

Diagnosis of Medial Knee Pain: Atypical Stress Fracture About the Knee Joint

Michael D. Rosenthal, PT, DSc, SCS, ECS, ATC, CSCS¹

Josef H. Moore, PT, PhD, SCS, ATC²

Thomas M. DeBerardino, MD³

Study Design: Resident's case problem.

Background: A 19-year-old female, currently enrolled in a military training program, sought medical care for a twisting injury to her right knee. The patient reported her symptoms as similar to an injury she incurred 1 year previously while enrolled in the same military program. The patient's past medical history included a nondepressed fracture of the medial tibial plateau and complete tear of the deep fibers of the medial collateral ligament.

Diagnosis: Physical exam revealed nonlocalized anterior and medial knee pain without evidence of internal derangement. Initial knee and tibia radiographs were unremarkable. Referral for orthopedic physician evaluation resulted in concurrence with the therapist's diagnosis and plan of care, and the patient was allowed to continue with limited physical training demands. Despite periods of rest, the patient's symptoms progressively worsened upon attempts to resume running. The examining therapist referred the patient for magnetic resonance imaging (MRI) due to the patient's worsening symptoms, normal radiographs, and concern for a proximal tibia stress fracture. MRI revealed a severe proximal tibial metaphysis stress fracture.

Discussion: Stress fractures are commonly encountered injuries in individuals subjected to increased physical training demands. Early evaluation may not yield well-localized findings and may mimic other conditions. Nonmusculoskeletal conditions should be considered in the management of patients with stress fractures. This resident's case problem illustrates the importance of serial physical examinations and collaboration with other healthcare practitioners in the comprehensive assessment and management of a patient with a severe stress fracture. *J Orthop Sports Phys Ther* 2006;36(7):526-534. doi:10.2519/jospt.2006.2125

Key Words: bone injury, female athlete triad, tibia

With the advancement of physical therapists as direct-access providers of care,^{24,33} it is important to be aware of unusual musculoskeletal conditions, contributing factors that may predispose patients to incur such injuries, the process of diagnosis, and the effective management of these injuries. Although there are numerous reports on lower extremity stress fractures,^{2,3,6,21,28,29,52} reports on the clinical presentation of stress fractures about the knee joint are limited.^{14,18,26,49,50}

Contributing factors for stress fractures are well documented in the literature.^{3,4,28,29} Sudden changes in training volume is the most frequently cited cause. Additionally, low bone density, excessive lower extremity pronation, tibial bone width, gender, and low physical fitness are commonly associated with these musculoskeletal injuries.^{3,16,25,28} In the past decade, awareness of the female athlete triad and its relationship to musculoskeletal injuries, particularly stress fractures, has been widely reported.^{4,6,18,37}

Diagnosis of stress fractures begins with a heightened clinical awareness and commonly includes the use of imaging studies. Clinical diagnosis of a stress fracture can be complicated by the lack of a widely accepted physical examination test and the potential for nonmusculoskeletal conditions to masquerade as overuse conditions. Clinicians should consider the possibility of underlying inflammatory disease, vascular abnormalities, musculoskeletal tumors, and referred pain from remote sources of musculoskeletal pathology. Although patients may associate the onset of their symptoms with trauma, practitioners must be aware of the possibility of other possible conditions in addition to musculoskeletal overuse or traumatic injuries. Patients with musculoskeletal tumors about the knee often report a traumatic in-

¹ Physical Therapist, Naval Special Warfare Center, San Diego, CA.

² Director and Associate Professor, US Army-Baylor University Doctoral Program in Physical Therapy, Academy of Health Sciences, AMEDDC&S, Fort Sam Houston, TX.

³ Director, John A. Feagin Jr Sports Medicine Fellowship, Keller Army Community Hospital, West Point, NY.

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Address correspondence to Dr Michael Rosenthal, 116 Rendova Circle, Coronado, CA 92118. E-mail: Michael.Rosenthal@navsoc.navy.mil

jury associated with the onset of their symptoms.³⁶ Ancillary tests, such as radiographic or laboratory studies, are frequently utilized in the evaluation and management of stress fractures. Radiological assessment is typically initiated with standard radiographs, despite their poor sensitivity for the diagnosis of stress fracture, especially during the first 2 to 3 weeks following the onset of symptoms.²⁸ The most sensitive radiological tests in the early phases of symptoms are a bone scan and magnetic resonance imaging (MRI). Incorporation of a thorough patient history, physical examination, ancillary testing, and involvement of other healthcare professionals is warranted to comprehensively manage patients presenting with complaints of musculoskeletal pain.

