

Treatment of Medial Tibial Stress Syndrome Using the MyoKinesthetic System: A Case Series

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By

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Abstract

Objective: The purpose of this case series was twofold: to compare and identify the physiological and muscular differences between those with MTSS and those without MTSS as well as assess the MyoKinesthetic System's (MYK) effect on medial tibial stress syndrome in a physically active population compared to ice massage and stretching the gastrocnemius/soleus complex and plantar fascia.

Methods: The case series was completed in a state college athletic training facility. Six participants, all physically active, were included in the study. Two of the participants were included in the experimental groups due to complaints of MTSS pain and 4 participants with no pain or prior history of MTSS were placed in the control group. Mean age for the six participants was 20.3 ($SD=1.86$). Each participant answered select patient-rated outcome measures (PROM) and were analyzed via a navicular drop test and MyoKinesthetic System posture screen. The participant randomly placed in experimental group A was treated with a MYK System treatment and the participant placed in experimental group B was treated with traditional methods (i.e. ice massage, stretching of the gastrocnemius/soleus complex, rolling of the plantar fascia). Evidence of improvement in participant's function and pain were based on the select PROMs.

Results: The participant in experimental group A (MYK) presented with a "normal" navicular drop measurement, whereas the participant in experimental group B (traditional treatment) showed an "abnormal" navicular drop measurement in her right foot only. The control group had a lower average navicular drop measurement than both experimental participants. The experimental participants had greatest dysfunction at the L5 and S1 nerve root levels based on the MYK System posture screen. Similarly, the control group exhibited dysfunctions at the L5 and S1 levels. The participant who received the MYK System treatment improved in all 6 PROMs and the participant treated with the traditional treatment reported decreases in her overall function and an increase in her perceived pain based on the 6 PROMs.

Conclusion: No relationship could be determined from the small, homogeneous sample size, but the trends in participant's responses to treatment were in support of the MYK System as an effective treatment for MTSS. No obvious postural differences were not found between the experimental and control groups.

Key Indexing Terms: Low Leg Pain, Manual Therapy, Central Nervous System, Physically

Active

Introduction

Medial tibial stress syndrome (MTSS) is defined as a debilitating pain along the posteromedial tibial border of the lower leg.¹⁻⁴ The incidence rate of MTSS in runners is 13.6% - 20%, in dancers is 22%, and in military personnel is 7.2% - 35%, constituting about 60% of reported lower leg injuries.^{1,2,4-7} Although MTSS is not considered a “new” injury, much about it remains unknown. The pathophysiology and most effective treatment for MTSS are in need of further research.

The pathology of medial tibial stress syndrome is undetermined with 3 theories in question: a bone stress reaction resulting from traction and bending of the tibia, a muscular imbalance or dysfunction, or an inflammation of the periosteum. Development of MTSS is credited to various external (e.g., footwear, training intensity, training frequency) and internal factors (i.e., biomechanical dysfunction).^{1,2,3,5} Healthcare professionals (i.e., Certified Athletic Trainer, Physician, Physician’s Assistant) are able to diagnose MTSS by identifying the location of pain,¹ type of pain,^{8,9} and occurrence of pain.¹⁰ Medial tibial stress syndrome pain is commonly located along the “posteromedial border of the tibia, a minimum of 5 cm in length”,¹ and described as “vague, diffuse pain”,^{8,9} which, occurs at the beginning of exercise, and is alleviated upon completion of activity.^{8,9} However, the severity of MTSS parallels the frequency and intensity of pain.^{8,9}

No method or modality has been found to be most effective in treatment of MTSS. A new manual therapy technique, the MyoKinesthetic System (MYK), may be a viable option for treating MTSS. The MYK System has been utilized in recent studies regarding treatment of the knee and low back pain by addressing postural imbalances and muscular dysfunction. Due to the recent development of MYK, there is little research in regards to its efficacy.

Thus, the purpose of this study was to not only compare and identify physiological and muscular differences between those with MTSS and those without, but to assess the MYK System's effect on MTSS in a physically active population compared to traditional, conservative treatment methods (i.e. ice massage, stretching the gastrocnemius/soleus complex, rolling of the plantar fascia).

Etiology

Many variables predispose physically active participants to MTSS including training surfaces, training techniques, footwear, and biomechanical dysfunctions.^{1,2,4,5,11,12} Training intensity and frequent changes and choice of training surfaces (e.g., grass, turf, concrete) influences the amount of stress on the tibia. Negative stress and lack of sufficient rest results in increased osteoclast activity and decreased osteoblast activity, thus hindering the remodeling process.^{1,2,5} Moen et al¹² determined in a case-control study that the development of MTSS was significantly linked to subjects with an increased plantar flexion range of motion (ROM) ($P = 0.001$), decreased hip internal rotation ROM ($P = 0.087$), and a positive navicular drop test ($P = 0.027$). Results were found to be supported by other studies conducted by Yates & White,¹ Bandholm et al,¹³ Bennett et al,¹⁴ and Raissi et al.¹⁵ Winkelmann et al² determined from 2 studies prior^{3,16} that body mass index (BMI), navicular drop, ankle plantar flexion range of motion (ROM), and hip external rotation ROM were risk factors for MTSS. Significant results were found in a cross-sectional study by Sobhani et al⁴ in regards to increased hip internal and external rotation ROM ($P = 0.004$, $P = 0.000$), navicular drop ($P = 0.015$), iliospinale height ($P = 0.017$), and trochanteric tibial lateral height ($P = 0.017$). Finally, a study performed by Noh et al⁵ determined significant relationships between angular changes in medial longitudinal arch (MLA) height, lateral longitudinal arch (LLA) height ($P = <0.05$, $P = <0.05$), and translational motion

at the MLA and LLA ($P = <0.05$, $P = <0.05$). Angular changes in MLA and LLA heights indicated excessive pronation resulting in stress on the foot and ankle.^{1,17} Increased translational motion at the MLA and LLA indicate reduced muscle activation of the plantar flexors resulting in decreased support of the arches.⁵ Based on the above-mentioned research, biomechanical dysfunction including plantar flexion ROM, varying hip rotation ROM, measured navicular drop, iliospinale height, trochanteric tibial lateral height, and angular and translational changes in MLA and LLA were suspected to influence development of MTSS in addition to external factors (e.g. training technique, training frequency, footwear).

