Risk Factors of Medial Tibial Stress Syndrome in Active Adolescents: A Validation Case Series

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ABSTRACT

Current literature reports that an increase in body mass index (BMI), navicular drop, ankle plantarflexion range of motion (ROM), and hip external rotation ROM are key modifiable risk factors in the development of medial tibial stress syndrome (MTSS) in physically active adults. The purpose of this validation case series was to investigate these four measures as risk factors of MTSS in adolescent athletes. In total, 100 cross country, volleyball, and/or basketball athletes (age = 15.89±1.31 years, 54 assigned female at birth) were included. The competitive sports season was the intervention in this case series and all athletes experienced 6 athlete-exposures per week. Of the 100 athletes, 21% (n = 21/100) of participants developed MTSS during their respective sports season. Demographic data were analyzed using measures of central tendency. Mean differences (MD) between the MTSS and non-MTSS groups were calculated for the main outcome variables. A Kruskal-Wallis one-way analysis of variance was used to determine differences in main outcome variables between groups. There were no significant differences in BMI ($p \geq 0.42$), navicular drop ($p \geq 0.27$), active ankle plantarflexion ROM ($p \geq 0.65$), or active hip external rotation ROM ($p \geq 0.77$) between MTSS and non-MTSS groups. The MD between groups were BMI = 0.22, navicular drop = 0.95mm, active ankle plantarflexion ROM = -1.36°, and active hip external rotation ROM = -0.40°. These results do not prospectively confirm adolescents who develop MTSS have a significant increase in the risk factors described in the literature. Therefore, more research should be performed to determine if the risk factors for MTSS between adults and adolescents differ.

Content Focus
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ARTICLE SUMMARY

Medial tibial stress syndrome (MTSS), often referred to as "shin splints," is described as an "exercise-induced, localized pain along the distal two thirds of the posterior-medial tibia,"[1] and is a common musculoskeletal condition in those who are physically active.[2-6] Runners are particularly affected by MTSS with an incidence rate as high as 13.6-20%.[2,3] Despite how common this condition is, there still is a lack of consensus within the literature about the etiology of the condition.[2,3] Multiple conjectures have been made about the anatomical source of the pain with myofascial strain, enthesopathy, periosteal inflammation, and bone stress reaction being the most widely accepted causes.[7] Our murky understanding of the involved tissue makes this condition difficult to treat and even more difficult to prevent. Identifying risk factors for MTSS could benefit a large proportion of those who are physically active, as it would provide clinicians with the necessary information to develop and implement risk reduction programming. Developing this programming would help minimize the negative effects of the risk factors.

A guiding systematic review and meta-analysis[2] that identified risk factors for developing MTSS in physically active individuals was selected for this case validation series. The authors of the review searched the Database of Abstracts of Reviews of Effects (DARE) and the Cochrane Database of Systematic Reviews (CDSR) for systematic reviews pertaining to risk factors of MTSS as well as the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE (OVID SP), EMBASE, and CINAHL for studies meeting the inclusion criteria. Studies were included in the review if they were original research, investigated risk factors associated with MTSS, compared physically active individuals with and without MTSS, were published in English, and were accessible, full papers, in peer-reviewed journals.

After removing duplicates and investigations that did not align with the research question, a total of 21 original research articles were included and the following relevant data points were extracted: research design, study duration, participant selection, population, groups, MTSS diagnosis, investigated risk factors, risk factor definitions, means, standardized deviations (SD), confidence intervals (CI), effect sizes, and odds ratios (OR). This information was then classified into risk factor categories including arch height or angle, BMI, bone parameters, calcaneus and rearfoot position and displacement, calf girth, flexibility/ROM, foot posture index, forefoot position, gait variables, leg angle and tibia angle, medical history and symptoms, Ober's test, strength, structure/alignment, training variables/fitness level, and demographic variables. The 21 included articles consisted of three cross-sectional, nine case-control, and nine prospective cohort studies. Individuals with increased BMI (mean difference [MD] = 0.79, 95% CI 0.38-1.20, $p < 0.001$, $I^2 = 0.00\%$), increased navicular drop (MD = 1.19mm, 95% CI 0.54-1.84, $p < 0.001$, $I^2 = 40.19\%$), increased ankle plantarflexion ROM (MD = 5.94°, 95% CI 3.65-8.24, $p < 0.001$, $I^2 = 0.00\%$), and increased hip external rotation ROM (MD = 3.95°, 95% CI 1.78-6.13, $p < 0.001$, $I^2 = 0.00\%$) were found to be more likely to develop MTSS. The increase in each of these four main outcome measures were deemed statistically significant when comparing physically active adults that did develop MTSS to those that did not develop the condition.