DIAGNOSIS

A 19-year-old female reported to the physical therapy clinic complaining of right knee pain. At the time of presentation, the patient was in the fourth week of a 7-week military training program that required extensive amounts of prolonged standing, marching, and jogging. While the daily training regimen was variable and progressive with regard to duration of weight-bearing activity and intensity, daily physical training sessions consisted of a 3.2- to 6.4-km jog and approximately 30 minutes of calisthenics. Additional daily training consisted of marching in formation. The patient reported running 4 to 5 days a week prior to initiating military training, with each workout consisting of a 3.2-km self-paced run on a flat surface in running shoes. The patient's pain began 3 days before the initial physical therapy evaluation, following a twisting injury while running.

One year prior to this episode, the patient reported sustaining a similar twisting injury to the right knee during the same military training program. The resultant diagnosis at that time, aided by MRI findings, was a rupture of the medial collateral ligament (deep fibers) and a nondepressed medial tibial plateau fracture. That injury resulted in the patient dropping out of training and delaying entry into the United States Military Academy for 1 year. She reported that the current episode felt like the previous injury but was not as painful and was pain-free except when running.

The initial single assessment numeric evaluation (SANE) score was 80. The SANE rating is determined by having the patient answer the following question: On a scale from 0 to 100, how would you rate your knee today (with 100 being normal)?⁵⁵ Her pain improved after a day of rest, but subsequent attempts to resume jogging and marching resulted in a recurrence and worsening of her medial knee pain. Initial physical examination revealed a normal gait pattern and static biomechanical lower extremity assessment demonstrated symmetrical rearfoot valgus of 3°, and standing Q-angles of 15° on the right and 12° on the

left. Active range of motion (AROM) of the knee and hip was symmetrical and pain free, and there was no evidence of knee joint effusion or soft tissue edema. Non-weight-bearing strength examination of the right hamstrings was 5/5, while quadriceps strength was limited and reproduced nonlocalized knee pain. Squatting and single-leg hopping was performed without symptom reproduction, but the activity revealed an excessive valgus movement of the knee upon landing for both lower extremities. The patient reported pain diffusely over the medial and lateral joint lines and peripatellar region with palpation. Special tests (McMurray's, Apley compression, Apley distraction, varus stress, valgus stress, Lachman, posterior drawer, and patella apprehension) were unremarkable for symptom reproduction or joint laxity. Five days of limited activity was prescribed by the physical therapist for the patient, consisting of no running or marching, and the patient was advised to return to the clinic following that time. Given her mechanism of injury, progressive training requirements over the past month, and diffuse knee pain, the diagnosis at that time consisted of a spectrum of possibilities ranging from localized musculoskeletal to nonmusculoskeletal pathology (Table 1).

The patient did not return at the 5-day mark as advised because her pain was improving. However, 10 days following the initial evaluation, her pain returned and she was referred to the orthopedic clinic by the physical therapist. Due to her prior medical history and recurring symptoms despite rest, a 4-view knee radiograph series was performed, which revealed the appearance of a small amount of joint effusion, increased sclerosis at the medial tibial plateau correlating to the region of her prior injury, and no evidence of an acute fracture or osteochondral lesion. Her diagnosis by the orthopedic physician at that time was right knee tendonitis and patellofemoral syndrome. She returned to the physical therapy clinic the following day, 2 weeks following the onset of symptoms, and complained of worsening pain with activity but no pain at rest. She now exhibited an antalgic gait, full and painless knee AROM, and no joint effusion or edema. Valgus stress and McMurray's test produced nonspecific medial knee pain. Tenderness to palpation was localized over the pes anserine region. Crutches, toe-touch weight bearing, ice, and ibuprofen were prescribed by the physical therapist and the patient was advised to return to the clinic in 3 days.