Pathology

Medial tibial stress syndrome affects the tibia only and is defined as diffuse pain along the distal or middle 1/3 posteromedial border of the tibia as a result of repetitive exercise.¹⁻⁴ The signs and symptoms of MTSS have been established, but no pathophysiological explanation has been determined. Medial tibial stress syndrome, as a result of the lack of knowledge, has been conceptualized using a stress reaction continuum to address and understand the trauma associated with varying levels of severity.¹⁸ Medial tibial stress syndrome may be due to a bone stress reaction caused by loading and bending of the tibia.¹² When weight-bearing, the tibia is loaded with one's total body weight. As a result, there is bending at the narrowest part of the tibia, which results in microdamage.^{12,18,19,20} The process of healing any type of micro damage is influenced by osteoblast and osteoclast activity. During periods of rest, osteoblast cells function as a means of creating new bone cells while osteoclast cells remove damaged bone cells.^{1,18} The micro damage from MTSS becomes difficult to repair on the cellular level due to the chronic, repetitive nature of the injury. Balance between osteoblast and osteoclast activity is disrupted,

resulting in greater levels of osteoclast activity. The strength and integrity of the bone is compromised, pain increases, and the overall health of the bone deteriorates.¹⁸

The second theory is based on muscular dysfunction and muscular imbalance of the lower leg.¹⁹ Muscular dysfunction is defined as the shortening or inhibition of a muscle,³ a result of overuse.³ The plantar flexors of the low leg (soleus, tibialis posterior, flexor digitorum longus) have been found to be the main source of stress on the tibia.^{4,20,21,22} As the muscles fatigue, function of the muscle decreases, and an increase in stress is placed on the tibia.^{20,22} The triceps surae, often shortened due to the muscles' involvement in gait, become less pliable due to shortening, decreasing range of motion, and causing muscular imbalance.¹⁹ Newsham et al³ cited Southerland et al,²³ Jacob,²⁴ Thorardson et al,²⁵ and Page et al,²⁶ stating that the flexor digitorum longus (FDL), a muscle important for support of the medial longitudinal arch and dissipation of forces during gait, fatigues and shortens due to overuse, causing MTSS pain. Noh et al⁵, addressed the role of the FDL, tibialis posterior, and soleus in explaining how overuse causes pulling against the periosteum, otherwise known as traction. Lastly, Bouche and Johnson,²⁷ theorized that the surrounding fascia also creates tension, which could influence muscular dysfunction.

The third and final theory commonly mentioned is periostitis. Periostitis, first associated with MTSS by Clement²⁸ in 1974, is defined as inflammation of the periosteum.²¹ According to Galbraith and Lavalley,¹⁹ chronic traction of the tibia is often a cause of periostitis. Following Clement,²⁸ Detmer²⁹ proposed in 1986 that periostalgia was the correct pathology, instead of periostitis. Since Clement in 1974²⁸ and Detmer in 1986,²⁹ bone stress reactions due to bending of the tibia and muscular dysfunction at the lower leg have been associated with MTSS through

the use of bone biopsies. As a result of the bone biopsies, periostitis and periostalgia were determined as unlikely pathologies.^{12,21}

Three main theories have been offered as appropriate pathologies of MTSS. The first theory pertains to the relationship between overuse, bony overload, and bone stress reactions. More use coupled with less rest leads to bony overload, which results in a bone stress reaction. Muscular dysfunction, the second theory, may also be considered MTSS as a result overuse, fatigue, and shortening of relevant muscles. The third and least likely theory, periostitis, has been discredited based on past research. Determination of a pathology is achievable through further research and doing so will allow for proper prevention and treatment methods for MTSS.

Treatment

Along with the pathology of MTSS, the most effective, non-invasive treatment for MTSS is undetermined. In the research, conservative treatment options have been coupled with a decrease in physical activity, requiring the participant (i.e., military personnel, athlete) to refrain from full participation in activity. In a systematic review, Winters et al¹⁸ reviewed 11 studies published between 1986 and 2013, 9 of the studies were randomized clinical trials (RCT), the remaining 2 were non-randomized clinical trials. The studies reviewed included a variety of treatment methods: iontophoresis, ice massage, phonophoresis, ultrasound, low energy laser, periosteal pecking, lower leg stocking, lower leg brace, pulsed electromagnetic field (PEMF), and extracorporeal shockwave therapy (ESWT). In sum, only the ESWT treatment method was found to produce significant results.

Winters et al¹⁸ Review

The 11 studies in the systematic review¹⁸ included 10 treatment types. Smith et al³⁰ conducted an RCT on military personnel using iontophoresis, ice massage, phonophoresis, and

ultrasound as treatment modalities for each experimental group. Four modalities were compared to a control group, which included a stretching regimen and limited levels of activity. The experimental participants reported a decrease in pain compared to the control group participants, however, no significant data was found to support one method over another.³⁰

In an RCT by Nissen et al,³¹ two groups of military personnel were treated with either a low-energy laser treatment or a sham laser treatment. The participants were treated 6 times within 2 weeks, with the goal of returning to duty and reaching one third and two thirds of the visual analog scale. By the end of the two weeks, neither group returned to duty quicker, nor did either group achieve specific visual analog scale scores quicker.³¹ Thus, neither the low-energy laser treatment or the sham laser treatment was superior.

A type of manual therapy, periosteal pecking, was also studied in one RCT by Robertson.³² Periosteal pecking, coupled with ultrasound, was compared to ultrasound alone in sports athletes for 2 weeks, 4 total treatments administered. Experimental participants receiving periosteal pecking and ultrasound reported lower Pain Disability Index scores, however, no significant differences were found in the Numeric Pain Rating Scale scores or the McGill Short Form Pain scores.³²

In an RCT by Moen et al,³³ the effects of graded running programs, coupled with various additional treatment methods were compared in athletes. One treatment group was randomly assigned to a six-phase graded running program only. The six-phased running program group was compared to the six-phased running program + stretching and strengthening of the calf musculature as well as the six-phased running program + compression stocking group. For each group, each phase was completed once the participant reported a pain score on the Visual Analog Scale of less than 4 within a phase. Participants were to perform their programs 3 times per

week, until they successfully completed the entire program. None of the treatment groups completed the six-phased running program significantly faster than the others.

