**Introduction**

Medial tibial stress syndrome (MTSS) and tibial stress fractures (TSF) are both forms of tibial stress injuries.1 MTSS and TSF are some of the most common injuries occurring in the lower extremities in the athletic and military populations.1-3 MTSS has reported incidences varying between 4 and 35% in athletic and military populations and TSF account for 25.9% to 49.1% of all stress fractures.1-3

 MTSS is a condition involving periostitis or symptomatic periosteal modelling occurring in the vicinity of the junction of the middle and distal thirds of the medial border of the tibia.1 It is defined as a diffuse painful area over a length of at least 5 cm on the posteromedial border of the tibia that occurs during exercise excluding pain from ischemic origin or signs of stress fracture.2  TSF is defined as a focal structural weakness that causes cortical disruption of the tibia occurring in response to the repeated application of submaximal stress.1  There are three forms of TSF: fatigue, insufficiency and pathological.3 This review will focus on fatigue TSF caused by abnormal muscular stress and torque to a bone that has normal elastic resistance and insufficiency TSF which occur when normal or physiologic loading stresses a bone that is deficient in mineral or elastic resistance.3 TSF are typically transverse and occur along the diaphysis of the tibia.4

 MTSS and TSF are considered conditions that occur on a “bone stress-failure continuum.”1 MTSS is generally a more mild expression and TSF is a more severe expression on this continuum.1 These two conditions do not occur concurrently nor necessarily in a temporal sequence.1 Even though these two conditions present similarly in the clinic there are fundamental differences that without proper diagnosis can lead to chronic pain and disability.1,2,5 Due to the high prevalence of MTSS and TSF it is imperative that clinicians are able to accurately diagnose these injuries.

 The purpose of this review is to further describe the etiology, the risk factors, diagnosis, treatment and prevention of MTSS and TSF. This review will assist clinicians in appropriately identifying and managing these two conditions.

**Etiology**

 There are two theories regarding the mechanism of injury causing MTSS and TSF, the periosteal traction based theory and tibial bending theory.1 The periosteal traction-based theory proposes that anatomical structures in the lower limb impart traction forces on the periosteum causing an irritation and damaging the bone.1 Researchers have performed biopsies of the lower limbs and found that increased tension on the soleus, flexor digitorum longus, flexor hallucis longus and tibials posterior muscles results in a linear increase in strain on the tibial fascia supporting the traction-based theory. 1,2 However, symptoms of MTSS and TSF are generally not present at the insertion sites of these muscles on the periosteum.1,2 A newer, more accepted theory suggests that chronic, repetitive loading at submaximal stresses results in tibial bending.1,2 Tibial bending can be caused by calf-muscle activation or by compressive loads that are not applied directly through the center of the curved tibia which results in increased tibia bending. 1,2 Tibial bending will precipitate bony damage at the site of greatest bending causing MTSS or TSF.1 The greatest amount of bending will occur at the most narrow diaphyseal width due to area moment of inertia.1 Currently, neither theory has yet to be confirmed; therefore, MTSS and TSF could be caused by repetitive traction on the periosteum, tibial bending or a combination of both.1,2

 According to Wolff’s Law, under normal physiologic loading bone exhibits an intrinsic ability to adapt and alter its structure by increasing cortical thickness, density and widening of the diaphysis to resist bending and prevent injury.1 During this bone remodeling process there is increased bony porosity which results in decreased stiffness and strength of the bone and consequently an increased risk for MTSS and TSF. 1 MTSS is likely caused by a bony overload during this bone remodeling phase in which the strain exceeds the threshold resulting in a compensatory hyperstimulation of this periosteal modeling.1,6 Osteoclasts outpace osteoblastic activity resulting in tibial osteopenia. However, some studies suggests that MTSS is actually caused from musculotendionous breakdown from repetitive stress.1,6 Histologic and further studies are needed to confirm these theories.7 TSF are most likely caused by micro-cracks in the bone matrix from chronic loading during the bone remodeling phase in which the bone is in a weakened state. 1

**Risk factors**

 There are several intrinsic and extrinsic risk factors that are correlated with the incidence of MTSS and TSF. It is necessary to understand the risk factors of these injuries in order to create a plan of treatment that modifies these risk factors and prevents further injury.

