, a variety of conditions may occur. In addition to insertional tendinopathy of the Achilles tendon, one may find retrocalcaneal bursitis, Haglund's deformity, and pre-tendinous bursitis. When the Haglund's deformity is symptomatic,it is usually found as a triad of insertional tendinopathy of the Achilles tendon, a prominent posterosuperior calcaneal process, and retrocalcaneal bursitis. Insertional tendinopathy can occur in the absence or presence of calcaneal bursitis. Numerous studies indicate that insertional tendinopathy occurs in up to 5%—20% of Achilles tendon overuse injuries.[28] Older individuals appear to be at higher risk for this injury.[28]

The insertion of the Achilles tendon is more complex than we thought for many years. At the osteotendinous junction of the Achilles tendon, histological examination reveals tendon, fibrocartilage and bone. There are three types of cartilage found here: sesamoid, periosteal, and enthesial fibrocartilage. The term "articular enthesis organ" has been applied to the insertion of the Achilles in view of the complexity of its insertion (with the presence of a complex of fibrocartilages, a fat pad, and bursae). 29) The sesamoidal fibrocartilage is located at the deeper portion of the tendon and is termed such since it is within the tendon. The periosteal fibro-

ITBS is associated with weak hip abductor muscles.

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cartilage is located on the opposing superior tuberosity of the calcaneus and is termed such since it is a modification of the periosteum. While rheumatologists began viewing this insertion as fundamentally different, the concept of enthesis organ is only slowly breaking ground in the discipline of sports medicine. What has been termed an insertional tendinopathy might more correctly be called an insertional enthesopathy.

An enthesis is by definition the insertion point of a tendon, ligament, fascia or articular capsule into a bone. This area has been found to be impacted by drug-induced enthesopathies by fluoroquinolone antibiotics (which may also affect the tendon prior to its insertion). In the case of the Achilles complex, the combination of tendon, fibrocartilage, fat pads, and bursa may be affected at any of those areas, or in multiple tissue types, which alters function and forces.[30]

Fibrocartilage functions to resist shear and strains at the enthesis. This new conceptualization has great and significant future implications for understanding of forces, function, and treatment of Achilles tendon insertional disorders.

Bone spurs which form at this location have been noted to not be within the substance of the tendon itself. The relationship of the "spurs" here to the fibrocartilage remains to be detailed.

Pain is present in the back of the heel. The pain is aggravated by running uphill, and by prolonged walking, standing, or running. Table 5 offers possible differential diagnoses of insertional enthesopathy of the Achilles tendon.

Tendinopathy may occur at the insertion of the Achilles tendon or within the main body of the tendon itself.

Non-Insertional Achilles Tendinopathy

The Achilles tendon is most often affected in non-insertional tendinopathy at a location 2 to 6 cm. proximal to its insertion into the calcaneus. The paratenon substitutes for a true gliding synovial sheath. It is comprised of fatty areolar tissue surrounding the Achilles tendon and is organized into a mesotenon. Werd has pointed out a clinical manner of distinguishing tendinopathy from paratendinopathy.[25] Upon palpation of the painful area, if the foot is dorsiflexed and plantarflexed and it is noted that the area of maximal tenderness does not move, the presumption is that the site of tenderness is within the paratenon itself, which is firmly attached to the surrounding tissues and does not move. If the tenderness shifts with dorsiflexion and plantarflexion, the tenderness is deemed to be within the tendinous tissue.

Additional Calf Injuries

Injuries to runners are also noted at the myotendinous junction, within the calf muscle itself, and to the plantaris.

Approach to Treatment

Conservative treatment is directed to decreasing strain on the tendon and allowing the tissue to repair itself. Relative rest, absolute rest or the use of a pneumatic walking boot may be required. NSAIDs are often used, and offer a decrease in symptoms and a more normal gait and motion pattern through pain reduction, although their anti-inflammatory effects are no longer thought to be of assistance.