Moen et al,³⁴ Johnston et al,³⁵ and Piantanida et al³⁶ performed one RCT each, studying the effects of using a lower leg brace while participating in a graded running program versus the effects of performing the graded running program only, in a military population. Time to completion of graded running program, perceived pain, global perceived effect, and the participant's ability to return to duty were all taken into consideration. Additionally, a participant's ability to run without 10 consecutive steps of pain was taken into account. No significant differences were found between the two treatment groups in regards to the considerations mentioned above.

In an RCT, Brinkman et al³⁷ tested the effect of using pulsed electromagnetic field (PEMF) against a placebo in an athletic pool. The PEMF group received treatment 8 hours a day, 7 days a week for 6 weeks while the second group received the placebo PEMF for the same amount of time. No significant differences were determined in regards to pain or global perceived effect.

In a non-randomized clinical trial,²⁰ the group of athletes treated with extracorporeal shockwave therapy (ESWT) with a 12-week home training program, rest, and ice reported improved global perceived effect and severity of pain compared to the second group, which was treated with 12-week home training program, rest, and ice only. In a second non-randomized clinical trial,³⁸ two groups of athletic participants were compared: ESWT + six-phased running program and six-phased running program only. Five total treatment sessions were administered with the objective of completing the program as quickly as possible. Participants in the group

with ESWT completed the six-phased running program significantly quicker compared to the group treated without ESWT.

Considering the experiments discussed above, ESWT was the only treatment method that was determined statistically significant in terms of return to play time. Experimental groups including different modalities were determined to be no more advantageous than control group treatment methods (e.g. ice massage, stretching and strengthening regimens).

The MyoKinesthetic System

The MyoKinesthetic System (MYK), introduced by Michael Uriarte in 1998, is a manual therapy technique that addresses postural abnormalities found in the human body.³⁹ Postural imbalances are a result of the afferent-efferent feedback loop in the central nervous system (CNS). Painful stimuli, once processed in the CNS, result in anatomically dysfunctional changes in order to relieve pain.^{40,41} As a result, both joint motion and mechanoreceptor firing are impaired.⁴² A full-body posture screen (Figure 1) is used to determine if there are any postural imbalances, muscle weaknesses, or peripheral neuropathy present along the kinetic chain (C1 to T1, L1 to S2), identifying the most dysfunctional nerve root level.³⁹ Each nerve root has a corresponding MYK System treatment, which focuses on different muscle movements advantageous for the nerve root level.⁴² The muscles treated along the nerve root levels are stimulated through active antagonist and passive agonist muscle movements along with a soft tissue massage. The tactile and movement components of the MYK System treatments address the spinothalamic and spinocerebellar tracts in order to influence nociceptor firing and overall tension of the muscle.^{43,44,45} Taking into account the bilateral nature of the CNS, patients are treated bilaterally.⁴⁶⁻⁴⁹ Theoretically, the bilateral treatment will improve efferent and afferent feedback, improving the overall function of muscles.⁵¹ The contraindications for MYK treatment

are based on contraindications associated with any type of massage and include range of motion, open wounds, infections, bleeding disorders, and fractures.⁵¹

Studies using MYK

Few studies have been conducted involving MYK as a treatment option. Brody et al⁵² conducted a study on the treatment of chronic low back pain (LBP) using MYK. In the study, a physically fit 22-year old male reported suffering from LBP for 2 years. The participant was treated with the L5 treatment during the first two appointments. After a second posture screen, the nerve root level where the most dysfunction occurred was L4. The participant was treated with an L4 treatment for the following visits. The participant reported no pain after 7 treatments and was discharged from the study after 10 treatments. Upon follow up, the participant had reported a 0 on the Numeric Rating Scale (-3), a Disablement in the Physically Active scale score of 1 (-12), a Patient-Specific Functional Scale score of 10 (+7), a 2% on the Modified Oswestry Low Back Pain Disability Questionnaire (-8%), and a score of 5 on the Global Rating of Change scale.⁵²

Similar results were found in a study by Brody et al³⁹ in 2017. Nine participants were included, reporting instances of low back pain. The average amount of time a participant had been experiencing chronic low back pain was 6 years ($SD=4.52$), and the average amount of time for acute low back pain was 8.67 days ($SD=10.79$). For all 9 participants, the average number of MYK treatments administered was 12.11 ($SD=6.25$) with an average number of days until discharge from the study of 28.67 days ($SD=9.38$). All participants reported no pain upon discharge and after 1 month, only 21% of the participants reported pain. In addition to the significant changes in participant's Numeric Rating Scale, Disablement of the Physically Active Scale, Patient-Specific Functional Scale, and Modified Oswestry Low Back Pain Disability

Questionnaire (OSW) scores, the posture of each participant was shown to be statistically significant in regards to changes from the MYK treatment.

A case of bilateral chronic knee pain was addressed in a study by Stevenson et al.⁵³ A 20-year old female active in softball reported chronic bilateral knee pain for 2 years. The clinician treated the girl with an S1 MYK treatment at the first visit. The participant reported immediate relief. After the second visit, there was a clinically significant improvement in function. Following the final visit with a total of 4 treatments administered over two weeks, the participant reported a Numeric Pain Scale of 1 and a Patient-Specific Functional Scale of 9. However, at a 16-week follow-up, the participant reported an increase in pain, 3/10 on the Numeric Pain Scale, and a decrease to a 4 on the Patient-Specific Functional Scale.

Although there are limitations to each study including sample size, lack of control group, as well as participant population, the significant findings of each study implicate that further research should be done in regards to the MYK System and its viability as a treatment.

