A REVIEW AND ANALYSIS OF CURRENT TREATMENT APPROACHES USED BY ATHLETIC TRAINERS FOR MEDIAL TIBIAL STRESS SYNDROME

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ABSTRACT

Certified athletic trainers (ATs) are often tasked to treat Medial Tibial Stress Syndrome (MTSS) in the athletic population. Further, they are expected to provide effective treatment approaches based on the scientific evidence. The goal of this study was to review current treatment options chosen by ATs and to assess possible relationships between AT's demographics and their chosen treatment options. This web-based survey was completed by 131 ATs. The survey collected demographic information and treatment options used. Data were analyzed to assess the relationships between treatment options and independent variables including clinical setting, education, and years of experience. Four relationships were found between independent variables and the use of treatment options. Based on a review of the literature, most treatment options selected by ATs are supported by existing evidence. It is essential for ATs to have knowledge of the best treatment option based on available resources in their particular clinical setting.

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CHAPTER 1: INTRODUCTION

1.1. Overview

The general population commonly uses the term “shin splints” to describe chronic lower leg pain. This term most often describes the pathological condition of Medial Tibial Stress Syndrome (MTSS) (Brushoj et al., 2008; Burrus et al., 2014; Edwards, Wright, & Hartman, 2005; Taunton et al., 2002). MTSS is characterized as exercise-related, dull to intense pain along the posteromedial aspect of the distal one-third to one-half of the tibia (Edwards et al., 2005; Yate & White, 2004). MTSS is commonly developed amongst those who are involved with running and jumping sports, such as basketball, tennis (Edwards et al., 2005), cross-country, field hockey (Reinking, 2006), and volleyball (Edwards et al., 2005; Reinking, 2006). MTSS accounts for approximately 5% of all running-related injuries (Taunton et al., 2002). Scholars report that the estimated range of incidence rates of MTSS is from 12% to 15.2% in high school cross-country runners (Bennett et al., 2001; Plisky, Rauh, Heiderscheit, Underwood, & Tank, 2007). Athletic Trainers (ATs) are commonly tasked with treating athletes complaining of MTSS symptoms.

Although there is a working definition of MTSS, its specific diagnostic characteristics are not yet clearly defined in the literature. A comprehensive literature review revealed that there are two main pathomechanical theories for the cause of MTSS: the tibial traction theory (Bennett et al., 2001; Bouche & Johnson, 2007; Michael & Holder, 1985) and the tibial bending theory (Moen et al., 2012; Rompe, Cacchio, Furia, & Maffulli, 2010). Tibial traction is defined as causing inflammation or damage in the muscle and bone interface (Bouche & Johnson, 2007; Michael & Holder, 1985). Tibial bending, the second main pathomechanical theory, has been defined as repetitive impact causing a bone stress reaction (Moen et al., 2012; Rompe et al., 2010). This stress reaction causes pain along the tibia and is considered to be involved with MTSS development (Fredricson, Bergman, Hoffman, & Dillingham, 1995; Gaeta et al., 2005; Mammoto, 2014; Moen et al., 2014).

Furthermore, researchers have published results related to therapeutic interventions to manage MTSS, including but not limited to: cryotherapy (Galbraith, & Lavallee, 2009; Yate, Allen, & Barnes, 2003), iontophoresis (Delacerda, 1982; Galbraith & Lavallee, 2009; Singh, Sethy, Sandhu, & Sinha, 2002; Smith, Winn, & Parette, 1986), phonophoresis (Galbraith & Lavallee, 2009; Smith et al., 1986; Singh et al., 2002), ultrasound (Galbraith & Lavallee; 2009; Smith et al., 1986), orthotics (Craig, 2009; Rompe et al., 2010; Yate et al., 2003), stretching (Craig, 2009; Loudon & Dolphino, 2010), strengthening (Craig, 2009; Madeley, Munetanu, & Bonanno, 2007), and Kinesio ® tape (Griebert, Needle, McConnell, & Kaminski, 2014). However, the literature does not present conclusive evidence for the effectiveness of the aforementioned treatments. Therefore, when treating MTSS, ATs may have difficulty determining the most appropriate, evidence-based treatment plan. In order to establish trends of treating MTSS symptoms, the current research project proposes to review treatment approaches used by ATs.

1.2. Purpose of Study

The purpose of this study was to review the current treatment approaches of MTSS symptoms used by Athletic Trainers (ATs). Additionally, as a secondary purpose, this study ran analyses to determine if there is a relationship between AT's demographics and their treatment choices related to treatment.

1.3. Significance of Study

MTSS is a common, chronic pathological condition amongst athletic populations involved in running and jumping activities. ATs determine and provide the therapeutic interventions to athletes who have MTSS so they may return to participation in athletic competitions. As the literature will show, numerous options for MTSS treatments with potential benefits are available for ATs.

1.4. Research Questions

a) What are the differences between the current MTSS treatment used by Certified Athletic Trainers compare to the current research?

b) What is the relationship amongst clinical settings, years of experience, and level of education when Certified Athletic Trainers' treatment options for treating MTSS in their practice?

1.5. Limitations

Limitations are an aspect of all research. One limitation to the current thesis project was the voluntary participation in survey research. The number of survey returns varied based on the rate of voluntary responses. In addition, only returned and completed surveys were included in the final analysis of data. This study asked only ATs in the United States; therefore, any conclusions made based off the results cannot be generalized to other health care professions or ATs in other countries. Time constraints may affect the analysis of research data. If a longer time window were available for data collection, the study could be influenced.

1.6. Delimitations

The clinical working definition of MTSS was provided to the participants by the researcher; therefore, the participants in this study were asked to provide treatment options for similar pathologies or other abnormalities. Due to limited time and resources, the literature that investigated or suggested the other therapeutic interventions was not reviewed.

1.7. Conclusion

As stated previously, the specific pathological definition of MTSS still needs to be articulated clearly, even though ATs are commonly tasked with treating MTSS symptoms in their clinical settings. The literature shows there are numerous options for MTSS treatment available to ATs. However, the literature does not present conclusive evidence for the effectiveness of the specific therapeutic interventions for MTSS. Therefore, having a clear picture of how clinicians use their expertise to address MTSS symptoms can provide evidence-based perspectives regarding effective MTSS treatments. Thus, this study reviewed the current treatment approaches used by ATs for MTSS and the efficacy of the treatment approaches from the literature. Additionally, this study ran analyses to determine if there is a relationship between AT's demographics and their treatment choices related to treatment.

CHAPTER 2: LITERATURE REVIEW

2.1. Purpose

The purpose of this study was to review the current treatment approaches for Medial Tibial Stress Syndrome (MTSS) used by certified Athletic Trainers (ATs). This literature review provided the background information associated with the characteristics of MTSS, such as the definition and etiology. Moreover, this review also provided the treatment approaches for MTSS because ATs are commonly tasked with treating patients complaining of MTSS symptoms. Therefore, ATs need to know the efficacy of the current treatment approaches. Knowing the best clinical practice will help ATs provide the most effective treatment.

2.2. Definition of MTSS

Medial tibial stress syndrome (MTSS) is a common cause of exercise-induced lower leg pain (Newman, Witchalls, Waddington, & Adams, 2013; Plisky et al., 2007; Yate & White, 2004). MTSS is frequently reported by members of athletic populations involved in jumping and running sports (Bennett et al., 2001; Edwards et al., 2005; Newman et al., 2013; Plisky et al., 2007; Yate et al., 2004). While there is no universal definition, most authors refer to the musculoskeletal condition as dull to intense pain over the distal one third to one half of the posteromedial border of the tibia (Bennett et al., 2001; Edwards et al., 2005; Plisky et al., 2007; Yate et al., 2004). Pain may last for a few hours or days after exercise (Yate et al., 2004). Often, modified activity or resting reduces patient-reported symptoms (Edwards et al., 2005). Differential diagnoses typically considered by ATs that may mimic the signs and symptoms of MTSS include chronic exertional compartment syndrome, stress fracture, popliteal artery entrapment syndrome, and nerve entrapment syndrome (Edwards et al., 2005; Newman et al., 2013).

2.3. Etiology of MTSS

The etiology of MTSS is not yet clearly defined in the literature. In the literature, scholars suggest an etiology of a periostitis on the tibia or a tibial bone stress reaction (Yate & White, 2004). However, researchers' suggestions are not sufficient to define the universal etiology of MTSS because soft tissue pathologies or bone stress reactions do not always occur or are not always diagnosed in patients. Therefore, many studies are focused on different aspects of MTSS, such as anatomy, pathomechanics, or histology, to investigate whether or not there is a causative factor for recurring symptoms (Beck &

Ostering, 1994; Bhatt, Lauder, Finlay, Allen & Bleton, 2000; Bouche & Johnston, 2007; Gaeta et al., 2005; Garth & Miller,1985; Mammoto et al., 2012; Michael & Holder, 1985; Moen et al., 2014; Stickley, Hetzler, Kimura & Lozanoff, 2009).

2.3.1. Anatomy of MTSS

The anatomical structures involved within the common location of MTSS symptoms, over the distal one third to one half of the posteromedial border of the tibia, are the soleus muscle, the flexor digitorum longus muscle, and the deep crural fascia. Two cadaver studies (Beck & Ostering, 1994; Michael & Holder, 1985) confirmed the soleus muscle is attached on the posteromedial border of distal tibia. Michael and Holder (1985) performed anatomical and electromyography (EMG) investigations of the soleus muscle to investigate whether the clinical appearance correlated with MTSS pain. The research objective was to characterize the soleus muscle and relate its attachment to the area involving the medial border of the tibia that presents pain in MTSS patients. In this study, anatomical investigation included 14 human cadaver dissections (28 legs) and ten live participants (two with and three without MTSS). The researchers dissected the 28 cadaver legs, performed EMG and muscle stimulation testing on the 10 live participants, and completed one open biopsy. The EMG test examined the medial soleus muscle and recorded tracings while the calcaneus was inverted and everted passively. Two MTSS participants (n=2) had a positive EMG tracing with passive inversion of the heel, although the other eight participants indicated negative tracing. The researchers took an open biopsy of bone and fascia of the soleus muscle from the medial border of the tibia on one patient with MTSS (this study does not indicate that whether or not this patient is 1 of the 2 patients with MTSS). As a result, the researchers identified the soleus muscle as a flat, thick, U- shaped muscle that consistently originates from the upper one third of the fibula and the posteromedial one third of tibia. The researchers also found that a fascia, a membrane of connective tissue that consistently separates and encloses the muscle fibers and attaches the soleus muscle, is connected just above medial malleolus. The insertion of the medial portion of soleus muscle was observed at the medial calcaneus. Overall, the EMG records show that the medial half of the soleus muscle is not only a strong plantar flexor muscle, but also an inversion muscle.

The researchers also revealed that on one MTSS patient at the histological level an increased metabolic activity, caused by a thickened periosteum, was associated with new bone reproduction. A biopsy over the medial border of the tibia was taken from one patient with severe MTSS showing a thickened periosteum. This study revealed that the contraction of the soleus muscle produces stress change at the medial border of the tibia in a pronated position. More specifically, the soleus muscle could be anatomically involved with the development of MTSS.

Similarly, Beck and Ostering (1994) dissected the legs of fifty cadavers to identify the structures over the medial tibia that have been associated with MTSS. The researchers noted the location of the tibialis posterior muscle, the soleus muscle, the flexor digitorum longus muscle, and the deep crural fascia to determine whether those structures may potentially contribute to strain at the site of the symptoms of MTSS. While dissecting one leg from each cadaver, the researchers recorded the range of the soleus muscle, flexor digitorum longus muscle, tibialis posterior muscle, and the deep crural fascia sit on the surface of the tibia to investigate the pattern of the attachment of fascia and muscle on the posterior aspect of the tibia. Beck and Ostering (1994) illustrated the attachment of both soleus and flexor digitorum longus muscles on the posterior aspect of the tibia. In their findings, those muscles did not attach consistently on the posterior aspect of the tibia. The soleus muscles were identified to sit on wide range of the tibial surface. They found that four of the 50 legs showed the attachment of the soleus muscle in the proximal one third of the tibia. Thirty-nine of the 50 legs had the attachment of the soleus muscle in the proximal two thirds of the tibia. In addition, in thirty cadavar legs the soleus muscles also attached to the distal one third to half medial border of the posterior tibia. These thirty cadavar legs included legs that showed the attachment of the soleus muscle to the proximal two thirds of the tibia and legs that did not. In 30 of the 50 (60%) human cadaver legs, the soleus muscle attached to the distal one third to half medial border of the posterior tibia.

Similarly, the location of flexor digitorum longus muscles sat on a wide range of the tibial surface. They also observed that 40 of the 50 legs showed the attachment of flexor digitorum longus muscle in the proximal one third of the tibia. In 49 of the 50 legs that attachment crossed over into the proximal two thirds of the tibia. This means that only one of 50 cadavar legs did not show an attachment in the proximal two thirds of the tibia. In addition, the flexor digitorum longus muscle attached to the distal one third to half medial border of the posterior tibia in 34 of the 50 (68%) human cadaver legs. The researchers found that both the soleus muscle and the flexor digitorum longus muscle appear on the medial border of the tibia at the symptomatic site of MTSS. They observed that a deep crural fascia was consistently attached along the entire length of the medial border of the tibia. However, the fibers of the tibialis posterior muscle were not observed on the common symptomatic site of MTSS. Beck and Ostering (1994) concluded that the soleus muscle, the flexor digitorum longus muscle, and the deep crural fascia are attached on the medial border of the tibia, which is the major muscle symptomatic site for MTSS.

Although Beck and Ostering (1994) explained that the common symptomatic site corresponded with the attachment of the soleus muscle, flexor digitorum longus, and the deep crural fascia, Stickley et al. (2009) proposed a different etiology of MTSS. The purpose of this study was to investigate the musculoskeletal structure relative to MTSS. These researchers dissected 16 human cadaver legs from above the patella to the foot, and measured the attachments of the flexor digitorum longus muscle and the tibialis posterior muscle from the distal tip of the medial malleolus to the most distal superior attachment on the tibia. The location of the attachment on the tibia for the flexor digitorum longus muscle and the tibialis posterior muscle were also recorded. As a result, they found deep crural fascia in all 16 samples of the medial tibia and the medial malleolus. The researcher found that only two cadavers had the soleus muscle attach on the distal one half of the tibia, but neither on the distal one third of the tibia. Only one cadaver had an attachment of the flexor digitorum longus muscle along medial tibial border, but that attachment was not on the distal one third of the tibia. In addition, only three samples had the tibialis posterior muscle attached along the medial tibial border, but all these attachments were identified in the proximal one half of the tibia. Stickley et al. (2009) concluded that deep crural fascia, rather than lower leg muscles, is more likely to be involved with MTSS (Stickley et al., 2009). Stickley et al. (2009) concluded that the attachment of the soleus muscle, tibialis posterior muscle, and flexor digitorum longus muscle are not supported by anatomical evidence; nevertheless, Stickley et al. (2009) did confirm Beck and Ostering's (1994) finding that the deep crural fascia consistently attaches along the entire medical border of the tibia.

2.3.2. Pathomechanics of MTSS

2.3.2.1. Tibial Traction Theory.

The existing literature indicates there are two primary pathomechanical theories about the cause of MTSS: tibial traction theory and tibial bending theory. The tibial traction theory suggests that the cause of MTSS is the inflammation of soft tissue on the tibia, which is the definition of periostitis (Bouche & Johnson, 2007). Therefore, according to this theory, MTSS is caused by the inflammation between muscle and bone interface (Bennett et al. 2001; Michael & Holder, 1985). In addition, this theory indicates that the plantar flexor muscles are involved with MTSS development. The tibial traction theory argues that a periostitis is initiated by the repetitive traction force generated with muscle contraction to the periosteum of posteromedial, distal tibia from the muscular fibers of the plantar flexor muscles (Michael & Holder, 1985; Bennett et al, 2001). The contractions of plantar flexor muscles, such as the soleus muscle and flexor digitorum longus muscle, appear to generate traction force to the periosteum on the common site of MTSS symptoms (Michael & Holder, 1985). Furthermore, the traction force on the distal, posteromedial tibia may also be involved with the development of MTSS. Michael and Holder (1985) stated the soleus muscle was found to be attached on the medial side of calcaneus and functioned as a strong plantar flexion muscle. The traction stress on this muscle was increased as the calcaneus was placed in a pronated position (Michael & Holder, 1985).

On the other hand, Bouche and Johnston (2007) investigated the plausibility of the tibial traction theory in a cadaver study. The researchers disarticulated and examined three cadavers at the knee. Then, the disarticulated lower legs were mounted on a load frame with a central rod applying downward force to the tibia. Examination cables with an actuator were attached to the posterior tibial muscle tendon, flexor digitorum longus tendon, and the soleus muscle tendon. The examination cable pulled upward, stimulating muscle pull. Four strain gauges were utilized to record strain in the tibial fascia, along the tibial crest three, six, nine, and 12 centimeters proximal to the tip of the medial malleolus. The fascial strain and tendon tension data were simultaneously collected at each strain gauge. The amount of downward force was applied and increased from 0 to 600 N. The downward force was held and applied consistently once the force reached at 600 N. A consistent linear relationship was found when the strain on the tibial fascia was increased at 0.0002 mm/ N, measured while the tension on the posterior tibialis, flexor digitorum longus, and soleus tendons were increased. (p=0.0001). The researchers concluded that fascial tension may be involved in the pathomechanics of MTSS (Bouche & Johnston, 2007).