Cross friction massage and ice application are often used. The modalities of ultrasound and high voltage galvanic stimulation may also be helpful. Heel lifts, and possible custom functional foot orthotics may also assist in reducing mechanical strain.

After the pain is reduced, a gentle and gradual return to activity and then speed is helpful. Avoiding hills or inclined treadmills is advised. Excessively cushioned shoes, which will increase the eccentric forces within the tendon, should be avoided.

Alfredson has proposed the use of eccentric stretching and strengthening with heavy loads, which when performed as described, is meant to cause pain.[31,32] Similar approaches have been suggested for several other tendinopathies, including patellar tendinopathy. Two review articles examining eccentric strengthening as treatment for a number of tendons were recently published.[33] The authors thought, in general, that

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TABLE 6

Treatment Suggestions for Achilles Tendinopathy

Relative rest, Absolute Rest. Activity must be reduced to prevent continued, repetitive overloading of the injured tissue.

Immobilization vs. Eccentric Stretching

Ice—symptomatic
Heel lift to reduce strain deformation and loads at the insertion.

Running alterations:
Avoid over cushioned shoes, which will increase the eccentric contraction of the calf muscle.

Avoid uphill running. Avoid incline on treadmill. Avoid over striding which increases the foot to leg angle in dorsiflexion.

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the evidence was weak and underpowered.

The current literature was described as having a "dearth of high quality research in support of the clinical effectiveness of EE (eccentric exercise) over other treatments in the management of tendinopathies."[33] Kingma, et al. agreed, that while the technique appeared promising "large methodologically sound studies ….are warranted."[34]

For severe, chronic, and unremitting tendinosis, surgery remains an option. The described surgical procedures include stripping of the paratenon, linear tenotomies, and excision of non-viable tissue.[28,35]

Treatment for Achilles tendinopathy is outlined in Table 5.

Stress Fractures and Stress Reactions of Bone: A Chronic Repetitive Stress Injury

Definition

The term stress fracture, while commonly used, does not represent the nature and diversity of this frequently found overuse injury. Repetitive stress injury (RSI) of bone, or stress reaction, are both better suited to describe this injury. The majority of injuries that are diagnosed as stress fracture do not demonstrate a fracture line and should not be termed a fracture. More severe stress injuries are similar to what is termed fatigue fractures in other materials. It should be noted that bone has been found to fail more frequently in tension than in compression.

In runners, the most frequently injured bones are the tibia, metatarsals, and calcaneus. The available data on the other bones offers varying data, but virtually all lower extremity bones may be affected, including the femur, navicular, fibula, cuboid, and cuneiforms.

TABLE 7

Differential Diagnosis of Lower Extremity Stress Fracture

Conditions that may appear to be a stress fracture

- Patellofemoral pain syndrome
- Osteoid osteoma
- Osteomyelitis
- Osteosarcoma
- Ewing Tumor
- Bone metastases
- Osteochondral fracture
- Accessory Navicular (painful)
- Inflammatory disorders
- Medial Tibial Stress Syndrome

Injuries of this nature were first noted by Briethaupt, a military physician, in 1855, who noted swelling and pain in the feet of Prussian military recruits.[36] In 1897, radiographic examination revealed the nature of the injury and "march fracture" entered the literature as reported by Stewchow.[37] A number of studies have followed which detail this injury in both a military population and within the athletic population. Estimates of the occurrence in the running population is that as many as 10% or more of injuries may be stress reactions in bone.[38]

An enthesis is by definition the insertion point of a tendon, ligament, fascia or articular capsule into a bone.

Background

Bone is a dynamic structure. As a biological material, it is subject to change as a result of environmental stimuli and in response to genetic predilection. The initial injury might be a biological or biochemical abnormality or failure at the cellular or bone multicellular unit (BMU) level. Bone adapts to many levels of intermittent, repetitive compressive and tension strains by an increase in density. In the presence of abnormally high and repetitive forces, the ability to heal by microdamage repair is not adequate, and more damage than repair occurs.[39] In short, an excessive amount of stress or repetitive stress is occurring without the bone having adequate rest to allow for adaptation to the stress. In essence, the stress that creates these injuries is too much, too soon for the bone.