Figure 1. *The MyoKinesthetic System Posture Screen*

POSTURE CHART			
HEAD			LUMBAR SPINE
Extension	_____	(C1-C3)	(L1-L5) Flexed _____
Flexion	_____	(C1-T1)	(L1-L4) Extended _____
Rotation	_____	(C1-T1)	(L1-L5) Lateral Bend _____
Lateral Flexion	_____	(C1-T1)	(L1-L5) Rotation _____
SCAPULA			HIP
Elevated	_____	(C3-C4)	(L3-S2) Flexion _____
Depressed	_____	(C3-C5)	(L1-L5) Extension _____
Abducted	_____	(C3-C5)	(L2-L5) Abduction _____
Adducted	_____	(C5-C8)	(L4-S2) Adduction _____
Upward Rotated	_____	(C3-C8)	(L2-S2) Internal Rotated _____
Downward Rotated	_____	(C3-C7)	(L2-S2) External Rotated _____
SHOULDER			KNEE
Flexed	_____	(C5-C8)	(L2-L4) Flexed _____
Extended	_____	(C5-C8)	(L2-S2) Extended _____
Abducted	_____	(C5-C8)	(L5-S2) Internal Rotated _____
Adducted	_____	(C5-C6)	(L2-S2) External Rotated _____
Medial Rotated	_____	(C5-C6)	
Lateral Rotated	_____	(C5-C8)	
ELBOW			ANKLE
Flexed	_____	(C7-C8)	(L4-S1) Plantar Flexed _____
Extended	_____	(C5-C7)	(L5-S2) Dorsiflexed _____
			(L5-S1) Inversion _____
			(L4-S2) Eversion _____
			(L5-S1) Supinated _____
			(L4-S2) Pronated _____
FOREARM			BIG TOE
Supinated	_____	(C6-T1)	(L4-S1) Flexed _____
Pronated	_____	(C5-C6)	(L5-S2) Extended _____
			(S1-S2) Abducted _____
			(L5-S1) Adducted _____
WRIST			TOES
Flexed	_____	(C6-C8)	(L5-S1) Flexed _____
Extended	_____	(C6-T1)	(L5-S2) Extended _____
Radial Deviated	_____	(C7-C8)	
Ulnar Deviated	_____	(C6-C7)	
THUMB			DERMATOME PAIN
Flexed	_____	(C7-T1)	C1 _____ L1 _____
Extended	_____	(C6-T1)	C2 _____ L2 _____
Abducted	_____	(C8-T1)	C3 _____ L3 _____
Adducted	_____	(C6-T1)	C4 _____ L4 _____
			C5 _____ L5 _____
FINGER			C6 _____ S1 _____
Flexed	_____	(C6-T1)	C7 _____ S2 _____
Extended	_____	(C7-T1)	C8 _____
Abducted	_____	(C8-T1)	T1 _____
Adducted	_____	(C8-T1)	

Methods

Experimental Design

The study was organized as a case series, focusing on 3 different groups of participants. Recruitment emails and fliers were sent to physically active populations. Individuals who expressed interest in the study were provided a consent form before their initial evaluation, which provided a detailed description of the purpose and procedures. The College at Brockport Institutional Review Board approved the research study.

Subjects

Participants were placed in 1 of 3 groups, experimental group A, experimental group B, or the control group, prior to answering the patient-rated outcome measures (PROM). Random group assignment for experimental groups A and B was based on an online number generator. Experimental group A included 1 participant (n=1) who was treated with the MyoKinesthetic System. Participants in experimental group B (n=1) received the traditional MTSS treatment: ice massage, gastrocnemius/soleus stretching, and rolling of the plantar fascia. Four participants were placed in the control group based on inclusion criteria. Inclusion criteria for each group was as follows: experimental group A and B (1) participants were physically active (2) experiencing diffuse, dull pain, and/or tenderness along the middle or distal 1/3 posteromedial border of the tibia (3) experiencing pain before, during, and/or after activity (4) area of pain was a minimum of 5 cm in length and (5) have been diagnosed by a Healthcare Professional (Certified Athletic Trainer, Physician, Nurse Practitioner). Inclusion criteria for the control group required that participants be (1) physically active (2) not experiencing any kind of musculoskeletal pain in the lower leg at the time (3) were not currently under any medical attention/care and (4) had not been diagnosed with MTSS within the past 5 years. Participants were administered treatment for up to 6 weeks. Following 6 weeks, the participant was discharged from the study, however,

treatment was offered if the participant was still experiencing pain. Participants in the control group attended 2 appointments and were discharged from the study upon conclusion of their second (and final) posture screen. All participant demographics are included in Table 1.

Table 1. *Participants' Demographics Details (n=6)*

Patient	Age/ Sex	Symptom Duration	Sport	MYK Tx	Trad Tx	# MYK Tx	# Trad Tx
<i>EXPA 144</i>	18/F	12 weeks	Pole Vault	L5	--	6	--
<i>EXPB 124</i>	18/F	16 weeks	Volley- ball	--	IM, St, R	--	7
<i>CON 331</i>	21/F	n/a	Weight lifting	--	--	--	--
<i>CON 326</i>	21/M	n/a	Football	--	--	--	--
<i>CON 553</i>	22/F	n/a	Volley- ball	--	--	--	--
<i>CON 515</i>	22/M	n/a	Tennis	--	--	--	--

IM, ice massage; St, stretching of gastrocnemius/soleus complex; R, rolling of plantar fascia; EXPA, experimental group A; EXPB, experimental group B; CON, control group; Trad, traditional; MYK, The MyoKinesthetic System

Instruments

Six patient-rated outcome measures (PROMs) were administered at the initial appointment for all 3 groups: (1) the Lower Extremity Functional Scale⁵⁴ (LEFS) (2) the Disablement in the Physically Active scale⁵⁵ (DPA Scale) (3) the Pain Specific Functional Scale⁵⁶ (PSFS) (4) the Global Rate of Change⁵⁷ (GRC) (5) the Well-Being Survey (6) the Numeric Pain Rating Scale⁵⁸ (NPRS). The navicular drop test⁵⁹ (NDT), performed by the principle investigator, and the posture screen,³⁹ performed by the co-investigator, were performed twice following the 6 PROMs, once during the initial visit, and once during the second consecutive visit. All appointments with the exception of the first and final (discharge) appointments required the participant to answer the PSFS, the GRC, and the NPRS. The DPA

Scale was answered once a week also. The control group answered the 6 PROMs once, during the initial evaluation. A description of each PROM is in Table 2 below.

The co-investigator performed the MYK System posture screen, evaluating each participant head to toe. Any imbalances found at the neck, thorax, shoulders, scapula, lumbar spine, hips, and extremities were marked and associated with a nerve root level.³⁹ Upon completion of the posture screen, the marked nerve root levels were added up. The nerve root level with the greatest number of imbalances was determined to be the treatment level.⁴² The posture screen was performed twice to test intra-rater reliability of the certified co-investigator (.58 [$P=.18$] (-2.0, .94)). The principle investigator was not a certified clinician at the time of the study, thus performing all study responsibilities aside from the MYK System posture screen and corresponding treatments. The principle investigator performed the NDT twice to test for intra-rater reliability (Right foot (.89 [$P<.05$] (.22, .99), Left foot (.50 [$P=.23$] (-2.6, .93)).