*Intrinsic risk factors*

 In a recent systematic review and meta-analysis of intrinsic risk factors for MTSS in runners the reviewers found that female gender, a previous history of MTSS, fewer years of running experience, previous orthotic use, increased body mass index, an increased navicular drop (pronation), and increased external rotation hip ROM in males were all significantly associated with an increased risk of developing MTSS in runners. 8 The reviewers note that the orthotic materials, designs, and nature of corrections were not specified in the papers used for their review and analysis. 8 Orthotics have variable effects on shock attenuation, kinematics, and neuromuscular control.8 Therefore, application of this finding should be used with caution. Other intrinsic risk factors that have been suggested for MTSS are increased plantarflexion, decreased gastroc-soleus flexibility and altered running kinematics; however, evidence supporting these factors is limited. 7,8

 A review of the literature identifies several common intrinsic risk factors for TSF. These risk factors include: female athlete triad (eating disorders, amenorrhea, osteoporosis), female sex, low levels of 25-hydroxyvitamin D, calcium and protein, low bone mineral density, consuming more than 10 alcoholic drinks per week , smoking, leg length asymmetries, pronation, increased knee stiffness with gait and impaired running mechanics.4,5,10-12 Researchers found that individuals with increased instantaneous and average vertical loading rates and peak tibial shock during running are at an increased risk for TSF.10-12

*Extrinsic risk factors*

 There are limited high quality studies investigating extrinsic risk factors for MTSS and TSF. The strongest evidence supports that excessive physical activity with limited rest periods, running more than 25 miles per week, running on hard surfaces, participating in repetitive, high impact and/or jumping sports, a sudden increase in physical activity, and shoes with less shock absorption are correlated with an increased risk for the development of MTSS and TSF. 1,4,5, 8, 9

 MTSS and TSF share several common risk factors indicating that risk factors may not be the best method for diagnosing these injuries. Nonetheless, identifying the risk factors and planning treatments to eliminate or reduce the effects of these risk factors is advisable to prevent further injury.

**Diagnosis**

 The correct diagnosis of MTSS and TSF is critical for clinicians in order to develop an appropriate plan of treatment.1 Failure to accurately identify TSF can result in progression to fracture, non-union, mal-union, chronic pain, prolonged recovery and/or disability.11 Upon initial glance the clinical presentation and patient history of MTSS and TSF can appear similar, but with a thorough review of patient history and objective exam a clinician should be able to identify the more likely diagnosis. 1,5,12

*Clinical presentation*

 Patients with MTSS will present with exercise induced lower limb pain.1,2,6,8 The pain will typically be in a diffuse area of at least 5 cm in length along the posteromedial aspect of the tibia where the middle and distal third of the tibia meet.2,13 In the more acute stages of MTSS patients will report pain that occurs only at the start of activity.2,13 As the symptoms worsen patients will complain of pain that persists throughout activity and potentially continue even after the termination of activity.2,13 Objectively, patients with MTSS will be tender to palpation along the posteromedial aspect of the tibia and in more advanced cases swelling may be present at the site of injury.2,13

 Patients with TSF will typically report an increase or change in activity within the last 3-7 weeks and an insidious onset of pain. 1 The pain will be focal at the site of injury (65.9 to 100 %).1,5 Initially, patients will report pain towards the end of activity. As the symptoms progress the pain will persist throughout activity and 81% of patients report pain with walking.1,5 In advanced cases patients may report night pain. On objective examination, patients will be tender to palpation at the focal site of injury, have pain with percussion of the lower limb, and have swelling at the site of injury and surrounding area (18-44%). 4,5,12 In chronic cases a palpable callus may also be present at the site of injury. 4

*Diagnostic tools*

 Diagnostic tools are more commonly used to assist with diagnosis of TSF than MTSS. Imaging diagnostics for MTSS have similar sensitivity and specificity values as the clinical examination; therefore, diagnostic imaging for MTSS is usually not used unless the diagnosis is unclear.1,13 Magnetic resonance imaging (MRI) is the most accurate study for when the patient presents with symptoms of MTSS but TSF needs to be ruled out. MRI can help differentiate between MTSS and advanced TSF; however, it is more challenging to differentiate between early TSF and MTSS.13Consequently, precaution and follow up of individuals with persistent MTSS is advised to rule out TSF development.

 The gold standard diagnostic tools for TSF are MRI and bone scintography.5 MRI is the more favorable of the tools because of its high level of both sensitivity (86%-100%) and specificity (100%) and superior capacity for early detection of stress injury.5,14 However, MRI and bone scintography are more expensive and not easily accessible.5 Standard radiographs which are lower cost and more accessible are therefore used as the primary tool for TSF diagnosis.5 In the acute stages of TSF standardized radiographs have low sensitivity (10%), but they become increasingly more sensitive overtime as bony changes occur.5 Depending on the nature of the patient’s case, standard radiographs are either repeated after a period of time (2-3 weeks) or patients are immediately referred for MRI studies to clarify the diagnosis.5 An algorithm has been developed to assist clinicians in the diagnosis of TSF and determining the appropriate use of diagnostic tools.5

