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Review Article

Rehabilitation Management of Medial Tibial Stress Syndrome in Recreational Runners: A Narrative Review

Pepin Marie Eve*

Physical Therapy Program, Wayne State University, USA

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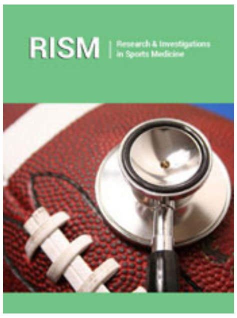

***Corresponding author:** Pepin Marie Eve, Physical Therapy Program, Wayne State University, USA

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Abstract

Background: Medial Tibial Stress Syndrome (MTSS) is an overuse clinical syndrome that is common in runners and can lead to functional limitations and running cessation.

Objective: To review the literature on etiology, risk factors, diagnosis, treatment and prevention of MTSS in runners.

Result: The etiology of MTSS is still a matter of debate but the theory of a continuum of overload from muscles to fascia to bone seems to be getting momentum. Risk factors are identified and discussed. MTSS can most often be diagnosed clinically following described criteria. Treatment is largely based on expert opinion, knowledge of biomechanics and tissue healing. A detailed treatment program is proposed. Prevention programs have yet to show efficacy in preventing MTSS, but shock absorbing insoles and a neuromuscular training program may be helpful.

Conclusion: Guidelines were proposed to help the clinician prevent, diagnose and treat MTSS

Keywords: Medial tibial stress syndrome; Shin splints; Running injuries; Overuse injury

Introduction

Medial Tibial Stress Syndrome (MTSS), commonly referred to as “shin splints”, is an overuse syndrome recognized by a constellation of clinical findings. It is defined as an exercise-induced pain along the posteromedial aspect of the lower leg that is provoked on palpation of the posteromedial border of the tibia over a length of ≥5 centimeters [1]. It is an inflammation of the musculoskeletal system that excludes other etiologies of lower leg pain such as stress fractures or ischemic pain [2]. It is one of the most common running related injuries, affecting 13.2 to 17.3% of runners [3] and can be a source of prolonged pain and lead to running limitations/cessation. The proper examination and treatment of this condition by health professionals and recognition/prevention by coaching staff is therefore crucial. Yet, from the author’s opinion, MTSS is often misunderstood, poorly managed and prevention programs not sufficiently implemented. Therefore, the objective of this review is to update the reader on new evidence-based knowledge of MTSS and give guided recommendations for evaluation, treatment and prevention. While pathophysiology of this clinical pain syndrome had not been determined conclusively, most experts and researchers will agree that it is no longer thought as purely a tibialis posterior dysfunction. Winters reports fasciopathy or bone overload as the most likely causes [4].

Fasciopathy or fasciitis involves pathology or inflammation of the deep crural fascia due to excessive traction. This may occur when the muscles are overloaded (especially eccentrically) during running and the excess strain is transferred from the muscles to the fascia toward the insertion on the tibia. This theory is thought to have merit due to cadaveric models showing tension on the tibial fascia that increase linearly with increased tension of the Tibialis Posterior (TP), Flexor Digitorum Longus (FDL) and soleus tendons [5]. Whether the pain comes from the inflamed fascia itself, the periosteum where the fascia attaches or both, has yet to be determined. Many suppose a continuum of overload from the musculotendinous system, to the fascia, to the periosteum and possibly to the bone itself [2]. Very few studies support the traction injury hypothesis [5], but several have documented that the attachments of soleus, FDL, and the deep crural fascia (but not the TP) are on the distal tibia in the location where symptoms are normally experienced [6]. However, individual anatomical differences seem to exist and several other anatomical studies have demonstrated that the attachments of most of the tibial muscles were more proximal than the location of pain and palpatory tenderness [7]. Winters [8] did document edema on the periosteum and the tibialis posterior upon ultrasonic examination of patients with MTSS, but these findings were just as frequent in athletes without MTSS. Bone overload is becoming increasingly popular as a proposed mechanism of pain in MTSS. Fascial traction from the posterior leg muscles (soleus, TP, FDL) can cause local bone overload which happens when bone resorption outpaces new bone growth [9].