It is important to keep in mind other contributing factors in the development of RSI of bone. Besides training errors and the biomechanical causes that we usually think of, a variety of systemic conditions can contribute to this injury. These factors include osteopenia, osteoporosis, other metabolic bone disorders, hormonal abnormalities, inadequate nutritional intake, and collagen disorders. In women, amenorrhea or oligomenorrhea may lead to deficient estrogen and low bone mineral density. The female athlete triad includes low bone density by definition, along with disordered eating and amenorrhea.[40] Overtraining may lead to decreased testosterone levels in men resulting in osteopenia. Patients of either gender having multiple stress fractures should likely have a bone density (DEXA) scan performed.

Diagnosis

Initial suspicion of a repetitive stress injury of bone (RSIB) or stress reaction often leads to the clinical diagnosis. The patient's history of injury, changing pattern of exercise, physical examination, and imaging studies lead the practition-

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er to the diagnosis. The classical presentation is in an athlete presenting with sudden onset of pain during or after a run. Usually, there has been a discernable change in training habits. Mileage may have increased, twice a day runs begun, speed work initiated, a new pair of running shoes used, or there has been aging of running shoes along with any other contributing factor. Physical examination will usually reveal a discrete area of tenderness. Certain bones are not as accessible to palpation as others are. The pelvic bones, femur, talus, and midtarsal bones are notoriously difficult to palpate and examine clinically. So, a high level of suspicion must be present to reach the diagnosis particularly in the rearfoot and midfoot; and the use of imaging should be considered.[41]

On the tibia, as is mentioned elsewhere in this article, a horizontal line of tenderness is often the differentiating clinical sign from the vertical tenderness of medial tibial stress syndrome. Immobilization in a pneumatic walker for four to six weeks or more is often helpful for tibial stress fractures, and a variety of other stress injuries of bone.[42] Calcaneal stress fractures may be suspected when there is tenderness upon lateral compression of the body, rather than at the medial calcaneal tuberosity or tenderness that is only plantar to the calcaneus.

In a group of military recruits, the majority (56%) of calcaneal stress reactions occurred in the posterior third of the bone and 79% occurred in the upper half of the calcaneus.[43] Earlier reviews noted that the injury occurred primarily in the posterior aspect of the calcaneus, but Sormaala notes the importance of suspecting a stress reaction in the more anterior portion of the bone. Stress fractures of the tarsal navicular should be suspected when there is dorsal tenderness extending proximally to distally. In addition to simple tenderness, tenderness to percussion or to the vibrations of a tuning fork have been used as pathognomonic signs.

The Achilles tendon is most often affected in non-insertional tendinopathy at a location 2 to 6 cm. proximal to its insertion into the calcaneus.

Diagnostic imaging includes radiographic evaluation, technetium-99 bone scan, and MRI. Often, an injury is not visible on radiographic examination. Bone scintigraphy is considered sensitive, while MRI is considered to be both sensitive and specific.[41] At early stages, the MRI shows marrow edema as an increased STIR signal and in fat-suppressed T2 images. On T1 sequences, a decreased signal is noted.[44] As the injury progresses to a stage of increasing severity, a low signal fracture line and bone callus may be visible.

A number of conditions may confound diagnosis and appear similar to stress fracture on certain imaging studies (Table 7). In other cases, asymptomatic bone marrow edema may be visible on MRI.[41]

Treatment

Conservative treatment works well for most RSI of bone. The key is finding the appropriate mechanical treatment to eliminate the pain of weight bearing. With the elimination of pain, the forces should be sufficiently low for healing and remodeling to take place. Weight-bearing exercise should be avoided. Multiple authors have recommended the use of a pneumatic walker for tibial stress fractures.[42,45] This may be used alone or with crutches, as needed. A cam walker, pneumatic walker or low pneumatic walker may alleviate pain faster and be clinically superior to a post-operative shoe for stress reactions of the

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TABLE 8

Pribut Pain Staging of Overuse Injuries in Athletes

Stage 0—No pain is present before, during or after activity. Minor discomfort may be experienced at various times during training or racing.