Table 2. *Description of Patient-Rated Outcome Measures*

PROM	Description
Lower Extremity Functional Scale (LEFS) ⁵⁴	The LEFS is a 5-point scale consisting of 20 questions. The purpose is to assess one's functional level of the lower extremity by requiring participants to rate their function on a scale of 0 (extreme difficulty/unable to perform activity) to 4 (no difficulty). The sum of the participant's responses is determined and compared to a perfect score of 80 points. The MCID was 9 points (90% CI). The LEFS was determined to be a reliable, valid, and sensitive measure.
Disablement in the Physically Active Scale (DPA Scale) ⁵⁵	The DPA Scale is a 5-point scale consisting of 16 questions. The DPA Scale is designed to assess impairment, functional limitations, disability, and quality of life, using a scale ranging from 1 (no problem) to 5 (patient is severely affected). The number of questions (16) is subtracted from the total sum of the 16 responses. A perfect score indicating no impairment, functional limitations, disability, or low quality of life is a score of 0. The MCID was 9 points for chronic injuries and 6 points for acute injuries. The DPA Scale was determined to be a reliable, valid, and responsive patient-rated outcome measure.
Patient-Specific Functional Scale (PSFS) ⁵⁶	The PSFS is a measure that requires each participant to report 3-5 activities that they feel they have decreased function in. Each activity is rated on an 11-point scale with 0 indicating the inability to perform the activity, to a 10, indicating an ability to perform the activity at the same level prior to the injury or problem. The 3-5 scores are averaged together to determine the overall score. The MCID was 2 points. The PSFS was found to be reliable, valid, and efficient as an outcome measure.
Global Rating of Change (GRC)	The GRC is one question pertaining to a participant's perceived change in regards to their condition/injury over time. Participants report using an 11-point scale, with -5 indicating the injury is "very much worse", 0 (about the same), and +5 indicating the injury is completely resolved. The MCID was 2 points. The GRC was determined a reliable and valid outcome measure.
Well-Being Survey (WBS)	
Numeric Pain Rating Scale (NPRS)	The NPRS is a single question requiring participants to rate their pain on an 11-point scale of 0 (no pain) to 10 (extreme pain). The MCID was 3 points (20%). The NPRS compared to other pain scales has been determined reliable, sensitive, and valid.
Navicular Drop Test (NDT)	The NDT is used to measure the Feiss Line, a clinical measure of one's medial longitudinal arch. The NDT has been determined to be a reliable and valid measure. A "good" navicular drop measure is within 6-8mm. A "poor" measure is any value greater than 10-15mm.
MYK System Posture Screen	The MYK System Posture Screen is used to evaluate each participant's posture. The total number of imbalances are determined, and the nerve root level with the greatest number of marked dysfunctions is the target nerve root level. Results correspond to a matching MYK treatment.

MCID, minimal clinically important decrease; MYK System, The MyoKinesthetic System; CI, confidence interval

Procedures

Participants who were in groups experimental A and B were diagnosed with MTSS before their initial visit. The principle investigator performed recruitment efforts, education on the purpose of the study, administration of the 6 PROMs (i.e. LEFS, DPA Scale, PSFS, GRC, Well-Being Survey, NPRS) the NDT, and the treatment for participants in experimental group B. The co-investigator performed the posture screen twice per participant in all 3 groups and performed the MYK System treatments for participants in experimental group A. All 6 PROMs and the NDT were administered to all 3 groups at the initial visit. The 3 groups were tested with the NDT at their second visits as well. For both experimental groups, only the PSFS, GRC, and NPRS were administered following the initial appointment. Additionally, both experimental groups answered the DPA Scale once a week. The experimental groups answered all 6 PROMs at their final/discharge visit. The control group answered all 6 PROMs at their initial appointments only. Participants were discharged if (1) they were treated for a total of 6 weeks or (2) there was evidence of significant changes in responses to the administered PROMs. Evidence of significant changes was based on previously established MCID values: LEFS ≥ 9 , DPA Scale ≥ 6 , PSFS ≥ 2 , GRC $\geq \pm 5$, NPRS ≥ 3 (20%). Participants in both experimental groups were treated as often as possible depending on schedules. The participant in experimental group A was treated bilaterally based on the nerve root determined by the posture screen. The participant in experimental group B performed ice massage, stretching of the gastrocnemius/soleus complex using a slant board, and rolling of the plantar fascia using a lacrosse ball. All tasks were performed bilaterally. Treatments for each group ranged from 10-15 minutes.

The participant in experimental group A (n=1) signed the consent form first. The participant answered the 6 PROMs, their navicular drop was measured by the principle

investigator, and the co-investigator performed the posture screen afterwards. Based on the results of the posture screen, the correct treatment for the participant was an L5 MYK treatment. The second appointment was scheduled upon completion. The second appointment consisted of answering select PROMs, a second NDT, and second posture screen. The patient was treated with the L5 MYK treatment again. Following treatments consisted of answering select PROMs and the L5 MYK treatment. The patient received treatment twice a week for 3 weeks while continuing to participate in all track and field practices and meets. The patient was discharged after 3 weeks of treatment. Each session lasted about 10-15 minutes.

During the initial appointment, the participant in experimental group B (n=1) signed the consent form, answered all 6 PROMs, their navicular drop was measured, and they were assessed using the posture screen. After all measures were completed, the participant was instructed on how to perform ice massage for 8-10 minutes, stretch the gastrocnemius/soleus complex for three sets of 30 seconds each leg, and roll out the plantar fascia for 1 minute each foot. A second appointment was scheduled afterwards. The second appointment consisted of answering select PROMs, undergoing a second NDT, a second posture screen, and the traditional treatment (i.e. ice massage, stretching, rolling). The participant was treated 1-2 times per week for 6 weeks. Each session lasted 10-15 minutes. The participant was discharged after 6 weeks of treatment.

After signing the consent form, participants in the control group (n=4) answered 6 PROMs, underwent the NDT, and a posture screen. Each participant scheduled for their second (and last) appointment. The final appointment consisted of a second NDT and a second posture screen only. Each appointment lasted 5-10 minutes.