This Bouche and Johnston (2007) study confirmed the findings from previous cadaver studies (Michael & Holder, 1985; Beck & Ostering, 1995). Michael and Holder (1985) found that the soleus muscle is consistently involved in the defined site of MTSS in 28 human cadaver legs. Also, Michael and Holder (1985) found that the two participants with MTSS had a positive tracing of EMG on the soleus muscle. Beck and Ostering (1995) also observed that the soleus muscle (68%), flexor digitorum longus muscle (60%), and the deep crural fascia are consistently attached on the defined site of MTSS in 50 human cadaver dissections. In addition, Bouche and Johnston (2007) and Stickley et al. (2009) supported the implication of fascia on tibial in MTSS in the cadaver study. Furthermore, Stickley et al. (2009) concluded the deep crural fascia is the most likely to be involved with MTSS from an anatomical standpoint.

2.3.2.2. Tibial Bending Theory.

On the other hand, the tibial bending theory ascribes the cause of MTSS to a bone stress reaction on the tibia (Moen et al. 2014). According to this theory, development of MTSS causes a bone stress reaction from repetitive bone overloading. Numerous authors have suggested that MTSS may be a bone stress reaction, which causes pain on the tibia (Bhatt et al. 2000; Fredricson et al., 1995; Moen et al., 2014; Yate & White, 2004). In the normal process of bone remodeling for adaptation, osteoblasts form new bone tissue in the cell groups in the bone, and osteoclasts play the role of bone re-absorption cells (Warden et al., 2014). The activities of osteoclasts and osteoblasts are essential to remodeling new bone tissue (Warden et al., 2014). During dynamic activity, the tibia has microscopic damage from activities of osteoclasts due to compressive force on the posteromedial border of tibia (Yate & White, 2004; Warden et al., 2014). The amount of microscopic damage depends on the load of magnitude during weight-bearing activity (Waldorff et al, 2010; Warden et al., 2014). Then, new bone tissue is laid down by osteoblasts to resist the future loading on the bone (Waldorff et al., 2010; Warden et al., 2014; Yate & White, 2004). However, in an acceleration of this cycle, more bone re-absorption occurs, causing microscopic damage in repetitive submaximal stress (Warden et al., 2014). This cycle of accumulation of bone microscopic damage can cause tibial bone stress reaction, tibial bone stress fracture, and eventually complete bone fracture (Warden et al., 2014). Furthermore, the distal tibia is a common site of tibial stress fracture because it has a narrow radius (Warden et al., 2014). Bones with narrow radii undergo more loading and bending force when weight bearing. The increased muscle fatigue, or dysfunction, can cause the increased tibial strain (Warden et al., 2014). Therefore, it has been hypothesized that muscle dysfunction from overuse can increase in focal tibial bending stress that exceeds bony adaptation (Milner, Ferber, Pollard, Hamill & Davis, 2006; Yate & White, 2004).

Furthermore, a review of the literature reveals four important findings that support tibial bending as a pathomechanic of MTSS: a) bone and periosteum abnormalities on a three phase bone scan (Michael & Holder, 1984); b) positive signs for tibial stress injury on CT scan (Gaeta et al., 2005); c) bone marrow swelling and periosteum thickening on MRI (Fredricson et al., 1995; Mammoto et al. 2012; Moen et al., 2014); and d) lower bone density on DEXA (Magnusson et al., 2001; Magnusson, Ahlborg, Karlsson, Nyquist, & Karlsson, 2003). Michael and Holder (1984) investigated a three-phase bone scan in patients to determine whether or not a diagnostic characteristic exists, and if characteristics do exist, then what do those characteristics reveal about the pathomechanics of MTSS. In order to investigate this research question, Micheal and Holder (1984) recruited ten athletes, five male and five female, to participate in this study. All had the following clinical characteristics: exercise-induced pain relieved by rest; dull to intense pain; tenderness along the posteromedial aspect of the tibia in the distal portion of the middle third; no sensory, motor, or vascular trauma; and pronated foot. A three-phase bone scan was used to obtain anterior, posterior, lateral, and medial images of both legs. This three-phase bone scan illustrated that nine of the ten participants presented 17 lesions on the tibia (n=15) and the fibula (n=2). Thirteen of the 15 lesions on the tibia were symptomatic. All of the symptomatic lesions involved the posterior aspect of the tibial cortex or the distal one-third length of the tibia. More specifically, two of the asymptomatic lesions were on the tibia and two of the asymptomatic lesions were on the fibula. In addition, nine of the 15 symptomatic lesions on the tibia extended from the distal portion of the middle third to the proximal portion of the distal third of the posterior tibial cortex. In fact, three of the 15 symptomatic lesions on the tibia involved the middle third of the posterior cortex, and two lesions involved the junction between upper and middle third of the tibia. Only one symptomatic lesion on the tibia involved the upper third of the posterior tibial cortex. Michael and Holder (1984) found that 12 of the 15 symptomatic lesions match MTSS development and symptoms. Therefore, this study suggests that bony abnormality can be associated with the development of MTSS.

The second finding, positive signs for tibial stress injury, was identified on CT scans (Gaeta et al., 2005). Gaeta et al. (2005) compared CT scans, MRIs, and bone scans in 42 athletes who suffered from tibial stress injury. All 42 participants fulfilled the inclusion criteria: a) unilateral or bilateral lower leg pain lasting less than 1 month, b) no history of injury, and c) normal appearance on a radiograph of the lower leg. Eight participants had symptoms bilaterally. Therefore, 50 legs were compared in this study to find the tibial abnormalities by using CT scans, MRIs, and bone scans. The CT scans showed positive cortical stress injury on the tibia in 21 of the 50 legs with tibial pain, while MRIs detected positive cortical stress injury on 44 of the 50 tibia, and bone scans detected positive cortical stress injury on 37 of the 50 tibia (Gaeta et al., 2005). The tibial abnormalities included fracture, cortical abnormality, bone marrow edema, and periosteal edema. The MRIs and the bone scans each detected two fractures, but the CT scans did not detect any. The MRIs, bone scans, and CT scans detected 25, 18, and two cases of bone marrow edema, respectively. The MRIs, bone scans, and CT scans detected 12, 8, and one cases of periosteal edema, respectively. MRIs and bone scans detected 17 and 13 cortical abnormalities respectively, whereas CT scans detected 21 cortical abnormalities. These findings are presented in Table 1.

Table 1

Comparison of Imaging Techniques According to Type of Tibial Stress Injury in 50 Tibia of 42 Patients

Findings	MRI	CT Scan	Bone Scan
Lesion			
Fracture	2	0	2
Cortical abnormality	17	21	13
Marrow edema	25	2	18
Periosteal edema	12	1	8
Positive	44	21	37
Negative	6	29	13

Note. "CT and MR Imaging Findings in Athletes with Early Tibial Stress Injuries : Comparison with Bone Scintigraphy Findings and Emphasis on Cortical Abnormalities." By Gaeta et al., 2005, *Radiology*, *235*, p. 554.

Gaeta et al. (2005) concluded that CT scans detected osteopenic change in the tibial cortex as the earliest sign of cortical abnormalities. High resolution CT scans indicated a sensitivity and specificity of 42% and 100%, respectively. There were statistically significant differences in detection of bone stress injury between MRI and bone scan (p<0.001) and between CT scan and bone scan (p<0.008). Therefore, MRI was the single best imaging technique to detect tibial abnormalities. However, CT scans detected cortical abnormalities, which are early signs of bone stress injury, better than MRIs or bone scans.

The third important finding to support tibial bending as a pathomechanic of MTSS is bone marrow swelling and periosteum thickening identified on MRIs (Fredricson et al, 1995; Mammoto et al. 2012;

Moen et al., 2014). In the MRI studies, scholars found frequent reports of bone marrow edema and periosteal edema related with tibial stress injury, including MTSS and stress fracture, due to the process of bone remodeling (Fredricson et al., 1995; Bergman, Fredricson, & Matheson, 2004; Mammoto et al., 2012; Moen et al., 2014). Bergman et al. (2004) found that MRIs can detect asymptomatic bone stress reactions. In this study, MRIs showed bone stress reactions in 9 of 21 competitive runners (43%), even though all 21 runners self-reported as asymptomatic (Bergman et al. 2004). This means that bone stress reactions occurred without corresponding clinical symptoms (Bergman et al. 2004). Moreover, Moen et al. (2014) evaluated the tibia of 52 athletes with MTSS using MRIs and found bone marrow edema or periosteal edema in 43.5% of the symptomatic legs. However, abnormalities of bone marrow or periosteum were found in both symptomatic and asymptomatic legs. For the early phase of bone stress reaction, abnormalities of bone marrow and periosteum can usually be observed on MRIs (Fredricson et al., 1995; Mammoto et al. 2012; Moen et al., 2014). While the bone stress reaction is not always symptomatic, it can follow a symptomatic stress reaction and progress to a stress fracture in response to repetitive stress applied to the bone (Bergman et al., 2004; Moen et al. 2014).

The fourth important finding to support tibial bending as a pathomechanic of MTSS is that the lower bone density of the tibia was identified in patients who suffered from MTSS on DEXA studies (Magnusson et al., 2001; Magnusson et al., 2003). Magnusson et al. (2001) investigated whether or not a lower tibial bone density is associated with MTSS patients as compared to non-MTSS patients. The researchers evaluated the bone density of the tibia in three groups: 18 male athletes with MTSS, 18 male athletes without MTSS, and 16 sex and age matched non-MTSS, non-athletes (Magnusson et al., 2001). In this study, MTSS presented exercise-induced pain at the middle to distal third of the medial tibia. DEXA measured bone mineral density in the spine, the proximal femur, the tibia, and the total body. The bone mineral density at the affected region of the tibia was measured statistically significantly lower by 23%±8% ($p<0.001$) in the athletic control group and 15%±9% ($p<0.01$) in the control group. Therefore, these four findings indicate that tibial cortex abnormalities in MTSS development probably relate to the tibial bending theory. However, the tibial bending theory remains as a hypothesis because the histological evidences are necessary to confirm this theory. This means that these findings may support the bone abnormalities as signs and symptoms of MTSS. However, these findings do not show the acceleration of bone remodeling causing microscopic damage. Therefore, further histological studies could be helpful in confirming tibial bending's role in overloading.

Although research shows MTSS reduces overall bone density, Magnusson et al. (2003) assessed whether or not there are any changes in lower bone mineral density after recovery from MTSS symptoms. This study assessed change of bone mineral density in 14 of 52 participants who recovered from MTSS symptoms (Magnusson et al., 2003). These participants were from an earlier 2001 study by Magnusson et al. The participants' bone densities were measured in the hip, tibia, and total body while their symptoms presented. The bone mineral density was again measured in the hip, tibia, and the total body after participants recovered from the symptoms. The local bone density increased significantly, 19%±11% in the symptomatic region ($p<0.001$) and 4%±3% in the total body ($p<0.001$) from the baseline. In addition, the total body bone mineral density was also significantly higher, 5%±5% higher ($p<0.05$), than the nonathletic control group. The researchers concluded that the localized low bone mineral density in the tibia, which corresponds to the pain associated with MTSS, is increased after the recovery. It still remains unclear whether the MTSS symptoms precede or result from low bone mineral density in the tibia. Treating MTSS could be helpful for other bone pathologies, such as bone stress fractures.

In summary, two theories describe the cause of MTSS: the tibial traction theory and the tibial bending theory. The tibial traction theory focuses on the inflammation of soft tissue of the interfacing tibia. The hypothesis is that repetitive tension on muscles or fascia causes MTSS. On the other hand, the tibial bending theory focuses on microscopic bone damage. The hypothesis is that repetitive tibial bending causes a stress reaction on the narrower radius of the tibia. In diagnostic studies, researchers confirmed that MTSS is more likely involved with bony abnormalities as suggested in the tibial bending theory (Fredricson et al, 1995; Gaeta et al., 2005; Magnusson et al., 2001; Magnusson et al., 2003; Mammoto et al. 2012; Michael & Holder, 1984; Moen et al., 2014). These four findings suggest that MTSS seems to stem from the tibial stress fracture and/ or its many ramifications (Moen et al., 2010). However, as stated earlier, because bone abnormalities are supported as an underlying condition in MTSS, treatment options for bone injuries could also be useful when approaching MTSS in clinical practice. These suggestions indicate that ATs should treat MTSS as a bone abnormality pathology rather than a soft tissue pathology.

Current AT clinical practice would be impacted if either theory is substantiated, resulting in appropriate treatment for patients with MTSS.

2.3.3. Histology

The literature suggests that tibial bone stress reactions from tibial bending seem to be more likely than periostitis from tibial traction (Bhatt et al. 2000; Moen et al., 2014; Yate & White, 2004). The histology findings in the literature are necessary to support the hypothesis that MTSS is more likely tibial bone stress reaction. In a bone biopsy study, Bhatt et al. (2000), found that bone remodeling is also likely to be involved in MTSS. Periostitis cannot be supported as a primary MTSS etiology at a histological level because Bhatt et al. (2000) found abnormally less osteocytes in MTSS patients compared with normal bone tissue. However, this does not mean periostitis can be ruled out completely because the inflammation marker, although seldom, has been found in MTSS patients (Bhatt et al., 2000). Bhatt et al. (2000) investigated the correlation of bone scans and histological findings in MTSS. The researchers examined 32 limbs from 22 patients who underwent surgery for specimens of periosteum and bone. A clinical characteristic of all patients included a diffused tenderness along the medial border of the distal tibia. The duration of symptoms ranged from 15 to 22 months prior to their operative treatment. All patients had bone scans for a clinical diagnosis of MTSS. During surgeries, biopsy specimens of periosteum and bone were collected from all 32 limbs. In total, 32 samples of periosteum and 26 samples of bone were reviewed for histological findings.

In this study, researchers reviewed the histopathology of periosteal abnormalities of the biopsy specimens and found: a) periosteal thickness, b) fibrosis, c) vascularity, d) mucin production, and e) iron deposition. Also, researchers reviewed bone abnormalities and found: a) lamellar structure, b) osteocyte loss, and c) chronic inflammation. As a result, bone scans showed 11 normal limbs, 16 cases of diffuse tubular uptake, and 5 cases of focal uptake changes. The most common abnormality of the periosteum was fibrous thickening, which is normally associated with an increased vascularity. However, chronic inflammation was rarely noted. Also, biopsies showed in 21 out of 32 limbs an abnormal periosteum of the tibia bone. On the other hand, 16 of 26 biopsies of bone were positive for histological findings. There were no statistically significant correlations for bone and periosteum changes between bone scans and biopsy in patients with MTSS(p=0.0028). These researchers concluded that abnormal bone and periosteal abnormalities occurred in most cases of MTSS. However, the correlation between histological and bone scans is weak.

The literature reports that a bone stress reaction, instead of the inflammation of the periosteum, is more likely to be the initial site of MTSS. However, periostitis cannot be ruled out completely as the etiology of MTSS because there are a few observations of inflammatory markers on periosteum in MTSS patients (Bhatt et al. 2000). The researchers found only three cases of chronic inflammation in 32 MTSS limbs (Bhatt et al. 2000). Recently, more evidence has been reported of a bone stress reaction as the etiology of MTSS (Bhatt et al. 2000; Fredricson et al., 1995; Mammoto et al., 2012; Moen et al., 2014). Even though a bone stress reaction is identified with signs of a bone remodeling process, it is not always a causative factor of MTSS because it can be asymptomatic in MRIs (Bergman et al., 2004). In conclusion, current diagnostic imaging studies indicate that MTSS is most likely a bone pathology.

2.4. MTSS Treatment

Individuals suffer from MTSS as a result of their participation in running activities such as basketball, tennis (Edwards et al, 2005), cross country, field hockey (Reinking, 2006), or military service (Smith et al., 1986; Rue, Armstrong, Frassica, Deafenbaugh & Wilkckens, 2004; Moen et al., 2010). In fact, approximately 5% of all running-related injuries are diagnosed as MTSS (Taunton et al., 2002). As stated earlier, although the etiology of MTSS is still unclear, several studies support theories on the causes of MTSS; for example, the chronic overuse of plantarflexor muscles (Beck & Ostering,1994; Delacerda, 1982; 2000; Madeley et al., 2007; Michael & Holder, 1985; Smith et al., 1986) and the repetitive overload of the tibia (Bhatt et al., 2000; Fredricson et al., 1995; Gaeta et al., 2005; Magnusson et al., 2001; Magnusson et al., 2003; Mammoto et al., 2012; Moen et al., 2012; Moen et al., 2014; Rompe et al., 2012). Because of MTSS's unclear etiology, establishing a treatment for MTSS may include minimizing or controlling symptoms and factors that may develop into MTSS (Craig, 2009; Moen et al., 2014; Thacker et al., 2000). This literature review will provide an overview of current research for MTSS treatment to analyze the effects of treatment options and provide an overview of the necessity for future research in MTSS treatment.