The patient presented for the follow-up visit walking without crutches, which she stated she had lost the previous day. The pain had substantially increased, and her knee was now constantly aching at rest and made worse with weight bearing. Physical examination now revealed mild soft tissue swelling over the pes anserine region and localized tenderness over the pes anserine region. The pain caused by

valgus stress and McMurray's test was more severe than when performed 3 days previously. Tuning fork and percussion tests did not elicit an increase in pain. Ultrasound applied over the proximal medial tibia at an intensity of 1.0 W/cm² and frequency of 1 MHz elicited an increase in the patient's resting pain after 45 seconds of application. The previous examinations conducted by the physical therapist were performed in a field medical setting, where the tuning fork and ultrasound unit were not available.

An MRI was ordered due to the worsening pain, despite avoidance of high-impact exercises (eg, running in formation), the normal radiographic results 5 days previously, and the need to pursue a more definitive diagnosis to aid in the patient's management, in particular the determination of continued training limitations. MRI has been recommended over bone scan, because it provides optimal specificity



Figure 1. T1-weighted MRI showing a fracture line extending approximately 75% of the width of the proximal tibial metaphysis.

TABLE 1. Differential diagnoses.	
Local Musculoskeletal	
Patellofemoral syndrome	
Medial meniscus tear	
Patellar tendonitis	
Lateral patella subluxation	
Pes anserine tendonitis	
Pes anserine bursitis	
Vastus medialis strain	
Saphenous neuropathy	
Medial collateral ligament sprain	
Medial tibial plateau fracture	
Medial tibial plateau stress fracture	
Proximal tibia stress fracture	
Tumors	
Osteochondroma	
Chondroblastoma	
Giant-cell tumor	
Osteoid osteoma	
Osteosarcoma	
Ewing's sarcoma	
Chondrosarcoma	
Fibrosarcoma	
Pigmented villonodular synovitis (PVNS)	
Localized nodular synovitis (LNS)	
Systemic Disease	
Thyroid disorder (Graves' disease)	
Lymphoma	
Leukemia	
Myeloma	
Vascular/Inflammatory	
Rheumatoid arthritis	
Reiter's syndrome	
Saphenous thrombophlebitis	
Deep vein thrombosis	
Remote Neuromusculoskeletal	
Hip dysplasia	
Lumbosacral pathology	
Obturator neuropathy	

in assessing underlying pathology, while at the same time providing a level of sensitivity equal to that of a bone scan.¹⁵ Crutches were once again prescribed and the patient was advised on strict non-weight bearing until she was seen after the MRI. The MRI exam was performed the following day and demonstrated a severe proximal tibial metaphysis stress fracture located approximately 2.5 cm distal to the injury sustained the previous year (Figure 1).

Given her small stature (170.2 cm and 52.2 kg) and recent increase in physical and psychological stressors, consideration was given to the possibility of underlying female triad syndrome. Amenorrhea, osteoporosis and disordered eating, the components of the female athlete triad, have been cited as key contributing factors to the development of stress fractures and warrant consideration in women presenting with stress fractures.^{4,6,18,37} She denied any weight change, menstrual irregularities, or caloric restriction over the past 2 months. She was amenable to consultation with a nutritionist, which revealed an average daily caloric intake of 1000 calories. Zanker and Cooke⁵⁷ reported a direct correlation between energy deficit, energy expenditure greater than energy intake, and reduced bone formation. Furthermore, when 1 component of the female-athlete triad is present, clinicians should have a heightened concern for the likelihood of the other factors being present as well.⁷ Further questioning regarding menstrual history at this time revealed a 6-month period of oligomenorrhea. The patient was given instructions to improve her dietary habits (eg, balanced diet and increased caloric intake) and was referred to the

women's health physician for further evaluation regarding the period of oligomenorrhea and concerns regarding the female athlete triad.

The women's health physician ordered laboratory and bone densitometry testing. The bone densitometry test demonstrated values within normal range. Laboratory testing involved serum, blood, and urine tests. Particular analyses, in which abnormal values may be related to the incidence of stress fracture or other diagnoses being considered, included serum calcium, alkaline phosphatase, parathyroid hormone, and thyroid stimulating hormone (TSH). Elevation of serum calcium can be produced by increased parathyroid hormone excretion and may also signify increased osteoclastic (catabolic bone cellular) activity.^{20,44} Osteoblastic activity results in the secretion of alkaline phosphatase and elevated levels may signify increased bone formation.²⁰ Laboratory testing was conducted approximately 10 weeks following diagnosis and all testing were within normal values. Testing conducted at the time of initial diagnosis may have been more likely to reflect any abnormalities.