Stage 1—Pain or stiffness after activity. The pain is usually gone by the next day.

Stage 2—Mild discomfort before activity that goes away soon after exercise is commenced. No pain is present in the latter part of the exercise. Pain returns after the exercise is completed (starting within 1 to 12 hours later and lasts up to 24 hours).

Stage 3—Moderate pain is present before sport. Pain is present during sport activity, but is somewhat decreased. The pain is an annoyance which may alter the manner in which the sport is performed.

Stage 4—Significant pain before, during, and after activity. The pain may disappear after several weeks of rest.

Stage 5—Pain before, during, and after activity. The athlete has stopped their sports participation because of the severity of the pain. The pain does not abate completely even after weeks of inactivity.

metatarsal area, and for other foot stress reactions.

During recovery, one should guide the athlete to appropriate cross-training activity. Swimming, bicycling, and maintenance of upper body strength should be implemented. Lower extremity exercises should be chosen as appropriate, and if deemed to not risk delayed healing or further injury.

A phased return to activity, allowing sufficient time for healing, is the key to a successful return to activity. In clinical practice, the author has found that weaning from the pneumatic walker seems to lessen the time to comfortable exit from the walker and prevent pain from returning and the necessity of returning to the use of the pneumatic walker. Most lower-extremity stress reactions take between 8 and 17 weeks for recovery.[38]

Medial Tibial Stress Syndrome (Shin Splints)

Shin splints, the term that just won't die, is gradually fading from use. The terms anterior shin splints, posteromedial shin splints, and a host of other terms came into vogue in the 1970's and 1980's. As long ago as 1967, Slocum encouraged the abandonment of the term shin splints from the medical literature.[46] Ten years later, James also supported the efforts to eliminate the term suggesting posterior tibial syndrome as an alternative.[47]

More recently the improved descriptive term medial tibial stress syndrome is coming into common use. The term was first applied by R. Drez and popularized by Mubarak in 1982.[48] This term is appropriate to use in the absence of a stress fracture or an exertional compartment syndrome. The older term, shin splints, never made clear what part of the leg was affected. Some have considered the shin to be the front part of the leg below the knee, the front part of the tibia, or the lower leg itself. We will omit consideration of anterior tibial leg pain and review the medial portion of the tibia that the term medial tibial stress syndrome (MTSS) refers to.

In runners, the most frequently injured bones are the tibia, metatarsals, and calcaneus.

Historically included entities within the realm of MTSS include: periostitis, traction periostalgia, tendinopathy, periosteal reaction, and fatigue failure of the connective tissue connecting muscle to bone.[49]

Where is the Pain? Symptoms and Description

By definition, the pain in MTSS occurs at the posteriomedial aspect of the tibia. Edwards has detailed an algorithmic approach to diagnosis and confirmatory tests to differentiate MTSS from nerve injury and compartment syndrome.[50] He suggests that MTSS may occur more often in the distal third of the tibia, and one should consider stress fracture more proximally. While his flow chart is interesting, it is severely flawed. MTSS is considered as a strong possibility with pain at rest in the presence of palpable tenderness. In the absence of pain at rest, but with palpable tenderness, he considers common or superficial nerve entrapment as the likely cause of lower limb pain.

Unfortunately, in the context of treating runners, this makes little sense. He notes elsewhere in his article that the pain in the early stages does fade with rest. Previous observations of overuse injuries and pain-staging better and more accurately define the pain seen with this condition.[51-53] See Table 8 for a staging of pain occurring in overuse injuries. Nerve compression or entrapment syndromes are usually considered when the history includes the description of pain that is burning in nature and may be associated with a subjective or objective observation of numbness. Exertional compartment syndromes, which present with a somewhat different set of symptoms, will not be reviewed within this paper.