OBJECTIVE

The purpose of this case validation series was to investigate these four main outcome measures as risk factors of MTSS in secondary school (grades 9 to 12) athletes at the point-of-care. With this information, comparisons to previous literature that has investigated these risk factors can be made to allow for better recommendations for MTSS prevention measures in the secondary school athlete patient population.

PATIENT POPULATION

The clinical practice setting for this study included student-athletes at five secondary schools in rural Indiana. In total, 100 athletes, 13 of which participated in more than one sport, were included. Participant demographics can be found in **Table 1** with the MTSS diagnoses. Those who participated in more than one sport were observed during both sports seasons if they did not develop MTSS during the first sport season. A breakdown of the number of participants by school and sex assigned at birth can be found in **Table 2**. Patients were included in this study if they were in high school and participated in cross country, volleyball, and/or basketball. Individuals were included regardless of MTSS history, however they had to be injury free at the time the risk factors were measured at the beginning of their respective sports season.

INTERVENTION

This case validation series followed the main findings from the guiding review which indicated that four main outcome measures were significantly different between those who developed MTSS and those who did not.

Table 1. *Participant demographics*

Age (y) (mean±SD)	15.89±1.31	
	n	MTSS Diagnosis n (%)
Sex Assigned at Birth (n)		
Female	54	10 (18.52%)
Male	46	11 (23.91%)
Sport Participation (n)		
Cross Country	46	14 (30.43%)
Volleyball	20	0 (0%)
Basketball	47	7 (14.89%)

Table 2. *Number of participants by school and sex assigned at birth*

	Males	Females	Total
School 1	27	29	56
School 2	6	13	19
School 3	8	3	11
School 4	5	0	5
School 5	0	9	9
Total	46	54	100*

*Of the 100 total participants, 13 participated in more than one sport (3 males, 10 females).

In this case validation series, the athletic trainer(s) at each school calculated BMI $(kg \div m^2)$ and measured navicular drop, ankle plantarflexion ROM, and hip external rotation ROM. Both ankle plantarflexion and hip external rotation were measured actively.

Although BMI is not a great predictor of body mass, specifically body fat percentage in an athletic population, individuals with an increased BMI compared to controls are more likely to develop MTSS.[2] A BMI of 18.5-24.9 would be considered a "healthy" height-to-weight ratio, so an individual with a BMI greater than this may develop MTSS because of the response of bones to loading. When tibial bowing or bending occurs, the load producing this bowing or bending stimulates periosteal activation, causing the tibia to become stronger to prevent bony overload.[8,9] Those with a higher BMI would be subject to a greater load and may require a more gradual and prolonged increase in activity levels to account for the slow, progressive process of osteogenesis that needs to occur to prevent the tibia from becoming injured due to overloading.[2]

Navicular drop and arch height have been shown to be related to tibial internal rotation during running.[2] Having a more rigid arch, one that is not hypermobile allowing the navicular to drop significantly while weight bearing, is good because it allows for more tibial internal rotation.[10,11] This may be one way the body is able to better absorb impact forces.[2] On the other hand, individuals with a greater amount of navicular drop experience a decrease in arch height, or increased foot pronation, leading to less tibial

