[Physical Therapy]

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Medial Tibial Stress Syndrome in Active Individuals: A Systematic Review and Meta-analysis of Risk Factors

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Context: Medial tibial stress syndrome (MTSS) is a common condition in active individuals and presents as diffuse pain along the posteromedial border of the tibia.

Objective: To use cross-sectional, case-control, and cohort studies to identify significant MTSS risk factors.

Data Sources: Bibliographic databases (PubMed, Scopus, CINAHL, SPORTDiscus, EMBASE, EBM Reviews, PEDRo), grey literature, electronic search of full text of journals, manual review of reference lists, and automatically executed PubMed MTSS searches were utilized. All searches were conducted between 2011 and 2015.

Study Selection: Inclusion criteria were determined a priori and included original research with participants' pain diffuse, located in the posterior medial tibial region, and activity related.

Study Design: Systematic review with meta-analysis.

Level of evidence: Level 4.

Data Extraction: Titles and abstracts were reviewed to eliminate citations that did not meet the criteria for inclusion. Study characteristics identified a priori were extracted for data analysis. Statistical heterogeneity was examined using the I^2 index and Cochran Q test, and a random-effects model was used to calculate the meta-analysis when 2 or more studies examined a risk factor. Two authors independently assessed study quality.

Results: Eighty-three articles met the inclusion criteria, and 22 articles included risk factor data. Of the 27 risk factors that were in 2 or more studies, 5 risk factors showed a significant pooled effect and low statistical heterogeneity, including female sex (odds ratio [OR], 2.35; CI, 1.58-3.50), increased weight (standardized mean difference [SMD], 0.24; CI, 0.03-0.45), higher navicular drop (SMD, 0.44; CI, 0.21-0.67), previous running injury (OR, 2.18; CI, 1.00-4.72), and greater hip external rotation with the hip in flexion (SMD, 0.44; CI, 0.23-0.65). The remaining risk factors had a nonsignificant pooled effect or significant pooled effect with high statistical heterogeneity.

Conclusion: Female sex, increased weight, higher navicular drop, previous running injury, and greater hip external rotation with the hip in flexion are risk factors for the development of MTSS.

Keywords: medial tibial stress syndrome; risk factors; meta-analysis

Medial tibial stress syndrome (MTSS) is a common condition in active individuals, including athletes and military personnel.[3,5,26,32,37,43,44] MTSS presents as diffuse pain along the posteromedial border of the tibia associated with activity. Although symptoms of MTSS are located at the interface of the crural fascia and bone, there is evidence that MTSS is associated with specific bone changes.[10,11,20,21]

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Nomenclature for MTSS historically has included such terms as shin splints, medial tibial syndrome, tibial stress syndrome, and soleus syndrome.[7,25,33,38] In this systematic review, MTSS was defined as including 3 characteristics: (1) pain along the posteromedial border of the tibia, (2) diffuse pain, and (3) pain that is activity related.

Over the past 2 decades, there has been an increase in obesity prevalence in the United States, with a concomitant increase in associated chronic disease conditions, including type II diabetes, heart disease, and stroke.[6,17,30] While the health benefits of physical activity in addressing these conditions are well known, physical activity may result in such overuse conditions as MTSS. The failure to successfully prevent MTSS is a reflection of our limited understanding of the risk factors. The purpose of this systematic review was to identify cross-sectional, case-control, and cohort studies that included MTSS risk data and to use a meta-analysis to identify significant risk factors across those studies.

METHODS

Data Sources and Search Strategy

Between October 2011 and May 2012, searches of electronic and print information sources were conducted to identify all potentially relevant articles. The data sources used in the search are available in the supplementary web materials (see Appendix 1, available at http://sph.sagepub.com/content/suppl). A PubMed search strategy was developed using 3 concepts: (1) the nomenclature used for MTSS, (2) anatomical location of MTSS, and (3) activity related to the development of MTSS, each with relevant medical subject headings (MeSH) and text words. The PubMed strategy was adapted for syntax and controlled vocabulary for the other electronic databases. No restrictions to publication year or language were applied to the searches. All citations were imported into a bibliographic management software program (EndNote; Thomson Reuters). The detailed search strategy for PubMed is located in the supplementary web materials (see Appendix 2, available at http://sph.sagepub.com/content/suppl).

