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Medial Tibial Stress Syndrome in High School Cross-Country Runners: Incidence and Risk Factors

STUDY DESIGN: Prospective cohort.

OBJECTIVE: To determine (1) the cumulative seasonal incidence and overall injury rate of medial tibial stress syndrome (MTSS) and (2) risk factors for MTSS with a primary focus on the relationship between navicular drop values and MTSS in high school cross-country runners.

BACKGROUND: MTSS is a common injury among runners. However, few studies have reported the injury rate and risk factors for MTSS among adolescent runners.

METHODS AND MEASURES: Data collected included measurement of bilateral navicular drop and foot length, and a baseline questionnaire regarding the runner's height, body mass, previous running injury, running experience, and orthotic or tape use. Runners were followed during the season to determine athletic exposures (AEs) and occurrence of MTSS.

RESULTS: The overall injury rate for MTSS was 2.8/1000 AEs. Although not statistically different, girls had a higher rate (4.3/1000 AEs) than boys (1.7/1000 AEs) ($P = .11$). Logistic regression modeling indicated that only gender and body mass index (BMI) were significantly associated with the occurrence of MTSS. However, when controlled for orthotic use, only BMI was associated with risk of MTSS. No significant associations were found between MTSS and navicular drop or foot length.

CONCLUSIONS: Our findings suggest that navicular drop may not be an appropriate measure to identify runners who may develop MTSS during a cross-country season; thus, additional studies are needed to identify appropriate preseason screening tools. *J Orthop Sports Phys Ther 2007;37(2):40-47. doi:10.2519/jospt.2007.2343*

KEY WORDS: injury risk, female athlete, navicular drop, shin splints

Overuse injuries of the shin are common in military recruits[2,38] and recreational[23,41,42,45] and competitive cross-country runners.[33,34,39] Medial tibial stress syndrome (MTSS) is an exercise-induced, localized pain along the distal two thirds of the posterior-medial tibia and can be a debilitating injury in runners.[11,18,27,28,43] In studies of recreational runners, MTSS has been reported as the most[41] or second most frequently diagnosed injury.[8] Clement et al[8] reported that the incidence of MTSS was higher among female runners (16.8%) than male runners (10.7%).

Improper foot biomechanics, such as a static pronated foot, lower standing foot angle (angle between the medial malleolus-navicular tubercle-first metatarsal head), varus rearfoot and/or forefoot, and greater maximum pronation and pronation velocity have been associated with MTSS in athletic populations, especially among runners.[27,40,43] An excessively pronated foot and increased navicular drop, a measure of pronation, appear to be associated with MTSS injury. Bennett et al[6] found that excessive navicular drop measurements correctly identified 64% of MTSS cases in high school cross-country runners. The combination of gender and navicular drop increased the accuracy of MTSS identification to 76%.[6] However, the authors measured navicular drop after injury occurrence and then compared the values to an equal control group of uninjured runners. A prediction rule based on a post hoc measurement may introduce bias into the study, which could influence the results.

Menz[26] suggested that navicular drop should be normalized to the size of the foot to be a valid measure of pronation. Navicular height divided by full and truncated foot length has been reported to have high concurrent validity.[46] Saltzman et al[36] reported that navicular height divided by foot length was most closely related to 3 measurements describing the medial longitudinal arch on radiograph (calcaneal angle, talar head height to truncated foot length ratio, and calcaneal-first metatarsal angle). In a prospective study of Navy SEAL candidates, Kaufman et al[16] measured the candidates' static foot position using navicular height in full weight bearing, divided by truncated foot length, to determine bony arch index. The authors reported an increased risk relationship between a greater normalized navicular height and overuse injury. To our knowl-

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edge, navicular drop normalized to foot length has not been studied in the high school running population.

