The Incidence and Risk Factors in the Development of Medial Tibial Stress Syndrome Among Naval Recruits

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Purpose: To identify the incidence of medial tibial stress syndrome (MTSS) in a group of naval recruits undergoing a 10-week basic training period and to determine potential risk factors.

Method: One hundred and twenty-four recruits (84 men and 40 women) were followed prospectively during basic training. Anthropometric and lower limb biomechanical data were recorded at the start of the program along with injury history and previous sporting activity for the 3 months prior to enlisting. Recruits were monitored during training for development of medial tibial stress syndrome and were asked to complete an exit interview at the end of the program.

Results: Forty recruits (22 men and 18 women) developed medial tibial stress syndrome, giving an incidence of 35%. A significant relationship existed between gender and medial tibial stress syndrome (P = .012), with female recruits more likely to develop medial tibial stress syndrome than male recruits (53% vs 28%). A risk estimate revealed a relative risk of 2.03. The biomechanical results indicated a more pronated foot type (P = .002) in the medial tibial stress syndrome group when compared to the control group. A risk estimate established that recruits with a more pronated foot type had a relative risk of 1.70.

Conclusion: Identifying a pronated foot type prior to training may help reduce the incidence of medial tibial stress syndrome by early intervention to control abnormal pronation. Findings of a higher incidence of medial tibial stress syndrome among female recruits require further investigation.

Keywords: shin splints; foot pronation; injury rates

Medial tibial stress syndrome (MTSS) is one of many overuse lower leg injuries found under the umbrella term of exercise-induced leg pain or shin splints. Stress fractures, chronic compartment syndrome, and MTSS are the 3 most common forms of exercise-induced leg pain, with MTSS having the highest prevalence. MTSS was first defined “as a symptom complex seen in athletes who complain of exercise induced pain along the posterior-medial border of the tibia.” It is a very common injury experienced by runners and military personnel. It accounts for between 13.2% and 17.3% of all running injuries and up to 22% of injuries seen in aerobic dancers. Among studies of military personnel, Almeida et al followed 176 male and 241 female naval recruits through an 11-week (men) and 12-week (women) training period, finding an overall incidence of 6.4% for MTSS. In the only prospective civilian study, an incidence of 13% was identified among 125 high school runners.

Although various studies have attempted to find the exact pathophysiology for this common condition, it still remains unresolved. Until recently, inflammation of the periosteum due to excessive traction was considered the most likely etiology of MTSS. Detmer opposed this theory, proposing periostalgia as the likely cause of MTSS after he found no evidence of inflammatory changes and consistently found adipose tissue interposed between the periosteum and the bone surface. Johnell et al first proposed the bone stress reaction theory after taking biopsies and finding osseous metabolic changes in 37 limbs with MTSS and no evidence of inflammatory changes. Recent studies have supported this view that MTSS is not an inflammatory process of the periosteum but instead a bone stress reaction that becomes painful. When a person begins an exercise program, the bone undergoes metabolic changes. These changes in the tibia are characterized by initial bone porosity due to osteoclastic chan-
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Peling on the compressed concave posteriomedial border. This is followed by the laying down of new bone to resist these compressive forces and strengthen the bone.\(^3\) The result is that the tibia becomes stronger than the pre-exercise state on the posteriomedial border. However, in cases of long-standing MTSS, it has been shown that the affected part of the tibia is 15% more porous than in control subjects and 23% less than in athletic control subjects.\(^4\)

A thorough clinical history and physical examination can accurately diagnose MTSS. MTSS commonly presents as diffuse, palpable pain, localized to the posteriomedial tibial border.\(^4\) It can occur anywhere along the posteriomedial border but most commonly affects the middle to distal thirds.\(^5\) The pain is usually described as a dull ache following exercise, which may last for several hours or days. In severe cases, pain may persist during normal activities of daily living.