Study Selection

Criteria for study inclusion were established a priori. To be included, studies had to be original research and participants' pain had to be diffuse, located in the posterior medial tibial region, and activity related. The selection of included studies began with title and abstract review, and irrelevant citations were eliminated. After the title and abstract review, duplicate citations were removed and the full-text articles for potentially relevant citations were obtained. A training set of full-text articles was selected and used by the authors to pilot test the determination of study inclusion/exclusion. After this pilot process and development of decision rules, the complete set of full-text articles selected for possible inclusion was divided into 2 subsets, and 2 pairs of authors reviewed their assigned subsets for inclusion/exclusion. Within each pair, articles were reviewed independently, and consensus was used to resolve disagreements. If the pair of authors could not reach consensus, the article was reviewed by all authors, with consensus used to determine possible eligibility. A final set of studies was selected that met the MTSS inclusion criteria (Figure 1).

Data Collection and Extraction

Prior to data extraction from the selected studies, a preliminary data collection form was developed and a training set of articles was selected. Pilot testing of the form and data extraction was similar to the previous pilot testing used for inclusion/exclusion. The set of studies selected for inclusion was again divided between the same pairs of authors for data extraction. The following key data, among others, were recorded for each individual study: study purpose, study design, setting, participant characteristics, activity associated with MTSS, definition of MTSS, diagnostic tests for MTSS, length of follow-up, risk factors, and risk factor results. When needed, selected study authors were contacted to obtain specific data.

Quality Analysis

Quality indicators were developed a priori from several sources.[8,12,14,22,28,40] For this systematic review, 2 quality indicators, not based on past literature, were added a priori. These 2 indicators included whether the reliability of risk factor(s) measures was reported and whether the risk factor(s) measures were direct or indirect. Quality items were scored as "met," "mixed" (met for some but not all risk factors), "not met," "unclear," and "not reported." Decision rules were used to clarify scoring of quality items. For example, the quality item "analysis" was deemed "met" when a multivariate technique was used to analyze the data. Before quality assessments of the final set of articles were reviewed, all authors discussed the items to further clarify and agree on scoring.

Two authors (R.R.R. and M.M.K.) independently reviewed the full text of the included studies for quality indicators. Consensus was used to resolve disagreements. When needed, consensus among all authors was used. Table 1 includes the quality indicators for all included studies.

Data Analysis

All included studies were reviewed for clinical heterogeneity by examining differences in measurement methods for risk factors. The risk factor data were extracted from each study, and the data were entered into meta-analysis software (Comprehensive Meta-Analysis, version 2.2.064; Biostat). Statistical heterogeneity was examined using the I^2 index and the Cochran Q test.[15] A random-effects model was used to calculate the meta-analysis. Because the included studies were not likely to have a common effect size, a random-effects model was chosen.[4] The random-effects model also is more conservative than the fixed-effects model.[4] Pooled summary results for risk factors were calculated when 2 or more studies reported on the risk factor.