This literature review covers studies of diagnoses typically considered by ATs stemming from the various definitions of "MTSS" or similar injuries to include a wide variety of target pathologies that are similar to MTSS. Because there is no universal definition, the researchers cited in this literature review may use the term "shin splints" as a condition that possibly includes MTSS (Brushoj et al., 2008; Burrus et al., 2014; Edwards et al., 2005; Taunton et al., 2002). Therefore, for the purpose of this literature review, inclusion criteria are not only MTSS, but also similar symptoms such as a description of pain along the medial tibia (Smith el al., 1986), either anterolateral or posteromedial tibial pain with palpation (Delacerda, 1982), a diagnosis of shin splints (Singh et al., 2002), or tibial stress fracture (Brand, Brindle, Nyland, Caborn, & Johnson, 1999; Rue et al., 2004). MTSS is also described as exercise-induced pain along an area of at least five centimeters on the posteromedial tibia upon a palpation (Mandeley et al., 2007: Moen et al., 2010; Moen et al., 2012). In fact, Griebert et al. (2014) simply uses a "diagnosis of MTSS" without any other descriptors (p. 2). These injury criteria were used in agreement with lower leg pathologies to develop a consistent characterization of MTSS.

In total, nine different treatments will be analyzed for MTSS or similarly characterized injuries: cryotherapy, iontophoresis, phonophoresis, ultrasound, resting, calf stretching, calf strengthening, orthotic use, and Kinesio® tape application. The literature reveals two important categories of MTSS treatments. First, there are treatments that aim at reducing or minimizing symptoms, which include: cryotherapy, iontophoresis, phonophoresis, ultrasound, and wearable support. The second important category is made up of various therapeutic interventions to minimize, or correct, possible factors related to MTSS development. These treatments include practices such as calf stretching, calf strengthening, orthotic use, and Kinesio ® tape application. This literature review will analyze and evaluate the published results for both categories.

2.4.1. Cryotherapy

Cryotherapy is a therapeutic intervention of removing heat from the body using many techniques such as ice pack, cold gel pack, ice massage, or cold immersion (Nadler, Weingand, & Kruse, 2004). Cryotherapy has been widely accepted in clinical applications for sports injuries (Nadler, Prybicienm, Malanga, & Sicher, 2003). The use of cryotherapy is popular for treating acute soft tissue injuries. In fact, a national survey completed by Nadler et al. (2003) reported that cryotherapy is the most common treatment used by ATs for athletic injuries. Respondents to this national survey were ATs working in high schools, colleges, professional sports teams, physical therapy clinics, or industrial settings. The researchers reported that the frequency of ice application rates more than doubles from physical therapy clinics (40%) to collegiate athletic training clinics (85%).

After an athlete is injured, it is important for ATs to control pain to enhance the recovery process. Pain reduction using cryotherapy is well-represented in the literature (Smith et al., 1985; Algafly & George, 2007). Algafly and George (2007) examined the effect of cryotherapy application on Nerve Conduction Velocity (NCV), Pain Threshold (PTH), and Pain Tolerance (PTO) in 23 male sports club players. Outcome measurements included changes of NCV, PTH, and PTO at baseline, at skin temperature of 10 and 15 degrees Celsius by utilizing an ice pack, and at a rewarmed 15 degrees Celsius after ice pack removal. For both the experimental and control groups, the researchers utilized electromyograms to measure NCV of the tibial nerve. Also, PTH and PTO were measured via pressure algometer at two different sites on the ankle; both sites are innervated by the tibial nerve. One site was the posterolateral aspect of lateral malleolus and other site was the proximal shaft of lateral fourth metatarsal bone. For the experimental group, ice packs were applied on the lateral malleolus only, leaving the lateral fourth metatarsal bone without an ice pack. Algafly and George (2007) reported that in the experimental group, NCV for the tibial nerve at baseline, 10 degrees Celsius, and 15 degrees Celsius was significantly ($p<0.05$) reduced as compared to NCV for the control group. In contrast, the control group recorded a constant value for NCV from the beginning through the end of data collection. Also, at the site of ice application, PTH and PTO for the experimental group increased at a statistically significant rate ($p<0.005$) when the skin temperature of the ankle was decreased to 10 degrees Celsius on the lateral malleolus with cryotherapy as compared to the control group. In addition, at a non-iced site for the experimental group, PTH and PTO increases were statistically significant ($p<0.005$) because the skin temperature was decreased by 10 degrees Celsius compared to the control site. Moreover, there was a significant association between decreased NCV of tibial nerve and increased in PTH and PTO ($p<0.05$, $r=0.71$) (Algafly & George, 2007). Therefore, Algafly and George (2007) concluded that cryotherapy application decreases NCV and increases PTH and PTO.

The study by Algafly and George (2007) confirms the cause and effect relationship between ice application and pain relief, which is typically the result clinicians seek for patient outcomes. Increased PTH and PTO due to ice application reduced NCV significantly. This analgesic effect was observed even for non-iced sites when another site is innervated by same nerve. These results support the use of cryotherapy for pain reduction via nerve transmission. However, while cryotherapy may be appropriate to alleviate symptoms, it may not address the underlying causes of MTSS. Nevertheless, although cryotherapy use for MTSS treatment has not been well studied, it is important to evaluate the effects of cryotherapy on injuries similar to MTSS for the purpose of this literature review because cryotherapy use by ATs is common in clinical situations (Nadler et al., 2003).

Numerous orthopedic experts have recommended ice application for the treatment of MTSS-like symptoms. Fredricson et al. (1995) concluded that ice massage may be helpful for bone stress reaction in order to relieve pain. Also, Couture and Karlson (2002) stated that the most effective treatment for MTSS-like symptoms is immediate ice massage. The Couture and Karlson (2002) and Fredricson et al. (1995)studies make their recommendations based on professional experience. In addition, while Burrus et al. (2014) stated that all MTSS patients should be treated with cryotherapy, rest, compression, elevation, stretching, physical therapy, and a leg brace, this recommendation was also based on an overall professional opinion.

Although the previous studies make their recommendations primarily based on professional opinion, a few randomized cryotherapy treatment studies on shin splints are available that support the effectiveness of cryotherapy to treat MTSS (Andrish et al., 1974; Smith et al., 1986). Andrish et al. (1974) compared the results of five treatments on patients with shin splints. In this study, 97 Marine recruit participants, diagnosed with shin splints during their training program, were randomly assigned to five treatment groups. Participants in group one applied ice to the affected body area three times daily and avoided running until they were pain free. Group two received the identical treatment to group one with the added component of aspirin four times daily for one week. Group three also received the identical treatment to group one with the added component of phenylbutazone four times daily for one week. Participants in group four received the identical treatment to group one with the added component of an additional three-minute calf muscle stretch three times daily for one week. Participants in group five wore a walking cast for one week. The criteria to recovery was that participants experienced an absence of symptoms when they ran approximately 500 meters. The participants had a follow-up examination every three days until recovery.

Table 2 illustrates the days until recovery for the five treatment groups. The average days of absence from running was 8.62. Group one, using ice and rest, resulted in a statistically significant outcome in the duration of recovery as compared to the other treatment groups (p=0.03). However, when compared with groups two through four, there was no significant treatment difference between treatment groups. Additional medication, calf stretching exercise, or walking cast did not increase the effects of treatment. While the researchers concluded that all of the treatment options were effective to reduce pain, the results of this study indicate ice is the most effective treatment to alleviate symptoms of shin splints.

Table 2

Comparison of the Average Days Missed from Running in Each Treatment Group

Treatment Group	Number of Participants	Average days missing from running
Group 1 (ice)	19	6.4
Group 2 (ice and aspirin)	25	9.6
Group 3 (ice and phyenylbutazone)	19	7.5
Group 4 (ice and calf stretch exercise)	16	8.8
Group 5 (a walking cast)	18	10.8

Note. "A Prospective Study on the Management of Shin Splints." By Andrish et al., 1974, *Journal of Bone and Joint Surgery*, *56*, p. 1699.

Similarly, although not specifically targeting MTSS, Smith et al. (1986) studied the effectiveness of ice massage for treating shin splints. While this study was not restricted to MTSS, Smith et al. (1986) qualified the similar definitive injury, "shin splint," as palpable pain along the medial tibia. The researchers compared the effectiveness of four different therapeutic modalities: ice massage, iontophoresis, phonophoresis, and ultrasound in a randomized controlled trial. All 50 participants from a military branch who had shin splints were divided into five groups. Four out of five groups received one of four therapeutic modalities. The fifth group, as the control group, did not receive any therapeutic modalities. All participants were monitored daily. For a patient outcome measurement, the participants recorded their pain, both prior to and after the treatment programs, on a scale of 1 to 10, with 10 being the highest degree of pain. The termination criteria for a period of treatment sessions included either 10 treatment sessions or until participants no longer experienced pain. During the period of treatment sessions, all participants avoided running, jumping, marching activities, or prolonged walking or standing. The ice massage group of 10 people performed ice massage for 10 minutes in a circular motion at the pain site, and all participants performed 30 seconds of active heel cord stretching after each treatment session, including the control group.

The results showed significant differences in the pain scales between the ice massage group and the control group. The average change on the pain scale for the group assigned to the ice massage treatment between pre- and post-treatment programs was 5.6±1.65. This means that participants experienced, on average, a decrease of more than 5 points on self-reported pain scale of 1-10 (10 means the highest degree of pain) after the ice massage treatment program. On the other hand, participants in the control group experienced an increase of pain after the experiment by -1.9±2.28 from baseline. According to Smith et al. (1986), ice massage is a statistically significant (p<0.01) effective treatment in reducing shin splints pain.

While both Andrish et al. (1974) and Smith et al. (1986) conclude that ice massage is an effective treatment to reduce shin splint symptoms, their inclusion criteria for shin splints differed. For example, Andrish et al.'s (1974) inclusion criteria was a diagnosis of shin splints. In contrast, Smith et al. (1986) used the inclusion criteria for shin splints as pain along the medial aspect of the tibia. While the Andrish et al. (1974) study inclusion criteria was a general diagnosis, the Smith et al. (1986) study required pain in specific place to be considered as a diagnosis of shin splints. Like the Smith et al. (1986) study, the definition of MTSS for this thesis project is a specific kind of pain in a specific spot: an exercise-related, dull to intense pain along the posteromedial aspect of the distal one-third to one-half of the tibia (Edward et al., 2005; Yate & White, 2004). Although the general population commonly uses the term of "shin splints" to describe chronic lower leg pain, like the Andrish et al. (1974) study, shin splints often also encompasses the symptoms of MTSS. Clinically, ATs may not change their treatment decisions for MTSS versus shin splints. Therefore, these articles can support cryotherapy regarding treatment for shin pain regardless of whether or not researchers specify MTSS or more general shin pain (Andrish et al., 1974; Smith et al., 1986). Scientifically, until research is conducted that specifically targets MTSS, it is not possible to make final conclusions about how cryotherapy affects MTSS. However, for the purpose of this literature review, these studies indicate the appropriateness of cryotherapy use to reduce shin pain by ATs in clinical situations.

2.4.2. Iontophoresis

Transdermal drug delivery techniques have the advantages of being safe, painless, and noninvasive as compared to injection techniques (Harris, 1982). Iontophoresis is a transdermal drug delivery technique used to deliver ionized medication into the target treatment area through a low-voltage direct current. Iontophoresis is used to administer anesthetics, analgesics, and anti-inflammatory drugs into musculoskeletal tissue. Since the definition of shin splints may include MTSS, the effectiveness of iontophoresis in various settings when treating shin pain is appropriate to consider in this literature review (Delacerda, 1982; Smith et al., 1986; Singh et al., 2002).

Delacerda (1982) examined the effect of hydrocortisone, an anti-inflammatory drug, administered to patients who had symptoms common in a shin splints diagnosis. Four male and eight female collegiate athletes with shin splints participated in this study. The inclusion criterion for shin splints was either anterolateral or posteromedial tibial pain with palpation. In total, 18 legs were treated with iontophoresis, seven had pain along the anterolateral tibia and 10 had pain along the posteromedial tibia. One subject had pain at both locations. The participants reported pain on subjective scale – mild, moderate, or severe – when a clinician palpated the affected area. Two participants reported mild pain, 12 participants reported moderate pain, and four participants reported severe pain. All participants experienced increased pain when walking, running, and climbing stairs. Half of the shin splint legs (n=9) received iontophoresis treatments with 0.5% hydrocortisone for the entire treatment program. The other half of shin splint legs (n=9) received three initial iontophoresis treatments with xylocaine, a pain relief drug. Following the three initial iontophoresis treatments with xylocaine, a 0.5% hydrocortisone was applied via iontophoresis for the remainder of the treatment sessions. All iontophoresis treatments were performed with an intensity of 5mA for a duration of 20 minutes, every other day. All participants continued their sports-specific training during treatment sessions. Treatments were applied until participants experienced no pain on symptomatic areas of the tibia, up to 10 treatments. In total, 82 iontophoresis treatments were performed including 27 xylocaine treatments and 55 hydrocortisone treatments. The average number of treatment sessions until absence of pain was 3.05. The maximum number of treatment sessions was six, and the minimum number of treatment sessions was one.

The group assigned to only the 0.5% hydrocortisone via iontophoresis treatment experienced alleviated symptoms and became asymptomatic. On the other hand, the group assigned to the xylocaine via iontophoresis and then the 0.5% hydrocortisone via iontophoresis treatment experienced a temporary absence of pain, from one to six hours, after treatment with xylocaine. However, their pain came back to the original intensity after the xylocaine via iontophoresis treatment. Then, like the first group after the 0.5% hydrocortisone via iontophoresis treatment, the second group reported alleviated shin splint symptoms. Therefore, the iontophoresis treatment application of the 0.5% hydrocortisone with intensity of 5mA for a duration of 20 minutes was reported as effective to reduce shin splint symptoms (Delacerda, 1982).

While Delacerda (1982) concluded the application of iontophoresis with 0.5% hydrocortisone is an effective treatment for symptoms of shin splints, there are some limitations to the study's design, which complicate its use in this thesis project because Delacerda (1982) only reported the average number of treatments until absence of pain. Therefore, the final conclusion cannot state whether or not iontophoresis is a statistically significant effective treatment for reducing shin splint pain. Indeed, the study results can only indicate that iontophoresis may be considered a potentially beneficial treatment option for shin splints (Delacerda, 1982).

As mentioned in the cryotherapy section, Smith et al. (1986) also investigated the effectiveness of iontophoresis for treating shin splints. Although this study was not restricted to MTSS, Smith et al. (1986) qualified shin splints as palpable pain along the medial tibia. Smith et al. (1986) compared the effectiveness of four different therapeutic modalities: ice massage, iontophoresis, phonophoresis, and ultrasound in a randomized controlled trial. All 50 participants from a military branch who had shin splints were divided into five groups. Four out of five groups received one of four therapeutic modalities. The fifth group, as the control group, did not receive any therapeutic modalities. For outcome measurement, the participants recorded their pain, both prior to and after the treatment programs, on a scale of 1 to 10, with 10 being the highest degree of pain. The termination criterion for a period of treatment sessions included either 10 treatment sessions or until participants no longer experienced pain. During the period of treatment sessions, all participants avoided running, jumping, marching, and prolonged walking or standing. The iontophoresis treatment group received iontophoresis treatments with 2 cc of dexamethasone sodium phosphate (4mg/ml) and 1 cc of 4% lidocaine hydrochloride with 2.5-5mA for 20 minutes. Participants in the control group did not receive any therapeutic modality, but were monitored daily. All participants, including the control group, performed 30 seconds of active heel cord stretching after each treatment session.

The results indicated significant differences in the pain scales between the iontophoresis group and the control group. The average change on the pain scale for the group assigned to the iontophoresis treatment between pre- and post-treatment programs was 5.0±1.15. This means that participants experienced, on average, a decrease of more than 5.0±1.15 on a self-reported pain scale of 1-10 (10 means the highest degree of pain) after the iontophoresis treatment program. On the other hand, participants in the control group experienced an increase of pain by 1.9±2.28 from the baseline. According to Smith et al. (1986), iontophoresis is a statistically significant ($p<0.01$) effective treatment in conjunction with dexamethasone sodium phosphate, an anti-inflammatory drug, and lidocaine hydrochloride, to reduce shin splints pain when compared to the control group.

Again, although the use of iontophoresis is recommended to treat shin splints, it is still necessary to confirm whether or not iontophoresis has the same effect on MTSS as it does on shin splints. Since studies show that iontophoresis is effective for treating shin splints (Delacerda, 1982; Smith et al., 1986), then it may be also considered to be effective for MTSS. However, while past studies (Delacerda, 1982; Smith et al., 1986) confirm that iontophoresis is effective in reducing shin splint symptoms, the inclusion criteria of shin splints were not consistent in terms of symptomatic location. For example, Delacerda (1982) defines inclusion criterion for shin splints as pain over anterolateral or posteromedial tibia with palpation. Pain over the anterolateral tibia does not match the inclusion definition for this particular literature search; however, pain over the posteromedial tibia seems to be a MTSS-like symptom. Since the author did not describe numbers for each of the symptomatic locations, the published results included data for the effects of iontophoresis for anterolateral pain. On the other hand, Smith et al.'s (1986) inclusion criteria was pain along medial tibia, a MTSS-like symptom. These results (Delacerda, 1982; Smith et al., 1986) indicate iontophoresis is an effective treatment in reducing shin pain.