Additional investigations such as plain radiographs, bone scans, and magnetic resonance imaging can be useful to clinically diagnose MTSS as well as rule out other forms of exercise-induced leg pain such as stress fracture. However, all 3 types of investigation have been associated with both false-positive and false-negative results.\(^6\) It has therefore been suggested that if the clinical picture indicates MTSS and there is no diagnostic dilemma, further investigations are unwarranted.\(^8\)

Various authors have proposed a wide variety of etiological factors for MTSS, including training on hard surfaces or uneven terrain, improper training techniques, increasing training intensity too quickly, changes in footwear, muscle imbalances or inflexibility, and biomechanical abnormalities.\(^29,31,35,40,50,55\) Although not linked directly to MTSS, a high body mass index (BMI) and a previous history of injury have been linked to the development of lower-limb overuse injuries.\(^25,26,34\)

Abnormal subtalar joint pronation has been associated with MTSS in a number of static and dynamic studies.\(^31,50,53\) These studies were all retrospective in nature, consisted of small sample groups, and often failed to correctly define the condition as MTSS, using instead the broader definition of shin splints. The only prospective study that determined foot pronation as a risk factor for MTSS is that of Bennett et al.,\(^11\) who followed high school cross-country runners through a training period. They measured the degree of foot pronation by recording the amount the navicular bone lowered between two standing positions, the neutral calcaneal stance position and the relaxed calcaneal stance position. This distance is termed the navicular drop, and the procedure measures the amount the medial longitudinal arch (MLA) lowers in the sagittal plane. However, Bennett et al performed this test only after the runner developed MTSS, so in truth it was a retrospective measurement and may have been an effect of developing MTSS rather than the cause of the condition.

The purpose of the present study was therefore to prospectively measure and monitor naval recruits during basic training to determine the incidence and potential anthropometric, foot posture, exercise history, and previ-ous lower-limb injury risk factors for the development of MTSS.

**METHOD**

The study was granted ethics approval from the Australian Defence Medical Ethics Committee and the La Trobe University Faculty of Health Sciences Human Ethics Committee. All subjects were recruited from HMAS Cerberus in Western Port, Victoria, Australia. All recruits at the commencement of training were offered the opportunity to voluntarily participate in the study. Subjects were assured that all information obtained would be confidential; they would remain anonymous, and a failure to participate would have no detrimental effect on their naval careers or the management of their MTSS if such a condition was detected.

Prospective data were collected at the start of basic training and consisted of the measuring of biomechanical parameters and the administering of a questionnaire. The exercises undertaken by the recruits during basic training took up an average of 16.2 hours per week; they involved a mixture of marching, doubling (running in step), circuit training, and cross-country running. During the training period, recruits were monitored for the development of MTSS. Following the completion of basic training, all recruits underwent a confidential exit interview to determine the incidence of lower limb injuries incurred during the training.

For the purpose of this study, MTSS was defined as “pain along the posteriomedial border of the tibia that occurs due to exercise excluding pain from ischaemic origin or signs of stress fracture.” The diagnosis of MTSS was based on the following criteria.

- **Pain History.** The pain was induced by exercise and lasted for a few hours or days after exercise. Pain was located on the posteriomedial border of the tibia. There was no history of paraesthesia or other symptoms indicative of other causes of exercise-induced leg pain.
- **Location.** The recruits identified pain along the posteriomedial border of the tibia. The site had to be spread over a minimum of 5 cm. Focal areas of only 2 to 3 cm are typical of stress fracture.\(^4\)
- **Palpation.** Palpation of the posteriomedial border of the tibia produced discomfort that was diffuse in nature and confined to the posteriomedial border of the tibia. In the areas of discomfort, the bone surface may feel uneven.

Those subjects who developed MTSS during the study were placed in the symptomatic MTSS group after meeting the following strict criteria:

- positive MTSS diagnosis,
- absence of symptoms indicative of other causes of exercise-induced leg pain, and
- absence of MTSS at the commencement of the study.
Any subjects with symptoms suggestive of other causes of exercise-induced leg pain were excluded from the study. Imaging investigations were not undertaken to confirm or exclude MTSS for the reasons previously stated. Any subject with a history of lower limb surgery or fracture likely to alter their normal lower limb alignment was excluded from the study.

Recruits were questioned about anthropometric data such as age, sex, height, and weight. A previous history of lower limb injuries, including exercise-induced leg pain, was recorded. A photograph dividing the anterior part of the lower leg into 5 distinct areas helped identify the site of any previous exercise-induced leg pain (Figure 1). For all previous or current injuries, the duration of pain, treatments implemented, and activity inciting the pain were recorded. All recruits were then questioned about their training schedule or sporting activities in the previous 3 months. The type of exercise, weekly frequency, duration, and type of exercising surface were recorded. Following the questionnaire, all subjects underwent a biomechanical assessment including measurements of ankle joint dorsiflexion and foot posture. The person undertaking these measurements was blinded to the results of the questionnaire.