Treatment

An orthopedic physician was consulted and the patient was instructed to use crutches, with a range-of-motion brace locked in extension, and advised on partial weight bearing of less than 12 kg. Additionally, she was advised that observed noncompliance with crutch use may result in application of a long leg cast.

The patient's rehabilitation program was designed to progress from low- to moderate- and eventually high-impact stress, utilizing her pain response as an absolute indicator of excessive progression and need to reduce exercise intensity. Treatment initially consisted of upper body ergometer, strengthening and flexibility exercises for the uninvolved lower extremity, knee AROM exercises, quad sets, and straight leg raises of the involved lower extremity with the knee brace on. Follow-up radiographs, 7 weeks following diagnosis, demonstrated significant healing and no indication of fracture progression toward the lateral aspect of the tibia (Figure 2). The patient reported no knee pain at this time, used crutches most of the time, and had no pain in her knee when she tried short intervals of weight bearing. Her treatment continued with progression of partial weight bearing (PWB), low-resistance stationary biking, and non-weight-bearing exercises.

Repeat radiographs 1 month later indicated subtle, increased sclerosis and cortical thickening. The patient reported no pain with PWB ambulation and her exercise regimen was advanced to include weight bearing as tolerated ambulation, standing heel and toe raises, heel taps, leg presses, and squats and lunges using her body weight only.

At 12 weeks the patient reported no pain with full weight-bearing ambulation, although mild discomfort was noted if she walked greater than 15 minutes. The knee range-of-motion brace was discontinued at 12 weeks. At 16 weeks she was able to walk 3.2 km and perform 20 minutes on the elliptical trainer without symptoms. Radiographs performed at 16 weeks following diagnosis showed abundant sclerosis and cortical thickening. A return-to-running program³² was implemented at this time in conjunction with twice-a-week lower extremity progressive-resistance exercises.

Five months following diagnosis, the patient was jogging 1.6 km, 3 times a week. Plyometric exercises were incorporated, with hopping in place, and progressed to double-leg multidirectional hopping and single-leg hopping. At her 6½-month follow-up appointment she reported running 4.8 km, 5 days a week, with mild medial knee pain lasting a few hours. She was advised to reduce the running volume to 3.2 km twice a week and to cross-train by using the stationary bike or elliptical trainer the other days of the week. Nine months following diagnosis, the patient denied having any lower extremity pain or functional limitations and her leg and knee were a 98 on the SANE scale. The patient also reported normal menses for the past 6 months. The resumption of normal menses may have been due to improved nutritional status, as the patient reported compliance with the prior nutritional recommendations, or reduced physical-training demands. The patient was instructed to increase her running volume no more



Figure 2. Radiograph at 7 weeks following diagnosis demonstrating callus formation, periosteal reaction, and absence of fracture lucency.

than 10% a week, adequate dietary intake was verbally reinforced, and she was given an educational pamphlet on the female athlete triad. The patient was accustomed to running in cushioned-style running shoes. Because she demonstrated normal foot mechanics with gait but excessive valgus knee movement with higher impact loading, we recommended she select a running shoe designed to provide more stability. She completed the academic year and passed required military physical fitness testing (timed 3.2 km run in less than 18 minutes) and military movement courses (gymnastics class and timed obstacle course test) without further injury.

DISCUSSION

This case illustrates the importance of diagnosis, follow-on care, and a multidisciplinary approach to the management of acute onset of knee pain in a physically active person. The patient's level of activity prior to initiating military training consisted of running 19 to 32 km per week in the 6 weeks prior to commencing training. Her onset of symptoms and injury from the previous year suggested the possibility of an exacerbation of her prior medial collateral ligament injury along, with an acute tendonitis component. Although her mechanism of injury and progression of symptoms were more in keeping with primary musculoskeletal pathology, additional underlying pathology was considered (Table 1).

