ORIGINAL ARTICLE

Risk factors associated with exertional medial tibial pain: a 12 month prospective clinical study

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Objective: To investigate in a military setting the potential role of intrinsic biomechanical and anthropometric risk factors for, and the incidence of, exertional medial tibial pain (EMTP).
Methods: A prospective clinical outcome study in a cohort of 122 men and 36 women at the Australian Defence Force Academy. Each cadet underwent measurements of seven intrinsic variables: hip range of motion, leg length discrepancy, lean calf girth, maximum ankle dorsiflexion range, foot type, rear foot alignment, and tibial alignment. Test–retest reliability was undertaken on each variable. A physician recorded any cadet presenting with diagnostic criteria of EMTP. Records were analysed at 12 months for EMTP presentation and for military fitness test results.
Results: 23 cadets (12 men, 11 women) met the criteria for EMTP after 12 months, with a cross gender (F/M) odds ratio of 3.1. In men, both internal and external range of hip motion was greater in those with EMTP: left internal (12°, $p = 0.000$), right internal (8°, $p = 0.014$), left external (8°, $p = 0.042$), right external (9°, $p = 0.026$). Lean calf girth was lower by 4.2% for the right leg ($p = 0.040$) but by only 2.9% for the left leg ($p = 0.141$). No intrinsic risk factor was associated with EMTP in women. EMTP was the major cause for non-completion of the run component of the ADFA fitness test in both men and women.
Conclusions: Greater internal and external hip range of motion and lower lean calf girth were associated with EMTP in male military cadets. Women had high rates of injury, although no intrinsic factor was identified. Reasons for this sex difference need to be identified.

The clinical presentation of exertional medial tibial pain (EMTP) is frequent in both civilian and military populations, with incidence rates reported between 4% and 19.5%.[1–4] This clinical presentation can include the diagnostic entities of medial tibial stress syndrome (MTSS), tibial stress fracture, chronic exertional compartment syndrome, and muscular and tendon injuries.[5 6] With mixed sex military training, women suffer disproportionately higher rates of exertional tibial pain[7] and overuse injury generally.[8] Such pain can be resistant to treatment,[5 9] and therefore compromises work in active occupations, as well as limiting sport and recreational exercise.

Clinically recognised intrinsic biomechanical risk factors for exertional medial tibial pain include abnormalities in foot mechanics,[1 10–13] calf tightness, leg length discrepancy,[14] and malalignment of the lower limbs.[6] Prospective studies have reported an association between overpronation and medial tibial pain.[10 13] However, most other biomechanical analyses have been cross sectional, and interpretation of these studies has been further hampered by inconsistent use of diagnostic terminology[1 15] and inclusion criteria. Although most clinicians and researchers now avoid the term ''shin splints'' and favour more specific nomenclature to reflect an anatomical basis for pathology,[6 15] there is still no gold standard that clearly distinguishes the various pathologies that can contribute to early cases of exertional tibial pain.[16] For example, even magnetic resonance imaging and triple phase bone scan has limited sensitivity and specificity for distinguishing shin pain arising from different structures.[16]

We therefore undertook this prospective clinical study to investigate individuals presenting with diffuse medial tibial pain related to exertion in a military setting. With the dearth of prospective risk factor studies, and the clinical importance of the condition, our primary aim was to investigate the potential role of intrinsic biomechanical and anthropometric risk factors for medial tibial pain. Our secondary objective was to describe incidence rates in male and female recruits.

METHODS

Subjects

This study was conducted at the Australian Defence Force Academy (ADFA). Before being accepted into ADFA, applicants must undergo a medical examination. Those applicants with a past or current history of tibial stress fracture, compartment syndrome, or significant medial tibial pain are denied entry. Of those who passed this examination and who were accepted into ADFA training, 164 (126 male, 38 female) of the167 first year cadet cohort (98%) agreed to participate in the study. As the pre-entry medical examination can precede the start of ADFA training (and baseline measurement in this study) by up to four months, we again asked participants about current symptoms of exercise induced lower leg pain, as a study exclusion criterion (no cases found).