In 2004, over 372000 students participated in interscholastic cross-country running in the United States.[30] However, few studies have examined risk factors in high school cross-country runners.[6,33] While excessive navicular drop was found to be predictive of MTSS, a limitation of Bennett et al's[6] findings was that they measured navicular drop postinjury. Therefore, the purpose of this study was (1) to determine the cumulative seasonal incidence and overall injury rate of MTSS and (2) to determine the relationship between navicular drop and MTSS in high school cross-country runners. It is important to prospectively identify modifiable risk factors so that strategies may be implemented to minimize injury occurrence. If risk for injury can be identified prior to the cross-country season using navicular drop normalized to full or truncated foot length, interventions such as custom orthotics or shoe wear prescription may be recommended to the runner to help minimize potential time lost from sport participation. As the development of MTSS is likely multifactorial, we also examined other previously reported risk factors such as gender, running experience, previous running injury, and body mass index (BMI).[6,7,10,15,17,34,48]

METHODS

The primary independent variable of interest for potential risk factors was navicular drop. Thus, the main power analysis was based on the power needed to detect a risk association between navicular drop and MTSS. A priori, based on Rauh et al's[34] shin injury rates, using a prospective cohort design, a power of 0.80, an alpha level of .05, a conservative expected estimate of 20% of noninjured (MTSS) runners having a navicular drop greater than 10 mm, an expected estimate of 45% of injured (MTSS) runners with a navicular drop greater than 10 mm, and an approximate relative risk of 2.0 or corresponding odds ratio of 3.5, a sample of 110 runners was determined necessary to show a statistically significant association between navicular drop and MTSS injury.

We followed 8 high school cross-country teams in Southwest Indiana during the 2004 season. Of the 130 eligible cross-country runners 105 (81%, 46 girls and 59 boys) consented to participate. The subjects were aged 14 to 19 years. Runners with current MTSS symptoms or stress fracture, or lack of medical clearance to participate prior to the beginning of the study were excluded. The study was approved by the Rocky Mountain University of Health Professions Institutional Review Board. All subjects provided informed consent and guardian/parental consent was obtained for athletes less than 18 years of age.

Injury and Participation Data

Coaches and certified athletic trainers were trained in using the Athletic Health Care System Daily Injury Report (DIR).[33-35] The DIR was completed on a daily basis for the entire season to record each runner's practice and cross-country meet participation, absences, limitations and time lost from participation due to injury. We met with the coaches and certified athletic trainers monthly to collect the injury reports. The DIR was reviewed and compared to the team's practice and competition schedule to ensure accurate and complete reporting. If a runner reported shin pain to the coach or certified athletic trainer, the principal investigator (a licensed physical therapist and certified athletic trainer) or the team's certified athletic trainer examined the runner to determine if he or she met the criteria for MTSS. MTSS was defined as continuous or intermittent pain in the tibial region, exacerbated with repetitive weight-bearing activity, and localized pain with palpation along the distal two thirds of the posterior-medial tibia.[6]

Navicular Drop

At the beginning of the season, the navicular drop of both feet was measured for each runner by 1 investigator (R.T.T.). A fine-tipped marker was used to mark the most prominent point of the navicular tubercle on the runner's feet in a sitting position. Then, in a unilateral standing position, the runner's foot was placed in subtalar neutral. Subtalar neutral was determined by palpating the neck of the talus, then the runner was asked to supinate and pronate his/her foot until the talus was equally prominent under the investigator's thumb and forefinger.[9] Runners were allowed to maintain their balance by placing a hand on a handrail during unilateral stance. A ruler was placed next to the medial foot perpendicular to the floor and was read (mm) at the height of the navicular tubercle. The runner was then instructed to relax the stance foot. The ruler was again read at the height of the navicular tubercle. The 2 measurements were recorded and the difference value was documented as navicular drop.