A growing number of scientists believe that the repeated bending and bowing forces to the tibia is the cause of bone overload in MTSS [9]. Some studies have shown reduced bone mineral density of the painful region of the tibia in athletes with long standing MTSS [10], lower cross sectional of cortical bone [11], altered bone geometry [11] as well as bone micro cracks [12], which often resolve when symptoms improve. This finding seems to support the bone overload hypothesis; however, these findings have not been replicated by all [3]. In summary, MTSS seems to be an overload syndrome where a breakdown in excess of remodeling leads to dysfunction and pain in the fascia, periosteum and bone of the medial distal tibia [13]. This could be caused by traction forces of the soft tissues attaching on the tibia and/or from bending forces on the tibia.

Etiological factors While overtraining is a risk factor for MTSS, it is surely not the only cause. Menendez [3] concluded, in a recent systematic review, that female sex, excessive static pronation and recent increases in walking/running distances were etiological factors for the development of MTSS in novice or recreational runners. Kinematic changes during running, such as increased pelvic drop, increased peak hip internal rotation, decreased knee flexion during the stance, early heel lift, abductor twist (midtarsal or midfoot joint compensation for the lack of dorsiflexion at the talocrural joint), increased navicular drop, and propulsive gait were also risk factors. A propulsive gait was defined as a failure to demonstrate a heel-to-toe gait between the heel off and toe off part of the stance phase. Menendez [3] proposes that overpronation might be the most critical risk factor for MTSS, since it was associated with many other etiological factors such as increased peak hip internal rotation, knee valgus and increased pelvic drop. While this may be true, one could also hypothesize that weak gluteal muscles and/or tightness in dorsiflexion would contribute to several of these findings as well. In the review by Menendez [3], all but one study was observational in design, and therefore offer very little knowledge to what caused the MTSS and merely shows an association of clinical findings seen in patients with MTSS.

A systematic review of military personnel and recreational sports that involve some running (such as soccer, tennis and volleyball) concluded that female sex, previous history of MTSS, fewer years of running experience, orthotic use, increased body mass index, increased navicular drop, and increased hip external rotation range of motion in males were all significantly associated with an increased risk of developing MTSS [14]. While this study is not specific to runners, it included only prospective studies which is more helpful to identify cause and effect. Finally, Naderi et al. [15] developed a prediction model that would identify college runners at risk of developing MTSS. They found that having a larger Body Mass Index (BMI) increased likelihood of developing MTSS by 85%, a higher dynamic arch index (indicating more foot pronation) during running increased likelihood by 15% and a higher Peak Soleus Activity (PSA) during the propulsion phase of running increased it by 5%. A previous history of vigorous Physical Activity (PA) decreased risks by 25% while a previous history of MTSS increased the risks by almost five-fold. The model using the variables of BMI, previous history of MTSS, increased dynamic arch index during running, history of vigorous PA and peak PSA correctly predicted 88.6% of the participants who developed MTSS. This prediction model has yet to be replicated by other researchers and in other population of runners. In summary, more research is needed to better understand the risks factors for the development of MTSS but the etiology of MTSS is clearly multifactorial. The evaluation of patients with MTSS should therefore be comprehensive and evaluate potential risk factors such as history of MTSS, current and past training loads, BMI, running gait mechanics, hip ROM, hip strength and foot pronation.

Examination

While MTSS is often determined to be just a “shin splint”, it should be differentiated from other causes of shin pain conditions to be managed most effectively. A thorough clinical examination is often most helpful [16], as many diagnostic tests are not accurate in diagnosing MTSS [4]. Winters et al. [4] describe a seven-step process to reliably diagnose MTSS. The most important diagnostic criteria are listed below:

a. Exercise induced pain along the medial border of the distal 2/3 of the tibia.

b. Pain provoked by loaded physical activity such as running and relieved by rest.

c. Absence of foot numbness or tingling in the foot.

d. Pain upon palpation of this posteromedial border of the tibia over a length of ≥5 centimeters.

e. Absence of signs or symptoms atypical for MTSS such as severe swelling, redness, severe weakness, tingling, pain at night or with bone percussion.