The study was approved by the Australian Defence Medical ethics committee.

Measurement protocol

We measured height (by stadiometer, to 0.5 cm) and weight (by electronic scale, to 0.1 kg), and recorded use of orthotics (yes/no). Fitness level was estimated from each subject's timed 2.4 km run at baseline measurement. The timed run was repeated six months later to note any change in fitness characteristics. Subjects also underwent a series of static bilateral lower limb anthropometric measurements, conducted by two physicians (SB, ET), three physiotherapists (RM, PN, LS), and one podiatrist (PB). Each tester was responsible for one measure (except the podiatrist, who

Abbreviations: ADFA, Australian Defence Force Academy; EMTP, exertional medial tibial pain; MTSS, medial tibial stress syndrome recorded both foot variables), according to the following protocol.

Hip range of motion
The hip and knee were flexed at 90° in the supine position; each hip was rotated internally and externally to a firm end feel; range of motion, relative to the initial position, was measured in degrees.[17]

Leg length discrepancy
The absolute leg length was measured using a tape measure (nearest 0.5 cm), in the supine position, from the anterior superior iliac spine to the superior surface of the most prominent aspect of the medial malleolus.[14]

Lean calf girth
With the subject standing relaxed and upright, a measuring tape was manoeuvred to obtain the maximum perimeter (mm) of the relaxed calf. A skin calliper was applied at this point, 10 mm distally to the left thumb and index finger used to raise a vertical fold on the relaxed calf. A corrected calf girth was obtained by subtracting the appropriate skinfold thickness from the girth measurement.[18 19]

Ankle dorsiflexion
In the upright position the feet were held parallel, and the subject was then asked to extend the hip, keeping the knee straight and the heel on the ground. A goniometer was set at the mid-point of the lateral malleolus and the angle recorded.[20]

Foot type
The subject's foot type was assessed visually while bearing weight, and classified as cavus, planus, or neutral according to the method described by Dahle[21] and also used by Bennell, where correlation coefficients of reliability were acceptable.[18]

Rear foot alignment
With the subject prone, the calcaneus was palpated at the medial and lateral borders. A dot was placed on the perceived middle of the calcaneus superiorly and inferiorly. With the subject then standing, the podiatrist placed the subtalar joint into the neutral position. An inclinometer was placed with the straight edge parallel to the two dots, keeping the instrument in the frontal plane. The calcaneal position was determined in degrees of inversion and eversion.[22]

Tibial alignment
Each leg was measured using a single leg standing position. The examiner palpated the medial and lateral aspects of the distal third of the leg, then visually determined the posterior medial–lateral bisection and placed a strip of adhesive tape along the bisection of each leg. The tape was 10 cm long and 0.5 cm wide, and extended from a point just proximal to the malleolus. Tibial alignment relative to the flat surface of the floor was measured using a goniometer marked in degrees.[23]

Intratest reliability
Fourteen volunteer controls were tested on two occasions, one week apart. Intratester reliability was established with intraclass correlation coefficients (right/left): hip external rotation (0.75/0.89), hip internal rotation (0.82/0.80), leg length (0.97/0.97), calf girth (0.96/0.93), skinfold (0.89/0.92), ankle dorsiflexion (0.82/0.80), rear foot angle (0.80/0.81) and tibial angle (0.53/0.59); and κ coefficient (right/left) for foot type (0.74/0.86). An acceptable intraclass correlation coefficient, or κ coefficient, was determined as >0.6 at the outset of our study.

Cadet training
There were four male and one female divisions of 35 to 40 cadets. Military training included regular sessions of marching, parade drill, and weapons handling. In addition, cadet divisions undertook compulsory two hour, twice weekly sessions of supervised physical training (PT), aimed at improving and maintaining upper and lower body endurance, strength, and flexibility. All cadets were issued with standard military boots for marching and other military training, and standard non-branded proprietary Australian Defence Force cross training shoes for their PT classes. Supervised running was no greater than 4 km, and high impact loading was not emphasised. Cadets underwent baseline and six month fitness assessments, including a 2.4 km timed run within a set time period. To prepare for the components of this test, cadets undertook rigorous training outside their study hours. Cadets were all provided with a standard training guide (three to four hours of running training per week) to assist them meet the acceptable level for the 2.4 km test, as failure to meet the standard required repeat testing and potential discharge from ADFA.