Foot Length

Each runner stood on a Brannock Foot-Measuring Device (The Brannock Device Company, Liverpool, NY), while full and truncated foot length (mm) was measured by 1 investigator (M.S.P.) for each foot.[3] The Brannock device is a common measuring device used in shoe stores to determine shoe size and width. The device measures full foot length as well as truncated foot length. A tape measure (mm) was placed on the Brannock device to obtain full foot length measurement (mm) rather than shoe size. A straightedge was placed from the moveable arch length pointer at the first metatarsophalangeal joint position to determine the truncated foot length on the tape measure. Full foot length was defined as the measurement from the most posterior aspect of the calcaneus to the tip of the longest toe.[36] Truncated foot length was defined as the measurement from the most posterior aspect of the calcaneus to the center of the first metatarsophalangeal joint.[36]

Pilot Reliability Study

Prior to the prospective study, 22 high school athletes were measured during

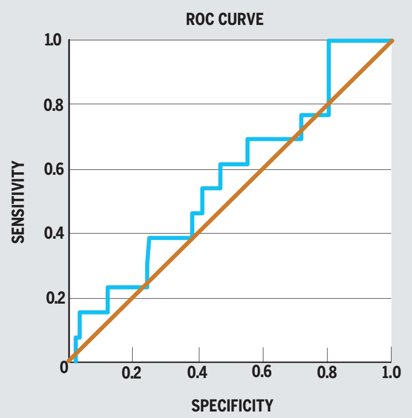

FIGURE. Receiver operating characteristic (ROC) curve for medial tibial stress syndrome related to normalized right navicular drop divided by truncated foot length. Diagonal segments are produced by ties.

their sports physicals to establish intrarater reliability for navicular drop and foot length measurements. The reliability was tested for 2 methods of measuring navicular drop. Navicular drop was initially measured by marking each height on an index card. Navicular drop was then measured using a ruler as described previously. Intrarater navicular drop measurement using a ruler was found highly reliable (intraclass correlation coefficient [ICC] = 0.88-0.91) and was therefore used in the prospective study. Similarly, high intrarater reliability was found for full-foot (ICC = 0.99) and truncated-foot length (ICC = 0.97-0.99) measurements with the Brannock device.

History Forms

All runners completed a baseline history form that addressed the runner's age, gender, height, body mass, limb dominance, history of lower extremity injury or pain, running experience (number of years running), and orthotic or tape use. At the end of the season, all runners completed a follow-up questionnaire that addressed injuries during the season, whether the athlete had a radiograph or bone scan to diagnose a stress fracture, orthotic or tape use, and type(s) of footwear used while running.

Data Analysis

We calculated several injury rates for MTSS. Cumulative seasonal incidence was the number of runners who incurred a new MTSS injury during the 2004 season, divided by the total number of runners. The overall injury rate was the total number of MTSS injuries (initial and subsequent) per 1000 athletic exposures (AEs). An AE was defined as each time a runner took part in a practice or meet without limitation of injury, thus being exposed to risk of injury.[33] Three time-loss classifications were used to assess injury severity: (1) mild, 1-4 days lost; (2) moderate, 5-14 days lost; and (3) major, 15 or more days lost.[33-35] Injury rate ratios and their 95% confidence intervals (CIs) were estimated to compare rates between girls and boys.

Descriptive statistics were calculated for runners' baseline characteristics. Navicular drop was normalized to full foot length and truncated foot length to account for foot size. Those in the group with less than or equal to a 10-mm navicular drop were considered the referent group.[29] Navicular height in subtalar neutral was also normalized to foot length (normalized navicular neutral height). In addition, because thresholds for navicular drop in runners have not been well established, receiver operating characteristic (ROC) curve analysis was used to identify the cutoff point for navicular drop, normalized navicular drop, and normalized navicular neutral height, using full and truncated foot length to normalize data (**FIGURE**). The point on the curve was identified by analyzing the sensitivity and specificity at multiple values for the navicular drop data and selecting the point that yielded the optimal sensitivity and specificity.[31] Navicular drop was also evaluated by the absolute difference between a runner's right and left navicular drop measurement, with a difference of less than or equal to 3 mm considered as the referent group.

From the questionnaire, BMI was calculated from body mass (kg) and height (m) as body mass/height^2. BMI was categorized using the following quartiles: Q1, low (<18.8); Q2, 18.8 to 20.1; Q3, 20.2 to 21.6; and Q4, high (>21.6). Q2 was used as the referent group. The questionnaire also addressed history of running experience and previous injury. Those who reported greater than or equal to 4 years of running experience or no history of previous running injury were considered the referent groups.