The foot posture index (FPI) is an observational test that determines whether a foot is in a pronated, supinated, or neutral position based on 8 parameters. These parameters can also distinguish between frontal, sagittal, or transverse plane positional differences. The FPI has been shown to have good intratester and intertester reliability, ranging from 0.73 to 0.87 and 0.68 to 0.78, respectively. This reliability coefficient is much higher than most clinical foot biomechanical measurements.

The FPI is based on the observation of 7 visual parameters, and the 8th parameter is determined by palpating the position of the head of the talus. All measurements are recorded with the patients standing at their natural angle of base of gait. The participants were required to stand on a platform and were instructed to walk up and down on the spot. After 10 seconds, they were asked to stop, place their arms by their side, face forward, and distribute their weight evenly through both legs and feet.

Different observations are seen for both foot pronation and supination. The 8 parameters required to assess overall foot posture for each foot were the following:

1. Prominence in the region of the talonavicular joint. Bulging in this area is associated with a pronated foot. Indention is observed in the supinated foot.
2. Calcaneal frontal plane position. It is everted in the pronated foot and inverted in the supinated foot.
3. Helbing's sign. As the calcaneus everts in the pronated foot, the tendo achilles can "bow," with the inferior part directed to the lateral side. In a supinated foot, the tendo achilles can bow, with the inferior part directed to the medial side.
4. Supra- and infra-lateral malleolar curvature. In a pronated foot, the curve below the malleolus is more acute than the curve above. In a supinated foot, the curve above the malleolus is more acute than the curve below.
5. Congruence of the lateral border of the foot. In a pronated foot, the lateral border develops a concave profile as the forefoot abducts on the rear foot. In a supinated foot, the lateral border develops a convex profile as the forefoot adducts on the rear foot.
6. Talar head palpation. In a pronated foot, the head of the talus is more prominent on the medial side, and in a supinated foot, it is more prominent on the lateral side.
7. Congruence of the MLA. The MLA is lowered in a pronated foot, particularly the proximal part of the arch. In a supinated foot, the proximal part of the arch is high.
8. Abduction/adduction of the forefoot on the rear foot. In a pronated foot, the forefoot abducts, resulting in more of the toes being visible on the lateral side (the too-many-toes sign). In a supinated foot, the forefoot adducts relative to the rear foot, resulting in the toes being more visible on the medial side.

Figure 1. Location of symptoms of exercise-induced leg pain. 1, proximal posteromedial tibial border; 2, middle posteromedial tibial border; 3, distal posteromedial tibial border; 4, anterior compartment; 5, anterior tibial border.
Some of these parameters can be seen in Figure 2. The parameters for the FPI were measured for both feet. Each parameter is graded from -2 to +2, whereby +2 is assigned for marked positive signs of pronation, -1 for moderate signs of pronation, 0 for neutral, -1 for moderate signs of supination, and -2 for marked signs of supination. Therefore, the final score ranges between -16 and +16. A normal foot has an aggregate score of +1 to +5. A pronated foot posture ranges from +6 to +11, with a value of +12 to +16 indicating a highly pronated foot. A supinated foot posture ranges from 0 to -4, whereas a significantly negative aggregate of -5 to -16 indicates a highly supinated foot posture. The mean values for groups are categorized based on the whole number and are not rounded up or down.

A decrease in ankle joint dorsiflexion has also been associated with excessive subtalar joint pronation and has been identified as a risk factor for MTSS. Testing ankle joint dorsiflexion with the knee both fully extended and flexed at 90° determines any difference in flexibility between the gastrosoleus complex and the soleus muscle in isolation. Ankle joint dorsiflexion can be measured clinically using a universal goniometer. Most studies of the reliability of goniometric measurement for passive or active ankle joint dorsiflexion have demonstrated high intratester reliability (0.82-0.90) with comparatively low intertester reliability (0.20-0.50). Intradetler reliability for ankle joint dorsiflexion, subtalar joint measurement, and the FPI were completed during a pilot study and were 0.83, 0.70, and 0.91, respectively.

The nonweightbearing parameter involved the measurement of the degree of ankle joint dorsiflexion with the knee fully extended and then flexed at 90°. Ankle joint dorsiflexion was measured using a universal goniometer (Zimmer Ltd., United Kingdom) that had numerical divisions marked on the goniometer in 1° increments. To ensure greater accuracy, the subtalar joint was held in the neutral position, preventing abnormal dorsiflexion that occurs through subtalar and oblique midtarsal joint pronation. Subtalar joint neutral is found by moving the joint through its range of motion to a point where the joint is neither supinated nor pronated. This point is where the medial and lateral aspects of the talus are congruous on both sides.