Like the Smith et al. (1986) study, the definition of MTSS for this thesis project is a specific kind of pain in a specific spot: an exercise-related, dull to intense pain along the posteromedial aspect of the distal one-third to one-half of the tibia (Edward et al., 2005; Yate & White, 2004). However, clinically, ATs may not change their treatment decisions for MTSS versus shin splints. Therefore, these studies can support iontophoresis regarding treatment for shin pain regardless of whether or not researchers specify MTSS or more general shin pain (Delacerda, 1982; Smith et al., 1986). Yet scientifically, until research is concluded that specifically targets MTSS, it is not possible to make final conclusions about how iontophoresis affects MTSS. Nevertheless, for the purpose of this literature review, these results indicate an appropriateness of iontophoresis use to reduce shin pain by ATs in clinical situations.

2.4.3. Phonophoresis

Similar to iontophoresis, phonophoresis is a transdermal drug delivery technique using therapeutic ultrasound application; this type of application assists in driving medications through the skin into the tissues, thereby opening pathways for medication diffusion (Starkey, 2004). Due to this mechanism, phonophoresis is a safe and noninvasive technique to deliver a variety of medications to targeted tissues (Davick, Martin, & Albright, 1988; Singh et al., 2002). Galbraith and Lavallee (2009) recommend using phonophoresis in MTSS treatment for reducing pain. Since the definition of shin splints may include MTSS, the effectiveness of phonophoresis in various settings when treating shin pain is appropriate to consider for this thesis project (Smith et al., 1986; Singh et al., 2002).

As mentioned in the cryotherapy section, Smith et al. (1986) investigated the effectiveness of four different therapeutic modalities for treating shin splints: phonophoresis, ice massage, iontophoresis, and ultrasound in a randomized controlled trial. Although this study was not restricted to MTSS, Smith et al. (1986) qualified shin splints as palpable pain along the medial tibia. All 50 participants from a military branch who had shin splints were divided into five groups. The inclusion criterion for shin splints in this study was pain along medial tibia. Four out of five groups received one of four therapeutic modalities. For outcome measurement, the participants recorded their pain, both prior to and after the treatment programs, on a scale of 1 to 10, with 10 being the highest degree of pain. The termination criterion for a period of treatment sessions included either 10 treatment sessions or until participants no longer experienced pain. During the period of treatment sessions, all participants avoided running, jumping, marching, and prolonged walking or standing. The phonophoresis treatment group received 33mg of dexamethasone and 16ml of lidocaine gel of 2% in a 60mg water-soluble base mixture applied with continuous ultrasound set on 1.5W/cm^2 for a duration of six minutes. Participants in the control group did not receive a therapeutic modality, but were monitored daily. All participants, including the control group, performed 30 seconds of active heel cord stretching after each treatment session.

The results indicated significant differences in the pain scales between the phonophoresis group and the control group. The average change on the pain scale for the group assigned to the phonophoresis treatment between the pre- and the post- treatment program was 5.20±1.14. This means that participants experienced, on average, a decrease of 5.20±1.14 on a self-reported pain scale of 1-10 (10 means the highest degree of pain) after the phonophoresis treatment program. On the other hand, participants in the control group experienced an increase of pain by 1.9±2.28 from baseline. According to Smith et al. (1986), phonophoresis is a statistically significant ($p<0.01$) effective treatment in conjunction with dexamethasone and lidocaine to reduce shin splints pain when compared to the control group.

As discussed in the iontophoresis section of this literature review, Smith et al. (1986) reported that iontophoresis treatment is an effective transdermal method to reduce MTSS symptoms to deliver medication. Therefore, it is important to review which transdermal method is more effective to treat MTSS. Thus, building on the Smith et al. (1986) study, Singh et al.’s (2002) study that compared the effectiveness of phonophoresis and iontophoresis in the treatment of MTSS is an appropriate study for this literature review. More specifically, Singh et al. (2002) compared the effectiveness of two transdermal drug delivery techniques: phonophoresis and iontophoresis. Singh et al. (2002) compared the two techniques using 1% diclofenac sodium, a non-steroidal anti-inflammatory drug in treatment for shin splints in athletic populations. This study had 25 athlete participants with shin splints diagnoses: 16 male and nine female. Participants were randomly divided into two groups: 12 in the phonophoresis treatment group and 13 in iontophoresis treatment group. The inclusion criterion for shin splints was a diagnosis of shin splints via clinical examination and functional tests. Both iontophoresis and phonophoresis treatments were performed five days weekly for two weeks. Phonophoresis treatments with 1% diclofenac sodium were given with continuous ultrasound set on 1.5W/cm^2 for a duration of 10 minutes. During the study, all participants were advised to rest from weight-bearing activities and to ice affected areas 10-12 minutes three to four times daily.

For recovery assessments, participants reported their pain on a perceived pain scale of 0-10 (10 indicating severe pain). They also performed a functional test consisting of distance hopping to assess any pain and discomfort when hopping on the affected leg after pre-/ post-treatment program. The pain scale report and the functional test were recorded on the first, seventh, and fourteenth days of treatment. Table 3 illustrates the change of pain scale from the first day to the seventh day. These results indicate that in the phonophoresis treatment group, reported pain improved 1.17±0.389 as compared to baseline. The functional score also improved 0.83±0.246. Table 4 illustrates the change of pain scale from the seventh day to the fourteenth day. These results indicate that each value improved; 3.08±0.515 for the pain scale and 1.63±0.311 for the functional score. Table 5 illustrates the change of pain scale from the first day to the fourteenth day. These results indicate that in the phonophoresis treatment group, the reported pain scale improved 4.17±0.577 from the original perceived pain. The functional score improved 2.50±0.369. Therefore, both phonophoresis and iontophoresis treatment applications were reported as effective to reduce shin splints symptoms and improve functional activities (Singh et al., 2002).

Table 3

Comparison of Pain Scale and Functional Score Improvement From the 1st Day to the 7th Day Between Iontophoresis Group and Phonophoresis Group

Outcome measurement	Iontophoresis	Phonophoresis	t value
Pain scale	1.35±0.427	1.17±0.389	1.10*
Functional score	0.81±0.253	0.83±0.246	0.26*

**Note:* p= not significant. Adapted from “A comparative study of the efficacy of iontophoresis and phonophoresis in the treatment of shin splint,” by Singh et al., 2002, *Physiotherapy,*(1), p. 19.

Table 4

Comparison of Pain Scale and Functional Score Improvement From the 7th Day to the 14th Day Between Iontophoresis Group and Phonophoresis Group

Outcome measurement	Iontophoresis	Phonophoresis	t value
Pain scale	2.96±0.721	3.08±0.515	0.49*
Functional score	1.65±0.376	1.63±0.311	0.21*

**Note:* p= not significant. Adapted from “A comparative study of the efficacy of iontophoresis and phonophoresis in the treatment of shin splint,” by Singh et al., 2002, *Physiotherapy,*(1), p. 19.

Table 5

Comparison of Pain Scale and Functional Score Improvement From the 1st Day to the 14th Day Between Iontophoresis Group and Phonophoresis Group

Outcome measurement	Iontophoresis	Phonophoresis	t value
Pain scale	4.35±0.591	4.17±0.577	0.77*
Functional score	2.54±0.380	2.50±0.369	0.26*

**Note: p*= not significant. Adapted from "A comparative study of the efficacy of iontophoresis and phonophoresis in the treatment of shin splint," by Singh et al., 2002, *Physiotherapy,*(1), p. 19.

According to Singh et al. (2002), when using 1% diclofenac sodium, the effectiveness of a phonophoresis treatment for shin splints pain was not significantly different from the effectiveness of an iontophoresis treatment (Singh et al., 2002). Furthermore, their study also included the application of ice for both study groups. This introduced the possibility that cryotherapy influenced the results for both phonophoresis and iontophoresis. Thus, the published results (Singh et al., 2002) can only indicate that there is not a significant difference between phonophoresis and iontophoresis in terms of treating shin pain when cryotherapy is also applied.

In addition, Singh et al. (2002) noted that athletic participants experienced decreased symptoms using phonophoresis to deliver 1% diclofenac sodium with a continuous ultrasound setting on 1.5W/cm^2 for a duration of 10 minutes on the target treatment area. Singh et al.'s (2002) results indicated that there was no statistical difference for effectiveness between phonophoresis and iontophoresis. Based on Smith et al.'s (1986) conclusion that iontophoresis is an effective treatment for shin splints and the lack of a statistical difference between iontophoresis and phonophoresis in Singh et al.'s (2002) study, it is reasonable to assume that phonophoresis is also an effective shin splint treatment.

2.4.4. Ultrasound

The utilization of therapeutic ultrasound is a popular treatment for musculoskeletal injuries (Watson, 2008). Therapeutic effects consist of both non-thermal mechanical and thermal heating effects (Watson, 2008). The non-thermal effect is produced by the pulsed output of the ultrasound (e.g., 50-percent duty cycle, meaning that the beam is applied intermittently) (Watson, 2008). The thermal effect is caused by a continuous output of the ultrasound (100-percent duty cycle, meaning that the beam is applied constantly) (Watson, 2008). The choice of which effect to use, non-thermal or thermal, is based on the treatment goals. To achieve these therapeutic effects, the typical acoustic vibration setting should be a high frequency (1-3 MHz).

The ultrasound non-thermal effect causes the desired physiological changes by generating microcirculation and acoustic streaming. These physiological changes include: mast cell degranulation, enhanced cell membrane function, increased intracellular calcium level, increased fibroblasts activity resulting in increased protein synthesis, increased vascular permeability, and increased collagen tensile strength (Watson, 2008). The ultrasound thermal effect also may cause the desired physiological changes by generating heat in the affected tissue. These physiological changes include: increased blood flow, increased tissue cell metabolism, and decreased sensory nerve conduction velocity resulting in reduced pain due to microfriction among tissue molecules (Starkey, 2004).

Brand et al. (1999) investigated whether or not the ultrasound non-thermal treatment can accelerate the healing process and decrease the pain level of lower extremity stress fractures. In total, nine individuals, three males and six females, participated in this study. Eight of the nine participants were high school or collegiate athletes who participated in soccer or basketball. All of the nine participants underwent diagnostic imaging examinations, including X-ray, bone scan, and MRI. Eight participants were diagnosed with tibial stress fractures based on the results of bone scans and X-rays; one participant suffered from an anterior tibial stress fracture and seven participants suffered from posteromedial tibial stress fractures. Additionally, one participant was diagnosed via MRI with a navicular stress fracture. After being diagnosed with lower extremity stress fractures, all participants received the low intensity ultrasound non-thermal treatment for 20 minutes, five times a week for four weeks. All participants maintained sports-specific activities during the treatment program. Outcome measurements included self-reported pain and functional performance tests of one-minute step-downs before and after the study. The participants recorded perceived pain on a scale of 1 to 10, with 10 being the highest degree of pain.

As a result, the average change on the pain scale between the pre- and post-treatment program measurements was 4.3±3 (p=0.02). This means that participants experienced, on average, a decrease of more than 4 points on a self-reported pain scale of 1 to 10 after the ultrasound treatment program. Also, the average change on the functional performance between the pre- and post-treatment program measurements was 8±6 (p=0.02). This means participants performed, on average, eight additional repetitions compared to the pre-treatment baseline. Brand et al. (1999) found a statistically significant improvement in perceived pain (p=0.02) and functional performance assessment (p=0.02) as measured before and after treatment. Thus, Brand et al. (1999) concluded that the 20-minute low intensity pulsed ultrasound has value when added to the traditional treatment for stress fracture because of an acceleration in healing and pain relief for patients with lower extremity stress fractures. Therefore, according to Brand et al. (1999), the low intensity pulsed ultrasound is an effective treatment to enhance the recovery of lower extremity stress fractures.

While Brand et al. (1999) concluded the application of low intensity pulsed ultrasound is an effective treatment for symptoms of lower extremity stress fracture, there are some limitations to the study's design that complicate its use in this thesis project. Because Brand et al.'s (1999) study design was that of a case group study, it did not have a control group. Therefore, the results of the study cannot distinguish the specific effect of low intensity pulsed ultrasound; a time lapse may have affected the results. Furthermore, participants in Brand et al.'s (1999) study had stress fractures at various sites, including: the anterior tibia, the posteromedial tibia, and navicular. In fact, seven of the nine participants had posteromedial tibial stress fractures. Although the placement of these seven stress fractures on the posteromedial tibia is comparable to the specific location of symptoms for this literature review's definition of MTSS, and while the Brand et al. (1999) study results can support the notion that low intensity pulsed ultrasound can be a potentially effective MTSS treatment, this support is limited in its applicability.

Rue et al.'s study (2004) also investigated the effectiveness of pulsed ultrasound for tibial stress fracture. More specifically, Rue et al. (2004) studied the therapeutic effects of pulsed ultrasound treatment in promoting the healing time and reducing the duration of symptoms in tibial stress fracture treatment in a double-blind, controlled study. All 26 participants from a military branch who had bilateral tibial stress fractures were divided into two groups: fourteen of the 26 participants (7 male and 7 female) in the ultrasound treatment group and 12 participants (6 male and 6 female) in the placebo treatment group. The inclusion criterion for the tibial stress fractures was a diagnosis based on findings from X-rays and bone scans. Rue et al. (2004) investigated a total of 43 tibial stress fractures from all 26 participants. The number of days until participants returned to full military duty was the outcome measurement. Participants in the ultrasound group received the standard care protocol including, protected weight bearing, aerobic exercise, calcium and multi-vitamin supplementation, and a 20-minute daily treatment session of the low-intensity pulsed ultrasound treatment on the fracture site, while participants in the placebo group received the identical protocol with a non-functional ultrasound treatment. As termination criteria, participants underwent radiographs when they experienced an absence of pain with palpation and could perform single leg hopping without pain. When the radiograph showed signs of bone healing, for example cortical thickening, the treatment program was terminated. The results indicated no significant difference ($p>0.05$) between the ultrasound and the placebo treatment groups in time to return to duty. The average days to return for each group were 56.2±19.6 and 55.8±15.5 days, respectively. Also, the total number of treatment sessions were 23.8±10.2 and 26.0±10.5 days, respectively. Rue et al. (2004) concluded that the 20-minute low-intensity pulsed ultrasound treatment is not supported for use in tibial stress fracture treatment.

In contrast to the Brand et al.'s (1999) results, these results by Rue et al. (2004) do not confirm the effectiveness of the ultrasound non-thermal effect when treating tibial stress fractures. This difference may be somewhat accounted for by the difference in study designs. The Brand et al. (1999) study was a case group. All participants received same four-week treatment program. The results showed the positive outcome of the low intensity pulsed ultrasound to the lower extremity stress fracture symptoms (Brand et al., 1999). However, Brand et al. (1999) were not able to establish that the participants' recoveries were from the low intensity pulsed ultrasound because the study did not factor in the possibility that the four-week time lapse affected recovery. On the other hand, the Rue et al. (2004) study was a controlled study to compare the differences between the actual treatment and the placebo treatment for tibial stress fractures. Thus, Rue et al. (2004) was able to consider the time lapse in the length of return to duty. These different study designs may account for the contradictions between the results of these two studies (Brand et a., 1999: Rue et al., 2004). In the end, it is yet to be confirmed whether low intensity pulsed ultrasound has the same effect on MTSS that it has on lower extremity stress fractures. Furthermore, ATs may change their treatment decisions about stress fractures, MTSS, and other shin splints pain because stress fractures often result from MTSS or other bone pathologies. Therefore, these studies can only be considered as partial support for low intensity pulsed ultrasound treatment as an effective treatment for MTSS.

It is also important to review how ultrasound thermal effect works for lower extremity pathologies similar to MTSS. As mentioned before, Smith et al. (1986) investigated the effectiveness of the ultrasound thermal effect for treating shin splints. Although this study was not restricted to MTSS, Smith et al. (1986) qualified shin splints as palpable pain along the medial tibia. The inclusion criterion of shin splints for the Smith et al. (1986) study included the same aspect of the tibia as the definition of MTSS in this thesis project. Smith et al. (1986) compared the effectiveness of four different therapeutic modalities: ultrasound, ice massage, iontophoresis, and phonophoresis in a randomized controlled trial. All 50 participants from a military branch who had shin splints were divided into five groups of 10. The inclusion criterion for shin splints in this study was pain along medial tibia. Four out of five groups received one of four therapeutic modalities. The fifth group, as the control group, did not receive any therapeutic modalities. For outcome measurement, the participants recorded their pain, both prior to and after the treatment programs, on a scale of 1 to 10, with 10 being the highest degree of pain. The termination criterion for a period of treatment sessions included either 10 treatment sessions or until participants no longer experienced pain. During the period of treatment sessions, all participants avoided running, jumping, marching, and prolonged walking or standing. The ultrasound treatment group received the ultrasound thermal effect at an intensity of 1.5 W/cm^2 for a duration of 6 minutes. Participants in the control group did not receive any therapeutic modality but were monitored daily. All participants, including the control group, performed 30 seconds of active heel cord stretching after each treatment session.