Various tumors can occur about the knee joint^{19,36} and clinicians should consider tumors as a contributing factor in posttraumatic knee pain. Muscolo et al³⁶ reported that misdiagnosis of knee tumors is often the result of an unquestioned initial diagnosis despite persistent or worsening symptoms. Symptoms often reported by patients with bone or soft tissue tumors include progressively worsening pain despite restricted loading of the area, night pain, localized swelling or warmth, fatigue, fever, weight loss, limited functional ability, locking, recurrent swelling, or palpable mass.^{19,22,39,40} Our clinical suspicion of a bone or soft tissue tumor was low as a result of the patient's noncontributory history and positive response to restricted-weight-bearing status. Although her pain did progress during the initial 2 weeks of management, the increase in pain was always associated with a self-selected trial of weight-bearing activities. Furthermore, her radiographs demonstrated no evidence of a tumor about the knee joint and radiographs from the previous year were also available to assess for interval change. Early utilization of MRI, which revealed the stress fracture, has been recommended based upon its sensitivity to differentiate local musculoskeletal conditions versus local tumors or systemic disease.^{11,45}

Systemic disease can also produce skeletal extremity pain. Common symptoms, not reported or observed in our patient, include unusual bleeding, easy

bruising, weight loss, fatigue, fevers, worsening pain (duration and intensity), night sweats, dyspnea, and lymphadenopathy. With definitive imaging studies available early in the course of patient management, and the patient responding to the subsequent course of intervention, laboratory testing was not conducted early on. Sprehe and Shetty⁴⁵ reported musculoskeletal complaints associated with malignancy may be evident before abnormal laboratory testing and that MRI is useful for early diagnosis. Laboratory testing was initiated following discussion with the women's health physician to further examine the possibility of underlying conditions (ie, Graves' disease) that may have contributed to the development of the stress fracture. Graves' disease was considered, based upon the patient's menstrual irregularity and subtle findings on physical exam (eg, prominent stare).^{17,51} The absence of any family members diagnosed with Graves' disease and her normal TSH test aided in ruling out this condition.

Consideration was also given to the possibility of an underlying inflammatory, vascular, or connective tissue disorder. However, our patient did not report or demonstrate any of the commonly associated symptoms (eg, weight loss, polyarthralgia, morning stiffness, urethritis, or changes in skin texture and appearance).¹⁹ Saphenous thrombophlebitis could produce pain in the region experienced by our patient; however, the normal gross appearance of both lower extremities (eg, the absence of swelling, changes in skin appearance, localized erythema, and prominent superficial veins) made this condition unlikely. Our examination also did not demonstrate any of the findings identified by Wells et al⁵³ for evaluation of deep vein thrombosis.

Regional knee pain can also be caused by more proximal sources of neuromusculoskeletal pathology. Obturator neuropathy was ruled out on the basis of no appreciable lower extremity weakness, muscle atrophy, or altered sensation. Saphenous neuropathy would be expected to produce medial lower-leg sensory changes, which were not present. Although lumbosacral spine pathology can refer pain to the anterior thigh, symptoms isolated to the anteromedial knee area have not been reported. Furthermore, movement testing did not reproduce any symptoms and the patient did not report relief or reproduction of symptoms with any movements or sustained positioning. Hip joint conditions (eg, congenital dysplasia or undiagnosed femoral head pathology), which may refer pain to the medial thigh or knee and are typically associated with limited range of motion and altered gait patterns, were not noted in our patient.

Psychogenic sources (eg, strategy of exit from military training) should also be considered by clinicians when examining patients with conditions resulting in withdrawal or limitations in work or sports participation. Even when psychogenic factors are

suspected, it is paramount that clinicians rule out all other potential causes for the presenting symptoms. Our level of suspicion was low because this was her second consecutive year pursuing this highly competitive, voluntary entry-level military training program. She also persisted in continuing to return to impact-loading activities, despite being given a valid excusal to refrain from physical training. Furthermore, our patient did not exhibit a trend of poor performance leading up to the initial presentation of her injury, as she was passing the required running and training evolutions up to the time of her knee injury.