Diagnostic criteria
All injured cadets unable to attend PT required a doctor's certificate excusing them from that session. This was obtained from a specific health facility from a single physician, blinded to the results of anthropometric measurements. Comprehensive clinical details were entered into the cadet's medical file. Twelve months after induction, a separate physician scrutinised all subject's clinical records and included those cadets who met the following criteria as having EMTP:

- An atraumatic history at least one week of medial tibial pain, exacerbated by running.
- The presence of at least 10 cm of diffuse palpation tenderness at the distal two thirds of the posteromedial tibial border.
- At least one training session lost because of the tibial pain.

The individual medical files provided data on side of symptoms, date of diagnosis (time from baseline measurement), details of subsequent tibial pain and other clinical presentations, results of further investigations, and physical restrictions placed on the cadet. We recorded the details of any injury that prevented ADFA fitness assessment participation.

Statistical analysis
Statistics were analysed using the Statistical Package for the Social Sciences (SPSS Inc, Chicago, Illinois, USA). Separated by sex, EMTP subjects were compared with non-EMTP subjects using univariate *t* tests (continuous variables) and χ^2 tests (categorical variable) at a two tailed significance level of $p<0.05$. For bilateral variables, means were compared against the respective side of injury.

RESULTS
Subjects
Throughout the 12 month period, six subjects (four male, two female) resigned (not included in analysis), none of whom had presented with tibial pain. The remaining 158 subjects consisted of 122 men and 36 women (table 1). There were significant differences between men and women for run times, height, weight, and lean calf girth.

Diagnosis
Twenty three subjects (12 male, 11 female) presented with EMTP over the 12 month period. Presentation rates did not

Table 1 Subject characteristics: mean (range) for men and women with and without exertional medial tibial pain

	EMTP men	Non-EMTP men	EMTP women	Non-EMTP women
N	12	110	11	25
Dx time (days)	46 (9 to 78)	–	118 (9 to 291)	–
Age (years)	18.7 (17.8 to 20.8)	18.4 (17.1 to 21.8)	18.0 (17.1 to 19.34)	18.2 (17.1 to 20.0)
Height (m)	1.79 (1.70 to 1.92)	1.79 (1.65 to 1.96)	1.67 (1.59 to 0.82)	1.68 (1.56 to 1.79)
Weight (kg)	74.4 (62.0 to 90.0)	74.5 (59.0 to 91.0)	61.0 (51.0 to 79.6)	60.2 (49.0 to 77.2)
BMI	23.0 (20.4 to 26.3)	21.3 (19.2 to 27.8)	21.8 (19.4 to 24.1)	21.4 (17.8 to 27.6)
Using orthotics at baseline (yes)	2	9	2	4
Baseline 2.4 km run time (s)	561 (512 to 608)	584 (495 to 646)	769 (727 to 840)	708 (579 to 843)
Run time 6 months after baseline (s)	570 (508 to 634)	576 (460 to 645)	733 (673 to 820)	701 (568 to 823)
Failed run test	5	1	4	5
LLD (cm)	0.0 (0.0 to 1.0)	0.3 (0.0 to 2.0)	0.0 (0.0 to 0.5)	0.34 (0.0 to 1.5)
(R) LCG (mm)*	344 (319 to 390)†	359 (316 to 429)	329 (305 to 385)	338 (291 to 380)
(L) LCG (mm)	347 (323 to 98)	357 (311 to 413)	335 (293 to 333)	337(298 to 378)
(R) ADF (°)	32 (25 to 45)	31 (18 to 52)	29 (20 to 38)	26 (18 to 42)
(L) ADF (°)	32 (25 to 42)	31 (18 to 48)	28 (20 to 35)	27 (20 to 40)
(R) RA (°)	inv 1 (inv 6 to ev 4)‡‡	inv 2 (inv 11 to ev 6)	inv 2 (inv 6 to ev 2)	inv 3 (inv 8 to ev 4)
(L) RA (°)	inv 3 (inv 10 to ev 2)	inv 2 (inv 10 to ev 8)	inv 1 (inv 6 to ev 4)	inv 1 (inv 8 to ev 2)
(R) IHR (°)*	48 (32 to 70)‡	40 (10 to 64)	41 (34 to 52)	40 (24 to 54)
(R) EHR (°)*	64 (42 to 90)§	55 (16 to 88)	61 (42 to 76)	61 (40 to 76)
(L) IHR (°)*	48 (28 to 72)¶	36 (10 to 60)	40 (24 to 56)	39 (26 to 54)
(L) EHR (°)*	59 (32 to 86)††	51 (18 to 90)	58 (32 to 70)	55 (32 to 84)