Crude odds ratios with a 95% confidence interval (CI) were calculated for MTSS for all runners and by gender, comparing the individuals in a high-risk group versus the individuals in a baseline or referent group for each of the potential risk factors. For multivariate analyses, the measure of association was the adjusted odds ratio, which was generated from a logistic regression analysis. In the multivariate regression model, we included those variables that were significant ($P \leqslant .05$) in the univariate analysis (BMI), and those which are known to potentially confound the risk relationship (gender, running experience, and orthotic use).

All analyses were completed using SPSS for Windows, Version 13.0 (SPSS Inc, Chicago, IL).

RESULTS

Baseline characteristics of the study sample are presented in **TABLE 1**. The runners' average (±SD) age, body mass, and height were 16.0 ± 1.0 years, 59.8 ± 9.3 kg, and 1.71 ± 0.10 m, respectively. All runners completed the preseason and end-of-season questionnaires. Girls reported a higher percentage of previous running injury (47.8%) than boys (33.9%).

During the 13-week cross-country season, 16 runners (15.2%) incurred 17 MTSS injuries. The MTSS injury rate in girls (4.3/1000 AEs) was not significantly different from the rate in boys (1.7/1000 AEs, P = .11) (**TABLE 2**). Most MTSS injuries were mild (2.5/1000 AEs), resulting in 1 to 4 days lost from participation.

The Figure shows the ROC curve for MTSS related to normalized right navicu-

TABLE 1 Baseline Characteristics of High School Cross-Country Runners During the 2004 Cross-Country Season

VARIABLES	TOTAL (n = 105) n (%)	GIRLS (n = 46) n (%)	BOYS (n = 59) n (%)
Body mass (kg)			
<54.0	26 (24.8)	22 (47.8)	4 (6.8)
54.0-59.0	32 (30.5)	17 (37.0)	15 (25.4)
59.1-65.5	21 (20.0)	5 (10.9)	16 (27.1)
>65.5	26 (24.8)	2 (4.3)	24 (40.7)
Height (m)			
<1.65	25 (23.8)	22 (47.8)	3 (5.1)
1.65-1.70	29 (27.6)	19 (41.3)	10 (16.9)
1.71-1.78	29 (27.6)	5 (10.9)	24 (40.7)
>1.78	22 (21.0)	0 (0.0)	22 (37.3)
BMI (kg/m^2)*			
<18.8	25 (23.8)	10 (21.7)	15 (25.4)
18.8-20.1	29 (27.6)	16 (34.8)	13 (22.0)
20.2-21.6	25 (23.8)	9 (19.6)	16 (27.1)
>21.6	26 (24.8)	11 (23.9)	15 (25.4)
Grade			
9th	12 (11.4)	4 (8.7)	8 (13.6)
10th	29 (27.6)	9 (19.6)	20 (33.9)
11th	35 (33.3)	22 (47.8)	13 (22.0)
12th	29 (27.6)	11 (23.9)	18 (30.5)
Running experience (y)			
0	3 (2.9)	2 (4.3)	1 (1.7)
1	10 (9.6)	3 (6.5)	7 (11.9)
2	19 (18.1)	12 (26.1)	7 (11.9)
3	19 (18.1)	9 (19.6)	10 (16.9)
≥4	54 (51.4)	20 (43.4)	34 (57.8)
Number of previous injuries			
0	63 (60.0)	24 (52.2)	39 (66.1)
1	25 (23.8)	15 (32.6)	10 (16.9)
2	11 (10.5)	7 (15.2)	4 (6.8)
≥3	6 (5.7)	0 (0.0)	6 (10.2)
Navicular drop (mm)†			
≤10	44 (41.9)	20 (43.5)	24 (40.7)
>10	61 (58.1)	26 (56.5)	35 (59.3)

** Body mass index, weight (kg)/height (m)^2.*
† Average of right and left navicular drop.

lar drop divided by truncated foot length. ROC curves for all other variables were fundamentally similar and the area under the curves varied from 0.480 to 0.590. None of the variables showed a significant relationship with MTSS.