At the completion of the 10-week basic training course, all recruits who participated in the study were required to undergo a brief anonymous and confidential exit interview. Recruits were questioned on the development of any lower limb injuries during the training period. For any injury, the site, duration, treatment, and activity that produced the discomfort were all recorded. For those with a history of exercise-induced shin pain, the criteria established for the diagnosis of MTSS were applied at this moment. The subject was questioned about the pain history and location of the pain using the photograph in Figure 1. If the pain was located along the posteromedial tibial border, the site was palpated to see if the pain could be reproduced. If all the components of the established criteria for MTSS were met, the subject was placed in the symptomatic MTSS group. All subjects not meeting these strict criteria were placed in the non-MTSS group.

Statistical analysis included t tests to determine any statistical significance between variables and between those who developed MTSS and those who did not. For any factor found to be significant, the clinical degree of significance was determined using relative risks and 95% confidence intervals using SPSS software (SPSS Science, Chicago, Ill). Relative risk is the ratio of the two risks, for example, the risk of developing MTSS with a previous history of the condition compared to risk of developing MTSS with no previous history.

RESULTS

One hundred and twenty-four naval recruits (84 men and 40 women) participated in the study. The mean age was 21.06 years with a range of 17 to 35 years (SD = 4.26). Prior to naval training, 116 (95%) recruits had undertaken some form of physical exercise. Eight recruits did not per-
form any weekly physical activity. The mean time spent exercising weekly for all recruits was 6.81 hours (SD = 6.06 hours).

During the training period, the recruits were required to complete 16.2 hours of intensive physical conditioning per week. Week 1 and 2 were composed of relatively light training compared to the following weeks. The physical training consisted of marching, doubling (running in step), circuit training, and cross-country running. Australian Defence force running shoes were worn for circuit training and running. In all other weightbearing activities, standard-issue heavy-duty military boots were worn.

At the completion of training, 112 of the initial 124 recruits remained in the study, thus representing a dropout rate of 10% within the study. Of the 12 recruits unavailable, 5 were discharged, 3 back classed, 2 hospitalized, and 2 unavailable due to other commitments. Of the 112 recruits followed prospectively through the training period, 78 (70%) were men and 34 (30%) were women.

Forty naval recruits (22 men and 18 women) developed MTSS during the training period, an incidence of 35%. Female recruits had a high incidence of MTSS, with 18 of them (52.9%) developing the condition compared to 22 male recruits (28.2%). Using a chi-square analysis, the relationship between group membership and gender was found to be $P = .012$, indicating a significant relationship between the development of MTSS and gender. A risk estimate for gender and the development of MTSS showed a relative risk of 2.03. Therefore, female recruits had twice the risk of developing MTSS than male recruits.

The mean age of the MTSS group was 20.95 years (SD = 3.92) with an age range of 17 to 33 years. The BMI of the MTSS group was 23.95 with a range of 18.12 to 30.35 (SD = 2.50). The control group had a mean BMI of 23.90 and a range of 17.91 to 32.37. There was no significant difference between the 2 groups ($P = .917$).

Prior to the training regime, 11 (28%) of the MTSS subjects did not perform any weightbearing training compared to 7 (10%) of control group subjects. If walking and nonweightbearing training (eg, swimming) are excluded, 17 (43%) of the MTSS and 10 (14%) of the control group did not undertake any exercise. However, as can be seen in Table 1, these differences were not statistically significant.

The location of symptoms in recruits who experienced exercise-induced shin pain can be seen in Figure 3. All recruits diagnosed with MTSS complained of pain along the distal, middle, or proximal posteromedial border of the tibia. The pain occurred mostly in the middle third of the posteromedial tibia, with 61% of all symptoms occurring in the middle third.

Twenty-eight recruits (70%) with MTSS did not seek medical assistance for their injury. Eight (67%) of those who sought medical assistance were restricted to lighter activities (ie, no running or marching). During training, recruits with MTSS missed or trained lightly on 64 days, compared to a total of 46 days for all other injuries. Forty of these forty-six days were seen in the non-MTSS group and six in the MTSS group.