*Significant mean differences ($p<0.05$) existed between men with and without EMTP presentation:
†p = 0.040; ‡p = 0.014; §p = 0.026; ¶p = 0.000; ††p = 0.042.
‡‡Rear foot alignment: inverted (inv); everted (ev).
ADF, ankle dorsiflexion; Dx, diagnosis; EHR, external hip rotation; EMTP, exertional medial tibial pain; IHR, internal hip rotation; L, left; LCG, lean calf girth; LLD, leg length discrepancy; R, right; RA, rear foot alignment.

differ between male cadet divisions. Twenty one cases were bilateral. The remaining two cadets (one male, one female) had symptoms limited to the left leg only. The incidence of 30.6% in women and 9.8% in men represents a cross gender (F/M) odds ratio of 3.1. Three subjects (one male, two female) were diagnosed subsequently with four tibial stress fractures (two unilateral, one bilateral) following the initial diffuse pain, confirmed in all cases by radionuclide bone scan (27, 43, and 54 days after the initial EMTP diagnosis).

Inability to participate in ADFA fitness assessment run component

Failure to attempt or pass the fitness test run components because of tibial pain (following EMTP presentation) occurred in five of 12 (42%) and four of 11 (36%) male and female EMTP subjects, respectively. In addition, five of 25 female non-EMTP subjects (20%) were also unable to attempt the run, with all five suffering from other chronic lower limb overuse injuries.

Risk factors

Concerning EMTP presentation, in either sex there were no statistically significant differences for body mass index, leg length discrepancy, foot type, rear foot angle, ankle dorsiflexion range, use of orthotics at baseline, run times at baseline, or change in fitness levels from baseline. For men only, there were significant differences for the other variables: hip range of motion (internal and external) and lean calf girth.

Greater internal (IHR) and external (EHR) mean hip ranges of motion were observed (fig 1): left IHR, 12° ($p = 0.000$); right IHR, 8° ($p = 0.014$); left HER, 8° ($p = 0.042$); right HER, 9° ($p = 0.026$). In men with EMTP, mean lean calf girth was less (fig 2), a difference that was statistically significant for right sided injury only: 15 mm, right ($p = 0.040$); 10 mm, left ($p = 0.141$).

DISCUSSION

Clinically relevant inclusion criteria to capture the syndrome of EMTP

Before discussing the implications of our findings, we will explain the rationale for using the clinical syndrome of EMTP as the primary focus of the study. In clinical practice, patients most often present with early EMTP, particularly in settings where military personnel, or elite athletes, are closely monitored by medical staff. Early in the course of their condition it can be difficult to differentiate the various tissue pathologies that can contribute to their shin pain at that time.[2, 15] The clinical syndrome that we have labelled EMTP for this study is likely to include precursors to stress fractures, or frank stress fractures, as well as MTSS. Whereas most