Early in the process, pain can occur after running or only at the beginning of a run. As the condition progresses, pain can be present throughout the run and can even persist long after a run is complete [17]. Newman et al. [18] reported that signs of pitting edema or pain upon moderate strength palpation (enough to squeeze water out of a sponge) over the distal 2/3 of the posteromedial lower leg were helpful to predict those who would later develop MTSS in military recruits. The authors report that the absence of shin edema nearly eliminates the likelihood of an individual developing MTSS. This could prove to be helpful to track athletes and allow for rapid training adjustments before symptoms even appear in those found at risk. This study has yet to be replicated and investigated in recreational runners. For a diagnosis of MTSS to happen, other sources of lower leg pain must be eliminated: stress fractures, peripheral arterial disease, popliteal artery entrapment syndrome, nerve entrapment and compartment syndrome being the most common. Some features specific to each condition can facilitate the differential diagnosis process (Table 1). In addition to making an accurate clinical diagnosis, knowledge of etiological factors should prompt the clinician to inquire about training regimen and previous running injuries, examine BMI, hip strength and ROM, as well as assess running gait and foot mechanics (evaluation of pronation).

Table 1: Differential diagnosis of shin pain [17].

Condition	Distinct Features/ Presentation
Stress fracture	More focal tenderness to the tibia (<5cm) than MTSS. The anterior tibia is more commonly affected than the posteromedial tibia. The pain is often more proximal than that caused by MTSS. Pain can also be reproduced by percussion.
Peripheral arterial disease	The pain increases with exertion more so than with loading. Pain decreases within 10 minutes of rest Often affects the posterior calf. Palpation of posteromedial border of the tibia does not reproduce pain. Distal pulses may be decreased with exertion. Pain often described as fatigue, discomfort of cramping type pain.
Popliteal artery entrapment syndrome	Affects primarily male athletes under the age of 30. Characterized by claudication leg symptoms or lower leg pain with high intensity exercises that include repeated ankle dorsiflexion and plantarflexion. Pain is most often posterior in the lower leg and described as a deep ache or cramping. Tenderness of the medial aspect of the tibia does not reproduce the symptoms but the posterior leg may be tender especially during or right after exercising. The pulse of the popliteal artery may be diminished distal to the entrapment, especially with passive ankle dorsiflexion and active plantar flexion with the knee extended.
Superficial nerve entrapment	Most commonly affecting the common peroneal, superficial peroneal, and saphenous nerves. Pain is aggravated by running, is described as sharp or burning, is associated with sensory and/or motor abnormalities. Palpation or percussion at the site of entrapment may reproduce symptoms. The symptoms are experienced in the lateral lower leg and dorsum of foot (peroneal nerves) or medial lower leg (saphenous nerve).
Acute or chronic Compartment syndrome	Pain is more diffuse and is often associated with sensory or motor changes. Pain is described as cramping, burning, aching or tightening [9]. Acute tenderness to palpation specifically at the posteromedial border of the distal tibia is not usually reproduced at rest.

Interventions

The most common intervention proposed for MTSS is rest followed by stretching. Other interventions often include strengthening of tibialis posterior, soleus and flexor hallucis, massage, foot orthotics, laser, ice, compression sleeves and education about safe training. While stretching and complete rest are the most advised interventions, they have little to no support in the literature [13]. Static stretching is not the most effective as a stand-alone intervention for most tendon/fascia disorders and has the potential to exacerbate acutely inflamed tissues. And, while rest is helpful at decreasing the inflammation in the acute phase, it does nothing to improve the strength of the involved tissues. A more comprehensive intervention is certainly needed. Few good quality randomized control trials exist on treatment effectiveness. The majority of the research published studied military personnel and very few have studied recreational runners specifically. A systematic review published in 2013 [19] concluded that: "Iontophoresis, phonophoresis, ice massage, ultrasound therapy, periosteal pecking (a form of dry needling where the needle reaches the periosteum) and Extracorporeal Shockwave Therapy (ESWT) could be effective in treating MTSS when compared with control (Level 3 to 4 of evidence)". "Low energy laser treatment, stretching and strengthening exercises, sports compression stockings, lower leg braces and pulsed electromagnetic fields have not been proven to be effective in treating MTSS (level 3 of evidence)."