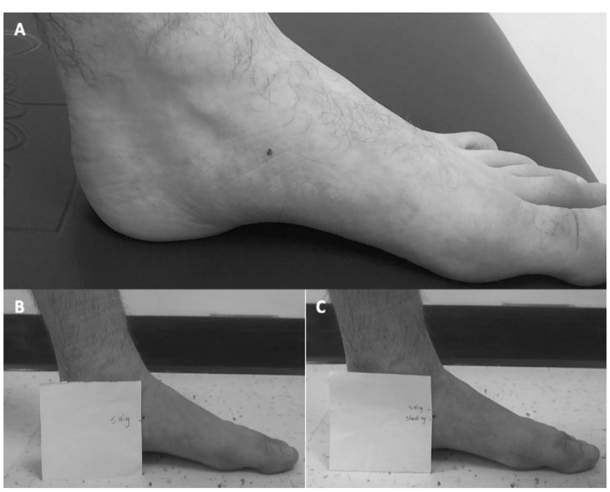

Figure 1. Navicular Drop.

A) The navicular tuberosity is marked on the patient's skin. B) Next, the level of the navicular tuberosity is marked on a notecard while the patient is non-weightbearing. C) The patient is then asked to stand, and the level of the navicular tuberosity is marked on the notecard while the patient is weightbearing. The distance between the two markings on the notecard is then measured in millimeters (mm).

internal rotation and a decreased ability to absorb impact forces.[16] Having a navicular drop ≥10mm represents an overly pronated foot,[12] meaning the tibia itself must absorb the majority of impact forces, predisposing individuals to MTSS.[16]

The relationship between plantarflexion ROM and the development of MTSS has less evidence than the previous risk factors.[2] Researchers have hypothesized those with greater degrees of plantarflexion, of which the normative active ROM is 50°,[12] are more likely to land on their forefoot when running as opposed to landing on the rearfoot.[4] This landing position may contribute to an increase in the amount of strain being placed on the posteromedial aspect of the tibia.[13] However, there are currently no investigations that have corroborated this hypothesis. Another possible explanation is that increased navicular drop and increased plantarflexion are interconnected. During the first half of the stance phase during running, foot pronation, which is a combination of ankle dorsiflexion, rearfoot eversion, and foot abduction, occurs.[14] Individuals with greater pronation, indicating increased navicular drop, may push through their first ray more forcefully during midstance, when the foot pronates to absorb impact forces.[2] These greater push off forces can lead to a greater active ROM in plantarflexion and therefore greater extensibility of the ankle dorsiflexors.[2] Increased extensibility of the anterior tibialis, a strong dorsiflexor which attaches to the base of the first ray, associated with greater plantarflexion ROM, may influence navicular drop due to its proximity to the navicular bone.[2] Though these biomechanical connections can be make hypothetically, there remains a lack of substantial evidence to make these connections definitive, further demonstrating the need for screening and prevention.