Stress fractures of the tibia are noted to be the most common of all lower extremity stress fractures.^{21,28,29} The mid-tibial region is reported to be the most commonly involved region. Proximal tibia stress fractures have been reported in the literature as well, but little detail has been provided regarding confounding findings on clinical examination and follow-on care.^{14,21,26} The key finding on physical exam is localized tenderness to palpation over the posteromedial aspect of the tibia.^{14,26} However, this can be misconstrued as pes anserine tendonitis or bursitis. The pes anserine region of insertion is noted to have an extensive supply of pain receptors and vascularity.⁵⁶ Our patient experienced vague medial knee pain with McMurray's test and valgus stress testing 2 weeks following the onset of symptoms; however, these tests produced no pain at the earlier examinations.

Application of ultrasound,^{5,10,28,34,38,43} tuning fork test,²⁷ fulcrum test,^{23,52} percussion test,^{1,15,21} and localized point tenderness^{14,26} have all been reported as useful in the physical examination of a potential lower extremity stress fracture. Only studies utilizing the ultrasound and tuning fork tests have reported sensitivity and specificity values (Table 2). Authors that used ultrasound^{5,10,28,34,38,43} used a variety of frequencies and intensities, and many of the studies did not document specific parameters utilized in their assessment of tibial stress fractures. Utility of the fulcrum test has only been reported in association with femoral shaft stress fractures.^{23,52} Application of the fulcrum test for suspected femoral shaft stress fractures involves a posterior-to-anterior-directed force in the region of reported thigh pain. When utilizing the fulcrum test on patients with suspected tibial stress fractures, we apply force in 2 directions in an attempt to stress the posteromedial region of the tibia. Posterior stress is applied with hand placement over the anterior shaft of the tibia and stabilizing the lower extremity at the talocrural joint. Stress is applied to the medial aspect of the tibia by applying a valgus force to the localized region of tibial pain. Anecdotally, the authors believe this test provides greater sensitivity and specificity than the other aforementioned tests when assessing for tibial stress fracture. Although the percussion test, percussing the

TABLE 2. Clinical diagnostic study results.

Test	Sensitivity ⁽⁹⁾	Specificity ⁽⁹⁾	Diagnostic Accuracy ⁽⁹⁾
TFT ²⁷	75%	67%	71%
US ⁴³	0%	100%	40%
US ³⁸	100%	80%	93%
US ³⁴	100%	91%	96%
US ¹⁰	53%	0%	44%
US ⁵	43%	49%	46%

Abbreviations: TFT, tuning fork test; US, ultrasound.

heel with the examiner's palm, has been reported^{1,15,21} as useful in the diagnosis of lower extremity stress fractures, no studies have reported on the sensitivity, specificity, or likelihood ratios of this test. Localized point tenderness over an area no larger than 5 cm has been recommended as a differentiating test in comparison to a larger region of tenderness, which would be suggestive of shin splints.¹ Due to the lack of a proven clinical test for diagnosing tibial stress fractures, clinicians should rely upon a thorough patient history, palpatory examination, ancillary testing, and serial examinations in a patient who fails to respond to early management.

The literature typically indicates a return to full activity within 12 weeks, although some patients have required up to 20 weeks from the time of initial diagnosis.^{21,26,28} Our patient required a slightly longer period of time until full resolution of symptoms and return to unrestricted activities. This may have been due to the severity of the stress fracture. However, Dutton et al,¹² in a study of tibial stress fractures, did not find a significant correlation between the severity of stress fracture as determined by bone scan and time to return to full activity. A future study utilizing MRI to more specifically delineate the severity of the lesion may confirm or refute Dutton's findings and assist in estimating the time course for recovery in patients with stress fractures. Furthermore, the location of the tibial stress fracture was not associated with a difference in the time to return to full activity.¹² Additional factors that may have contributed to our patient's prolonged recovery period were ongoing female-athlete-triad factors, ibuprofen use⁵⁴ in the early stages of her care, suboptimal adherence to the early restricted weight-bearing stages, or overaggressive return to running.