A few controlled trials have been published since then. Naderi et al. [20] reported that adding arch-support foot orthoses offered additional benefits over a control intervention of ankle exercises, ice massage and ESWT [20]. Newman et al. found ESWT to be no more effective than sham therapy at improving pain or running distance [21]. This is in contrast with others [8] who reported earlier return to running when ESWT was used [22]. Contrary to the strong design of Newman who used randomization, double blinding and sham control group, two of the studies showing benefits have important limitations, which include using retrospective data [22] and lacking randomization [23]. However, Newman's findings are based on 28 subjects only. Egerton [24], in a recent review, reported a lack of evidence to support interventions aimed at managing tibial loads in patients with "tibia pain". Interestingly, only one intervention included in the review focused on active interventions (strengthening and stretching) while all the others investigated passive modalities (brace, orthosis, compression stockings). When considering that MTSS is a mismatch between load applied to the tissues and the tissues' ability to tolerate that load, it appears that active interventions would be essential for a safe return to sport. In the absence of clear evidence, clinicians must use clinical experience, knowledge of tissue physiology and path mechanics, evidence from other overuse injuries, and expert opinion to guide decision making. Treatment must be specific to the objective deficits found in the patient and address personal/ environmental factors. It must balance irritability of the patient and stage of healing with patient goals. While staying patient-centered, the general goals of the acute phase should be to: 1) decrease pain and inflammation, 2) prevent complications, 3) maintain ROM, strength and aerobic conditioning without aggravating the injury, 4) address the causes for the dysfunction 5) reduce or redistribute loads. Refer to Appendix 1 for a more detailed treatment protocol.

Appendix: Suggested rehabilitation program developed from current best evidence and expert opinion.

	Proposed Interventions
Inflammatory Phase	Iontophoresis, phonophoresis or ultrasound therapy Ice massage for 5 minutes at a time Periosteal pecking Extracorporeal shockwave therapy Modified rest and activity modification Maintain cardiovascular fitness through cross training (swimming, cycling, elliptical..) Address nutritional, vitamin D and/or hormonal deficiencies Train hip strength and core stabilization (clams, bridges, side lying hip abduction, quadruped hip extension, hip thrusts, forward and side planks…) Consider using soft or hard taping during activities Pain free isometric exercises to lower leg muscles (TA, TP, Soleus, FDP) Intrinsic foot exercises (toe abduction, short foot exercise) Address lack of dorsiflexion if present, through mobilization, manipulation or stretches
Proliferative Phase	Progress lower leg exercises from isometrics to concentric to eccentric (heel raises, ankle exercises with resisted band, Alfredson eccentric heel raises protocol) Progress the number of repetitions and/or intensity of resistive training regularly Progress hip, lower leg and foot training to standing positions and other functional positions (running stance) Emphasize anti-pronation exercises in functional positions (chops, lunges with arm reaches) Exercise on a variety of surfaces including unstable surfaces and at times without shoes
Remodeling Phase	Add plyometrics exercises (jumps, bounds and hops) Include high load strength training (80+% of 1RM) Add variability in training surfaces and speed of execution Add cognitive load and upper extremity movements while working lower legs and core Emphasize running specific exercises to mimic the demand of the sport Running gait mechanics retraining with focus on increasing step rate, increasing step width and avoiding over-striding
Return to sport	Progressive return to running related activities Vary running surfaces –avoid canted surfaces early on Include uphill running and delay return to downhill running Consider shock absorbing insoles when running or custom orthotics if heavy pronator