 This algorithm initially calls for a radiograph of the affected limb. If the radiograph is positive for TSF, treatment is initiated immediately.5 If the radiograph is negative for TSF and there is not a need for an urgent diagnosis the patient is instructed to rest and avoid stress to the affected limb for 2-3 weeks after which a subsequent radiograph will be taken.5 If the image is still negative but clinical suspicion persists an MRI or bone scintography are ordered to confirm diagnosis.5 If the patient has a negative initial radiograph and is in need of an urgent diagnosis MRI or bone scintography are advised to confirm a diagnosis.5 If any of the imaging suggests a high risk fracture or is negative and differential diagnosis is suspected the patient should be referred to a specialist for further assessment.5

*Clinical assessment tools*

 Diagnostic imaging is often expensive, not accessible and can involve exposure to radiation; consequently, less invasive clinical tools have been suggested to assist with the diagnosis of MTSS and TSF. 4,5,14,15 Two specific tests have been described in the literature for clinical assessment of MTSS, the Shin Palpation Test (SPT) and the Shin Oedema Test (SOT).15 The SPT requires palpation of the distal two thirds of the posteromedial lower leg including the posteromedial border of the tibia and associated musculature observing for pain reproduction. 15 The SOT requires sustained palpation (5 sec) of the distal two thirds of the medial surface of the tibia bilaterally observing for signs of pitting edema.15 These tests have also been used as predictors of MTSS development in military personnel.15 A positive SPT and a positive SOT indicates a 4.63 and a 76.1 times greater likelihood of developing MTSS within 16 months respectively in military personnel. 15

 Several clinical assessments for TSF have also been suggested in the literature. The hop test (single leg hopping to assess for severe localized pain) has been used clinically; however, no scientific evidence supports its diagnostic validity for assessing TSF.14 Behrens et al. also suggests the use of the Fulcrum Test for stress fractures of the femur, but no literature was found confirming its use for TSF.4,16 Schneider et al. assessed the clinical usefulness of ultrasound and tuning forks as diagnostic tools for stress fractures in a systematic review and meta-analysis.14 Ultrasound and tuning forks have been considered as diagnostic tools for TSF because of their ability to provoke pain from irritation of the damaged periosteum (site of TSF). 14 Schnieder et al. determined that the ultrasound method had a pooled sensitivity of 64% and specificity of 63%, while the tuning fork test had a sensitivity ranging from 75% to 92% and a specificity of 19% to 67%.14 The researchers concluded that while there has been several studies suggesting their use as diagnostic tools, overall the quality and number of these studies is limited.14 Therefore, clinical tools such as ultrasound, tuning forks, hop tests and fulcrum tests are not supported as stand-alone diagnostics tests for TSF.4,14

**Treatment**

*Conservative*

 Optimal treatment of MTSS has yet to be determined. In a systematic review of treatment interventions for MTSS, Winters et al identified studies that assessed the effects of iontophoresis, phonophoresis, ice massage, ultrasound, low-energy laser treatment, periosteal pecking, stretching and strengthening exercises, a sports compression stocking, lower leg braces, extracorporeal shockwave therapy (ESWT) and pulsed electromagnetic ﬁeld on the symptoms of MTSS.17 There are studies suggesting that iontophoresis, phonophoresis, ice massage, ultrasound, periosteal pecking (form of acupuncture) and specifically extracorporeal shockwave therapy are effective treatments for MTSS (Level 3 to 4 of evidence).17 However, the studies included in this review had methodological bias and lacked homogeneity in outcome measures used.17 Additionally, the reviewers suggest that because MTSS is a bony overload injury studies assessing interventions promoting bone development and remodeling like graded running programs and plyometircs should be completed.17 Consequently, the author concludes that initially MTSS should be treated conservatively with rest, ice, compression, elevation and NSAIDs.11 Rest and stress avoidance are suggested until patients are asymptomatic with walking.1,13 Limited weight bearing exercises and physical therapy are advised during this time to maintain strength, flexibility and cardiovascular fitness and prevent further weakening of the bone and soft tissues and further injury. Activity levels should be guided by symptoms and gradually progressed until the patient is asymptomatic with pre-injury activity levels.11