The results indicated significant differences in the pain scale between the ultrasound group and the control group. The average change on the pain scale for the group assigned to the ultrasound thermal effect between pre- and post-treatments was 4.8±0.92. This means that participants experienced, on average, a decrease of more than four points on a self-reported pain scale of 1-10 (10 means the highest degree of pain) after the ultrasound treatment program. On the other hand, participants in the control group experienced an increase of pain after the experiment by -1.9±2.28 from baseline. According to Smith et al. (1986), the ultrasound thermal effect is a statistically significant ($p<0.01$) treatment for effectively reducing shin splints pain. Because Smith et al.'s (1986) inclusion criterion was pain along the medial tibia, a MTSS-like symptom, Smith et al.'s (1986) results can also support the use of ultrasound for MTSS symptoms. However, it is still necessary to confirm in future studies whether ultrasound thermal effect has the same effect on MTSS that it does on shin splints.

Smith et al. (1986) used the inclusion criteria for shin splints as pain along the medial aspect of the tibia. Like the Smith et al. (1986) study, the definition of MTSS for this thesis project is a specific kind of pain in a specific spot: an exercise-related, dull to intense pain along the posteromedial aspect of the distal one-third to one-half of the tibia (Edward et al., 2005; Yate & White, 2004). However, clinically, ATs may not change their treatment decisions for MTSS versus shin splints. Therefore, these studies can support the ultrasound thermal effect regarding treatment for shin pain regardless of whether researchers specify MTSS or more general shin pain (Smith et al., 1986). Yet scientifically, until research is concluded that specifically targets MTSS, it is not possible to make any final conclusions about how ultrasound affects MTSS. Nevertheless, for the purpose of this literature review, these results indicate an appropriateness of the use of the ultrasound thermal effect by ATs in clinical situations to reduce shin pain.

As stated before, in a case study, Brand et al. (1999) concluded that the ultrasound non-thermal effect is an effective treatment to the lower extremity stress fracture. Five years later, Rue et al. (2004) published a contrasting report that showed that there is not a significant difference between ultrasound non-thermal effect and non-functional ultrasound for tibial stress fractures. In summary, there is one supporting study for the ultrasound thermal effect to treat stress fracture; however, there is a lack of consistent evidence to support the ultrasound non-thermal effect as an effective treatment for stress fracture. Moreover, ATs may not use the same treatments for stress fractures as for MTSS or shin pain because stress fracture is considered to be caused by bone pathologies (Bergman et al., 2004; Moen et al., 2014). In the end, the therapeutic ultrasound thermal effect may be of additional value to traditional treatments or one of multiple interventions for shin pain, but not specific to MTSS.

2.4.5. Wearable Support

Wearable supports are used to treat MTSS-like symptoms. For example, the use of casting or bracing immobilization is recommended in cases of severe symptoms of MTSS with possible progression to stress fracture (Galbraith & Lavallee, 2009; Moen et al., 2009). Treatment options for stress fracture can be considered for use in MTSS treatments because MTSS is likely to involve bone stress reactions, which progressively develop into stress fractures (Bergman et al., 2004; Moen et al., 2014). Thus, an argument can be made that treatment options for stress fractures, such as immobilization with casting or bracing, are suitable for MTSS treatment (Moen et al., 2010). Two wearable supports used to treat MTSS-like symptoms are the pneumatic leg brace and the lower leg compression stocking. The pneumatic leg brace is designed to stabilize the affected site by transferring the weight-bearing load to the soft tissues of the lower leg and is commonly used for immobilization in stress fracture treatment (Swenson et al., 1997). In contrast, the lower leg compression stocking is a wearable support that provides compressive pressure to lower limbs during intermittent loading (Ali, Creasy, & Edge, 2011; Bovenschen, Booji, & Van Der Vleuten, 2013; Moen et al., 2012).

An extensive literature review reveals limited research on wearable support for treatment of MTSS. The single study that investigated the effectiveness of a pneumatic leg brace in MTSS treatment was done by Moen et al. (2010). All participants were members of the Military who fulfilled the inclusion criteria: exercise-related lower leg pain on the posteromedial tibia and, upon palpation, pain for at least five centimeters along the length of the posteromedial tibia. In the study, six participants in an experimental brace group and eight participants in a control group completed a running program. Only the experimental group received a pneumatic leg brace in addition to the rehabilitation program. The primary outcome measurement was the time to completion for a six-phase personalized intervention running program (Moen et al., 2010). The secondary outcome measurement was a pain scale using the Sports Activity Rating Scale (SARS) score (Moen et al., 2010). The functional activity was described as 0, indicating severe complaints in daily activities, to 100, indicating no complaints during heavy sports activity. All participants were required to self-report pain and symptom progression. All participants received a standard rehabilitation program five times a week that included stretching, strengthening, and ankle stability exercises. The participants also performed the running program three times a week. The participants could not move to the next phase of the running program and therapeutic exercises until they could complete the current phase without pain greater than 4 out of 10 on a 1-10 pain scale, with 10 being the highest degree of pain.

Moen et al. (2010) noted there was no statistically significant difference between the with-brace group (58.8±27.7 days) and the without brace group (57.9± 26.2 days, p=0.57). Moreover, their results show no statistically significant difference (p=0.17) between the brace group and the control group after the rehabilitation program, although both groups' SARS improved significantly (with brace p=0.02, without brace p=0.0004) as compared to their baseline. Moen et al. (2010) concluded that a pneumatic leg brace did not have an additional therapeutic effect in MTSS treatment.

The second wearable support that presents a potential for MTSS treatment benefit is a lower leg compression stocking. The sports compression stocking is a wearable garment that provides compressive pressure to the lower limbs during intermittent loading (Ali, Creasy, & Edge, 2011; Bovenschen, Booji, & Van Der Vleuten, 2013; Moen et al., 2012). Roelofsen, Klein-Nulend, and Burger (1995) conducted an animal study to show the mechanical stimulation by intermittent hydrostatic compression and assumed that direct compression provides loading to the tibia and the surrounding soft tissue. Although they did not show that MTSS patients benefited from direct compression, they did show that compression enhances bone-specific gene expression. Enhancing bone-specific gene expression is important because MTSS is hypothesized to involve bone stress reactions, which can progress to stress fractures. Therefore, the use of lower leg compression stockings is an appropriate option to treat MTSS.

In contrast to Moen et al's 2010 study that focused on the effectiveness of a leg brace for the treatment of MTSS, Moen et al.'s 2012 study illustrated the effectiveness of a lower leg compression stocking for MTSS treatment was specifically targeted. In this study, Moen et al. (2012) compared the effectiveness of three interventions: a graded running program (n=25), a graded running program with lower leg compression stockings (n=25), and a graded running program with calf strengthening and stretching (n=24). Seventy-four athletes with MTSS participated in this study. Inclusion criteria for MTSS were exercise-induced pain, pain on the posteromedial border of the tibia, pain for at least five cm on the posteromedial tibia by palpation, being physically active in sports, and symptoms lasting for at least three weeks. The participants could take the compression stockings off only when they were seated or laying down for more than 15 minutes. Moen et al. (2012) used the same procedure for primary outcome and progression through the running program as was used in the previously described study, Moen et al. (2010).

Moen et al.'s (2012) results indicated that a running program, a running program with additional calf exercises, and a running program with a compression stocking, were not statistically different (p>0.05) for the running program time to completion. The participants in the graded running program only took 105.2 days to complete the program. Moreover, the participants in the graded running program with additional exercises and those participants in a graded running program with a compression stocking took 117.6 and 102.1 days, respectively. In total, 14 participants did not complete the study due to a lack of progress. Moen et al. (2012) concluded that no difference was found among the treatment groups for time to completion of a graded running program.

Thus, Moen et al.'s (2010) and Moen et al.'s (2012) studies do not confirm an additional treatment benefit from a pneumatic leg brace or a compression stocking because MTSS patients in these studies did not show a difference in the time to completion of the running program. In addition, the recovery time, 60 days (Moen et al., 2010) and 105 days (Moen et al., 2012) on average, is not realistic for athletic competitors in clinical situations. Therefore, both Moen et al. (2010) and Moen et al. (2012) proposed that prolonged rest may be more beneficial than wearable supports to treat MTSS.

2.4.6. Stretching

Stretching is believed to increase the flexibility of the body segment that is targeted (Taylor, Brooks, & Ryan, 1997). The literature suggests stretching is an effective clinical technique to increase joint range of motion, decrease muscle soreness, and prevent injury (Heuser & Pincivero, 2009). In addition, calf stretching is suggested to treat MTSS because calf stretching is hypothesized to increase the range of motion of dorsiflexion and to mitigate fatigue of calf musculature (Fredricson et al., 1995; Galbraith & Lavallee, 2009). Therefore, this literature review will address the wider context of calf stretching as a possible MTSS treatment.

As mentioned in the cryotherapy section, Smith et al. (1986), in a randomized controlled trial, compared the effectiveness of four therapeutic modalities in shin splints treatment: ice massage, iontophoresis, phonophoresis, and ultrasound against a control group that used only calf stretching. Although this study was not restricted to MTSS, Smith et al. (1986) specified shin splints as palpable pain along the medial tibia, which for the purpose of this literature review qualifies the study for consideration. Fifty participants from a military branch who had shin splints were divided into five groups of 10. All participants, including the control group, performed 30 seconds of active heel cord stretching after each treatment session. Four out of the five groups received one of four therapeutic modalities. The fifth group, as the control group, used only calf stretching without any additional therapeutic modality. For outcome measurement, the participants recorded their pain, both prior to and after the treatment programs, on a scale of 1 to 10, with 10 being the highest degree of pain. The termination criteria for a period of treatment sessions included either 10 treatment sessions or until participants no longer experienced pain. During the period of treatment sessions, all participants avoided running, jumping, marching, or prolonged walking or standing.

The average change on the pain scale for the control group assigned to only calf stretching between pre- and post-treatment programs was -1.90±2.28 from the baseline. This means that participants in the control group experienced, on average, an increase of two points on a self-reported pain scale of 1-10 (10 being the highest degree of pain). According to this study (Smith et al., 1986), only the control group, which used calf stretching as the treatment option, did not show a positive outcome. Therefore, Smith et al.'s (1986) study indicates that calf stretching alone failed to make a difference for these participants.

Loudon and Dolphino (2010) investigated the effectiveness of a combination of off-the-shelf foot orthotics and calf stretching for the treatment of MTSS. Individuals who had a history of stress fracture and surgery of lower extremity were excluded from this study. Twenty-three people (12 male and 11 female), aged 22 to 44 years old (M=28.1, SD=5.9) who suffered from MTSS participated in this study. Inclusion criteria for MTSS included a dull pain along the posteromedial aspect of the middle to the distal tibia of at least five cm, having pain during walking or running, and pain diffusion on the posteromedial border of the tibia by palpation. Also, the participants must have experienced symptoms of MTSS in at least one of following activities: passive ankle dorsiflexion, resisted plantar flexion, 20 toe raises, or 10 single-leg hops. All participants were asked to wear the off-the-shelf foot orthotics and to participate in a home stretching program consisting of calf stretching 3 x 30 seconds with the knee bent and 3 x 30 seconds with the knee straight for three weeks. The participants wore foot orthotics during walking and performed calf stretching twice a day. Outcome measurement in this study included a pain scale during walking from 0 to 10, with 0 indicating no pain and 10 indicating the worst possible pain. Moreover, the individual's change in quality of life was measured via the Global Rating of Changing (GRC) questionnaire at the end of the intervention, which is a 15-point scale measurement. An improvement of 50% in the pain scale after therapeutic intervention was considered successful.

In total, the mean pain level was recorded 5.7±1.8 before the intervention and 3.3±2.1 after the intervention. Fifteen participants achieved the successful outcome level as defined by the GRC questionnaire. Five of the 11 female participants reached a successful outcome level, whereas 10 of the 12 male participants reached a successful outcome level. The pain level average in the successful group dropped from 5.3±1.9 before the intervention to 1.9±1.3 after the intervention, which was reported as a significant difference ($p<0.00$). There was also a significant difference ($p<0.0001$) between groups in the GRC questionnaire score. The mean score of the successful group was a 4.3, which was considered as "moderately to quite a bit better" (Loudon & Dolphino, 2010, p. 18). On the other hand, the unsuccessful group scored a 0.80 on average, which was considered as "no change" (Loudon & Dolphino, 2010, p. 18). Thus, using a combination of off-the-shelf orthotics and calf stretching is a statistically significant ($p<0.0001$) treatment for MTSS. Based on the results of this non-randomized trial, Loudon and Dolphino (2010) concluded that the initial treatment for MTSS may include off-the-shelf foot orthotics and calf stretching. Furthermore, as also stated earlier, males responded more favorably to the combined intervention of prefabricated foot orthotics and calf stretching than did females.

However, this study failed to confirm whether the positive outcome was from the combination of calf stretching and foot orthotics, or whether calf stretching or foot orthotics alone could have the same affects because this study only evaluated the effect of the combination of calf stretching and foot orthotics in MTSS treatment. Moreover, due to the fact that male participants in this study responded twice as well to the intervention than as did female participants, questions can be raised as to why there is such a marked gender difference. Therefore, the effectiveness of calf stretching alone needs to be confirmed in future research.

Overall, this review of the existing literature illustrates the inconsistency of the effect of calf stretching as a MTSS treatment. Although the definitions for shin splints in both Smith et al. (1986) and Loudon and Dolphino (2010) used a similar pathology as defined in this thesis project, neither study confirmed calf stretching alone as an effective MTSS treatment. However, Loudon and Dolphino (2010) did show that the combination of foot orthotics and calf stretching was an effective intervention for MTSS. Although Loudon and Dolphino (2010) did not confirm the effect of calf stretching alone to treat MTSS, calf stretching remains a potentially effective treatment for MTSS.

2.4.7. Strengthening

The literature suggests the strengthening of calf muscles is beneficial as a treatment for MTSS (Craig, 2008; Galbraith & Lavelle, 2009; Madeley et al., 2007). More specifically, Craig (2008) suggests that MTSS patients may achieve a positive outcome from increasing the strength and the endurance of the soleus muscle in treatment for MTSS. Moreover, Warden et al. (2014) proposes that when the plantarflexion muscles are fatigued, the traction force straining the tibial periosteum can be increased. On the other hand, Craig (2009), Thacker et al. (2000), and Yate et al. (2003) suggested that a lack of endurance, or strength and/ or muscle imbalance are involved with MTSS development. Therefore, this review of the existing literature will include the strength and endurance of the plantarflexor muscles for MTSS.

Madeley et al. (2007) investigated whether any differences exist in the muscular fitness of the ankle plantarflexor muscles in athletes who have MTSS as compared to athletes without MTSS. Inclusion criteria for MTSS was pain along the posteromedial border of the tibia with palpation and pain presenting for a few hours or days induced by exercise and rated as greater than 40 on a scale of 100, with 100 indicating the worst possible pain. Athlete participants (total of 60) were divided into two groups of 30: MTSS and control. All participants performed the standing heel-rise test to assess the endurance of the ankle plantarflexors. The participants were asked to perform the standing heel-rise test at a rate of every two seconds. When participants could not follow this pace or perform with the proper form, the examiner terminated the testing and recorded the number of repetitions. As a result, the MTSS group (23±5.6) recorded a statistically significant fewer mean number of repetitions of the heel-rise test ($p<0.001$) as compared to the control group (33±8.6). Thus, Madeley et al. (2007) found that MTSS participants had an endurance deficit in the ankle plantarflexor muscles. However, Madeley et al. (2007) did not investigate whether or not this lack of endurance in the ankle plantarflexor muscles was a cause or an effect of MTSS.

Because Madeley et al. (2007) did not investigate the specific relationship between the lack of endurance of plantarflexor muscles and MTSS development, Moen et al.'s study (2012) that investigated the effects of calf strengthening in MTSS treatment is appropriate to review. As noted in a previous section, Moen et al. (2012), Moen et al. (2012) compared the effectiveness of three interventions: a graded running program (n=25), a graded running program with a lower leg compression stocking (n=25), and a graded running program with calf strengthening and stretching (n=24). Moen et al. (2012) indicated that the time to complete the running program was not statistically significant different ($p>0.05$) for a running program, a running program using a compression stocking, and a running program with additional calf exercises. As previously stated, Moen et al. (2012) concluded that there was no difference among the treatment groups for time to completion of a graded running program with the addition of calf strengthening exercises. However, these results do indicate that athletes with MTSS can expect a recovery time of 102.1-117.6 days when using a graded running program. Because this study does not confirm any additional value in the use of a calf strengthening and/ or stretching program, Moen et al. (2012) suggests that a prolonged rest may be beneficial to treat MTSS. In addition, Moen et al. (2012) argues that the recovery time of 105 days on average is not realistic for athletic competition.