Decreasing pain and inflammation can be achieved with modified rest, pain modalities and ESWT. Modified rest could include performing other aerobic activities, unweighted running (unweighted treadmill or water running) and/or decreasing the volume/intensity of running to where symptoms improve. This would help maintain fitness, reduce load on the tissues and prevent complications. Cryotherapy has been commonly used historically, although evidence for its effect is lacking. Ice may be used primarily in the acute phase, as to not risk delaying the healing process. ROM and submaximal isometric strengthening could be performed for pain modulation. Although the effects on MTSS are not known, isometric exercises have been shown to be effective with tendinopathies and other acute musculoskeletal conditions [25]. Addressing biomechanical flaws can be initiated in this phase (hip and core strengthening for example, with perhaps an emphasis on non-weight bearing resistive exercises for hip abductors and external rotators) and referral for orthotics as needed. Ruling out nutritional and hormonal deficiencies are crucial due to their role in bone homeostasis. Vitamin D and calcium supplementation have been recommended, especially for athletes showing a deficiency [12]. Some advocate circumferential non-elastic taping distal to the pain to redistribute the muscle forces away from the inflamed area (similar thought process as the elbow strap for lateral epicondylitis). Others suggest a tape (elastic or non-elastic) longitudinal to the muscle to decompress the affected tissues, improve circulation, normalize muscle function and/or plantar loading [26]. The effectiveness of one over the other is not known [27] but in the authors' experience, the softer taping may be more comfortable during active training and stay longer than rigid taping. Aggressive massage, strengthening or stretching that could increase strain on the involved tissues, bone fascia interface and bone itself and are not recommended in this stage. The goals of the subacute phases should be directed at increasing load tolerance capacities and addressing factors causing excessive loading to the tibia and surrounding tissues. This can be achieved by: 1) increasing the bone mineral density of the tibia, 2) increasing strength of the muscles, tendons and fascia attaching to the medial tibia 3) improving pronation control, 4) improving shock absorption ability and decreasing bending stresses to the tibia, 5) educating regarding weight loss 6) improving running gait mechanics, 7) educating on healthy training principles and a progressive return to running.

Increasing bone mineral density of the tibia

The goal is to increase bone strength so that the tibia can withstand bowing and bending forces and for bone growth to outpace bone resorption. For that purpose, resistive strength training of the lower leg muscles seems important. Although not specifically demonstrated for the tibia, progressive resistive and impact exercises have been shown to improve femoral neck bone mineral density in people at risk of fragility fractures [28]. The effect of resistive training on bone density seems site specific. Therefore, prescribing progressive intermittent impact weight bearing exercises as well as progressive resistive exercises to the muscles that attach on the posteromedial tibia is likely important. Florio [29] demonstrated an increased tibia cortical bone formation with lower extremity isometrics exercises and suggests a variety of joint angles and directions of resultant muscle forces to target various areas of the tibia bone. To be effective, resistive training must be of sufficient intensity/duration to have benefits. The optimal dosage has yet to be determined but 2-3 sessions a week at a moderate to high intensity for at least eight months is usually advocated [28]. Finally, nutritional insufficiency or imbalances, Vitamin D, calcium or hormones deficits should be addressed for optimal bone health.

Increase strength of the lower leg muscles, tendons and fascia

Despite the lack of evidence for strengthening, simulating the mechanical properties of the soft tissues to improve load tolerance is a sensible option [4]. Eccentric training has been shown effective at rehabilitating various tendons and should likely be incorporated in the training of the runners post MTSS. Due to their likely involvement, strengthening of soleus, TP and FDL is advocated. Evidence for improving fascial strength is scarce. High-load strength training of the plantar fascia has shown promising results for patients with plantar fascia pain and is believed to be effective at stimulating new collagen formation. In the Rathleff study, high tensile loading was created by placing a towel roll under the toes while performing unilateral heel raises, which created simultaneous application of strong contractile and tensile stresses [30]. Similar principles could perhaps be applied to the tibial fascia (strong contraction while the muscles are fully lengthened in weight bearing) such as performing resistive inversion and plantar flexion (backpack or resistive band) while weight bearing at the end of a step. This needs investigation.