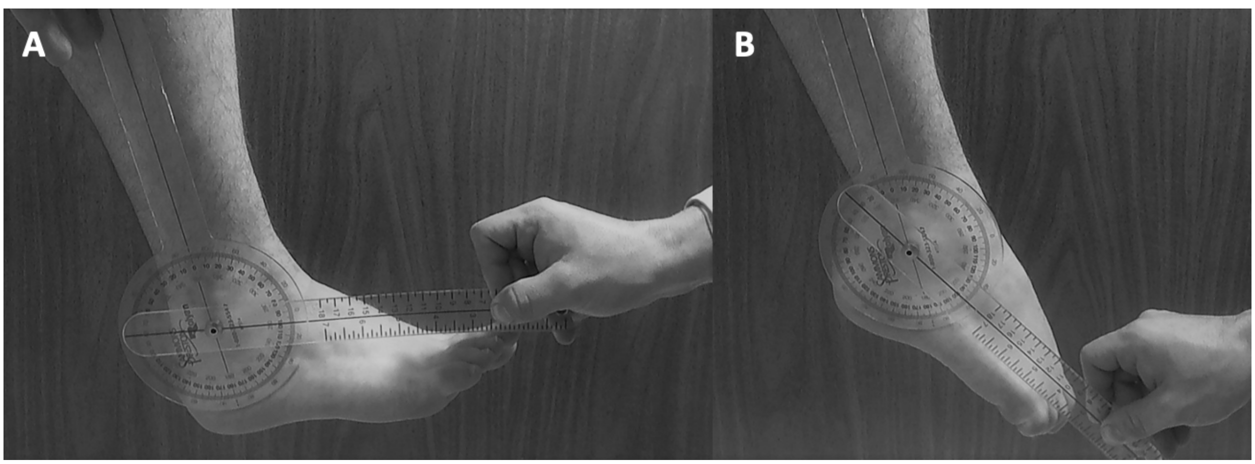

Figure 2. *Active Ankle Plantarflexion ROM Measurement with Goniometer*

A) Starting Position: The fulcrum of the goniometer is placed over the apex of the lateral malleolus, the stationary arm is aligned parallel to the axis of the fibula using the head of the fibula as a distal reference, and the moving arm is aligned parallel to the axis of the 5th metatarsal during movement. B) The patient is asked to plantarflex their ankle and the clinician ensures all parts of the goniometer remain correctly aligned.

Possibly more unclear than the connection between plantarflexion and MTSS is the association between increased hip external rotation ROM and MTSS.[2] The normative active ROM for hip external rotation is 45°.[12] Hip external rotation ROM greater than this could lead to excessive medial tibial loading; however, the same is true for decreased hip ranges of motion,[4] as well as limited evidence suggesting greater internal rotation can lead to MTSS.[17] Changes in the available degrees in various ranges of motion of the hip may result from anteversion or retroversion of the femoral neck,[15] changing the orientation of the femur on the tibia.[2] Another possible theory is that the total arc of rotation at the hip, meaning the total degrees of hip internal and external rotation combined, could influence tibial loading, though there is limited empirical evidence to make a concrete connection here.[2] Even so, more research should be conducted to identify the relationship between hip external rotation ROM and ankle plantarflexion ROM on the development of MTSS.

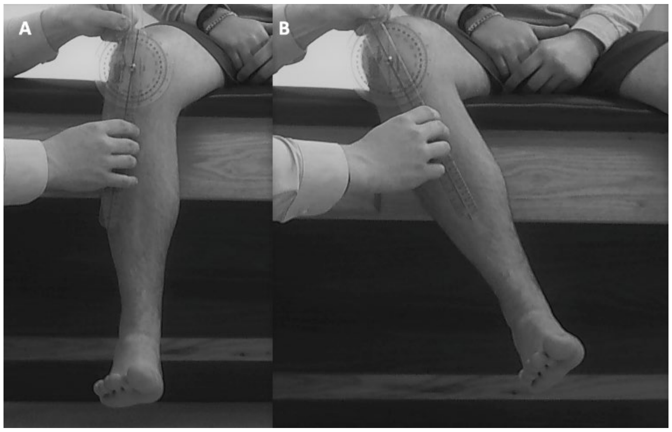

Figure 3. *Active Hip External Rotation ROM Measurement with Goniometer*

A) Starting Position: The fulcrum of the goniometer is placed over the middle of the patella, the stationary arm is aligned perpendicular to the floor or tabletop, and the moving arm is aligned parallel to the axis of the tibia during movement using the center of the talocrural joint as a distal reference. B) The patient is asked to externally rotate their hip and the clinician ensures all parts of the goniometer remain correctly aligned.

MAIN FINDINGS

Participants of this case validation series were divided into two groups, MTSS and non-MTSS, based on the development of the condition. Descriptive statistics were completed for both groups. Measures of central tendency were used to analyze the demographic variables and main outcome measures. Mean differences were calculated between the two groups. The groups were not normally distributed, so a Kruskal-Wallis one-way analysis of variance was used to determine differences.

During their respective sport season, 21% (n = 21/100) of participants developed MTSS. The supervising athletic trainer at their respective school used the following diagnostic criteria for MTSS: injury must have been exercise-induced, pain must be localized, and pain must be along the distal two-thirds of the posteromedial tibia.[1] The means and standard deviations for each main outcome variable by group can be found in Table 3 with the normative values for the general population for comparison. The MD between groups was calculated by subtracting the mean of those who did not develop MTSS from those that did. The MD of each of the measures were as follows: BMI = 0.22, navicular drop = 0.95mm, active ankle plantarflexion ROM = -1.36°, and active hip external rotation ROM = -0.40°. There were no significant differences in BMI ($p \geq 0.42$), navicular drop ($p \geq 0.27$), active ankle plantarflexion ROM ($p \geq 0.65$), or active hip external rotation ROM ($p \geq 0.77$) between participants who did and did not develop MTSS.