Michael and Holder[54] described the clinical characteristics of early MTSS as including:

1) Induced by exercise, relieved by rest;
2) Dull ache to intense pain;
3) Tenderness posterior medial border of tibia;
4) Pronated feet;
5) Normal x-ray films.

Risk Factors

Thacker[49] reviewed the avail-

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TABLE 9

Selected Entities Causing Plantar Heel Pain

Mechanical
- Plantar Fasciopathy

Repetitive Trauma
- Stress fractures
- Rupture of plantar fascia

Neurological
- Posterior tibial nerve—tarsal tunnel syndrome
- Medial calcaneal nerve
- Medial plantar nerve
- Lateral plantar nerve

Arthritic
- Seronegative Spondyloarthropathies
- Rheumatoid Arthritis
- Fibromyalgia
- Gout

Misc.
- Infection
- Bone cyst or tumor
- Apophysitis

able epidemiological literature and found a general consensus that there were a variety of potential risk factors detailed in the literature. The risk factors most often cited include: younger age, female gender, change in distance, frequency, speed, surface of runs, change of running shoes, excess pronation, and a previous history of injury. As is often the case in the medical literature, contrary studies are often found. Contrary studies are also cited on age, gender, mileage, hill running, running surface, previous activity level and flexibility. In our constant quest for high level studies that are reliable and meet the requirements of evidence-based medicine, we often find ourselves wandering in the mire of the literature and decide that the evidence is thin for much of what we think we know. We remain with the knowledge of the importance of having a basic understanding of causative factors in the context of carefully assessing an individual patient.

Imaging

While clinical signs and symptoms will lead you to the diagnosis in many cases, it still may be helpful to rule out a stress fracture. Radiographs should be taken in questionable cases, but they are often insufficiently sensitive to show many stress fractures and offer no information that would demonstrate MTSS.

Both triphasic bone scans (diffuse, superficial, linear uptake) and MRI (diffuse linear signal on T2) have been used to demonstrate stress fracture and, in many cases, they may demonstrate linear patterns suggesting MTSS; although negative studies do not preclude the diagnosis of MTSS.

MTSS—Causes

There are a variety of theories of the pathogenesis of MTSS. Periostitis was one widely believed to be the cause of the pain, but histologically inflammation was not found.[55] Periostalgia has been applied to pain at this site in the absence of inflammation. Johnell, et al., found metabolic changes in bone with no inflammation and believed MTSS to be a stress reaction of bone. Other theorists have proposed traction injury at the posterior tibialis and/or soleus muscles.[54]

Bates in 1985 postulated that excessive pronation and eccentric contraction of the soleus and posterior tibial muscles were contributing factors in the development of MTSS.[56] Factors that increase bending moments or traction at these sites include a planus foot type, tarsal coalition, leg length inequality, and muscle imbalance.[57]

The tibialis posterior muscle origin has been noted to be in the upper two thirds of the interosseus membrane, medial fibula, and lateral tibia. It is somewhat proximal to where the bulk of the tenderness is usually noted clinically. Beck and Osternig performed cadaver dissections which demonstrated that the soleus, flexor digitorum longus and deep crural fascia were close to the usual areas in which symptoms were found and the posterior tibialis muscle was found a considerable distance proximally.[58] In spite of the downplaying of the tibialis posterior by its anatomical position, under eccentric contraction, Pribut postulates that it should still substantially increase the strain in the medial tibia.

Shin splints, the term that just won't die, is gradually fading from use.

Bouché and Johnson researched traction resulting upon the tibial fascia when forces are applied to the posterior tibial, soleus, and flexor digitorum longus tendons.[59] In their discussion, they noted that these muscles eccentrically contract during stance to counter midtarsal and subtalar joint pronatory forces, which earlier had been linked to MTSS.[60] Bouché and Johnson's study demonstrated a direct linear relationship between forces applied to those muscles and strain measured at the muscle bone interface, and the conclusion they reached was that "eccentric contraction of the superficial and deep flexor tendons of the leg is the key pathomechanical factor ..." in the creaton of MTSS.[59] Bouché also noted that exercising on hard floors had been found to increase eccentric contractions of these muscles. The research of Bouché sits well with the concepts earlier espoused by Michael, et al. in their article entitled "The Soleus Syndrome."[54] Michael's suggestion that the soleus could contribute to "shin splints" was based on cadaver, EMG, and muscle stimulation research.