Runners with a navicular drop of greater than 10 mm and a greater than 3 mm left-to-right difference in navicular drop had a similar risk of MTSS compared to runners with a navicular drop of less than or equal to 10 mm or a left-to-right difference of less than or equal to 3 mm, respectively ($P>.05$) (**TABLE 3**). The power of this analysis to detect a clinically meaningful 3-fold difference in these rates was 0.89 and 0.85, respectively. Runners in the Q3 BMI group (20.2-21.6 kg/m^2) were 5 times more likely to incur MTSS than runners in the Q2 referent group.

After adjusting for factors that were associated with risk of MTSS in the univariate analyses and gender (as it was nearly significantly associated with MTSS), the adjusted model for MTSS included gender (female) and higher BMI (**TABLE 4**). However, when we controlled for orthotic use, only BMI was associated with risk of MTSS in the final adjusted model.

The final model was examined for outliers and goodness of fit, using standardized residuals and other diagnostic methods. With all 105 subjects, the Nagelkerke R^2 was 0.126, and the Hosmer and Lemeshow χ^2 was 6.07 ($P = .53$). The Cook's distance for each subject was assessed and none were greater than 1.00 (the greatest was 0.173). However, 5 subjects had standardized residuals greater than 3.00, indicating they were possible outliers. The logistic regression was repeated with these 5 subjects excluded, and the model did improve slightly. With an n of 100, the Nagelkerke R^2 was 0.347 and the Hosmer and Lemeshow χ^2 was 4.95 ($P = .67$). In spite of the improvement in the model, no additional predictor variables were statistically significant; therefore, we chose to retain all 105 subjects in the analysis. Support for this position comes from the fact that with the full data set, all of the DFBetas for each predictor variable were less than 1.00, and a review of the data for these 5 subjects failed to reveal any unique characteristics.

DISCUSSION

The purpose of this study was to determine the incidence and identify risk factors for MTSS among high school cross-country runners. The percentage of runners who incurred a MTSS injury was 15.2%, for an overall injury rate of 2.8/1000 AEs. After adjusting for gender and orthotic use, runners with a higher BMI were at increased risk of MTSS.

TABLE 2 Injury Rates of Medial Tibial Stress Syndrome in High School Cross-Country Runners

	TOTAL (n = 105)		GIRLS (n = 46)		BOYS (n = 59)			
	n	RATE*	n	RATE*	n	RATE*	RATE RATIO†	95% CI‡
Overall	17	2.8	11	4.3	6	1.7	2.5	(0.9, 8.2)
Injury severity§								
Mild	15	2.5	10	3.9	5	1.4	2.7	(0.8, 7.6)
Moderate	2	0.3	1	0.4	1	0.3	1.4	(0.1, 107.0)
Major	0	0.0	0	0.0	0	0.0	NA	NA

** Overall injury rate: number of medial tibial stress syndrome injuries/1000 AEs; AE, athletic exposure: each time a runner took part in a practice or meet without limitation of injury, thus being exposed to risk of injury (total, 5986 athletic exposures; girls, 2533 athletic exposures; boys, 3453 athletic exposures).*
† Rate ratio, girls/boys.
‡ All 95% confidence intervals P>.05.
§ Injury severity: mild (1-4 days lost), moderate (5-14 days lost), major (≥15 days lost).