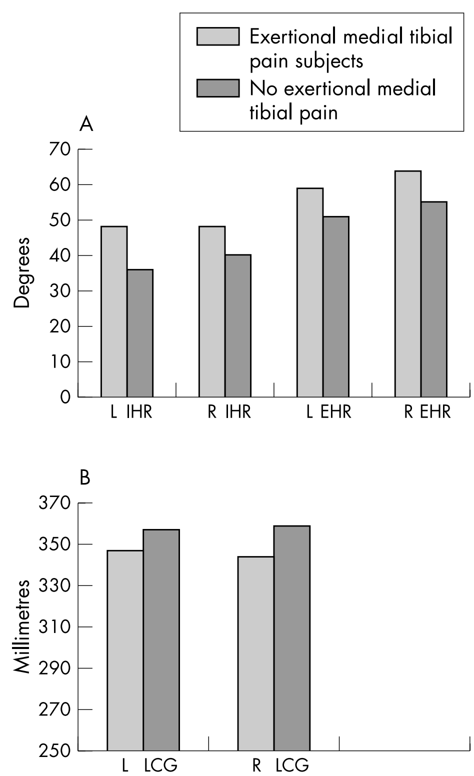

Figure 1 (A) Internal (IHR) and external (EHR) hip rotation in men (in degrees). (B) Lean calf girth (LCG; mm) in men. L, left; R, right.

established stress fractures show focal tenderness, and almost 100% are positive on triple phase bone scan,[24] early cases may present with more diffuse medial tibial pain[2 15] consistent with EMTP, as defined here.

We chose not to limit our study to what is commonly referred to as MTSS in clinical practice, as there are no agreed diagnostic criteria for MTSS, and no investigation can currently provide an established gold standard. The sensitivity and specificity for triple phase bone scan and magnetic resonance imaging in symptomatic "acute shin splints" are reported to be 84%, 33%, and 79%, 33% respectively[16]; furthermore, the majority of asymptomatic legs tested in that study showed abnormalities on both magnetic resonance imaging and triple phase bone scan. The use of these investigations as entry criteria for our study would have excluded an unacceptable number of symptomatic cases on the basis of a negative scan, and might have failed to discriminate for the presence of symptoms. Given the challenges of diagnostic specificity, we examined a clinical syndrome and attempted to be as inclusive as possible, while acknowledging the potential multiple pathology of the cohort. The important point is that our study population represents the group that presents to clinicians, seeks advice, and may require time off from work or sport. Thus we sought to identify risk factors that could be targeted to reduce the clinical burden of EMTP. This has particular relevance to the military setting, but is important also in the setting of recreational sport.

Risk factor analysis

In men, greater external and internal ranges of hip motion were associated with EMTP presentation. Internal range of motion has not previously been found to be associated with medial tibial pain presentations. External hip range of motion of more than 65° has been shown to predict tibial stress fracture in (male) Israeli Army trainees,[25] but has not been linked to other causes of EMTP. Our study was not designed to explain the mechanism that might underlie a specific risk factor causing tibial pain. However, it could be speculated that available hip ranges of motion may be associated with specific running style patterns, possibly affecting the degree of loading of the medial tibia on impact.

In men with EMTP, right lean calf girth was 4.2% lower than in non-EMTP men ($p = 0.044$). Also, left lean calf girth was 2.9% less, but this was not statistically significant in this small sample ($p = 0.141$). Seemingly small, the observed differences of 10 to 15 mm may be important, as Bennell *et al* showed that each 10 mm reduction represented a fourfold increased risk of tibial stress fracture (for women), related possibly to lowered regional bone density or reduced shock absorbing capacity.[18] Wakeling *et al* have reported that myoelectric activity in the leg is "tuned" in response to ground reaction forces,[26] and this damping effect may be important in injury prevention. The myoelectric activity and degree of lean muscle mass supporting the lower limb may ultimately determine its capacity to adapt positively to loading forces and withstand injury.

Female sex predicted exertional medial tibial pain (odds ratio 3.1) and an inability to complete ADFA training requirements. Overall, nine of 36 women (25%) could not attempt the run component of the fitness assessment owing to medical limitations, and EMTP was the major contributing factor for this group. In contrast, 95% of men passed the run test, despite five (of six) being prevented from attempting the run because of ongoing symptoms of EMTP. This difference raises concerns over the risk of exposure of women to such training environments. Recent military studies have suggested that women are particularly at risk when trained at standards equal to men.[7 8] Medical discharges for overuse injury in the British army rose from 4.6% to 11.1% when fitness levels for women were standardised with men (1.5%).[8] There are significant personal and organisational costs associated with such high rates of injury, suggesting the need to understand why women are at higher risk for EMTP. It has been speculated that the training environment may be better suited to men, thus placing women at additional risk.[7 8] Alternatively, the sex differences may be intrinsic, or a combination of both. Our study did not find an intrinsic variable that could predict EMTP in women. However, the small number of women reduced the power of our analysis, and further studies in larger groups of women are required.