Statistical Analysis

Using SPSS Version 24.0 (IBM, Armonk, NY), the mean and standard deviation of the navicular drop measures and posture screen results were calculated for the participant in experimental group A and the participant in experimental group B. The navicular drop measures and posture screen results for each participant in the control group (n=4) were averaged together. The intra-rater reliability of the principle investigator and co-investigator were calculated via SPSS Version 24.0 (IBM, Armonk, NY).

Results

In the study, 2 participants were clinically diagnosed with MTSS and treated for current pain. The 4 participants in the control group were completely devoid of any lower leg related pain. All 6 participants were evaluated via a posture screen, performed by the co-investigator. One participant was treated with the MYK System and 1 participant was treated with the traditional treatment of ice massage, stretching of the gastrocnemius/soleus complex, and rolling of the plantar fascia. Both participants treated for MTSS pain remained active in their sporting events while undergoing treatment. Those in the control group attended 2 appointments each, as a means of comparing posture screens and navicular drop measurements between participants with MTSS pain and those without. The participant in experimental group A was discharged before 6 weeks due to significant decreases in pain. The participant in experimental group B was discharged at 6 weeks, with pain ratings similar to her initial appointment. The mean age for all participants (n=6) was 20.3 ($SD=1.86$). The average age in the experimental groups was 18.0 ($SD=0.00$) with an average symptom duration of 14.0 weeks ($SD=2.83$) before the initial appointment. Six MYK treatments were administered to the participant in experimental group A. Seven traditional treatments were provided to the participant in experimental group B. The

participant in experimental group A reported a decrease in pain upon discharge. The participant in experimental group B reported no change in her perceived pain. Presented in Table 3 are the PROM responses and mean values of the NDT and MYK System posture screen using SPSS Version 24.0 (IBM, Armonk, NY).

Table 3. Patient-Rated Outcome Measure Responses (n=6)^a

Outcome Measure	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		MCID (points)
	A	B	A	B	A	B	A	B	A	B	A ^b	B	A	B ^c	
EXP Group															--
LEFS	66	68	--	--	--	--	--	--	--	--	77	--	--	65	9
DPA Scale	20	16	--	--	--	--	--	18	7	17	1	14	--	16	6-9
PSFS	7.3	6.6	7	6	7.3	5.6	7.3	5.6	8	5.5	9.3	5.6	--	5.3	2
GRC	3	4	0	4	-1	3	2	2	5	2	5	2	--	3	≤±5
WBS	41	47	--	--	--	--	--	--	--	--	34	--	--	51	--
NPRS	4	4	3	3	3	5	2	3	1	4	1	4	--	4	3 (20%)
	Mean value ± SD														
EXP group	A (n=1)				B (n=1)				CON (n=4)						
NDT	--														
R	8±1.41				10±1.41				6.1±2.23						
L	6±0.00				8±0.00				5.6±2.07						
PS	4±0.00				5±0.00				3.8±1.39						

a. The mean and standard deviation of the navicular drop for EXPA, EXPB, and an average of the control group participants (n=4) were calculated, b. EXPA official discharge appointment, c. EXPB official discharge appointment; LEFS, Lower Extremity Functional Scale; DPA Scale, Disablement in the Physically Active; PSFS, Patient-Specific Functional Scale; GRC, Global Rate of Change; WBS, well-being survey; NPRS, Numeric Pain Rating Scale; NDT, Navicular Drop Test; R, right; L, left; PS, MYK posture screen; EXPA, experimental group A; EXPB, experimental group B; CON, control group; MCID, minimal clinically important decrease.

Lower Extremity Functional Scale

Participant EXPA144 (participant in experimental group A) initially reported a 66 out of 80, indicating decreased function in her lower extremity. After 5 MYK System treatments over the course of 3 weeks, EXPA144 rated her lower extremity function at a 77 out of 80, improving by 11 points. A MCID for the LEFS is 9 points, indicating a minimal clinically important difference in EXPA144's LEFS initial and discharge scores. EXPB124 (participant in experimental group B) initially reported a 68 out of 80 in regards to her perceived lower extremity function. After 6 traditional treatments over the course of 6 weeks, EXPB124 decreased in her perceived lower extremity function, reporting a 65 out of 80. EXPB124's discharge value did not meet the established MCID.

Disablement in the Physically Active scale

EXPA144 reported an initial score of 20, a score of 7 after receiving 4 treatments, and a discharge score of 1 after receiving 5 treatments. EXPA144's perceived disablement improved by 13 points after her fourth MYK System treatment and by 19 points after 5 MYK System treatments. The MCID for the DPA Scale of 6-9 points was surpassed by EXPA144's perceived total improvement of 19 points. EXPB124 reported an initial DPA Scale score of 16. EXPB124 perceived her disability to be worse after 3 traditional treatments (score of 18), improved after 5 total treatments (score of 14), and worse after 6 total treatments, concluding with a perceived total of 16 on her DPA Scale. EXPB124's discharge value did not meet the established MCID.

Patient-Specific Functional Scale

EXPA144 reported an initial PSFS score of 7.3 out of 10. EXPA144 perceived her PSFS score to have decreased by .3 after 1 MYK System treatment, but her scores at following appointments increased, with a perceived discharge score of 9.3 out of 10 points. EXPA144's

improvement in the PSFS met the established MCID of 2 points, indicating a clinically important increase. EXPB124 did not experience any increase in her perceived PSFS scores. Her initial score of 6.6 out of 10 declined after 6 traditional treatments, concluding with a discharge PSFS score of 5.3 out of 10. EXPB124's discharge value did not meet the established MCID.

Global Rating of Change

EXPA144 initially score her perceived GRC at a +3 indicating her pain as “somewhat better”. After 1 MYK System treatment, her perceived GRC indicated her condition to be “about the same” (0). EXPA144 reported a decrease in her GRC score to -1 after her second treatment, feeling her condition to be “a tiny bit worse (almost the same)”. Her perceived GRC score increased after 3 treatments, improving from a +2 to a discharge score of +5 (quite a bit better). Comparing initial and discharge scores, EXPA144's scores did not meet the established MCID. However, considering her second and third measures of 0 and -1, EXPA144 did meet and surpass the MCID of $\leq \pm 5$. EXPB124 reported an initial score of +4 (moderately better), but reported a decline in her perceived GRC scores after treatments 2 through 5. Her discharge GRC score improved to a +3 (somewhat better) from her previous score of +2 (a little bit better) at day 6. EXPB124's change in perceived GRC scores did not meet the MCID.