Improving pronation control

Decreased medial longitudinal arch and increased pronation has been demonstrated as foot intrinsics [31], plantar flexors and invertors fatigue [32]. This is consistent with many others who advocate that increasing muscle strength and endurance of all foot intrinsics as well as antipronator muscles (especially the TP muscle but also soleus and TA) should be a priority in preventing injuries related to pronation. Sets of high repetition exercises (15 to 50) are suggested to improve endurance of these muscles. Foot intrinsic training (that includes short foot exercises) and resistive training of hip abductors and internal rotators have the potential to improve foot posture, and are therefore recommended [33]. This is supported by Sanchez et al. who reported that a comprehensive exercise program that included cues to modify foot contact during walking, ankle and toe exercises, balance training and proximal strengthening was effective at reducing excessive pronation [34].

Orthotics may be advised based on preliminary evidence that custom-made orthotics may be more effective than no insoles for reducing pain in military subjects with MTSS [35]. A 2mm pad under the medial longitudinal arch and a 5mm pad underneath the calcaneus improved foot position in runners with MTSS but symptom reduction was not investigated [36]. Other research has demonstrated that arch-support orthoses normalize foot-pressure distribution patterns during running in individuals with MTSS [37]. Medial posting appears to be the most effective foot orthotic feature to reduce the peak rearfoot eversion and to control excessive foot pronation [38]. Finally, since patients with a lack of dorsiflexion ROM often demonstrate compensatory pronation, it is advisable to perform posterior glides of the talocrural joint as well as soleus and gastrocnemius stretches if they are indeed restricted in mobility/flexibility [3].

Improving shock absorption ability and decreasing bending stresses to the tibia

Increasing leg muscle strength/endurance can be beneficial for that purpose, perhaps due to the ability of the muscles to absorb shock and counteract bending forces on the tibia. This is indirectly supported by research that show that muscle weakness and fatigue increase strain on the tibia [39]. Eccentric contractions are effective at absorbing shock, which could decrease the stress transmitted to the fascia-tibial interface. Herring describes a plyometric/conditioning program that includes progressive eccentric stress loading to help prepare an athlete for a return to sport after tibial fasciitis [2]. While helpful in guiding the clinician with load progression, the effectiveness of the eccentric/plyometric programs needs investigation. Shock absorbing insoles may be of utility for improving shock absorption and have been shown to decrease the risks of stress fractures and bone stress reactions in military participants [40]. Educating new runners on progressing running load is crucial to avoid excessive tibial forces.

Educating regarding weight loss as needed

High BMI is a known risk factor for MTSS, most likely due to the increased external load and forces caused by the excess weight. Runners with excessive body weight have a lower arch height as measured by the Dynamic Arch Index (DAI) and greater running related fatigue of plantar flexor and invertor muscles compared to that of runners with normal weight. The increased muscle fatigue further changes the foot pressures, foot impact and DAI [15]. It is also sensible to think that weight loss could, in addition to help normalize muscle function, foot pressures and arch height, decrease the bending forces on the tibia while running. Although weight reduction, through dietary modification, has also been shown to improve ankle strength related to body mass [41] and decrease plantar pressure in some areas of the foot, to the author's knowledge, no evidence exists for the improvement in tibial forces or the improvement in symptoms in patients with MTSS. Nevertheless, for the well-being of the patients, providing guidelines on healthy eating and regular safe physical activity is recommended especially for overweight patients.