TABLE 3 Medial Tibial Stress Syndrome Injury Risk in High School Cross-Country Runners by Potential Risk Factors

		TOTAL (n = 105)		
CHARACTERISTIC	n AT RISK	% INJURED	OR	(95% CI)
Gender				
Male	59	10.2	1.0	
Female	46	21.7	2.5	(0.9, 7.4)
Navicular drop (mm)*				
≤10	38	15.8	1.0	
>10	67	14.9	0.9	(0.3, 2.8)
Left-to-right difference in navicular drop (mm)				
0-3	82	17.1	1.0	
>3	23	8.7	0.5	(0.1, 2.2)
BMI (kg/m²)†				
Q1 low	25	16.0	2.6	(0.4, 15.4)
Q2	29	6.9	1.0	
Q3	25	28.0	5.3	(1.0, 28.2)‡
Q4 high	26	11.5	1.8	(0.3, 11.5)
Grade				
9th	12	16.7	1.0	
10th	29	6.9	0.4	(0.0, 3.0)
11th	35	17.1	1.0	(0.2, 6.0)
12th	29	20.7	1.3	(0.2, 7.6)
Running experience (y)				
0-3	51	15.7	0.9	(0.3, 2.7)
4+	54	14.8	1.0	
Previous injury				
0	63	11.1	1.0	
1+	42	21.4	2.2	(0.7, 6.4)

** Navicular drop of at least 1 limb ≤10 or >10 mm.*
† Body mass index quartiles for all subjects: <18.8, 18.8-20.1, 20.2-21.6, >21.6.
‡ P<.05

To our knowledge, this is the first study to report rates of MTSS using a denominator that accounted for actual number of practice and competitive-event exposures in high school runners, which may affect the injury rate. We reported our overall rates of MTSS by adjusting for AEs for future comparisons to other running and athletic studies who might report MTSS rates also using the same denominator.[33,33] As Bennett et al[6] did not report rates of MTSS by AE, our findings cannot be directly compared with their study of 125 high school cross-country runners. However, for comparison purposes, our cumulative seasonal incidence estimates of MTSS for the overall sample (15.2%) and girls (21.7%) was similar to their cumulative incidence estimates of 12% and 19.1%, respectively.[6] The characteristics assessed in our study were not significantly different between girls and boys. While others have suggested women may be more likely to report their injury symptoms than men,[2] we did not observe this phenomenon in our study.

In our study, most MTSS injuries caused runners to miss 4 or less days from participation in practices or meets. We are unaware of any study that has reported time lost due to MTSS among high school runners. Our findings, however, are comparable to other high school cross-country studies that reported that most injuries are minor,[33,33] and also suggest that most MTSS injuries were reported and managed early in the inflammatory stage.

We found that runners with higher BMI were more likely to incur MTSS. We are unaware of any other study that has reported this association in a similar population. While this finding is consistent with other studies in military recruits,[13,15,19,20] BMI remains an equivocal risk factor for any type of lower extremity injury in other studies of high school, recreational, and recruit populations.[23,33,38] A limitation of our finding may be that we used runners' self-report of height and body mass, which may not be comparable to studies that used direct measurement.

Runners who reported a previous running injury were over 2 times more likely to incur an MTSS injury, but the association was not statistically significant (odds ratio [OR], 2.18; 95% CI: 0.7, 6.4), with similar reports among girls and boys. Other researchers have reported an association between prior injury and current injury.[23,33] As the small number of MTSS cases observed likely accounted for the nonstatistical finding, the trend suggests that prior injury may play a role in the occurrence of MTSS and warrants further investigation.

Also noteworthy, we found that runners who had a MTSS injury were 3 times as likely to report orthotic use (OR, 3.0; 95% CI: 0.9, 9.4), but the association was not statistically significant due to the small number of runners who incurred a MTSS injury. Further, we observed that runners who reported orthotic use were 4 times more likely to report a previous injury (OR, 4.0; 95% CI: 1.5, 11.0). Thus, runners who reported orthotic use may have been fitted with orthotics to address pain or injury that occurred previously. As girls were over 3 times more likely to report orthotic use than boys (OR, 3.3; 95% CI: 1.2, 8.9), this relationship may help explain gender becoming not statistically significant with MTSS in the final model that adjusted for orthotic use.