The relationship between endurance and calf exercise as a treatment option for MTSS is inconclusive. Although, Madeley et al. (2007) revealed the deficit of muscular endurance of calf muscle and suggested potential benefits of calf exercise in treatment for MTSS, they did not specifically investigate the effectiveness of calf strengthening as treatment for MTSS. Furthermore, although Galbraith and Lavallee (2008) and Craig (2009) reported in their meta-analyses that calf strengthening is suggested to increase muscular fitness in rehabilitation programs for MTSS, the research has yet to confirm these assumptions. In fact, the results published by Moen et al. (2012) do not provide conclusive evidence of the effectiveness of calf strengthening. Moen et al.'s (2012) randomized controlled trial is another example of common treatment options that do not make a difference in the treatment of MTSS. Therefore, according to clinical trials (Madeley et al., 2007; Moen et al., 2012), the effectiveness of calf strengthening is inconsistent to provide the evidence of the effectiveness in treatment. Nevertheless, calf strengthening is commonly used as a treatment for MTSS in clinical practice.

2.4.8. Orthotics

A foot orthotic is a device to address the pathomechanical structures of foot conditions (Benard et al., 2006). With foot orthotics, abnormal foot posture, such as flat feet and high arch, would be treated (Bernard et al., 2006). Abnormal foot structure, overuse, and bone stress are considered risk factors of MTSS (Galbraith & Lavallee, 2009; Newman et al., 2013). Benard et al. (2006) argued that using foot orthotics can treat the symptoms of shin pain and stabilize the foot mechanics that may cause the underlying foot mechanical etiology. Therefore, if individuals who suffer from MTSS have abnormal foot posture and/ or alignment, they may receive relief from symptoms by wearing foot orthotics (Craig, 2009; Galbraith & Lavallee, 2009; Thacker et al., 2000). In fact, the use of orthotics is a suggested clinical intervention to correct foot posture as both prevention and treatment for MTSS (Craig, 2008; Galbraith & Lavallee, 2009; Thacker et al., 2002). Also, Craig (2008) suggests that clinical practice in athletic training should include the use of orthotics for controlling excessive foot pronation and providing sufficient shock absorption in order to prevent athletic injuries. This review of the existing literature will address the effectiveness of foot orthotics use as a treatment for MTSS.

As discussed in a previous section, Loudon and Dolphino (2010) investigated the effectiveness of a combination of off-the-shelf foot orthotics and calf stretching in MTSS treatment. Also as previously stated, Loudon and Dolphino (2010) concluded that the initial treatment for MTSS may include off-the-shelf foot orthotics and calf stretching. Furthermore, males responded more favorably to the combined intervention of prefabricated foot orthotics and calf stretching than did females. Thus, using a combination of off-the-shelf orthotics and calf stretching is a statistically significant (p<0.0001) effective treatment for MTSS. However, this positive outcome is from using a combination of off-the-shelf orthotics and calf stretching. Therefore, the effectiveness of the use of foot orthotics alone needs to be confirmed in future research. Moreover, due to the fact that male participants in this study responded twice as well to the intervention than did female participants, questions can be raised as to why there is such a marked gender difference. Therefore, more research needs to be done to confirm this outcome and investigate the potential gender differences.

As previously noted, Benard et al. (2006) stated that a foot orthotic is a device to address the pathomechanical structures of foot conditions. Reinking et al. (2012) studied the relationship between foot type and foot orthotics use. In total, 213 cross-country student athletes in high school and college participated. The researchers included MTSS, chronic exertional compartment syndrome, stress fracture, tendinopathy, nerve entrapment syndromes, and vascular syndrome as qualifying symptoms to investigate lower leg pain associated with exercise. The researchers met with all participants before the cross-country season to classify foot type and to inspect orthotics. In addition, the participants completed a questionnaire regarding orthotics use and pain during exercise.

Thirty-seven of the 213 participants used foot orthotics, and 31 of those 37 reported a history of lower leg pain associated with exercise. However, only 17 of the 31 participants who reported lower leg pain associated with exercise used foot orthotics because they expected to reduce their lower leg pain. Fifteen of those 17 reported pain relief when wearing foot orthotics. The remainder of the 31 participants (14 participants) with a history of lower leg pain associated with exercise used foot orthotics for reasons other than lower leg pain relief. Of these 14 participants, two reported a reduction of pain. Furthermore, the researchers did not discover any association between orthotics use and foot type: pronation, neutral, or supination (Reinking et al., 2012). Reinking et al. (2012) concluded that one-sixth (31/213) of the cross-country runners wear foot orthotics for exercise induced leg pain. The majority of the participants using foot orthotics for reported lower leg pain also reported a decrease of pain (Reinking et al., 2012). According to Reinking et al. (2012), 16 of 31 (51.6%) cross-country runners using orthotics responded positively, reporting a decrease in lower leg pain associated with exercise. Because the researchers included MTSS as one of the target pathologies, Reinking et al.'s (2012) result indicates that using orthotics remains a potentially effective treatment option for MTSS.

These two studies (Loudon & Dolphino, 2010; Reinking et al., 2012) support the use of foot orthotics in treatments for MTSS. However, Reinking et al's study (2012) covered many symptoms associated with MTSS and pronated, neutral, and supinated foot shapes. Also, Loudon and Dolphino (2010) had participants wear foot orthotics and stretch their calves; therefore, they may have received some of the reported benefits from stretching. Thus, it is important to review the literature examining these variables more specifically.

For example, Andreasen et al. (2013) investigated the effectiveness of foot orthotic and therapeutic exercise for chronic lower leg pain in individuals having excessive foot pronation. Eighty individuals with excessive foot pronation and chronic pain participated in this study. The inclusion criteria were that the participants had greater than six degrees of calcaneal valgus angle in a relaxed position via an assessment by the researchers. Also, participants had chronic pain located between the knee and foot during walking and running for at least three months. Among the participants, the chronic pain location or specific injuries included general foot, Achilles tendon, forefoot, ankle, heel, navicular, arch, or shin splints. Researchers randomly assigned 20 participants into four groups. The four intervention groups consisted of standard care, therapeutic exercise, foot orthotics, and combination of therapeutic exercise and foot orthotics. Outcome measurements at baseline, four, and 12 months included a self-reported pain scale out of 100 during walking, running, and resting, as well as static and dynamic foot evaluation. The researchers used photographic examination for three static foot evaluations: a) the navicular height in non-weight bearing and weight bearing positions; b) the navicular drop, comparing the navicular height between non-weight bearing and weight bearing positions; and c) the angle of the calcaneus between the middle of the calcaneus and the bisection line of gastrocnemius. A dynamic foot evaluation measured the angle of the medial longitudinal arch in the sagittal plane by electronic goniometer. This angle was converted into the navicular height. Also, the angle of the maximal calcaneus during the gait pattern was monitored during walking on a treadmill.

Andreasen et al. (2013) found a statistically significant pain reduction rate ($p<0.05$) in all four groups during resting, walking, and running at the four and 12-month follow-up. In the static foot posture, a statistically significant decreased navicular drop ($p<0.05$) was found in the exercise therapy-only group and the combined foot orthotics and exercise therapy group at the four-month follow-up. But this effect ($p<0.05$) was only observed in the combined foot orthotics and exercise therapy group at the 12-month follow-up. Also, at the four-month follow-up, the combined foot orthotics and exercise therapy group showed a statistically significant rate of change in the navicular drop ($p<0.05$) as compared to the standard intervention group. At the 12-month follow up, the combined foot orthotics and exercise therapy group also indicated this effect ($p<0.05$) compared with both the standard intervention and foot orthotics group. The researchers reported a statistically significant change ($p<0.05$) in two groups, exercise therapy and the combined foot orthotics and exercise therapy, at the four-month-follow up. Only the combined foot orthotics and exercise therapy group had same effects at the 12-month follow up. Tables 6 and 7 provide detailed information for all variables. Andreasen et al. (2013) concluded that all therapeutic interventions were effective for reducing chronic lower leg pain for both short and long intervention durations, but none of the treatments seemed to be any better than the others. Therefore, this study suggests that foot orthotics used with additional exercise therapy was effective to reduce chronic lower leg pain associated with MTSS.

Table 6

Comparison of Pain Scale From the Baseline to 12 Months Among Four Different Treatment Groups

Pain Scale (Out of 100)	Timeline	Standard care	Orthotics	Exercise	Orthotics and Exercise
Resting	0 month	15.6	25.0	13.2	15.3
	4 months	15.2	12.9*	10.3	8.1*
	12 month	8.8	13.9*	8.5	9.3*
Walking	0 month	37.0	44.7	31.2	37.1
	4 months	25.1	26.4*	19.6*	23.7*
	12 month	22.0	27.7*	19.5*	18.5*
Running	0 month	44.4	53.4	48.2	42.0
	4 months	42.9	38.0*	34.7*	36.5*
	12 month	21.3*	35.1*	34.2*	36.6

**Note:* Statistical significance depending on the *p*-value: Significant at the $p<0.05$ level. Adapted from "Exercise therapy and custom-made insoles are effective in patients with excessive pronation and chronic foot pain – A randomized controlled trial." By Andreasen et al., 2013, *The Foot*, *23*, p. 26.

Table 7

The Change of Static Foot Posture From the Baseline to 12 Months Among Four Different Treatment Groups

Static Foot Posture	Timeline	Standard care	Orthotics	Exercise	Orthotics and Exercise
Calcaneal angle	0 month	9.3	12.0	13.0	10.4
	4 months	7.8	11.0	10.6	8.6
	12 month	5.6	11.4	11.0	9.5
Navicular drop	0 month	3.7	3.7	4.9	4.4
	4 months	3.6	3.2	3.1*	2.3*
	12 month	3.5	3.6	3.5	2.1*

**Note:* Statistical significance depending on the *p*-value: Significant at the $p<0.05$ level. Adapted from "Exercise therapy and custom-made insoles are effective in patients with excessive pronation and chronic foot pain – A randomized controlled trial." By Andreasen et al., 2013, *The Foot*, *23*, p. 26.

This review of the literature indicates that foot orthotics are potentially beneficial as a MTSS treatment. Loudon and Dolphino (2010) have shown that the combination of orthotics use and calf stretching were an effective intervention for MTSS. Reinking et al. (2012) and Andreasen et al. (2013) found that foot orthotics were effective devices to reduce chronic lower leg pain associated with exercise because both studies included MTSS or shin splints in the studies. Since these studies included MTSS as a target pathology for foot orthotics, their use remains as a potentially effective treatment for MTSS. For the purpose of this literature review, these studies indicate that the appropriateness of using foot orthotics to reduce shin pain by ATs in clinical practice.

2.4.9. Elastic Therapeutic Tape

Elastic Therapeutic Tape, known as Kinesio® Tape, is becoming increasingly popular in clinical practice (Griebert et al., 2014; Thelen, Dauber, & Stoneman, 2008). The literature shows that Kinesio® tape has positive outcomes for foot pain (Griebert et al., 2014; Tsai, Chang, & Lee, 2010), knee pain (Aytar et al., 2011; Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013; Griebert et al., 2014; Osorio et al., 2013), and shoulder pain (Griebert et al., 2014; Osorio et al., 2013). The literature also suggests Kinesio® tape may provide five clinical benefits: a) stimulated cutaneous mechanoreceptors, resulting in more signals to the Central Nervous System (CNS); b) aligned fascial tissues; c) increased space between the dermal tissue and muscle; d) improved muscular functions; and e) promoted circulation and lymphatic drainage (Griebert et al., 2014; Thelen et al., 2008). Because of the clinical benefits cited in these studies, it is important to review the existing literature as to whether or not Kinesio® tape is an effective therapeutic intervention for patients with current or previous histories of MTSS.

However, the literature is limited on the relief of MTSS-specific symptoms by Kinesio® tape. After an exhaustive review of the available literature, a single study was found that investigated the effectiveness of the application of Kinesio® tape for biomechanical changes of foot posture as a treatment for MTSS. Griebert et al. (2014) examined the differences in the rate of foot loading between healthy participants and those with MTSS and the effects of Kinesio® tape on the rate of foot loading among the participants with MTSS. The 40 participants were divided into two groups of 20; a MTSS group and a healthy group. The 20 participants in the MTSS group had a current or previous history of MTSS; eight participants reported having a current diagnosis of MTSS. The participants in the healthy group had no history of MTSS. Researchers randomly determined the test leg for the testing procedure in the healthy group. In the MTSS group, the leg which subjects self-reported the most symptoms of MTSS was tested. When participants reported MTSS bilaterally, the leg with more severe symptoms was tested. Participants in the MTSS group received the Kinesio® taping application from an athletic trainer who was specifically trained in taping techniques. The Kinesio® taping procedure used was that of a Y-strip of

Kinesio® tape applied on the proximal third of the medial tibia. Then, the half of the Y-strip was applied along the anterior and posterior aspects of the medial malleolus and under the medial longitudinal arch of the foot. No tension was applied to the proximal and distal ends of the tape; the remainder of the tape was applied with 75% stretching tension. The purpose of this taping technique was not indicated. Then, for data collection, all participants walked across a pressure mat under three conditions: before tape application as baseline, immediately after tape application, and at 24 hours post-tape application. The researchers recorded the pressure of foot loading during data collection.

Griebert et al. (2014) revealed a significantly (*p*=0.021) higher rate of loading in the medial portion of the midfoot in healthy participants (0.329±0.08) than in participants who suffer from MTSS (0.242±0.14) at baseline. This means that the medial portion of the midfoot in the healthy participants had shorter time-to-peak force than that of the participants who suffer from MTSS. After Kinesio® tape application, Griebert et al. (2014) found that this pattern was not immediately present (*p*=0.542) after treatment or 24 hours (*p*=0.177) after treatment. In fact, immediately after Kinesio® tape application, the loading rate in MTSS participants was increased for the lateral forefoot (*p*=0.022) and medial midfoot (*p*=0.043) from baseline. In addition, for MTSS participants 24 hours post-Kinesio® tape application, the rate of loading in the lateral forefoot did not remain constant as compared to baseline (*p*=0.29). However, the rate of loading in the medial midfoot was significantly higher (*p*=0.031) than baseline. Among healthy participants, no treatment effects were observed during this study. Thus, Griebert et al. (2014) concluded that the patients with a current or previous history of MTSS have a higher rate of medial foot loading during walking. A higher rate of medial foot loading may be related to MTSS development. Furthermore, Kinesio® tape can alter the medial foot loading of patients up to 24 hours post taping.

Griebert et al.'s (2014) study concluded that Kinesio® tape provides a correction for altered foot kinematics during gait. This finding confirms the argument in the literature that minimizing or reducing collapsed medial foot during gait should be included in treatment options for MTSS (Craig, 2009; Moen et al., 2014, Thacker et al., 2000). Therefore, it is important to review the literature that focuses on the effects of elastic therapeutic tape applications for changing foot posture. There is a single study that was conducted by Luque-Suarez et al. (2013) who examined the effects of elastic therapeutic tape for altering static foot posture. Luque-Suarez et al. (2013) investigated the effectiveness of elastic therapeutic tape procedure for altering excessive foot pronation as compared to a sham taping application. Sixty-eight college student participants with excessive pronated feet volunteered for this study. The inclusion criteria were based on Foot Posture Index (FPI) scores. According to FPI, total foot posture is scored between -12 to +12, and secondary rear foot posture is scored between -6 to +6. In addition, FPI scores pronation, supination, and neutral foot postures using six parameters. Each parameter scores between -2 to +2. The inclusion criteria for this study is a total FPI score of 6 to 12 and no history of ankle injury or symptoms within the previous 6 months. The participants were divided into an experimental taping group (n=34) and a sham taping group (n=34). Participants in the experimental taping group received a mechanical correction using the kinesiotaping procedure, with tension from the fibula, around the calcaneus, to the medial tibia. On the other hand, participants in the sham taping group received a procedure that looked similar, but without any stretching tension or mechanical corrections. Researchers assessed static foot posture before tape application and after tape application at one minute, 10 minutes, 60 minutes, and 24 hours. The researchers used FPI in order to assess foot posture, and during FPI assessment, all participants were in a relaxed position.

Results indicate there was no significant ($p>0.05$) difference in total FPI scores between the experimental group and the control group for any time (Table 5). However, this study did identify a significant change ($p=0.05$, and 0.04, respectively) on the rear foot FPI score between the experimental group (2.74±1.71) and the control group (3.59±1.74) at 10 and 60 min post-taping application (Table 6). Thus, based on either the total or rear foot FPI scores, Luque-Suarez et al. (2013) found elastic therapeutic tape is effective for reducing rear foot pronation for no longer than 60 min post-tape application. Thus, Luque-Suarez et al. (2013) confirmed the effects of Kinesio® tape for changing static foot posture for a short duration.

Table 8

Changes of Total Foot Posture Index after Treatment at 1 Min, 10 Min, 60 Min, and 24 Hr Between Experimental Group and Sham Taping Group

Post-Treatment	Experimental Group	Sham Group	*p* value
1 min	4.76±2.41	5.15±2.29	0.47
10 min	5.53±2.02	5.18±2.42	0.55
60 min	5.35±2.59	5.94±2.16	0.32
24 hr	6.56±2.50	6.38±2.37	0.85

**Note.* Statistical significance depending on the *p*-value: Significant at the $p<0.05$ level. Adapted from "Effects of kinesiotaping on foot posture in participants with pronated foot: A quasi-randomised, double-blind study," by Luque-Sarez et al., 2014, *Physiotherapy, 100*(1), p 39.