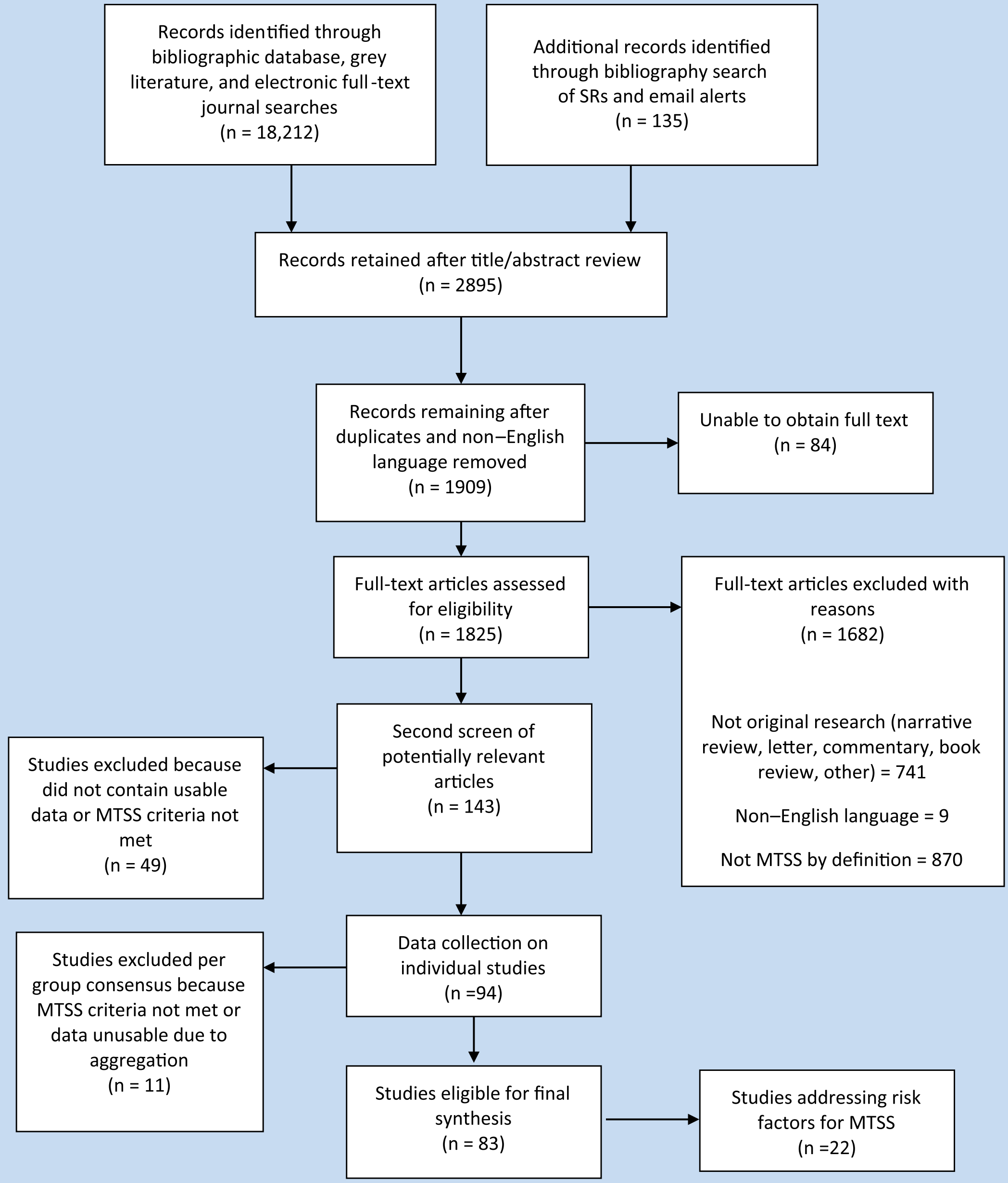

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of process. MTSS, medial tibial stress syndrome; SR, systematic review.

RESULTS

The initial search of the bibliographic databases, grey literature, and electronic full-text journal searches yielded 18,212 articles. An additional 135 articles were located through searching the reference lists of systematic reviews and automated PubMed searches of MTSS. Title and abstract review combined with removal of duplicates, and non–English language articles resulted in 1825 full-text articles assessed for eligibility. These articles were reviewed to assess whether they met inclusion criteria, provided usable risk factor data, and had comparable measurement methodology to allow for comparison. From the 1825 articles, 83 articles met inclusion criteria based on the definition of MTSS. These 83 articles were reviewed, and 22 articles with MTSS risk factor data were selected for this systematic review (Figure 1). From these 22 articles, 27 different risk factors were selected based on the availability of risk data from 2 or more studies and low clinical heterogeneity based on risk factor measurement techniques (Table 2). The supplementary web materials provide the study characteristics for all 22 selected studies (see Appendix 3, available at http://sph.sagepub.com/content/suppl). The risk factors selected for

Table 1. Study quality

Study	Quality Items[a]								
	Design	Homogeneous Participants	Follow-up Length[b]	Follow-up ≥80%	Reliability of Risk Factor(s)	Risk Factor(s) Direct[c]	Diagnosis of MTSS[d]	Adjustments[e]	Analysis[f]
Bennett et al[3]	P	green	green	orange	green	green	green	red	green
Burne et al[5]	P	green	green	green	yellow	green	green	green	red
Hubbard et al[16]	P	green	orange	red	yellow	yellow	grey	green	green
Magnusson et al[21]	P	red	green	red	red	green	green	red	red
Moen et al[26]	P	green	orange	orange	red	green	green	orange	green
Plisky et al[32]	P	green	green	green	yellow	yellow	green	red	green
Raissi et al[34]	P	green	green	green	yellow	yellow	green	red	red
Yagi et al[43]	P	green	green	orange	red	green	green	orange	green
Yates and White[44]	P	green	green	green	yellow	yellow	grey	red	red
Bandholm et al[1]	CS	orange	NA	NA	green	green	grey	red	green
Bartosik et al[2]	CS	green	NA	NA	yellow	yellow	green	red	green
Eickhoff et al[9]	CS	orange	NA	NA	red	red	red	red	green
Franklyn et al[10]	CS	orange	NA	NA	orange	orange	green	orange	green
Lee[18]	CS	orange	NA	NA	yellow	green	green	Multiple analyses	Multiple analyses
Madeley et al[19]	CS	green	NA	NA	red	orange	grey	red	green
Magnusson et al[20]	CS	red	NA	NA	red	green	green	red	green
Messier and Pittala[24]	CS	orange	NA	NA	red	yellow	green	red	green
Rathleff et al[36]	CS	green	NA	NA	red	yellow	green	orange	green
Tweed et al[41]	CS	orange	NA	NA	red	green	green	orange	green
Viitasalo and Kvist[42]	CS	orange	NA	NA	green	green	grey	red	green
Rathleff et al[35]	CC	green	NA	NA	red	green	green	orange	green
Sommer and Vallentyne[39]	CC	orange	NA	NA	red	red	grey	red	green