Treatment and Prevention

Thus far, a number of studies have surprisingly failed to show prevention from graded increase in exercise programs. There are a number of possible experimental design measures that might show differences better, but at this point the evidence that would back up common sense is not there. Thacker notes serious "methodological flaws" in the studies he reviewed.[49]

It is important to include rest and relative rest at the top of recommendations. Two to four weeks of rest may alleviate much of the pain in early MTSS. Training alterations prior to the development of MTSS need to be carefully analyzed and recommendations should be made based upon this analysis. A biomechanical analysis of the lower extremity should be performed, and shoe and custom orthotic recommendations are made as needed.[50] Excessive pronation has been found to be a contributing factor.

NSAIDS, while not directly addressing inflammation, are useful adjuncts to pain control and allow the early resumption of normal motion patterns and strengthening and stretching exercises. Gastrosoleus stretching should be undertaken. Core muscle strengthen-

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ing is becoming increasingly used for a variety of lower extremity overuse injuries and should be evaluated for strength deficit.

During the rest period, the athlete will need to be given a program of alternative exercise. This may consist of low impact cardiovascular exercises such as swimming, stationary bicycle, or pool running. It may be supplemented with upper body weight training. Gradual return to activity and incrementally building up distance and intensity should assist in a smooth return to normal activity.

Plantar Fasciopathy, Plantar Heel Pain Syndrome

Plantar fasciitis is one of the most frequently found foot injuries among runners. As with several other entities, we are discovering that many of the terms we have called this by are likely incorrect. The heel pain we most often see has been called many things including plantar heel pain, heel spur syndrome, and recently plantar heel pain syndrome.[61] In the term fasciitis, the -itis ending denotes an inflammation. Perhaps if we redefined -itis, we could still use fasciitis and tendonitis, but the death of the term plantar fasciitis is rapidly approaching.

Lemont examined specimens and found no inflammation present. Instead, he found changes analogous to that found in tendinosis: myxoid degeneration, collagen degeneration, increased vascularization, and vascular engorgement of the adjacent bone marrow.[62] Evidence of inflammation was not seen. While Lemont indicated that plantar fasciitis should be considered plantar fasciosis, this latter term is probably best termed fasciosis after biopsy, and plantar fasciopathy is a more suitable term.

The term plantar heel pain syndrome can be used to include conditions of pain in this region in both the absence and presence of an inferior calcaneal spur.

The origin of the plantar fascia is an enthesis similar to the Achilles tendon. Fibrocartilage is found at its site of origin. Growing heel spurs appear to take shape deep to the plantar fascia and have been noted to grow within developing cartilage via endochondral and intramembranous ossification, most likely at the site of the enthesis and in close association with the flexor digitorum brevis.[63] New thinking is that this is not a traction injury but an enthesophyte formed in the enthesis via stimulation of the bone by stress. Pribut has hypothesized that even in the absence of direct traction injury at the site of origin of the plantar fascia, there will be sufficient strain in the enthesis and in the calcaneus to stimulate bone and cartilage production and sufficient strain to also create other calcaneal stress injuries. Early changes occurring in the enthesis fibrocartilage near the calcaneal surface include the appearance of cartilage cell clusters and longitudinal fissure formation with erosion of subchondral bone.

By definition, the pain in MTSS occurs at the posteriomedial aspect of the tibia.

Symptoms

Pain upon arising in the morning is one of the hallmarks of plantar heel pain syndrome. The pain is noted to be on the plantar or plantar medial aspect of the heel. Tenderness is usually found upon palpation of the medial calcaneal tuberosity. It is important to distinguish plantar fasciitis from a tear of the plantar fascia, which most often occurs 2-6 cm anterior to the origin of the plantar fascia and from a calcaneal stress fracture. The tenderness of most calcaneal stress fractures is linear and found on the body of the calcaneus, often on both the medial and lateral sides. Nerve entrapment may also cause pain in this region. Table 9 details some of the clinical entities that can cause plantar heel pain.