 Patients with TSF will require between 4 and 12 weeks of rests to allow for complete bone healing.1,4 Length of rest is dependent upon the severity and the site of the TSF. 4 Fredericson grading system categorizes TSF into four stages with the higher stages (Grade III-IV) indicating a more severe fracture requiring increased length and intensity of treatment. For Grade III and IV TSF patients may require a period of non-weight bearing followed by gradually progressed weight bearing until the patient is asymptomatic with normal walking. 1,4,11 A 2-phase protocol for the treatment of most low-risk stress fractures (Grade I and II) has previously been described.11 Phase 1 of this protocol begins with pain control using ice massage, physical therapy modalities, and NSAIDs. 11 Minimal-impact aerobic activities (using elliptical machine, cycling, pool running, etc.) and physical therapy can also be used to help maintain cardiovascular fitness, strength and flexibility.3,11 Phase 2 begins once the patient has been pain free for 10–14 days.11 One week after the resolution of focal bony tenderness, running may be resumed at half the usual pace and distance prior to injury.11 A supervised, progressive running program with ample amounts of rest is implemented over 3 to 6 weeks until the patient returns to their pre-injury level.11 Periodic radiographs should be taken every 1-3 weeks to ensure optimal healing before progressing with increased weight bearing and higher level activities.5 Pneumatic compression, walking boots, antigravity treadmill training, ultrasound and electrical bone stimulation can also be used to enhance bone healing; however, there is limited scientific evidence supporting their effectiveness. 4,5,11 In the case of certain types of TSF such as anterior TSF which have poor healing prognosis an orthopedic specialist should be consulted to advise on surgical or additional treatments.1,4,5

MTSS and TSF require a period of rest to assist with bony healing and remodeling, but following this period of rest a gradual progression of activity is advisable. Gradual progression is necessary to strengthen the tibial cortex and allow increased remodeling of the tibia and resorption of micro-damage to prevent re-injury.7 Progression should be guided by pain elicitation for both MTSS and TSF; as well as, radiographic imaging for TSF.5,7

*Surgical*

 Surgery is generally not recommended for MTSS and only in severe cases of TSF. 1,13 The surgical interventions for MTSS that have been evaluated are fasciotomy along the posteromedial border of the tibia and removal of a periosteal strip form the posteromedial border, reducing the traction over the periosteum.13 Initial outcomes of these surgeries are generally good; however, return to pre-injury status are less favorable.13 Surgery for TSF is only recommended for high risk fractures such as anterior TSF and non-union fractures.1,4 The most commonly used surgical intervention for these TSF is intramedullary nailing with a reamed intramedullary nail and locking screws. This surgery is an effective intervention for the treatment of these complicated TSF.4 Following surgery these patient’s normally have radiographic healing within 3 months and return to competitive play within 4 months.4

**Prevention**

 Despite the high incidence of TSF and MTSS in active individuals and the impact that that these injuries can have on them, there is little evidence regarding preventative measures for these injuries.

 Several preventative strategies for the development of MTSS have been suggested and studied primarily in military personnel. 13 These preventative measures include; progressive training programs, lower extremity stretching and strengthening, various footwear and insoles to control pronation and provide shock absorption. 2,7,13 The only preventative measure that was found to result in a statistically significant decrease in the incidence of MTSS was shock absorbing insoles.7,13,18

 Although there is limited supporting scientific evidence, Patel et al. recommends several measures for the prevention of stress fractures such as TSF.5 These recommendations include; addressing modifiable risk factors, modifying activity level and training patterns to ensure adaptation and adequate rest, addressing contributing abnormal biomechanics, utilizing shock absorbing shoe inserts and daily supplementation of calcium and vitamin D (2,000mg and 800 IU respectively).5

 Prevention of MTSS and TFS requires knowledge of their etiology and risk factors and until these have been confirmed by high-quality, scientific studies prevention of these injuries will be challenging.8 The available evidence suggests that MTSS and TSF are overuse injuries that are caused by “too much, too fast and too soon.” Therefore, prevention should focus on controlling these factors by using a progressive training program that allows for adequate amounts of rest and addressing any contributing, modifiable risk factors that have been suggested in this paper.1,5,7,18

**Summary**

 Overall, there are limitations in the research on MTSS and TSF specifically in regards to their etiology, risk factors, treatment and prevention. Nonetheless, MTSS and TSF are forms of tibial stress injuries that clinically can present similarly, but differentiation between the two is imperative in order to prevent non-union, chronic pain and disability.1 Patient history, clinical presentation and diagnostic tools can be used to assist with this differentiation.1,2,5 Once diagnosed these injuries should immediately be treated using conservative measures such as rest, ice, compression, elevation and NSAIDs.5,11 The degree of rest and stress avoidance is dependent upon the type, severity and site of the injury. 5-7 Surgical intervention is rarely recommended except in the case of high risk fractures such as anterior TSF, non-union fractures or chronic cases.5,7,17 Patients’ activity levels should gradually be progressed and guided by elicitation of pain and radiographic images (TSF) until return to pre-injury level of activity has been reached.11 Gradual progression of activities, modification of risk factors, abnormal biomechanics and running mechanics, shock absorbing inlays, pronation control insoles and calcium and vitamin D supplementation are suggested means for the prevention MTSS and TSF. 5,17

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