CC, case-control; CS, cross-sectional; MTSS, medial tibial stress syndrome; P, prospective.
[a]Color code: green, met; red, not met; yellow, mixed (met for some but not all risk factors); grey, not clear; orange, not reported.
[b]Athletes followed by season; recreational and military, 6 weeks.
[c]Risk factors were measured directly.
[d]Made by a health care provider.
[e]History of MTSS or orthotic use was controlled for in design or analysis.
[f]Statistical analysis appropriate for the design of the study.

Table 2. Risk factors by study

Study	Age	Dflex ROM With Knee ext	Dflex ROM With Knee flex	BMI	Dflex isom Strength	Eversion isom Strength	Eversion ROM With Running	Eversion ROM	Hip ext rot ROM With Hip flex	Female Sex	Height	Hx MTSS	Hip int rot ROM With Hip flex	Inversion ROM	Inversion isom Strength	Lean Calf Girth	Leg Length Difference	Navicular Drop	PFlex ROM	Previous Running Injury	Q Angle	Stand Foot Angle	Tibial Varum	Walking Speed	Weekly Mileage	Weight	Years Running
Bennett et al[3]										•								•									
Burne et al[5]	•			•					•	•	•		•			•	•									•	
Hubbard et al[16]			•		•	•		•				•		•	•			•					•		•		•
Magnusson et al[21]											•															•	
Moen et al[26]	•	•		•				•	•		•		•	•		•		•	•			•					
Plisky et al[32]				•						•								•		•							•
Raissi et al[34]										•								•		•	•						
Yagi et al[43]		•	•	•					•	•	•		•					•			•					•	
Yates and White[44]	•	•	•	•						•		•															
Bandholm et al[1]																		•									
Bartosik et al[2]	•	•	•	•													•							•			
Eickhoff et al[9]										•																	
Franklyn et al[10]	•										•															•	
Lee[18]	•	•		•	•	•	•			•	•				•		•		•		•				•	•	•
Madeley et al[19]	•			•							•																
Magnusson et al[20]											•															•	
Meisser and Pittala[24]							•										•				•						
Rathleff et al[36]				•							•													•		•	
Tweed et al[41]		•																									
Viitasalo et al[42]							•							•									•				
Rathleff et al[35]																		•						•			
Sommer and Vallentyne[39]	•																					•					

Dflex, dorsiflexion; ext, extended; ext rot, external rotation; flex, flexed; int rot, internal rotation; isom, isometric; MTSS, medial tibial stress syndrome; Pflex, plantarflexion; ROM, range of motion.

Table 3. MTSS risk factors grouping based on pooled effect and statistical heterogeneity

Significant Pooled Effect		Nonsignificant Pooled Effect	
Low Heterogeneity	Moderate-High Heterogeneity	Moderate-High Heterogeneity	Low Heterogeneity
Female sex Higher weight Higher navicular drop Previous running injury Greater hip ext rot with hip flexed	Higher BMI Greater eversion with running	Lean calf girth Hip int rot with hip flexed Leg length difference Q-angle Dflex ROM with knee extended Dflex ROM with knee flexed Inversion isom strength Pflex ROM Standing foot angle Years running History of MTSS	Age Height Eversion ROM Inversion ROM Dflex isom strength Eversion isom strength Tibial varum Walking speed Weekly mileage

BMI, body mass index; Dflex, dorsiflexion; ext rot, external rotation; int rot, internal rotation; isom, isometric; MTSS, medial tibial stress syndrome; Pflex, plantarflexion; ROM, range of motion.

analysis were organized into 7 categories: demographics/body composition, static posture, gait variables, training variables, injury history, joint mobility, and muscle strength. From the meta-analysis, risk factors were placed into 1 of 4 groups (Table 3) based on the presence or absence of a statistically significant pooled effect and the extent of statistical heterogeneity based on the I^2 index and Cochran Q value. To be considered low statistical heterogeneity, I^2 was less than 32.5% and/or the Cochran Q value was nonsignificant ($P > 0.05$).