Treatment

Entire issues and seminars are devoted to plantar heel pain and its treatment. We will briefly review current therapy. A survey of members of the American Academy of Podiatric Medicine detailed the most common treatments that they employ for plantar heel pain syndrome.[61]

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TABLE 10

Outline of Treatment Recommendations for Plantar Heel Pain Syndrome

Relative or Absolute Rest
Stretching
Cryotherapy
NSAIDs (for pain, not inflammation)
Night splints
OTC Insert
Custom Foot orthoses
Shoes—torsion & flexion stability
Check Stability of running and walking shoes, replace if necessary
Avoid barefoot walking
Avoid calf raises and stair dips and other forefoot-only contact exercises

Injuries...

For early heel pain of less than six weeks duration, the most frequent recommendations were for avoidance of walking barefoot or walking in flat shoes, over the counter inserts, regular calf stretching, cryotherapy, non-steroidal, anti-inflammatory drugs (NSAIDs), and strapping of the foot. At an intermediate stage, when pain has been present for six weeks to six months, the respondents usually recommended a custom orthotic. Corticosteroid injections were also frequently recommended—although, in view of Lemont's findings, the rationale of such injections needs to be reconsidered.[62] Night splints were also sometimes used.

Additional measures recommended for late stage plantar fasciopathy include immobilization via the use of a cast or pneumatic walker, plantar fasciotomy, and extracorporeal shockwave therapy.

It is important to examine your patient's running shoe to make certain that flexion and torsional stability is present. If the shoe is excessively flexible, more forces will be created within and near the plantar fascia, most likely via the windlass effect. If the pain has been severe enough to cause the patient to miss several weeks' worth of running, a slow and gradual return is important to avoid recurrence of injury or a new overuse injury. Intrinsic muscle strengthening and calf muscle stretching need to be performed by the athlete regularly. An outline of treatment recommendations follows in Table 10.

Summary

The study and quest for understanding athletic injuries is a lifelong undertaking. We have tried to give a picture of some of the most common running injuries in this article and to detail the evolution of thought that has occurred over the last few decades on these commonly seen but still little understood clinical entities. We hope your interest has been piqued to continue learning about these maladies and that you develop a method of assessing the literature to better treat your patients. To enhance your knowledge of sports medicine in a face-to-face setting, I encourage you to attend lectures on these topics. Venues which include information of interest to the podiatric sports medicine physician include the Annual APMA Scientific Seminar featuring a track put on by the AAPSM, regional meetings which feature the AAPSM and a variety of lecture series at the podiatric medical colleges which are jointly put on with the AAPSM. Information on these meetings can be found at the website of the AAPSM (www.aapsm.org). ■

The term plantar heel pain syndrome can be used to include conditions of pain in this region in both the absence and presence of an inferior calcaneal spur.

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EXAMINATION

Continuing Medical Education

See answer sheet on page 133.

1) Stress fractures occurring in the lower extremity in runners are best demonstrated using:
   A) a bone scan
   B) computed tomography
   C) x-ray
   D) tuning fork

2) Diffuse activity along the posteriomedial aspect of the tibia visible on bone scintigraphy probably indicates:
   A) osteogenic sarcoma
   B) stress fracture
   C) medial tibial stress syndrome
   D) osteomyelitis

3) In reference to the impact on the patellofemoral complex, the vastus medialis oblique is:
   A) a static stabilizer
   B) a dynamic stabilizer
   C) a passive stabilizer
   D) a destabilizer

4) The patella has the least amount of medial stability at:
   A) zero degrees of flexion
   B) 20 degrees of flexion
   C) 45 degrees of flexion
   D) 90 degrees of flexion.