Average navicular drop has been reported to range from 3.0 to 9.5 mm in healthy subjects,[5,6,10,21,24,29,30,33,37] with the average navicular drop observed in runners with MTSS to be 6.8 to 8.9 mm.[6,10] The mean (±SD) values for navicular drop in our study (11.0 ± 3.6 mm for noninjured runners and 11.2 ± 4.5 mm for runners who developed MTSS) were generally higher than previously reported values. This discrepancy in findings may be due to differences in the specific measurement technique. The height of the navicular tubercle is commonly marked on an index card placed next to the foot, with the distance between the marks during neutral and relaxed stance reflective of the navicular drop. Depending on the thickness of the marker used to draw the line on the index card, this has the potential to underestimate the actual navicular drop distance. As we were unaware of any study that has determined if this method is more reflective of actual navicular drop than direct measure with a ruler, we conducted a reliability study of each method prior to undertaking this investigation. Our findings demonstrated that both techniques were reliable (index card, 0.84-0.88; ruler, 0.88-0.91).

Currently, there is no standard criterion for what defines an abnormal navicular drop. We employed a ROC curve analysis to identify a threshold value for navicular drop; however, no value was found that could accurately predict runners who would sustain a MTSS injury. Therefore, we used both a 7-mm[6] and 10-mm[29] criterion, with neither demonstrating a significant risk association between navicular drop and MTSS. Furthermore, navicular drop and navicular neutral height, each normalized to the truncated foot length, failed to significantly predict MTSS in the runners we studied.

Although Bennett et al[6] suggested navicular drop as a risk factor in their prediction model for onset of MTSS, our study did not confirm their results. While our study had a similar sample size and occurrence of MTSS injury, the difference may be due to study design. Bennett et al[6] measured injured runners' navicular drop after they had reported their MTSS symptoms then compared them to a randomly selected group of noninjured runners whose navicular drop measurements were assessed at the end of the season. We measured the navicular drop of our runners prior to the season and then followed them prospectively during the season, thus minimizing any measurement bias. The prospective design of our study minimized researcher bias and allowed collection of accurate exposure data for each individual runner.[33] Further, 3 methods were used to capture MTSS injury data, including collecting the DIR from coaches, injury reports from certified athletic trainers, and end-of-season questionnaires from athletes. Of the 16 new MTSS cases reported, 50% were initially noted on the DIR by the coach, 25% were reported by the certified athletic trainer, and 25% were noted only on the end-of-season questionnaire. Any injury listed on the end-of-season questionnaire that could not be confirmed with the coach or certified athletic trainer was not included in the analysis. Only injuries that met the definition of MTSS were included in injury rates and risk model analyses.

Several studies of biomechanical measures of pronation have reported similar results as our findings. Wen et al[35] as-

TABLE 4 Adjusted Odds Ratios for Potential Risk Factors for Medial Tibial Stress Syndrome (MTSS) in High School Runners

RISK FACTOR	CATEGORY	MTSS AOR (95% CI)*	MTSS AOR (95% CI)†
Gender	Male	1.0	1.0
	Female	3.2 (1.1, 10.0)§	2.9 (0.9, 9.6)
BMI‡	Quartile 1 (≤18.7)	3.1 (0.5, 19.5)	3.7 (0.6, 24.5)
	Quartile 2 (18.8-20.1)	1.0	1.0
	Quartile 3 (20.2-21.6)	7.0 (1.3, 40.0)§	7.3 (1.2, 43.5)§
	Quartile 4 (>21.7)	2.1 (0.3, 13.8)	2.5 (0.4, 17.8)
Orthotic use	No		1.0
	Yes		2.4 (0.7, 8.3)