Demographics/Body Composition

Two of the 6 risk variables in this category (sex and weight) had a significant pooled effect with low heterogeneity ($I^2 < 31\%$) across studies (8 studies included sex, 7 studies included weight). The meta-analysis revealed that female sex (Figure 2) and increased weight (Figure 3) were both risk factors for MTSS. Although greater body mass index (BMI) was a risk factor for MTSS based on the pooled effect, the 9 studies were moderately heterogeneous ($I^2 = 61\%$). While 8 of the 9 studies found greater mean BMI in the MTSS group, Lee[18] found BMI to be lower in the MTSS group. The other 3 risk factors in this category (age, height, and lean calf girth) were not significant risk factors for MTSS based on pooled analysis. Both age (8 studies) and height (9 studies) had low heterogeneity across studies; the lean calf girth variable was examined in 2 studies with high heterogeneity ($I^2 = 74\%$). Moen et al[26] found the MTSS group to have a greater lean calf girth, whereas Burne et al[5] reported smaller calf girth in the MTSS group.

Static Posture

The only postural variable that was a significant predictor of MTSS based on the meta-analysis was a greater navicular drop value (Figure 4). The 8 studies that examined navicular drop

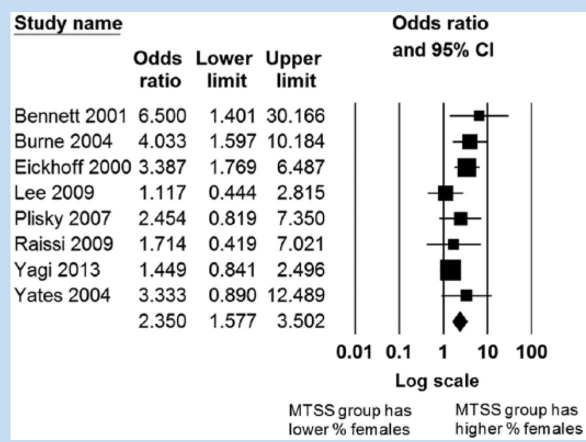

Figure 2. Forest plot for female sex as a risk factor for medial tibial stress syndrome (MTSS).

had low to moderate heterogeneity ($I^2 = 39\%$) with a nonsignificant Q value. Standing foot angle (SFA), Q angle, tibial varum, and limb-length discrepancy were nonsignificant as risk factors for MTSS based on pooled analyses. The 2 studies[16,42] that reported tibial varum data had low heterogeneity ($I^2 = 0\%$). Conversely, there was high heterogeneity across the studies that reported SFA ($I^2 = 74\%$), Q angle ($I^2 = 68\%$), and limb-length difference ($I^2 = 86\%$). Sommer and Vallentyne[39] reported that subjects (folk dancers) with an SFA < 140° were at greater risk for MTSS, but Moen et al[26] did not corroborate that finding. For Q angle, 2 studies reported a smaller Q angle as a risk for MTSS,[34,43] and 3 studies[18,24,43] reported the Q angle was greater in the MTSS group. Finally, the results of the 4 studies

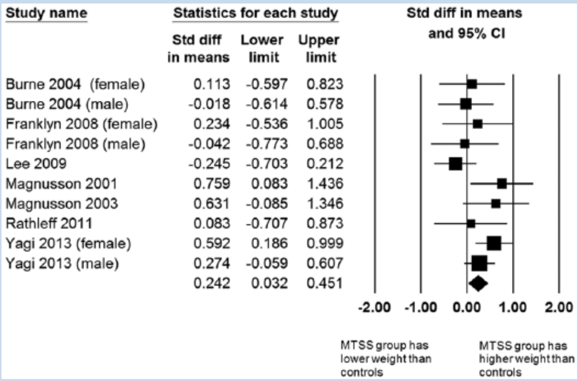

Figure 3. Forest plot for weight as a risk factor for medial tibial stress syndrome (MTSS).

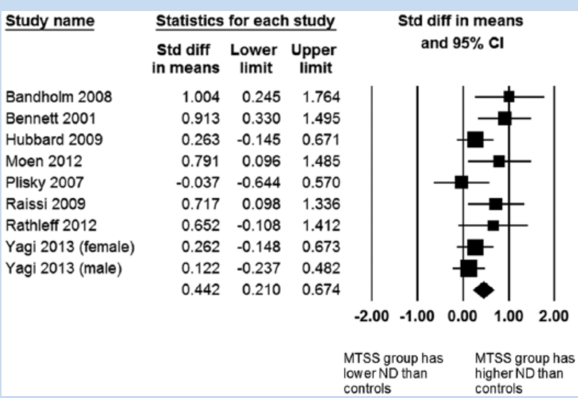

Figure 4. Forest plot for navicular drop (ND) as a risk factor for medial tibial stress syndrome (MTSS).

examining limb-length differences and MTSS had highly variable and nonsignificant results.