5) Factors considered important to the development of patellofemoral pain syndrom include:
   A) abnormal pronation of the foot
   B) patella alta
   C) weak hip abductor muscles
   D) all of the above.

6) Pain that develops after running in the anterior region of a patient's knee is most likely to be what is appropriately termed:
   A) Runner's Knee
   B) Patellofemoral pain syndrome
   C) chondromalacia patellae
   D) runner's meniscus

7) Evidence in studies has indicated that a large contributing factor to iliotibial band syndrome is:
   A) weak hip abductor muscles
   B) over pronation of the foot
   C) high arches
   D) soft shoes

8) The pain of iliotibial band syndrome is most often experienced in the region of the:
   A) anterior knee
   B) posterior aspect of the knee
   C) medial aspect of the knee
   D) lateral aspect of the knee.

9) The most frequently occurring Achilles tendon injuries in runners are best termed
   A) Achilles tendonitis
   B) Achillocytis
   C) Achilles bursitis
   D) Achilles tendinopathy

10) All of the following types of footgear could aggravate pain in the Achilles tendon area except:
   A) negative heel shoes
   B) firm heel shoe, flexible at ball, with 1/4" heel lift
   C) well-cushioned shoes
   D) shoes with a stiff and hard-to-bend sole.

11) The insertion of the Achilles tendon and the plantar fascia are similar in that they both:
   A) insert into the talus
   B) are both improved with stiff running shoes
   C) are improved by jumping jacks and running in sand
   D) are entheses

12) The histological findings of tendinosis include:
   A) myxoid degeneration
   B) parakeratosis
   C) inflammatory exudates
   D) copius lymphocytes

13) Stress fractures of the tibia do not usually demonstrate:
   A) horizontal line of tenderness
   B) diffuse linear vertical uptake on scintigraphy
   C) negative findings on x-ray
   D) focal area of concentrated uptake in proximal 1/3 of tibia on scintigraphy

14) In the detection of stress fractures of the lower extremity, the following imaging study is considered sensitive and specific:
   A) Te-99 Bone Scinigraphy
   B) MRI
   C) Ultrasound
   D) X-ray

15) Pain and tenderness at the posteriomedial aspect of the tibia in runners:
   A) is best treated with corticosteroid injections
   B) is most often a stress fracture
   C) is caused by a tight or a weak anterior tibialis muscle
   D) often falls into the category of posterior tibial stress syndrome

16) The following statement about patellofemoral pain disorder is false:
   A) the preferred name of

Continued on page 132

Continuing Medical Education

EXAMINATION

(cont'd)

this condition is anterior knee pain
B) pronation of the foot has been found in studies to be a risk factor
C) studies indicate weak hip abductors to be associated with PFPS
D) the subchondral bone, extensor retinaculum and infrapatellar fat pad are possible sources of pain in PFPS.

17) All of the following statements about the Achilles tendon insertion are true except:
A) Fibrocartilage is found at the insertion of the Achilles tendon
B) Sesamoidal cartilage is found at the insertion of the Achilles tendon
C) periosteal cartilage is found at the insertion of the Achilles tendon
D) articular cartilage is found at the insertion of the Achilles tendon

18) Surgical treatment of Achilles tendinosis most commonly would likely include any of the following except:
A) stripping of the paratenon
B) excision of non-viable tissue
C) Gastrocnemius recession (e.g., Strayer Procedure)
D) linear tenotomy

19) The tibialis posterior muscle originates from the:
A) distal medial aspect of the tibia
B) the proximal interosseus membrane, medial fibula and lateral tibia
C) proximal 2/3 of the tibia only
D) distal fibula and tibia

20) Although evidence based proof is weak, overuse running injuries are thought to be contributed to by all of the following except:
A) carbohydrate loading
B) overtraining
C) shoes losing shock absorption and wearing down substantially
D) starting marathon training never having run more than 20 minutes at a time

See answer sheet on page 133.

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ENROLLMENT FORM & ANSWER SHEET (cont'd)

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The Top Five Running Injuries Seen in the Office
(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

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