Early management of this patient's tibial stress fracture was discussed among the orthopedic and physical therapy staff, due to the severity of the lesion noted on the MRI exam. The military medical system is unique in that physical therapists are often credentialed to order radiological and laboratory tests. For patients initially presenting to physical therapy and subsequently diagnosed with a stress-related bone injury of lesser severity, consultation with other specialists may not be necessary, so long as

the patient improves with initial management and other potential underlying diagnoses are appropriately ruled out. Due to the severity of this patient's stress fracture, prior medical history, and failure to improve with early management, consultation with the orthopedic surgeon was indicated. Consideration was given to casting and non-weight-bearing ambulation, patellar-tendon-bearing cast, and progressive weight bearing with a knee range-of-motion brace. The patellar-tendon-bearing cast option was eliminated due to concern of increasing the stress along the proximal tibia via the patellar tendon insertion. Non-weight-bearing cast immobilization was not implemented, as protected weight bearing was anticipated to produce a better healing response. Progressive weight bearing with the knee range-of-motion brace was chosen to allow pain-free compression stress to the area and minimize torsional or valgus strain. Removal of weight-bearing stimulus has been reported to result in a 30% reduction in the calcified matrix over the course of just a few weeks.²⁰ Allowance of weight bearing was further supported by Kimball's recommendation, which reported delayed healing if weight-bearing stimulus was removed.²⁶

To promote tissue adaptation, changing loading patterns (ie, magnitude, volume of training, and direction of applied stress) is recommended.³⁵ The gradual progression of pain-free exercises allowed for bone healing and adaptation to the imposed demands. Long bones of the lower extremity are optimally designed to absorb axial loading (compressive forces) and least designed for shear stress.⁸ The initial mechanism of injury involved torsional forces, and her jump-landing pattern, to a greater extent than running gait, demonstrated excessive knee valgus, which likely contributed to stress fracture development. Incorporation of plyometric exercises was based upon prior research supporting its use as a method to enhance bone healing and increase bone strength.^{30,31,47} Additionally, it was important to include various exercise challenges to prepare the patient for the military training requirements she would incur upon return to unlimited-duty status. This individual's premilitary conditioning primarily consisted of varying amounts of jogging and did not include lower extremity strengthening or plyometric exercises. Research by Turner⁴⁶ reported that bone cells (eg, osteocytes, osteoblasts, and osteoclasts) accommodate to routine mechanical loading and are more likely stimulated by dynamic, short-duration loading. Bone becomes desensitized (eg, loss of mechanosensitivity) to continuous unchanging mechanical loading, resulting in no strengthening effect from continued loading.⁴⁸ The recommendation to allow 8 hours of rest between the aerobic conditioning exercises and plyometric training was done to allow restoration of the mechanosensitivity of the bone. Eight hours of recovery has been found to be

sufficient for restoring bone mechanosensitivity and enhancing the osteogenic effect of impact-loading exercises.^{41,42}

The treatment plan for stress fractures presented in the orthopedic literature is often rest, followed by progressive increase in weight-bearing activity. It has been our experience that return to pain-free, full activity is unnecessarily delayed in athletes advised to simply avoid painful activities. Patients often test the leg with excessive activity and sustain a flare-up of symptoms, resulting in a recurring pattern of improvement, followed by regression, necessitating a reduction in activity then gradual resumption of activity. While this may give the perception of a nonadherent patient, it may be more accurately due to a lack of exercise guidance, progression of exercise variables, and supervision. Implementation of a comprehensive rehabilitation program and guidance in transition through various types and stages of exercise by a rehabilitation specialist may enhance the recovery process (tissue adaptation), retard deconditioning, and prevent injury recurrence, although there are no definitive studies available that provide specific guidelines or advocate involvement of the rehabilitation specialist. Due to the numerous contributing factors in an individual patient's development of a stress fracture, a protocol for stress fracture rehabilitation is difficult to apply. Individualized rehabilitation is recommended, with an emphasis on thorough evaluation and treatment of the kinetic chain and the application of tissue-healing guidelines to the progression of exercise variables.^{31,35} Thorough investigation into the contributing factors (eg, female athlete triad) may also indicate a need for a multidisciplinary treatment approach.

CONCLUSION

With the increasing role of physical therapists in direct-access settings, it is incumbent upon clinicians to be aware of less frequently encountered musculoskeletal conditions. Furthermore, collaboration with other medical specialists is important to provide the highest quality management, particularly when additional health concerns may contribute to musculoskeletal injury. With early recognition, most patients who sustain a stress fracture have an excellent prognosis; however, serious complications or recurrence may occur.

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