Gait Variables

Only 2 gait variables were assessed for MTSS risk in 2 or more studies. The pooled effect of rearfoot eversion during running revealed significantly greater eversion in the MTSS groups as compared with controls, but the 3 pooled studies were highly heterogeneous (I^2 = 92%). Self-selected walking speed was not a significant predictor variable for MTSS, with very low heterogeneity (I^2 = 0%).

Training Variables

Neither of the 2 training variables (years of running experience and weekly training mileage) were risk factors for MTSS based on the meta-analysis. The statistical heterogeneity for years running was high (I^2 = 87%), as Hubbard et al[16] reported that fewer years running was a risk factor for MTSS whereas Lee[18] reported that more years of running was a risk factor for MTSS. Plisky et al[32] did not find years running to be risk factor for MTSS in high school runners. Weekly mileage was not a risk factor based on pooled data from 2 studies,[16,18] and the studies had low heterogeneity (I^2 = 24.3%).

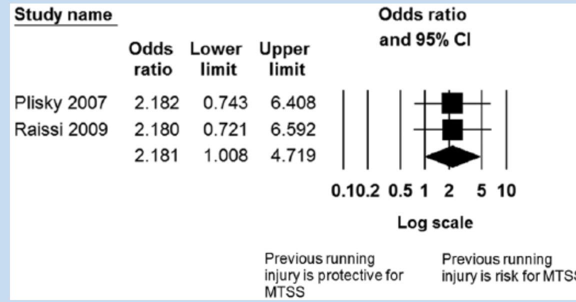

Figure 5. Forest plot for previous running injury as a risk factor for medial tibial stress syndrome (MTSS).

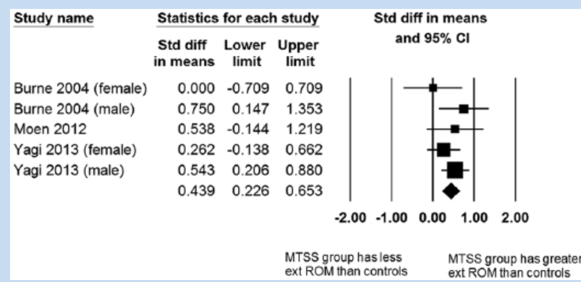

Figure 6. Forest plot for hip external range of motion (ROM) with hip flexed as a risk factor for medial tibial stress syndrome (MTSS).

Injury History

Pooled analysis revealed that a previous running injury was a risk factor for MTSS (Figure 5), with low heterogeneity (I^2 = 0%) across 2 studies.[32,34] History of MTSS did not have a significant pooled effect, and the 2 studies[16,44] providing these data had high heterogeneity (I^2 = 93%). Hubbard et al[16] reported a significant risk ratio of 5.3 (95% CI, 3.43-8.21), whereas the risk ratio reported by Yates and White[44] was 1.5 (95% CI, 0.78-3.0).

Joint Mobility

Greater hip external rotation range of motion (ROM) with the hip flexed had a significant pooled effect as a risk factor for MTSS (Figure 6) across 3 studies[5,26,43] with low heterogeneity (I^2 = 0%), whereas the pooled effect of hip internal rotation ROM was not significant with the same 3 studies showing high heterogeneity (I^2 = 85%) for this variable. Both eversion and inversion ROM were not risk factors for MTSS based on the meta-analysis (nonsignificant pooled effect), although both factors had low statistical heterogeneity (I^2 < 23%). Neither dorsiflexion ROM with the knee flexed nor with the knee extended were risk factors for MTSS based in the pooled effect, and both factors showed high statistical heterogeneity (I^2 > 83%).

Plantarflexion ROM with the knee extended also was not a significant risk factor for MTSS, and the 2 studies examining this factor[18,26] also showed high statistical heterogeneity.

Muscle Strength

None of the 3 isometric ankle strength factors (inversion, eversion, or dorsiflexion) were significant risk factors for MTSS. Two studies[16,18] investigated these 3 strength variables, and for both eversion and dorsiflexion isometric strength, the heterogeneity was very low (I^2 = 0%) while the pooled effect was nonsignificant. The inversion strength variable results were markedly different between the 2 studies with high heterogeneity (I^2 = 82%), as Hubbard et al[16] found no difference between groups with and without MTSS but Lee[18] found that weaker isometric inversion was a risk factor for MTSS.