Improving running gait mechanics

As discussed above, abnormal running mechanics has long been proposed as a risk factor for MTSS [3]. Over-striding could create excessive load on the tibia; abnormal pronation undue demand on the anti-pronator muscles; and pelvic obliquity abnormal bending forces on the tibia. Therefore, it appears advisable to perform a running gait assessment followed by a running-biomechanics retraining program for clients with MTSS. A Cochrane systematic review [42] concluded that running gait biomechanics can indeed be altered by a running modification training program. The most effective strategy found to reduce running injury risk factors was through sensor driven real-time visual feedback of kinetics or kinematics variable [42]. Despite changes in running mechanics observed after retraining, the evidence of effectiveness for patients with MTSS is scare. Barton recommends individually tailored gait retraining to reduce impact and bending forces on the tibia [43] which could include increasing step rate, as well as cues to increase step width and reduce impact forces. Increasing step rate may be effective at decreasing contact forces [43,44] and cues to land on the ball of the foot showed large decreases in Ground Reaction Forces (GRF) when running [44]. However, some have revealed that GRF metrics such as peak impact and loading rates are poorly associated with tibial forces, making the significance of these findings uncertain [45]. In addition, some experts worry that adopting a forefoot pattern could lead to unwanted strong tension of the soleus which could perpetuate the injury. The author and most experts will venture that avoiding over-striding (by landing with the tibia more perpendicular with the ground and only slightly anterior to one's center of mass) and increasing step rate might be the most effective strategies for decreasing risks of MTSS.

Educating on a progressive return to running and healthy training principles

Moen [23] compared a progressive running program with either additional stretching/strengthening or sports compression stocking. Although no statistically significant differences were found between groups, most participants successfully completed the running progression program in about 3 months (102 days for the stocking group and 117 days for the running with exercise group). No evidence exists as to the effectiveness of this running progression program, but it's well laid out progression could offer some guidance to the clinician in advising a safe return to running [46]. A gradual increase in velocity, distance and frequency of running is strongly advised. A maximum of 10% increase in weekly mileage is often reported, although not substantiated by research. Only weekly distance increases of 30% compared to 10% have been correlated with increased injury risks [47]. A variety of factors including the severity and duration of the injury, prior history of overuse injuries, running experience and ability, developmental age, as well as bone and tissue strength should be considered when determining progression. The preparation for running should include sport specific exercises that will mimic the tensile and compressive loads of running. Dynamic stretches, technical drills and strengthening in a split stance and at fast speed are just a few examples. In order to return to running, there must be a gradual improvement in load tolerance. Symptoms can be used to guide the clinician as far as progression/load tolerance. Some experts advise to keep the pain to 2/10 or less while others have a 0/10 pain tolerance policy for any bone related injury. The newly developed medial tibial stress syndrome score, a patient-reported outcome measure, may be a good adjunct to pain rating scores and help monitor symptoms severity and guide load progression [48].

Prevention

Two systematic reviews of the literature were found on the prevention of MTSS. Both concluded that there was little evidence to support any of the commonly used interventions to prevent MTSS (including foam heel pads, shock absorbing insoles, stretching of plantar flexors, footwear and incremental running programs) but that results from shock absorbing insoles was most promising [49]. Several randomized controlled trials have been published since then, and most have shown no significant differences between intervention groups and controls. The great majority of studies have been performed on military personnel. The only two interventions shown to decrease the risks of MTSS were: 1) neoprene insoles and semi-rigid insoles compared to standard insoles [9] and 2) Neuromuscular Training (NMT) in track athletes. Mendez-Rebolledo [50] reported an incidence rate of MTSS of 0.82 per 1000 hours of exposure in the NMT group (which included integrated jumps, landings and running, with strength, endurance, agility, balance and core training) compared to an incidence of 5.96 in the control group which received standard anaerobic, strength, and aerobic training. Although the value of prevention programs is not clearly demonstrated, clinicians may be able to make some recommendations based on other studies. Struznickel et al. [12] demonstrated a decreased in serum vitamin D in patients with MTSS who also demonstrated microfractures upon advanced testing [12]. The authors recommend vitamin D supplementation to achieve levels of 25-OH-D≥30μg/L in order to prevent MTSS. Soft tape application reduced the rate of medial foot loading in participants with current or previous history of MTSS, which could mean slower rate of pronation and a reduction of potentially harmful forces [26]. A rigid taping application to the arch was effective at normalizing navicular height during jogging and could assist in prevention of MTSS in those with excessive pronation as measured by the navicular drop test [51]. Results from a systematic review revealed that motion control shoes may be effective in reducing the amount of foot pronation and peak vertical impact forces during running [52] and may be a more practical option than taping applications. The current evidence on footwear is however not sufficient to inform shoe prescription [53]. Sharma et al. [54] demonstrated that a gait retraining program with exercises to increase strength, flexibility and neuromuscular control was effective at reducing risks of MTSS in 450 army recruits [54]. The gait retraining component used foot sensors to cue the participants to land more lightly, on the lateral heel and with a rearfoot eversion. Running on even surfaces as well as softer surfaces seems like a good option [49]. This is consistent with the finding that running on concrete is a risk factor for running related injuries [55] and supported by the finding that running on hard surfaces such as asphalt increases peak foot pressures [56] and tibial impact [57] compared to running on grass. Vitor concluded that high foot pressures sustained over long distances, could overload the musculoskeletal system (as it tries to attenuate the loads) and increase risks of overuse injuries [56]. Running on a treadmill appears effective at reducing plantar loads [58]. However, running on softer surfaces to prevent injuries such as MTSS is not supported by all. Fu [59] reported that running on different surfaces did not always affect tibial impact and plantar pressures. Potthast [60] concluded that impact forces were more related to muscle force and joint angles than the type of running surfaces. Some report increased tibial acceleration, a measure correlated with tibial impact, when running on grass compared to concrete. A possible explanation for this finding is that athletes adapt to the softer surfaces by stiffening their leg muscles when landing. The impact of higher leg stiffness (in anticipation for the soft ground) on injury risks in unclear, as some suggest either increased or decreased injury rates. In the absence of clear directions, the author believes that running on a variety of surfaces and alternating footwear is wise.