Well-Being Survey

Currently, the WBS has not been established as a reliable and valid outcome measure with any calculated MCID value. However, EXPA144's initial score regarding her perceived well-being was a 41. Upon discharge, EXPA144's perceived her well-being to have improved by 7 points. EXPB124 perceived her well-being at the initial appointment to be a 47 and her well-being at discharge to be a 51. According to the investigators of the WBS, lower scores indicate a

healthier perceived well-being. Thus, EXPA144 appeared to experience an increase in her perceived well-being, whereas EXPB124 experienced a decrease in her well-being.

Numeric Pain Rating Scale

EXPA144 reported her pain at the initial appointment to be a 4 out of 10. Her perceived pain decreased at each consecutive treatment session. EXPA144 perceived her pain to be a 1 out of 10, indicating an improvement in her pain by 3 points, which meets the established MCID (3 points or 20%). EXPB124's initial pain was also reported at a 4 out of 10. However, her pain fluctuated from the first treatment session to the final treatment session. EXPB124's discharge pain was reported to be a 4 out of 10, which was neither an improvement nor a decline in her perceived pain. EXPB124 did not show clinically important differences in her perceived pain.

Navicular Drop Test

The principle investigator measured each participant's navicular drop twice (Right foot (.89 [$P < .05$] (.22, .99), Left foot (.50 [$P = .23$] (-2.6, .93)). EXPA144 exhibited an average navicular drop of 8mm ($SD = 1.41$) in the right foot and a navicular drop of 6mm ($SD = 0.00$) in the left foot. According to the established guidelines,⁵⁹ EXPA144 did not have abnormal navicular drop measurements. EXPB124's measured navicular drops were 10mm ($SD = 1.41$) in the right foot and 8 mm ($SD = 0.00$) in the left foot. EXPB124 exhibited an abnormal navicular drop measurement in her right foot, perhaps contributing to the cause of her MTSS pain. The navicular drops of each participant in the control group ($n = 4$) were averaged together. The average navicular drop of the right foot was 6.1mm ($SD = 2.23$) and the average navicular drop of the left foot was 5.6mm ($SD = 2.07$).

Posture Screen

The co-investigator assessed each participant's posture twice using the MYK System posture screen (.58 [$P=.18$] (-2.0, .94)). In both posture screens, the co-investigator determined the L5 to be EXPA144's most dysfunctional nerve root level. An S1 nerve root level was determined to be the location of most dysfunction for EXPB124 in both posture screens. The average nerve root levels identified to be most dysfunctional within the control group were the L5 and S1 levels.

Discussion

The current study compared the effectiveness of two MTSS treatments to each other, and to a no-treatment control group. The effects of each treatment on MTSS can be examined via the outcome measures provided above in Table 3. The participant in experimental group A, treated with the MYK System, showed vast improvements in her overall function and pain level, as shown by the 6 PROMs. The participant in experimental group B, treated using traditional methods (i.e. ice massage, stretching of the gastrocnemius/soleus complex, rolling of the plantar fascia), showed a lack of improvement. EXPA144 experienced almost complete resolution of her symptoms within 3 weeks, reporting clinically important differences in all but 1 (GRC) of the PROMs. EXPB124 presented with symptoms of MTSS after 6 weeks of treatment and was discharged from the study, reporting no clinically important differences in her PROM scores. Considering the number of treatments each participant received, the MYK System appeared to be more effective in returning EXPA144 to pre-injury status. With 1 participant in each condition, these results must be viewed with caution, but if this trend of better performance was seen with larger group sizes, this would suggest that the MYK System treatment is a more effective treatment than traditional methods used in this study.

Although there is little data to support the WBS as an effective and meaningful outcome measure, understanding the dynamic between well-being and injury status could assist in an improved analysis of the well-being scores of the 2 experimental group participants. A relationship between sports injuries and declined psychological health (i.e. mood, anxiety, depression) has been supported by research.⁶¹ Those who suffer from injuries, certainly chronic injuries, begin to permanently see themselves as one of the “injured athletes”. As a result, patients begin to feel increased vulnerability, decreased self-esteem, and decreased overall capability.⁶² Considering EXPA144’s reported WBS scores, her perceived well-being at the initial appointment was 7 points higher at discharge. However, EXPB124 experienced a decline in her perceived well-being, reporting an initial score of 47 and a discharge score of 51. Where EXPA144 reported improvements in all 6 PROMs, EXPB124 reported a decline or maintenance in her PROMs. Based on research,⁶¹ EXPB124’s lack of improvement in her injury status may have influenced her decline in perceived well-being. On the other hand, her decreased well-being may have influenced her lack of improvement. EXPA144 may have experienced the same relationship in regards to her vast improvement and improved perceived well-being score. A factor to consider when comparing the two participants is the amount of time each participant was in pain before undergoing treatment. EXPA144 reported symptoms for 12 weeks prior to participation in the study. EXPB124 reported symptoms for about 16 weeks before treatment. The additional month of symptoms EXPB124 experienced, which could have contributed to a higher initial WBS score of 47, may have affected her perceived well-being and symptom relief.

Comparing the navicular drop measurements of EXPA144 and EXPB124, the difference between the right and the left measurements are within 2mm. Only EXPB124 exhibited an abnormal navicular drop measurement. An average navicular drop of 10mm ($SD=1.41$) was

measured in her right foot. An abnormal navicular drop measurement is $\leq 10-15$ mm. The remaining measurements (EXPA144 and the left foot of EXPB124) were within 6-8mm, which is considered to be a normal navicular drop measurement. Comparison of the 3 groups, the average navicular drop measurements of the control group participants (n=4) were lower than the average measurements of EXPA144 and EXPB124. Where the average measurements of both experimental groups ranged from 6-10mm, the average measurement in the control group ranged from 5.6-6.1mm. Lower average navicular drop measurements in the control group could be a reason for their lack of MTSS pain, based on prior research indicating abnormal (larger) navicular drop measurements as an etiological factor of MTSS.^{1,2,3,5,12-17}