** AOR, odds ratios adjusted for all significant variables in the table plus previous injury; CI, confidence interval.*
† AOR, odds ratios adjusted for all variables in the table plus previous injury and orthotic use; CI, confidence interval.
‡ BMI, body mass index: weight (kg)/height (m)^2.
§ $P<.05$

sessed the arch index (navicular height divided by truncated foot length) of over 300 runners compared with previous injury questionnaires and reported a low right arch index was related to previous shin injury within the past year. However, they concluded that lower extremity alignment was not a risk factor for running injury in their study.[35] Similarly, Hreljac et al[14] measured arch height of 40 club runners using calipers in a standing position, but found that this measure did not discriminate between injured and noninjured runners. They concluded that preseason screens would not successfully predict running injuries.[14] A recent study of 87 recreational runners were subjectively classified as having a pes cavus, neutral, or pes planus foot, and graded ankle pronation of neutral, mild, or moderate, and the results indicated no significant difference in arch position or ankle pronation in respect to injury incidence.[22]

Although navicular drop measurement intrarater reliability observed in our study was high, we did not evaluate interrater reliability. While some studies have shown navicular drop to have moderate to strong intrarater reliability as a measure of talonavicular joint motion, the interrater reliability reports are conflicting but generally lower.[6,12,24,26,29,37] This discrepancy may also partially explain the variability of results. To more reliably measure arch height, McPoil et al[25] suggests measuring the height of the dorsum of the foot, rather than the navicular tubercle.

Limitations of the study include that a relatively small sample of runners were followed for only 1 season; thus, it is possible that some risk factors were not found to be statistically significantly associated with MTSS. Another possible limitation of the study was the ability of the DIR to capture minor MTSS injuries. The DIR reporting system has been used by other researchers[33-35] to improve recording of injuries that did not limit participation past the initial day of injury. However, the recording of time lost to injury did not capture pain or injury that did not result in time loss from a practice or meet. Beachy et al[4] changed their injury classification slightly from the National Athletic Injury/Illness Reporting System.[32] Their lowest injury category of "minor" was defined as "no time lost."[4] The authors reported that 64.5% of all injuries were in the minor category. Yates and White[38] reported that 70% of subjects who developed MTSS did not seek medical intervention for their symptoms. Almeida et al[2] showed that 4.6% of male recruits and 1.3% of female recruits with MTSS did not report their symptoms during training. The findings from these studies suggest that athletes with shin pain may continue to practice with symptoms. We found through interview and an end-of-season questionnaire that 25% of the cross-country runners with MTSS did not limit themselves in practice or report their shin pain to the coach. Thus, with respect to MTSS, the DIR may not have been sensitive enough to identify runners meeting the study operational definition because their participation was not limited or prevented and they would not have sought assessment by the certified athletic trainer. Taunton et al[31] had runners complete a questionnaire 3 times throughout a 13-week running program to determine injury. Their system classified injury as grade 1 ("pain only after exercise"), grade 2 ("pain during exercise, but not restricting distance or speed"), grade 3 ("pain during exercise and restricting distance and speed"), and grade 4 ("pain preventing all running").[31] The authors reported that 35.5% of the reported injuries were grade 2.[31] With the DIR, only injuries equivalent to grades 3 and 4 in this system would have been captured. Future studies should investigate the use of questionnaires or interviews several times throughout the season to identify runners with shin pain. This might increase the reporting and identification of runners who meet criteria for MTSS. The DIR might also be modified to include a "no time lost" category to capture minor injuries, considered as a grade 1 and 2 injury in Taunton et al's[31] system. Finally, data collection might be improved if the DIR is collected on a weekly rather than monthly basis to capture injuries the coach or certified athletic trainer might neglect to record.

CONCLUSION

After logistic modeling, only gender (female) and increased BMI were found related to MTSS, but only BMI remained significant when controlled for orthotic use. This study did not find a relationship between navicular drop, normalized navicular drop, normalized navicular neutral height, or navicular drop right-to-left difference and MTSS. The results of this study indicate that navicular drop may not be an appropriate measure to identify runners who may develop MTSS. Finally, as others have shown girls to have higher rates of shin overuse injuries or stress fracture in high school, recreational, and recruit populations, further studies need to investigate other risk factors for MTSS. Future research should consider the measurement of arch height using the dorsum of the foot.[25] This measure should be taken preseason and athletes followed prospectively throughout the season to determine the measure's relationship to injury. ◉

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