If one believes the theory of bone related stress, the guiding principles suggested by Warden et al. [61] to develop and maintain healthy bones are worth serious consideration (Table 2). In the author's opinion, healthy and sufficient nutrition, good sleep hygiene and adequate recovery between workouts is important. Finally, although not proven, most experts seem to agree that prior vigorous PA and a progressive increase in distance, frequency and speed seems to be crucial for MTSS prevention [62]. A conservative approach may therefore be advised, especially for those who wish to start a running program without significant prior exercise or running experience. Other vigorous activities (biking, swimming, skiing, speed-walking...) may be recommend before initiating a running program and/or performed concomitantly with the running.

Table 2: Guiding principles to develop and maintain healthy bones.

Optimize both growth before puberty by encouraging multi-sport participation that include cyclic loading (such as badminton, gymnastics, cheerleading, volleyball and ballet) and recommending against early specialization.
Choose a sport that requires bouts of dynamic weight bearing and are multidirectional
If doing continuous unidirectional sport such as running, consider periodization or days without running for at least 1 day every week and 1 week every 3 months.
Look for training errors and excessive workload by comparing the workload of the previous week to that of the average workload for the previous 3-6 weeks.
Add short bouts of plyometric exercises several hours after a running session
Progress running duration before running intensity
In those running most days of the week, incorporate treadmill running, water running or other body weight support running or other cardiovascular exercises to reduce bone workload at least once a week
Increase running cadence
Perform resistive muscle training to increase muscle endurance and strength.

Conclusion

Are we left in the dark when managing patients with MTSS? Treatment and prevention strategies lack clear evidence. The interventions most studied are passive, not always consistent with current knowledge of tissue loading and not patient centered. Studies often lack sufficient intervention details to inform clinical decision-making. In the author's opinion, the active interventions reported also often lack sufficient duration, intensity, specificity and progression to be effective. Despite the lack of evidence, recent studies on pathogenesis of MTSS, gait mechanics and tissue healing are informative and can guide clinical decision-making. Understanding the balance between tissue breakdown and regeneration, along with knowledge of effective interventions for overload injuries in other body parts, can help clinicians emerge from the shadows and enhance the specificity of interventions for patients with MTSS. This narrative review summarizes the evidence related to MTSS and suggests specific clinical recommendations for evaluation and management. To the author's knowledge, this is the first rehabilitation protocol for MTSS that is detailed, specific and informed by current evidence. Finally, this review highlights the need for further high-quality research studies to better inform the clinician in the evaluation, prevention and treatment of runners with MTSS.

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