Variation in identified nerve root dysfunction appeared across the 3 study groups. Nerve roots C6 and C7 innervate the neck, dorsal lateral arm and forearm, thumb, and middle finger.^{63,64} The L4 nerve root has been determined to innervate the tibialis anterior (along with the L5 nerve root), the rectus femoris, and the peroneal nerve.⁶⁵ Based on current research, the lateral head of the gastrocnemius and the anterior compartment of the lower leg (i.e. tibialis anterior, extensor hallucis longus, extensor digitorum brevis) are innervated by the L5 nerve root.⁶⁶ The S1 nerve root innervates muscles of the superficial posterior compartment (i.e. soleus, medial head of gastrocnemius) as well as the abductor hallucis.⁶⁶ EXPA144 was treated with the L5 MYK System treatment due to the high level of dysfunction found via the posture screen. However, EXPB124 was found to exhibit the greatest number of imbalances at the S1 level. One control participant showed greater dysfunction at their C6 and C7 levels. A second control group participant was determined to have the most dysfunction located at the L4 and L5 levels. However, the average nerve root level with the greatest dysfunction for the control group was both the L5 and S1 levels. Considering nerve root innervations explained above, EXPA144

exhibited postural imbalances located within the anterior compartment of the lower leg and the lateral head of the gastrocnemius. EXPB124 exhibited postural imbalances within her superficial posterior compartment and abductor hallucis. The control group participants on average, exhibited both the L5 and S1 imbalances. Considering the similarities, it is difficult to determine if there are specific differences in posture between the experimental groups and the control group. Although there were 2 control group participants who exhibited high levels of dysfunction at the L4 level and C6 and C7 levels, neither experimental group participant exhibited similar signs. Thus, it could be proposed that the C6 and C7 nerve root levels are not involved in the development of MTSS. Comparing the lumbar and sacral nerve root levels commonly detected within the 6 participants, the L4 nerve root appears to be unlikely, but cannot be determined as unrelated in development of MTSS. The similarity of the 6 participants' posture screens makes it difficult to detect any relationship and form hypotheses. A greater number of participants is necessary in order to understand why the 2 experimental group participants were dysfunctional at differing nerve root levels (L5 versus S1). In addition, a larger sample size may assist in understanding why there was little difference when comparing the most dysfunctional nerve root levels between the experimental group participants (L5 versus S1) and the control group participants (L5 versus S1).

No studies to date have been conducted testing the efficacy of the MYK System in treating physically active patients with symptoms of MTSS. Although the sample size was too small to run statistical analyses, the outcomes of the two experimental participants support the thesis. The trends in EXPA144's outcome measures over the course of 6 treatments were similar to the trends present in previous MYK System studies.^{39,52,53} In the studies performed by Brody et al⁵² and Stevenson et al,⁵³ each individual participant reported improvements within 4 to 10

MYK treatments, meeting established MCIDs. Both participants reported decreases in their NPRS scores and improvements in their PSFS scores upon discharge.^{52,53} Likewise, 9 participants in a subsequent study by Brody et al³⁹ reported significant differences in their PROMs after an average of 12.11 ($SD=6.25$) MYK System treatments. However, a difference between the previous MYK studies and this study is the duration of pain prior to the initial appointment. Aside from the average acute symptoms of 8.67 days ($SD=10.79$), the instances of chronic pain ranged from 2 years to 6 years ($SD=4.52$).^{39,52,53} The history of pain was greater in prior studies compared to this study, where there was an average pain history of 14 weeks ($SD=2.83$). History of pain could be an indicator of how many treatments on average are necessary to alleviate symptoms. However, no relationship can be concluded considering the varying averages of MYK System treatments administered in previous studies and this one. Additionally, comparison of postural differences as well as inclusion of a traditional treatment group or a control group were not present in previous MYK System studies.^{39,52,53} Although no statistical analyses were performed, the outcomes of this study produced similar results to prior studies. In order to produce more conclusive and supportive data, further research is necessary using a larger sample size in each of the 3 groups.

Limitations

The study contained a number of limitations, which could have affected the outcome. The sample size for the current study was 6 participants, with 4 in the control group. As such, the sample size was too small to perform statistical analyses. Observing the true effects of each treatment type is hindered due to the lack of participants in experimental group A and experimental group B. Of note, the one participant who was treated with the MYK System treatment demonstrated improvements, whereas the participant who received traditional

treatment did not. Future research is needed to determine if this trend holds true across multiple participants. Additionally, the small sample size resulted in an inability to detect and begin to understand any postural or muscular differences between those with MTSS and those without. In regards to patient demographics, the subject pool included the athletic population only. Not only is there an underrepresentation of the athletic population due to the small sample size, but there is a total lack of representation of other physically active populations (i.e. dancers, military personnel). Perhaps there is a relationship between MTSS, specific postural imbalances, and type of physical activity. However, no trends can be assumed in regards to symptom alleviation or postural imbalances. Also, bias may not have been avoided due to the co-investigator's history and knowledge of the MYK System treatment as well as the principle investigator's knowledge and experience with the MYK System treatment. A final limitation was the coordination of schedules. Scheduling treatment times between the principle investigator (full-time student, Athletic Training student), the co-investigator (full-time Certified Athletic Trainer), and the participants (i.e. students, athletes, student athletes) was difficult and affected appointment frequency. In future studies, it is imperative to have a larger, more heterogeneous sample size as well as more availability and consistency when scheduling treatment sessions.

Conclusion

Continuation of the study is necessary to determine whether the MYK System is an effective treatment method for MTSS. EXPA144's improvement, shown by her PROM responses, indicates the MYK System as an effective treatment, whereas EXPB124's responses and overall deterioration indicate the traditional treatment as an inadequate solution for MTSS. Further data collection is necessary to support these findings and generate a relationship. In regards to postural differences shown via the posture screen, no relationship or trend was able to

be identified due to the small sample size. Navicular drop measurements of the experimental groups versus the control group appeared to be greater, but no significance could be determined. Considering the outcomes of each participant upon discharge, incorporating a follow-up questionnaire of the same 6 PROMs could assist in observing the efficacy of the MYK System in regards to its long term effects on MTSS.

Aforementioned in the limitations section, lack of significance may be a result of the small, homogeneous sample size. Therefore, further research utilizing larger sample sizes and different physically active populations is necessary to not only examine the effectiveness of the MYK System as a treatment for MTSS, but to explore the relationship between postural imbalances and MTSS.

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