Table 9

Changes of Rear-Foot Posture Index After Treatment at 1 Min, 10 Min, 60 Min, and 24 Hr Between Experimental Group and Sham Taping Group

Post-Treatment	Experimental Group	Sham Group	p value
1 min	2.62±1.71	3.09±1.86	0.21
10 min	2.59±1.44	3.29±1.57	0.05
60 min	2.74±1.71	3.59±1.74	0.04
24 hr	3.59±1.63	3.50±1.80	0.97

**Note.* Statistical significance depending on the *p*-value: Significant at the $p<0.05$ level. Adapted from "Effects of kinesiotaping on foot posture in participants with pronated foot: A quasi-randomised, double-blind study," by Luque-Sarez et al., 2014, *Physiotherapy, 100*(1), p 39.

Thus, according to these two studies (Griebert et al., 2014; Luque-Suarez et al., 2013), Kinesio® tape application can support a change in static foot posture (Luque-Suarez et al., 2013) and in dynamic foot posture (Griebert et al., 2014). However, the mechanism of changing either static or dynamic foot posture with Kinesio® tape were not investigated (Griebert et al., 2014; Luque-Suarez et al., 2013). Although Grirbert et al. (2014) found that rates of medial midfoot loading in MTSS patients move to non-MTSS levels with Kinesio® tape, they did not investigate whether or not the loading changed with Kinesio® tape could relieve the MTSS symptoms. Moreover, the researchers (Griebert et al., 2014) only assessed the loading force during walking, which is not an impact activity for MTSS. On the other hand, Luque-Suarez et al.'s study (2013) confirmed the effect of kinesiotaping application for static foot posture change for a short duration. The participants did not have a current or previous history of MTSS in the study (Luque-Suarez et al., 2013); therefore, it is still necessary to confirm that the patients who suffer from MTSS will receive same effect with kinesiotaping. Thus, the findings from these two studies are not specific to determine whether changing foot posture via Kinesio® tape application reduces the symptoms of MTSS and the load on the medial tibia during athletic activities.

2.4.10. Summary

Although there is a working clinical definition of MTSS, the literature does not provide a consistent definition for MTSS pathology. Moreover, there are several hypotheses concerning pathomechanics of MTSS, but again, the literature does not confirm absolute pathomechanics of MTSS. Furthermore, the literature indicates that researchers accept several treatment options. Cryotherapy, iontophoresis, phonophoresis, ultrasound, orthotics, stretching, strengthening, and elastic therapeutic tape remain the potential treatment approaches for MTSS. However, this literature review discovered inconsistent results among the studies, therefore evidence is inadequate to conclude their treatment effectiveness. This led to the question as to how clinicians should apply this information to their clinical practices. Therefore, it was important to investigate which treatments are chosen to treat MTSS by ATs.

CHAPTER 3: METHODOLOGY

3.1. Purpose

The purpose of this study was to review the current treatment approaches of MTSS symptoms used by Athletic Trainers (ATs). Additionally, as a secondary purpose, this study ran analyses to determine if there was a relationship between AT's demographics and their treatment choices related to treatment. The following definition was used throughout the project.

Medial Tibial Stress Syndrome (MTSS): Exercise-related dull to intense pain along the posteromedial aspect of one third to one half of distal tibia (Bennett et al., 2001; Edwards et al., 2005; Plisky et al., 2007; Yate et al., 2004).

3.2. Research Design

This study was conducted with a goal of answering the following research questions:

a) What are the differences between the current MTSS treatment used by Certified Athletic Trainers compare to the current research?

b) What is the relationship amongst clinical settings, years of experience, and level of education when Certified Athletic Trainers' treatment options for treating MTSS in their practice?

A non-experimental, cross-sectional descriptive questionnaire via a web-based survey study design was used to review the treatment approaches used by ATs.

3.3. Participants

After approval by the Institutional Review Board (IRB) at North Dakota State University, the researcher obtained 1,000 email addresses of certified ATs currently practicing in the United States of America from the National Athletic Trainers' Association (NATA). The researcher then sent a recruiting email that contained a consent form and a link to proceed to the survey. By proceeding to the questionnaire after the informed consent, ATs were consenting to participate. Their participation in the web-based survey was strictly voluntary. They could skip questions and/or withdraw at any time without penalty. Subjects had to meet the following inclusion criteria: a) 18 years of age or older; b) BOC® certified Athletic Trainer; and c) practice in the United States of America. Subjects who were not yet certified ATs or were retired ATs were excluded from this study.

For inclusion criteria, the subjects could have had other professional degrees including, but not limited to: Doctor of Medicine (MD), Doctor of Osteopathy (DO), Doctor of Naprapathy (DN), Doctor of Chiropractic (DC), Doctor of Pharmacy (Phar.D.), Doctor of Dentistry (DDS), Physical Therapist (PT), Occupational Therapist (OT), Physical Therapy Assistant (PTA), Occupational Therapy Assistant (OTA), Nursing practitioner (NP), Master of Business Administration (MBA), and Master of Education (MEd).

Additionally, they could have had other certifications including, but not limited to: Certified Strength and Conditioning Specialist (CSCS), Certified Personal Trainer (CPT), Orthopedic Clinical Specialist (OCS), Performance Enhancement Specialist (PES), Corrective Exercise Specialist (CES), Postural Restoration Certified (PRC), Postural Restoration Trained (PRT), and Certified Kinesio Taping® Practitioner (CKTP). Furthermore, the participants could have had clinical techniques and experiences from such, but not limited to, workshops and lectures, as: Graston Technique, Functional and Kinetic Treatment with Rehab (FAKTR), RockTape, Postural Restoration Institute (PRI) courses, Functional Movement System (FMS), and Selective Functional Movement Assessment (SFMA). Additional education, certifications, and workshops could have revealed their interests and potential biases in their clinical practices as ATs. Therefore, the participant demographic background information could have allowed the researcher to analyze for trends among professional associations and certifications and MTSS treatment options.

3.4. Procedures

A web-based survey, via email, was used in this study due to the unique characteristics of this study population and method’s efficiency for data collection. Prior to data collection, this study needed to be approved from the Institutional Review Board (IRB) at North Dakota State University. After approval by the IRB at NDSU, the researcher obtained 1,000 email addresses of randomly selected certified ATs from the National Athletic Trainers’ Association (NATA). A random sample was key to this study because every AT in the United States would have had the same probability of being chosen. Once 1,000 randomly chosen ATs were available, the researcher then sent a recruitment email for the research project. The purpose of the research and its relevance were described by the recruiting email. Also, the researcher contact information was provided in the recruiting email in case potential participants had concerns and/or questions. Once the subjects decided to participate in the study, they were asked to visit the study’s website for more information, including a statement of informed consent. Before participants proceeded to the survey, they had to click on a “Yes” indicating they had read the information and consent. Once they proceeded to the online survey from the link, the survey questionnaire took about 10 minutes to complete. The survey included demographic information, a choice of treatment options survey responders thought were most effective, and an opportunity for survey responders to indicate how they used the treatment options. All participants received a follow-up email two weeks later. The survey returns were accepted for four weeks: 2020/ Mar/ 17 to 2020/ Apr/ 28.

3.5. Data Collection

Data was collected from a sample of the 1,000 certified ATs in the United States who received the survey. Participants’ demographic information including survey results were stored on a password protected computer. Only members of the research group were able to access the survey and subsequent responses.

It was unlikely that the researcher would be able to gather survey results from all the 1,000 ATs asked to respond. For example, previous survey research has shown a 60%-80% response rate should be considered as excellent (Portney & Watkins, 2000). However, in the athletic training field, the range of response rates in previous studies using online surveys was lower, from 6%-34% (Massie, Strang, &Ward, 2009; Neil et al., 2017). Nulty (2008) summarized eight previous online survey studies to find an average response rate of 33%. Therefore, this research study followed the numbers from Nulty’s (2008) study. This means that at least 333 expected responses were analyzed in this study. According to Nulty (2008), the most prevalent methods for boosting web-based survey response rates include repeating reminder emails to non-respondents. Therefore, the researcher sent a follow-up email to the ATs two weeks later. Additionally, the researcher needed to focus on timing the survey during an off-season in order to accommodate ATs schedules. If the response rate does not achieve 33% of the sample population, the limitation of a low response rate will be addressed in the Discussion section.

3.6. Instrumentation

This study used a web-based Qualtrics® (Qualtrics LLC, Provo, UT) instrument containing specific questions related to treating MTSS in clinical settings. The survey was evaluated by two content experts prior to a pilot study; they provided appropriate feedback to develop the instrumentation. Another

Qualtrics expert provided appropriate adjustments for the web-based Qualtrics survey. After the survey evaluation by these three experts, the pilot study was completed on October 24, 2018 by 12 individuals to validate the survey. Respondents to the pilot study were asked to give feedback regarding clarity and overall format to adjust, if necessary, the survey instrument.

The survey incorporated information regarding demographics followed by 28 open- and close-ended questions covering: a) choosing treatment options to treat MTSS and b) indicating specifics and parameters of those treatments. Respondents chose their most-likely-to-use treatment option to treat MTSS. The survey for this research study can be found in Appendix B.

3.7. Data Analysis

Data were analyzed using IBM® SPSS statistics software version 25.0 (IBM®, Armonk, New York). Independent variables included work setting, education level, and years of experience. Dependent variables included the following treatment options: cryotherapy, iontophoresis, phonophoresis, electrical stimulation, ultrasound, rest, calf stretching, calf strengthening, orthotics, Kinesio® Tape, and other. Pearson Chi-Square tests were conducted to assess significant relationships between independent variables and each treatment option. Significant relationships were further assessed using post hoc crosstabulation to evaluate residuals.

CHAPTER 4: MANUSCRIPT

4.1. Introduction

Medial Tibial Stress Syndrome (MTSS), commonly termed “shin splints,” is defined as chronic, exercise-related, dull to intense pain which occurs along the posteromedial aspect of the distal one-third to one-half of the tibia (Brushoj et al., 2008; Burrus et al., 2014; Edwards et al., 2005, Taunton et al., 2002; Yate & White, 2004). MTSS is most common amongst those involved in running and jumping sports (Edwards et al., 2005; Reinking 2006) with incidence rates estimated as high as 15.2% in high school cross country runners (Bennett et al., 2001; Plisky et al., 2007).

Although there is an accepted clinical definition of MTSS, the etiology of its symptoms is multifactorial and largely unknown (Couture & Karlson, 2002; Moen et al., 2012). Therefore, given this lack of precision, the exact cause of exercise-related shin pain is difficult to determine (Couture & Karlson, 2002; Moen et al., 2012). Despite an accepted clinical definition of MTSS, many previous studies have used varying definitions (Brand et al., 1999; Delacerda, 1982; Mandeley et al., 2007: Moen et al., 2010; Moen et al., 2012; Singh et al., 2002; Smith et al., 1986; Rue et al., 2004), and this inconsistency between studies makes it difficult to compare the effectiveness of therapeutic interventions. In turn, studies that focus on effective treatment options do not consistently address a clinical definition of MTSS rather their own definition of MTSS. Therefore, when Athletic Trainers (ATs) treat patients who suffer from this injury, they lack evidence-based treatment options and must make clinical decisions based solely on anecdotal philosophies.

Previous research investigating specific interventions to treat MTSS lacks strong scientific evidence due to poor study design. It is difficult to confirm which therapeutic interventions are effective due to the poor methodological quality of existing research. In an early study, Smith et al. (1986) compared four different therapeutic modalities including ice massage, iontophoresis, phonophoresis, and ultrasound to treat shin splints. The researchers defined shin splints as palpable pain along the medial tibia, which differs from the accepted clinical definition. They found that all treatments were effective to decrease pain; however, no one treatment was superior to another. Therefore, any of the aforementioned treatment options may be effective for treating pain associated with shin splints. In addition, some studies that focused on MTSS evaluated a combination of interventions as opposed to a single treatment option.

For example, Loudon and Dolphino (2010) found that a combination of off-the-shelf orthotics and calf stretching was effective to reduce the symptoms of MTSS. However, because the variables in the study were confounded, it is unclear which treatment was effective. Overall, the methodological quality of studies investigating MTSS treatments were poor because they were not randomized controlled trials (RCTs).

In fact, only two RCTs focusing on specific interventions to treat MTSS have been published. Additionally, both studies used the universally accepted clinical definition of MTSS, thus increasing the methodological quality of these investigations (Moen et al., 2010; Moen et al., 2012). The pneumatic leg brace (Moen et al., 2010) and the compression stocking (Moen et al., 2012) were evaluated for their effectiveness to treat this injury. However, neither study could confirm either intervention as effective. Therefore, similar studies may be beneficial to review these and other treatments as clinical considerations. Again, although both of these studies were sufficiently free from bias because they were RCTs, they did not report conclusive findings regarding the treatment options investigated.

Due to the lack of evidence for various treatment options demonstrated in the previously described studies, the evidence is weak for management of MTSS (Brand et al., 1999; Delacerda, 1982; Mandeley et al., 2007: Moen et al., 2010; Moen et al., 2012; Singh et al., 2002; Smith et al., 1986; Rue et al., 2004). Additionally, previous studies used unstandardized definitions of MTSS. Therefore, inconsistency amongst studies makes it difficult to conclude the effectiveness of treatment options. Due to the lack of literature specific to MTSS, we needed to review the current treatment approaches currently used by ATs.

4.2. Methods

4.2.1. Participants

Participants included a sample of 1,000 Athletic Trainers (ATs) practicing in the United States. Inclusion criteria included being 18 years of age or older, a Board of Certification (BOC) certified AT, and practicing in the United States. Exclusion criteria included non-certified students and retired athletic trainers. Participants were recruited via an email through the National Athletic Trainers' Association (NATA). The email included a consent form and link to the survey. Out of 1,000 ATs recruited, 134 ATs started the questionnaire resulting in a response rate of 13.4%. Out of the 134 participants, three did not complete the survey in its entirety resulting in a total of 131 responses used in the analysis. Thus, the final response rate was 13.1%. Participation in the web-based survey was strictly voluntary and participants could skip questions or withdraw at any time.

4.2.2. Instrumentation

Instrumentation for this study included a survey delivered through Qualtrics® (Qualtrics LLC, Provo, UT). Prior to distribution, the survey was validated by Qualtrics experts and pilot tested by 12 individuals. Data from the pilot study were not included in the final analysis.

The beginning of survey was collecting demographic information. The demographic data the researcher was the most interested in was clinical setting. Clinical settings would be one of the most significant factors regarding clinical decisions for MTSS treatment because there could be a limited therapeutic modality choices for ATs to select. The demographic information was followed by 28 open- and closed-ended questions regarding treatment options for MTSS. Respondents were asked to choose the treatment options they were most likely to use. The survey for this research study can be found in Appendix B.

4.2.3. Procedures

Prior to participant recruitment, this research study was approved by the university's institutional review board (IRB). After IRB approval, the researcher sent a request to the National Athletic Trainers' Association to reach out to 1,000 ATs currently practicing in the United States. Upon the request, 1,000 ATs were randomly selected and received an email containing the informed consent and a link to the web-based survey. The sample population had the opportunity to read information about the purpose of the study. Once the subjects decided to participate, they were asked to visit the study's website for additional information, including a statement of informed consent.

Before proceeding to the survey, participants were required to click "Yes," indicating they had read the information and were consenting to participation in the study. After proceeding to the online survey, the questionnaire took approximately 10 minutes to complete. A follow-up email was sent every two weeks after the initial recruitment email to remind participants about the study. The survey responses were accepted for six weeks: March 17, 2020 through April 28, 2020.

4.3. Results

The sample was comprised of 134 ATs. Data were slightly skewed (setting=1.753, education=1.147, experience=1.633); however, kurtosis was less than three (setting=2.003, education=1.998, experience=2.246). Therefore, the distribution was considered to be normal. Independent variables included work setting, education level, and years of experience. Descriptive statistics for independent variables are presented in Table 10. Dependent variables included the following treatment options: cryotherapy, iontophoresis, phonophoresis, electrical stimulation, ultrasound, rest, calf stretching, calf strengthening, orthotics, Kinesio® Tape, and other. Descriptive statistics for dependent variables are presented in Table 11.