Of the 26 recruits that had a history of MTSS prior to enlisting, 11 (42%) developed the condition during the training period. Therefore, 28% of the MTSS group had a previous history of MTSS. This produced a relative risk of 1.52, so recruits with a previous history of MTSS were statistically more likely to develop the condition than were their colleagues with no history.

By the beginning of the 4th week of training, 27 recruits (68%) of the MTSS group had developed the condition. All recruits diagnosed with MTSS were symptomatic at the end of the training program.

All recruits were questioned about the specific training exercises that caused the pain associated with MTSS. The results can be seen in Figure 4. Thirty-four of the forty recruits identified some form of training as the main cause of the symptoms, with running accounting for 63% of recruits’ symptoms.

MTSS was bilateral in 35 cases and unilateral in 5, resulting in 75 limbs being examined. The means and standard deviations for ankle joint dorsiflexion with the knee extended and flexed for both the MTSS and control groups can be viewed in Table 2. These results indicate that although the MTSS group had slightly less ankle joint dorsiflexion with both the knee extended and flexed, the results were not statistically or clinically significant ($P = .11$).

Table 3 reveals the means and standard deviations for the FPI of the MTSS and non-MTSS groups. There was a statistically significantly greater FPI total for the MTSS group compared to the non-MTSS group ($P = .002$). This indicates that MTSS subjects have a significantly more

<p>| TABLE 1 | Mean, Standard Deviations, and t Tests for the Total Weekly Hours of Exercise by the Medial Tibial Stress Syndrome (MTSS) and Non-MTSS Groups |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Non-MTSS Group (n = 72) | MTSS Group (n = 40) |</p>
<table>
<thead>
<tr>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weekly hours exercising</td>
<td>6.12</td>
<td>4.91</td>
<td>7.45</td>
<td>5.45</td>
</tr>
<tr>
<td>Total weekly weightbearing exercise hours</td>
<td>4.11</td>
<td>4.82</td>
<td>4.00</td>
<td>3.25</td>
</tr>
<tr>
<td>Total weekly weightbearing exercise hours excluding walking</td>
<td>3.68</td>
<td>5.53</td>
<td>2.41</td>
<td>7.12</td>
</tr>
</tbody>
</table>
pronated foot type. A risk estimate was performed, and a relative risk of 1.70 was identified. Recruits with a pronated foot type were almost twice as likely to develop MTSS than were those with a normal or supinated foot posture.

Figure 5 shows the FPI categories of the MTSS and non-MTSS groups. The MTSS group occupied a higher relative percentage of the pronated FPI category. Of the MTSS subjects, 22.5% (9 of 40) were placed in the normal (+1 to +5) category, compared to 51.4% (37 of 72) of non-MTSS subjects. Twenty-nine MTSS subjects (72.5%) occupied the pronated category, compared to thirty-two (44.4%) of non-MTSS subjects. Only 2 subjects fell into the supinated category, both of which were non-MTSS subjects.

TABLE 2
Means and Standard Deviations for Ankle Joint Dorsiflexion

<table>
<thead>
<tr>
<th>Group</th>
<th>Knee position</th>
<th>Mean (degrees)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTSS*</td>
<td>Extended</td>
<td>10.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Control</td>
<td>Extended</td>
<td>11.7</td>
<td>4.5</td>
</tr>
<tr>
<td>MTSS</td>
<td>Flexed</td>
<td>16.86</td>
<td>5.7</td>
</tr>
<tr>
<td>Control</td>
<td>Flexed</td>
<td>18.5</td>
<td>5.8</td>
</tr>
</tbody>
</table>

* MTSS, medial tibial stress syndrome.

The incidence of MTSS has varied among civilian and military populations. In 2 military studies, the incidence has varied from 4.0% to 6.4%. In contrast, the only civilian population study reported a much higher incidence of 13%. Compared to these reports, the present study reported a very high incidence of MTSS. A number of factors exist within the study that could explain this higher incidence rate. In the current study, both male and female recruits performed an average of 16.2 hours of physical activity weekly. In comparison, naval recruits in the Almeida et al study undertook 12.7 hours of physical activity weekly. This represented a 33% increase in weekly training for recruits participating in the current study. The weekly level of exercise in the Andrish et al study is unknown.