Table 3. *Side-by-side comparison of the results to normative values between groups (MTSS and non-MTSS)*

	Normative Values	**MTSS Group (n=21)**	**Non-MTSS (n=79)**
BMI	Healthy = 18.5-24.9	22.36±4.35 (95% CI 20.50-24.22)	22.14±3.09 (95% CI 19.05-25.23)
Navicular Drop	Normal ≤ 10mm	8.33±3.14 (95% CI 6.99-9.67mm)	7.38±3.63 (95% CI 6.58-8.18mm)
Active Ankle Plantarflexion ROM	0-50°	55.24±9.54° (95% CI 51.16-59.32°)	56.59±10.75° (95% CI 54.23-58.96°)
Active Hip External Rotation ROM	0-45°	33.98±7.30° (95% CI 30.85-37.10°)	34.38±9.91° (95% CI 32.19-36.57°)

DISCUSSION

The purpose of this validation case series was to investigate risk factors of MTSS in an adolescent sporting population. Identifying risk factors in this population would be a necessary step for the development and implementation of preventative training programs to reduce the incidence rate of this injury. The current investigation found no significant differences between the four main outcome measures between patients who developed MTSS and those who did not. The average BMI of individuals in this study fell within the normative range (18.5-24.9) for both individuals who developed the condition and those who did not. Similarly, the average navicular drop for both groups was between 7.38±3.63mm and 8.33±3.14mm for the non-MTSS and MTSS groups respectfully, which would be considered in the normative range below 10mm. Overall, active ankle plantarflexion ROM for both groups was approximately 5-7° greater than population normative values. However, since this finding was present in both groups, the difference between groups was not found to be significant. Lastly, the average active hip external rotation ROM for both groups was about 11° less than population normative values. Though previous literature has suggested both increased and decreased hip ranges of motion could affect tibial loading,[4] both those who developed MTSS and those who did not develop MTSS demonstrated a decrease in external rotation ROM.

In this study, there were some key limitations that need to be addressed in future research. This study included a small sample size (n = 100) and the patient population of this study was solely adolescent athletes between the ages of 13 and 18. Adolescent athletes may have different anthropometric characteristics that predispose them to developing MTSS when compared to adults. Another limitation of this study was the use of ROM measures as a surrogate for gait analysis. While ROM theoretically influences biomechanics, an in-depth biomechanical analysis should be utilized to more accurately identify these changes. In addition, this study was conducted during the COVID-19 pandemic which saw sports teams regularly quarantine when an individual on a team tested positive for the virus. This may have had an effect on the number of individuals in the study who experienced MTSS because the quarantine period created unusual rest periods throughout the sports season, where patients were not subjected to the same training regimen and decreased loading of the tibia. Additionally, with the consistent changes in training load, we did not include training load and mileage ran for each participant. Finally, when conducting a multi-site investigation at the point-of-care, coordination and collaboration are paramount for data collection.

Future studies should utilize larger sample sizes and investigate the differences between adolescents and adults who develop MTSS from those that do not develop MTSS. Specifically, research should continue to investigate the influence of hip external rotation ROM and running biomechanics. Also, information related to training load and training intensity should be considered in future research on this topic, as previous investigations have shown that increased training load can predispose individuals to MTSS.

CLINICAL BOTTOM LINE

Adolescents with significantly greater BMI, navicular drop, active ankle plantarflexion ROM, and/or active hip external rotation ROM may not be more likely to develop MTSS. More research should be performed with a larger sample size as well as to investigate if the risk factors for MTSS between adults and adolescents differ. A reduction in the total number of adolescents experiencing MTSS should also have a larger impact on the entire healthcare system, reducing the time and financial burden that is exacerbated treating preventable conditions.

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