Table 10

Descriptive Statistics for Independent Variables

Variable		Frequency	Percent
Setting	College	51	38.1
	High School	43	32.1
	Clinic	12	9
	Professional	6	4.5
	Industrial	7	5.2
	Amateur	2	1.5
	Military	2	1.5
	Other	11	8.2
Education	Bachelors	30	22.4
	Masters	89	66.4
	Terminal	5	3.7
	Other	10	7.5
Experience	<1	3	2.2
	1-5	47	35.1
	6-10	52	38.8
	11-15	18	13.4
	16-20	0	0
	21-25	1	0.7
	≥26	12	9

Table 11

Descriptive Statistics of Dependent Variables

Variable	Frequency	Percent
Cryotherapy	107	86.7
E-stim	39	29.8
Iontophoresis	5	3.8
Phonophoresis	7	5.3
Ultrasound	39	29.8
Resting	101	77.1
Stretching for calf	109	83.2
Strengthening for calf	98	74.8
Orthotics	71	54.2
Kinesio® Tape	50	38.2
Other	72	55.0

Pearson Chi-Square tests were conducted to assess significant relationships between independent variables and each treatment option. Significant relationships were further assessed using post hoc crosstabulation to evaluate residuals. Specifically, adjusted residuals were utilized to take into account the expected number of ATs compared to the actual number of ATs using different treatments based on each independent variable (setting, education level, and years of experience). Statistically significant associations were found between setting and use of cryotherapy, χ^2 (7, *N*=131) = 18.12, *p*=.011, with clinic and amateur sports settings having significantly less use than expected. In addition, setting and use of ultrasound was significant, χ^2 (7, *N*=131) = 15.87, *p*=.026, with ultrasound used significantly more often in college settings, and significantly less in secondary schools. Setting and use of calf stretching (*p*=.010) were also significantly related, χ^2 (7, *N*=131) = 18.50, *p*=.01, with professional sports and military/law enforcement using stretching significantly less and college settings using it significantly more. Lastly, there was a significant association between education level and use of phonophoresis, χ^2 (3, *N*=131) = 9.93, *p*=.019, with the education level of “other” using phonophoresis significantly more. Results of the post hoc analysis are presented in Table 2.

Table 12

Post-hoc Analysis of Residuals

Significant Association	Setting	Adjusted Residual Yes	Adjusted Residual No
Setting & Cryotherapy	Clinic	-2.2	2.2
	Amateur Sports	-3.0	3.0
Setting & Ultrasound	College	3.8	-3.8
	Secondary School	-2.1	2.1
Setting & Calf Stretching	College	2.1	-2.1
	Professional Sports	-2.2	2.2
	Military/Law Enforcement	-3.2	3.2
Education & Phonophoresis	Other	2.3	-2.3

4.4. Discussion

Much of the existing literature pertaining to MTSS treatment is focused on the effects of various treatment techniques and modalities as opposed to what treatment methods ATs actually use in their clinical practice (Andrish et al., 1974: Brand et al., 1999: Galbraith & Lavallee, 2009: Loudon & Dolphino, 2010: Smith et al., 1986: Rue et al., 2004:). Thus, the purpose of this study was to investigate the treatment techniques used by ATs to treat MTSS, as well as to determine if additional variables such as clinical setting, years of experience, or level of education, were related to clinical decisions.

The most common treatment option selected by ATs was cryotherapy (Table 10). We found significantly less use of cryotherapy (p=.011) in clinic and amateur sports settings (Table 12). Use of cryotherapy as a treatment modality for shin splints is supported by the findings of Smith et al. (1986) who reported ice massage was an effective method for treating shin splints. Furthermore, researchers reported rest and cryotherapy are the most important treatments in the acute phases of MTSS based on a review of the literature focusing on conservative treatment options for MTSS (Galbraith et al. 2009: Couture and Karlson, 2002: Fredricson et al., 1995). In addition to the experts' opinions, the clinical effect of cryotherapy would be helpful to control pain in clinical practice for ATs, especially when treating MTSS in this study (Nadler et al. 2003; Smith et al. 1986).

Of the 131 ATs included in our study, thirty-nine (39.8%) chose therapeutic ultrasound as a treatment method for MTSS. We found ultrasound was selected as a treatment option significantly more often in the college setting while it was used significantly less in secondary schools. Due to the skeletally immature population in high schools, ATs in secondary schools may hesitate to use ultrasound. In the college setting, ATs may not have to consider the growth period. There have been mixed results pertaining to the efficacy of therapeutic ultrasound for treating MTSS (Brand et al., 1999: Smith et al., 1986: Rue et al., 2004). When Smith et al. (1986) compared four separate therapeutic modalities, the results illustrated the ultrasound thermal effect was effective to reduce symptoms of shin splints. Later, Brand et al. (1999) reported that non-thermal ultrasound was effective for decreasing lower extremity pain, specifically pain related to stress fracture; however, this finding was not specific to MTSS. In contrast, findings of another study indicate that pulsed ultrasound may not be an effective method for treating tibial stress fracture (Rue et al., 2004). The findings in the literature lack evidence to conclude that the ultrasound treatment is effective for MTSS as well as pain resulting from other lower extremity pathologies (Smith et al., 1986: Brand et al., 1999: Rue et al., 2004). While this study found that ATs in the college setting were more likely to use this modality as a treatment, there is a lack of consistent evidence to support the effectiveness of therapeutic ultrasound to treat MTSS.

In a review of the literature, Galbraith and Lavallee (2009) found daily calf-stretching and strengthening exercises were beneficial in the treatment of MTSS. Similarly, in the present study, 83.2% of ATs indicated they use calf stretching and strengthening exercises to treat MTSS. Interestingly, we found significantly fewer ATs working in professional sports and military/law enforcement settings used calf stretching to treat MTSS. While outside the scope of this study, we hypothesize that ATs in these settings may use alternative approaches to increase range of motion such as Instrument Assisted Soft-tissue Mobilization (IASTM) (Palmar et al., 2017). When Loudon and Dolphino (2010) investigated the effectiveness of a combination of off-the-shelf foot orthotics and calf stretching for MTSS treatment, they found the combination treatment approach was an effective intervention for MTSS. Although the researchers did not confirm the effect of calf stretching alone to treat MTSS, it remains a potentially effective treatment option. Stretching the calf is an easy treatment method to implement with a low risk of injury. Therefore, even though the effect of calf stretching independently to treat MTSS is not confirmed, ATs may be able to employ calf stretching in a busy clinical setting, such as a secondary school.

The fourth statistically significant association was between education level and treatment option with the “other” education level using phonophoresis significantly more. Only 5.3% of responders chose phonophoresis when treating MTSS. However, use of phonophoresis to treat MTSS is supported within the literature (Smith et al. 1986; Singh et al. 2002). In two studies comparing the effectiveness of different therapeutic modalities, including phonophoresis, researchers concluded it was an effective method for treating symptoms associated with MTSS (Smith et al. 1986; Singh et al. 2002). However, both of the aforementioned studies found no significant difference between phonophoresis and iontophoresis for treating MTSS. Based upon limited supplies and/ or facilities, ATs may not always to be able to choose phonophoresis to treat MTSS.

In research, statistical significance is important as it indicates the reliability of study results. However, it is also important to consider clinical significance in the field of athletic training to determine the impact of results on clinical practice. Based on the results of the present study and a review of the literature, clinical recommendations for treatment of MTSS include the use of cryotherapy and resting in the acute phase (Andrish et al., 1974; Smith et al., 1986; Galbraith & Lavallee, 2009). In case where the athlete reports severe pain, ATs should consider using transdermal drug delivery, such as iontophoresis and phonophoresis, to alleviate MTSS symptoms (Smith et al., 1986; Singh et al., 2002). Simultaneously, stress fractures or other lower leg injuries should be ruled out with further diagnostic imaging when symptoms are unmanageable or improvements are lacking (Bhatt et al. 2000; Fredricson et al., 1995; Mammoto et al., 2012; Moen et al., 2014). In the sub-acute phase, calf stretching and strengthening is important for restoring and retraining of functional movement (Galbraith & Lavallee, 2009; Madeley et al., 2007). Moreover, the use of Kinesio® taping and orthotics would be helpful to maintain both static and dynamic optimal foot posture (Griebert et al., 2014; Luque-Suarez et al., 2013). When ATs treat MTSS, it is important for them to consider the specific signs and symptoms the athlete displays to determine the best treatment intervention or combination of therapeutic interventions for specific athlete.

Despite an increasing amount of research on MTSS treatment options, the cause of MTSS symptoms are still unclear. Our results suggest that most treatment options made by ATs follow the suggestions or findings from the literature. Clinically, ATs are able to make decisions for their practice based on their knowledge in their settings. However, due to limited supplies and/or facilities, ATs cannot always choose the most effective treatment options when treating MTSS. While strong evidence is helpful when making clinical decisions, ATs also need to know the best treatment options for various situations.

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APPENDIX A. INFORMED CONSENT IN QUALTRICS®

North Dakota State University
Health, Nutrition and Exercise Science
Dept. 2620, PO Box 6050
Fargo, ND 58102

Title of Research Study: Review of Current Treatment Approaches for MTSS Used by Certified Athletic Trainers

This study is being conducted by the Principal Investigator- Katie Lyman, HNES, Dept 2620; 231-8208, katie.lyman@ndsu.edu.

Why am I being asked to take part in this study?
You are being asked to participate in this study because:

- You have been selected at random from the National Athletic Trainers' Association membership database according to the selection criteria provided by the student doing the survey.

You can participate in this study if you meet the following criteria:

- you are 18 years of age or older.
- you are a BOC certified athletic trainer.
- you are currently practicing in the United States of America.

What is the reason for doing the study?
The purpose of this study is to review current treatment approaches for MTSS used by ATs. The data collected from this survey will be used to address gaps in the current research and therapeutic approaches used by ATs when treating MTSS.

What will I be asked to do? OR what information will be collected from me?
You will be asked to complete a survey to answer questions about your demographic information and clinical choices when treating MTSS.

Where is the study going to take place, and how long will it take?
The study will be conducted online. It will take approximately 10 minutes to completes the study.

What are the risks and discomforts?
There are no known risks associated with participation in this study other than the personal time it takes to complete the survey. Please note that some of the questions are about your clinical choices in athletic training practice, which some may be hesitant to answer. You may withdraw at any time.

What are the benefits to me?
The benefits you may expect to receive from participating in this research study include a better understanding of the research process and an increased awareness of your clinical practice for MTSS treatment.

What are the benefits to other people?
We are conducting this study so that we may learn about the fundamental clinical choices of ATs when treating MTSS. Your responses to this survey may be used to assist in the development of MTSS therapeutic interventions and improve clinician understanding.

Do I have to take part in this study?
Your participation in this research is completely voluntary. If you choose to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What are the alternatives to being in this study?
You can choose to not participate in the study.

Who will have access to my information?
All information collected in this study shall remain confidential. The data, including your returned survey, will be anonymous and stored on a password-protected computer in a locked office. We will keep all collected data that can identify you private; only those on the research team will have access to your information.
If you withdraw before the completion of the survey, your information will be removed and we will not collect additional information.

What if I have questions?
Please direct any questions you may have to the researchers: Katie Lyman at katie.lyman@ndsu.edu.

What are my rights as a research participant?
You have rights as a research participant. All research with human participants is reviewed by a committee called the Institutional Review Board (IRB), which works to protect your rights and welfare. If you have questions about your rights, an unresolved question, a concern or complaint about this research you may contact the IRB office at 701.231.8995, toll-free at 855-800-6717 or via email (ndsu.irb@ndsu.edu).
The role of the Human Research Protection Program is to confirm that your rights are protected in this research; more information about your rights can be found at www.ndsu.edu/irb.

Documentation of Informed Consent:
You are free to make a decision whether or not to be in the research study. By clicking “Yes” below, you indicate that you have read the information above and are consenting to complete the survey.

APPENDIX B. SURVEY

Section 1: Demographic Information

Please answer the following demographic questions.

1. In which type(s) of clinical setting(s) are you employed?
    a. College/ University
    b. Secondary School
    c. Clinic
    d. Professional Sports
    e. Industrial/Occupational/Corporate
    f. Health/Fitness/Sports Clubs/ Performance Enhancement Clinics
    g. Amateur/Recreational/Youth Sports
    h. Military/Law Enforcement/Government
    i. Other

2. Which NATA districts are you currently practicing in? Check all that apply to you in your current practice.
    a. District 1 (CT, ME, MA, NH, RI, VT)
    b. District 2 (DE, NJ, NY, PA)
    c. District 3 (DC, MD, NC, SC, VA, WV)
    d. District 4 (IL, IN, MI, MN, OH, WI)
    e. District 5 (IA, KS, MO, NE, ND, OK, SD)
    f. District 6 (AR, TX)
    g. District 7 (AZ, CO, NM, UT, WY)
    h. District 8 (CA, NV, HI)
    i. District 9 (AL, FL, GA, KY, LA, MS, TN)
    j. District 10 (AK, ID, MT, OR, WA)
3. How long have you worked as a certified athletic trainer?
    a. Less than a year
    b. 1-5 years
    c. 6-10 years
    d. 11-15 years
    e. 16-20 years
    f. 21-25 years
    g. 26+ years
4. What is your highest degree earned?
    a. Bachelors degree
    b. Masters degree
    c. Terminal degree
    d. Other

5. Please indicate any additional professional degrees you may have earned (e.g., MD, DO, PT, OT, PTA, OTA, etc.)

6. Please indicate any additional credentials you may have earned. (e.g., CSCS, PES, CES, etc.)

7. Please indicate any workshops or lectures for specific certifications you may have attended. (e.g., Postural Restoration Institute®, Graston Technique®, FAKTR, RockTape, Kinesio® tape, FMS/SFMA)

Section 2: Treatment of MTSS

Please answer the following questions regarding the definition of Medial Tibial Stress Syndrome (MTSS). For the purpose of this study, MTSS refers to

"Exercise-related dull to intense pain along
the posteromedial aspect of one third to one half of the distal tibia."

1. Please choose which treatment options you use to treat MTSS. Please check all that apply to your clinical practice. If you do not have access to any of the options listed or you do not use any of the methods, please choose "Other" and indicate how you treat MTSS in the response box.
   ___ Cryotherapy
   ___ Estim for pain
   ___ Iontophoresis
   ___ Phonophoresis
   ___ Ultrasound
   ___ Resting
   ___ Stretching for calf
   ___ Strengthening for calf
   ___ Orthotics
   ___ Kinesio® tape
   ___ Other (Please indicate in the response box below)

2. If you use cryotherapy for the treatment of MTSS, please choose the option you use most often. Choose only one option from the list below.
   ___ Ice pack
   ___ Ice massage
   ___ Cold gel pack
   ___ Cold whirlpool
   ___ Cold spray
   ___ Cold and compression unit
   ___ Other (Please indicate in the response box below)

3. If you use e-stim for the treatment of MTSS, please choose all the following options you use. Otherwise, please write N/A in the box.
   ___ E-stim for pain
   ___ E-stim for muscle contraction
   ___ E-stim for other purpose

4. If you use cryotherapy, please indicate how long you typically apply the cryotherapy technique for each treatment in minutes in the response box below.

5. If you use iontophoresis for the treatment of MTSS, please identify the medication(s) you use most often.

6. For iontophoresis, which type of iontophoresis application, you would use to treat MTSS.
   ___ Generator and electrodes
   ___ Battery operated
   ___ Completely Passive

7. For iontophoresis, please indicate in minutes typical treatment duration time.

8. For iontophoresis, please indicate the frequency of treatment you use to treat MTSS. Otherwise, please write N/A in the box.
   ___ Everyday
   ___ Every two days
   ___ Every three days
   ___ Every four days
   ___ Every five days
   ___ Every six days
   ___ Every week
   ___ Other (Please indicate in the response box below)

9. If you use phonophoresis for the treatment of MTSS, please list the medication(s) you use most often.

10. For phonophoresis, please indicate the frequency of treatment you use to treat MTSS. Otherwise, please write N/A in the box.
   ___ Everyday
   ___ Every two days
   ___ Every three days
   ___ Every four days
   ___ Every five days
   ___ Every six days
   ___ Every week
   ___ Other (Please indicate in the response box below)

11. For phonophoresis, please indicate in minutes typical treatment duration time.

12. If you use ultrasound for the treatment of MTSS, please choose one of the following therapeutic effects that you want to achieve.
   ___ Thermal effect
   ___ Non-thermal effect

13. For ultrasound, please indicate the specific parameters you use to treat MTSS;
Frequency: _______________MHz
Duty cycle: __________________%
Treatment time: ____________min
Intensity: _______________W/ cm^2

14. If you prefer to have the patient rest, please choose all the following options you use. Otherwise, please write N/A in the box.
___ Walking boot
___ Elimination of activity
___ Modified activity
___ Crutches
___ Casting
___ Other (Please indicate in the response box below)

15. If you use calf stretching for the treatment of MTSS, please choose all the following options you use. Otherwise, please write N/A in the box.
___ Stretch for gastrocnemius muscle
___ Stretch for soleus muscle
___ Stretch for other muscles (Please describe target muscle in the response box below)

16. If you use calf strengthening for the treatment of MTSS, please choose all the following options you use. Otherwise, please write N/A in the box.
___ Strengthening for soleus muscle
___ Strengthening for gastrocnemius muscles
___ Strengthening for other muscles (Please describe target muscle in the response box below)

17. If you use foot orthotics for the treatment of MTSS, please choose all the following options you use. Otherwise, please write N/A in the box.
___ Custom orthotics
___ Prefabricated orthotics (Over-counter orthotics)
___ Other (Please indicate in the response box below)

18. If you use Kinesio® tape to treat MTSS, please choose all the following techniques you use.
___ Facilitation of muscle (treating underactive muscles)
___ Inhibition of muscle (treating overactive muscles)
___ Fascial correction
___ Mechanical correction
___ Functional correction
___ Ligament/ Tendon correction
___ Space correction
___ Circulatory/ Lymphatic

19. In the response box below, please describe any other treatment methods you use to treat MTSS not indicated in the survey. Otherwise, please write N/A in the box.