Studies on foot mechanics have implicated overpronation as a risk factor for EMTP related presentations.[10–13] In our study, neither foot type nor rear foot alignment was associated with the clinical syndrome of EMTP. However, our static measures did not specifically measure pronation, a dynamic function. Our study was not designed to answer the question of whether or not orthotics reduces the risk of EMTP. This would require a prospective study with much larger numbers of orthotics users, or ideally an appropriately designed randomised controlled trial. Given the small number of participants who used orthotics in this study, and the distribution between subgroups (EMTP, non-EMTP), it is most unlikely that orthotic use confounded the results.

It has been proposed that calf tightness amplifies the possible role of overpronation by increasing traction on the soleus origin, commonly attributed to MTSS pathology.[6 27] Calf stretching is often advocated as a measure for prevention and treatment of medial shin pain, despite the lack of evidence of efficacy.[6] A prospective military shin splint study showed no preventative effect of stretching,[28] and calf tightness was not associated with injury in our study.

Variations in tibial angle have been reported as risk factors for "shin splints"[1] and MTSS.[6] We excluded this biomechanical variable from the outcome analysis, as test–retest reliability showed an intraclass correlations of less than 0.60 for the two legs.

Clinical implications

Thus the clinical syndrome of EMTP is common in a military setting, and women appear especially prone to injury in the current military training environment. Medical personnel and training organisations should consider carefully the particular risk factors in women that account for their relatively higher rates of medial tibial injury. We found few intrinsic factors that may predict EMTP, although men with increased range of hip motion or low lean calf girth may be at increased risk.

Strengths and limitations of the study

This is one of very few prospective studies of EMTP in athletic populations. The very high recruitment and retention rate is a study strength, as are the use of common, clinically relevant, easily performed measures that require little equipment, and the blinded protocol for EMTP diagnosis.[18] We publish test–retest reliability for all the anthropometric measures, but many studies to date have not reported this. The relative consistency of training protocols and footwear inherent in a military setting, as well as the completeness of military and medical records, add to the value of the study.

Factors that limit the conclusions we can draw include the fact that extrinsic factors, such as unrecorded additional training, may have influenced our results, but it is a challenging variable to measure this accurately with training diaries.[29] We noted, however, no significant differences in fitness level change between groups. Improved technology (for example, accurate pedometers with automatic data downloads and so on) will permit this limitation to be addressed more easily in future studies. The potential multiplicity of pathology related to our entry criteria reduces the external validity of our results to specific pathological conditions (for example, stress fractures). The small number of women compared with men may account for the lack of any intrinsic risk factor association in this group. Optimally, a power analysis of sex (not undertaken in our study) would assist planning in future studies. Furthermore, static measures such as foot type do not necessarily correlate with dynamic measures.[30] Future studies analysing intrinsic risk factors for EMTP in both women and men would include the use of dynamic measures of gait biomechanics (for example, with a kinematics multicamera biomechanical analysis system). Such studies would require substantial funding for equipment, data collection, and analysis. Finally, we also note that military studies do not immediately generalise to a civilian setting.

In summary, in male cadets greater internal and external ranges of hip motion and lower lean calf girth were associated with the clinical syndrome of EMTP. No intrinsic variable was associated with EMTP in women, although future studies with more power are required. For men and women in this military setting, the presentation of exertional medial tibial pain frequently preceded an inability to complete training standards owing to ongoing disability, thus placing their occupation at risk.

Conclusions

We found that some biomechanical factors were associated with male EMTP presentation in this military setting. However, the increased incidence of EMTP in women, without any identifiable risk factor, requires the attention of military training organisations. Further research is required to understand why these sex differences exist.

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