Recruits’ awareness of the condition could have also affected the reported incidence. Prior to the commencement of the study, all recruits were briefed and given information regarding the symptoms of MTSS. They were notified that reporting the condition to the researchers would remain confidential and not detrimental to their career. As a consequence, recruits were comfortable in coming forward with any type of shin pain to the researchers. It is known that military trainees often hide injuries from fellow recruits or officers. In the Almeida et al study, 35% of all injuries were unreported. This may be reflected in the current study as only 30.7% of recruits who developed MTSS sought medical treatment. This hiding of injuries highlights one of the problems associated with using military populations in injury epidemiological studies.

DISCUSSION

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It is also possible that the symptoms associated with MTSS were relatively mild in some recruits and therefore did not require medical treatment. Recruits with minor or vague symptoms were not included in the symptomatic group, and all recruits diagnosed with MTSS had complained of symptoms for a minimum of 7 days. It is difficult to gauge the severity of MTSS, particularly when motivation to continue exercising is high. Some studies have tried to grade the condition using bone scintigraphy,7,8,13,57 or MRI.6,20 However, the results have been mixed and are often conflicting.59 The use of a visual analog pain scale could have helped gauge severity, and this is being incorporated in a further study. Confirmation of the diagnosis by imaging techniques would have strengthened the study, and it is recognized that this is a potential limitation.

Two thirds of the MTSS group developed the condition by the 4th week of training. It is known that the bone-remodeling sequence at the start of an exercise program commences approximately 5 days after stimulation and that the bone is relatively weakened for the first 8 weeks.9,19 This is one of the main concepts of the bone stress reaction theory in the pathophysiology of MTSS and stress fractures. The early development of symptoms, most commonly in the middle third of the tibia, in relatively unconditioned recruits as seen in this study would tend to support the bone stress reaction theory as the cause of MTSS.

Until recently, few well-controlled studies reporting whether gender affected the development of MTSS have existed. Yates55 reviewed all MTSS studies, finding a cumulative number of men and women in previous studies that were almost equal (89 men and 80 women). In a large study reporting gender differences in musculoskeletal injury rates, Almeida et al7 followed 176 men and 241 women through boot camp army training. During this period, 12 men (6.9%) and 14 women (5.9%) developed MTSS. More recently, Bennett et al11 followed 125 high school long-distance runners through an 8-week training period. They found that women at an increased risk of developing MTSS, with 13 of 68 women (19%) and 2 of 57 men (3%) developing MTSS.

The increased risk to women was also seen in the present study, with a risk estimate for gender and MTSS demonstrating a relative risk of 2.03. Therefore, female recruits had twice the risk of developing MTSS than males in the study. Foot posture, BMI, previous injury history, or prior exercise levels cannot account for the differences in incidence rates between genders as they were comparable between the sexes.

Higher female injury rates among military populations have been well documented.27,30,44 It has been shown that injury rates are higher when women train alongside men and are expected to achieve the same exit fitness levels.1,12,27 This may be because women are generally smaller in stature. Anecdotal evidence in the current study may support this, as many female recruits reported that MTSS was precipitated when they had to "keep up" with male recruits while marching or doubling (jogging in step). This may have resulted in overstrenuous gait changes with abnormally long stride lengths, thus increasing the risk of developing MTSS. This theory is supported by Jones et al,25 who found that the shortest 25% of women had a greater risk of injury than the taller 75% (relative risk = 1.7, P = .02). Men and women trained separately in the Almeida et al study, which may have resulted in the non-significant result when comparing gender. Changes have now been made to the naval-training program with male and female recruits training separately. The incidence of MTSS and other lower limb injuries with the new training program is now the subject of a further study.

There has been some confusion in the literature as to the exact location of the pain associated with MTSS. Various authors have described MTSS pain as occurring in the proximal, middle, or distal thirds of the posteromedial tibial border or the anterior border. This study attempted to identify the location of pain associated with MTSS clinically, without the use of imaging techniques. This was achieved by dividing the tibia into the anterior muscle compartment, anterior tibial crest, and the posteromedial distal, middle, and proximal thirds of the tibia. The results from the current study supported those by Batt et al,8 who found that the distribution of posteromedial pain in MTSS subjects occurred most commonly in the middle third, followed by the distal third and far less frequently in the proximal third. Therefore, our results support the commonly held belief that MTSS can occur within all posteromedial tibial thirds but most frequently occurs along the posteromedial distal two thirds of the tibia.