DISCUSSION

The purpose of this systematic review was to identify cohort, case-control, and cross-sectional studies that included MTSS risk data and to use a meta-analysis to identify significant risk factors across those studies. A total of 22 studies were included in this systematic review and meta-analysis, representing a total of 235 potential risk factors. However, only 27 risk factors were identified that could be analyzed in the meta-analysis. Either there was unusable data or there was only a single study that examined a particular risk factor and, as such, there was no opportunity to pool results. We recognize that of those 208 risk factors not subject to meta-analysis, some may, in fact, be risk factors for MTSS but, at present, that conclusion is based on a single study.

Our level of confidence in the identification of significant or nonsignificant risk factors was based on the pooled effect and the statistical heterogeneity of the risk factor. Table 3 summarizes the 27 risk factors by a cross-tabulation of the pooled effect and heterogeneity. Five factors (female sex, higher weight, higher navicular drop, previous running injury, and greater hip external rotation with the hip in flexion) were found to have a significant pooled effect and low heterogeneity (see Figures 2-6). These are the factors in which we have high confidence for increased risk for the occurrence of MTSS. On the other end of the spectrum, 9 factors (age, height, eversion ROM, inversion ROM, dorsiflexion isometric strength, eversion isometric strength, tibial varum, walking speed, and weekly training mileage) did not show a significant pooled effect and had low statistical heterogeneity. These are factors that likely do not increase the risk for MTSS occurrence. The other 2 categories include 13 risk factors that display moderate to high heterogeneity in pooled analysis, limiting the confidence in the results of the meta-analysis regarding whether the factor actually is or is not a risk factor for MTSS (see Appendix 4, available at http://sph.sagepub.com/content/suppl).

Female sex increases the risk for MTSS, which is in agreement with the systematic review and meta-analysis by Newman et al[31] and the critical review by Moen et al.[27] The mechanism by which female sex causes this increased risk is not known at this time. Newman et al[31] proposed that this increased risk may be related to differences in running kinematics between men and women, but this has not been subject to investigation at present. In their study of MTSS among naval recruits, Yates and White[44] found that female recruits were at greater risk of MTSS and suggested this might have been related to women training with men and "overstriding" to match the men's cadence in marching.

Hamstra-Wright et al[13] and Newman et al[31] both found BMI to be a risk factor for MTSS. Hamstra-Wright et al[13] used 4 studies in their meta-analysis and we used those 4 plus an additional 6 studies that met our inclusion criteria. Newman et al[31] used 5 studies in their meta-analysis: 3 common to our analysis, 1 that did not meet our inclusion criteria, and the study by Hubbard et al,[16] which reported height and weight for the participants but did not directly report BMI values. We also found a significant pooled effect, but the heterogeneity was moderate (I^2 = 60.7%) so we did not include BMI as a high-confidence risk factor for MTSS. We did find, however, that increased weight was a risk factor for MTSS when pooling the results across 7 studies (see Figure 3). Our meta-analysis indicated that difference in height was not a risk factor for MTSS, so the findings of BMI as a risk factor reported by Hamstra-Wright et al[13] and by Newman et al[31] may be related to differences in weight between the MTSS and non-MTSS groups.

A greater navicular drop emerged from the meta-analysis as a risk factor for MTSS, which is consistent with the findings of both Hamstra-Wright et al[13] and Newman et al.[31] This measurement is employed by clinicians as a measure of foot pronation[29] and has been shown to have a relationship with rearfoot motion during walking.[23] Of the 8 studies included in the meta-analysis for navicular drop, 5 reported a significantly greater navicular drop in the MTSS groups[1,3,26,34,35] (MTSS group: range, 6.0-7.7 mm; noninjured athletes: range, 3.6-5.4 mm). In 2 of the other 3 studies,[16,43] the MTSS group had a greater navicular drop value than the non-MTSS group, but the difference was not significant. Plisky et al[32] found no difference in the percentage of athletes with MTSS who had a navicular drop >10 mm as compared with athletes without MTSS.