Although variability existed, 91% of all symptoms of MTSS from the current study occurred to the posteromedial distal and middle tibial thirds. Beck and Osternig10 found that although large individual differences existed for inferior attachments of the soleus and flexor digitorum longus muscles, the mean inferior attachments were 48% and 35%, respectively, along the posteromedial tibia. Therefore, based on our clinical findings, the current study supports the view held by Batt et al8 that MTSS is more likely to be related to a bone stress injury rather than a primary traction periosteal injury because the soleus, tibialis posterior, and flexor digitorum longus muscles originate too far proximally to be linked to distal symptoms.

Milgrom et al33 found that maximum tibial bending occurred at the narrowest diaphyseal width, the weakest portion of the bone. The middle third of the tibia corresponds to the narrowest diaphyseal width, where the symptoms of MTSS most commonly occurred. These facts would support the bone stress reaction theory. It is known that bending forces play a significant role in the development of stress fractures.23 Several authors have hypothesized that MTSS and stress fractures are related along a continuum of bone micro-damage and reparative processes, whereby MTSS is a relatively mild expression and stress fracture is a severe extreme.8,13,27 Tibial stress fractures most commonly occur in the middle or distal thirds on the posteromedial border.

One of the main aims of the study was to determine if there were biomechanical differences between the 2
groups. The MTSS subjects scored higher on the FPI compared to the non-MTSS subjects. The mean score for the MTSS group placed them in the pronated category (+6 to +11), whereas the mean score for the non-MTSS group positioned them in the normal category (+1 to +5). The results were statistically significant (P = .002). The results of the asymptomatic group are comparable to the results of the largest study using the FPI, where the mean value was 4.9. The FPI results of the current study also appear clinically significant as the mean score between groups differed by 2 reference points. For a pronated foot type, the relative risk of developing MTSS was 1.70.

The results from the present study support previous retrospective studies that have identified a pronated foot type or excessive subtalar joint pronation as being a cause of MTSS. Limitations exist within this study because the FPI does not assess dynamic foot function and the pronated foot posture may not have been reproduced during walking, marching, or running gait. However, it has many advantages, including its reliability, its validity, the short time it takes to complete the test, and its not requiring of expensive gait analysis equipment.

Subtalar joint pronation is an integral component in absorbing ground reaction forces during gait. An excessive amount or change in timing or velocity of pronation has been proposed to require the smaller intrinsic foot muscles and larger extrinsic anti-pronatory muscles to fire for longer while contracting eccentrically. As a result, muscle fatigue occurs earlier, which subsequently increases the amount of force absorbed more proximally on the tenoperiosteum and bone. The cause of the increased pronated foot position seen in the MTSS group was not due to a lack of ankle joint dorsiflexion.

Excessive eccentric muscle contraction has been linked to the development of overuse injuries, including MTSS. Richie et al. studied the difference between eccentric and concentric muscle activity in 10 runners who ran on 3 different surfaces of varying hardness. He found that subjects who exercised on hard, noncompliant surfaces such as concrete produced the greatest eccentric medial shin muscle activity and muscle preactivation to improve intrinsic shock absorption, subsequently leading to fatigue. Naval training consists of high-impact exercises such as running and marching on hard, unyielding surfaces such as asphalt. Therefore, considerable levels of intrinsic shock absorption are required, accentuating eccentric muscle activity, and may contribute to the development of the condition. Therefore, it is likely that an increased amount of force is absorbed more proximally on the tenoperiosteum and bone and this may contribute in the pathogenesis of MTSS. High-risk groups such as women or those with a pronated foot type may require shoe inserts or orthoses to reduce intrinsic shock absorption, thus reducing the force absorbed by the tenoperiosteum and bone. Possible changes to the running shoe or navy boot to incorporate more shock-absorbing materials or anti-pronation structure could be beneficial. Also, training on softer surfaces such as grass will reduce the amount of intrinsic shock absorption required.

A pre-fitness-training program that incorporates the essential naval-training activities of walking, marching, and running should be designed that gradually increases in intensity. This program may better prepare recruits for the demands of physical training, thus decreasing the incidence of MTSS.

CONCLUSIONS

MTSS is a common injury among military recruits undergoing basic training and frequently results in lost training days. This research has highlighted both gender and a pronated foot type as 2 significant risk factors for MTSS. Controlling excessive foot pronation and enabling female and male recruits to train separately should be undertaken to attempt to reduce the incidence of MTSS among military recruits.

REFERENCES