Previous injury history is commonly identified as a risk for a lower extremity overuse injury. Newman et al[31] reported that a history of MTSS was a risk factor for the repeat occurrence of MTSS, but this was not confirmed by Hamstra-Wright et al.[13] Our meta-analysis showed that history of MTSS had a nonsignificant pooled effect for relative risk and displayed high statistical heterogeneity (I^2 = 88%). Newman et al[31] based their conclusion on the meta-analysis of 6 studies, but only 2 of those 6 studies[16,44] met our inclusion criteria. We did, however, find that history of any previous running injury was a significant risk factor for the development of MTSS. The pooled odds ratio for any running injury as an MTSS risk was 2.181 with low heterogeneity (I^2 = 0%), although the lower limit of the 95% confidence interval is very close to an odds ratio of 1 (1.008).

Based on the meta-analysis, the final factor that increases risk for MTSS is greater hip external rotation with the hip flexed.

Our findings are consistent with both previously published meta-analyses on MTSS risk factors.[13,31] In 2 of the 3 studies used in our meta-analysis,[5,43] the authors analyzed and reported male and female hip ranges of motion separately. In both of those studies, we treated the male and female data as separate data sets, resulting in 5 data sets for the meta-analysis. Newman et al[31] reported that in both studies, the differences in male hip external ROM were significant and the female differences were not significant. However, in the study by Moen et al,[26] the male and female subjects were combined in the analysis, which did not reveal a significant difference between groups. We are in agreement with Hamstra-Wright et al[13] that the mechanism underlying the increased risk for MTSS as a result of increased hip external rotation ROM is not known at this time. The difference in this risk factor between men and women also remains unclear. We did not find that pooled effect for hip internal ROM was significant, and this factor also exhibited high statistical heterogeneity between studies (I^2 = 85%).

Limitations

One feature of this systematic review that differentiates it from other MTSS systematic reviews was our use of a strict definition of MTSS. As stated earlier, for a study to be included in this review, the definition of MTSS used in the study had to include 3 characteristics: (1) pain located along the posteromedial border of the tibia, (2) diffuse pain, and (3) pain that was activity related. This strict definition can be viewed as a limitation of our study as it restricted the number of studies included in our review. However, we believe that this strict definition increased our confidence that the diagnostic entity was consistent across studies and minimized the clinical heterogeneity with respect to the condition of interest.

A second limitation of this meta-analysis is that we used a random-effects model for all pooled effect calculations. We made this decision based on the variations across studies both in terms of participants and how the studies were conducted. As the random-effects model is more conservative than the fixed-effect model, this model is less likely to show significant pooled effects. Newman et al[31] made the decision to use random-effects modeling when the I^2 value was >25% and to used fixed-effects modeling if the I^2 was ≤25%. Hamstra-Wright et al[13] used random-effects modeling when the I^2 value was ≥20% and used fixed-effects modeling if the I^2 was <20%. In this meta-analysis, we found that the 5 factors (years running, history of MTSS, standing foot angle, plantarflexion ROM, and inversion strength) showed a significant pooled effect when we used a fixed-effects model, but the pooled effect was not significant when we used a random-effects model. In all of these cases, the I^2 value was >70%. Newman et al[31] found both years running and history of MTSS to be significant risk factors using random-effects modeling, whereas we did not find either to have a significant pooled effect. Hamstra-Wright et al[13] found plantarflexion to be a significant risk factor using a fixed-effects model based on the heterogeneity of the 4 studies (I^2 = 0%), whereas we did not find a significant pooled effect based on the results of the 2 studies that met our inclusion criteria with high heterogeneity (I^2 = 85%).

The 2 risk factors that were common to the 2 previously published meta-analyses on MTSS risk factors[13,31] and our study are increased navicular drop and increased hip external ROM with hip flexed. Both Newman et al[31] and our study also found female sex to be a significant risk factor; Hamstra-Wright et al[13] did not study sex as the authors only considered continuous variables. Therefore, these 3 risk factors were common to all 3 systematic reviews with meta-analysis.

CONCLUSION

This systematic review and meta-analysis revealed 5 risk factors that showed a significant pooled effect and low statistical heterogeneity: female sex, higher weight, higher navicular drop, previous running injury, and greater hip external rotation with the hip in flexion. Based on our strict definition of MTSS and requirement for risk factor measurement consistency, these factors also had low clinical heterogeneity, contributing to our confidence in these findings. The risk factors that did not show a significant pooled effect and had low statistical and clinical heterogeneity were age, height, eversion ROM, inversion ROM, dorsiflexion isometric strength, eversion isometric strength, tibial varum, walking speed, and weekly training mileage. Based on these results, we believe that these factors do not likely increase the risk for MTSS. Identification of risk factors is critical in the prevention of overuse injuries in active individuals, and the pooling of data across multiple studies increases our confidence in those risk factors that need to be considered in preventative strategies.

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