Prevention and treatment of exercise related leg pain in young soldiers; a review of the literature and current practice in the Dutch Armed Forces

Wes O Zimmermann,[1,2] P H Helmhout,[1] A Beutler[2]

[1]Department of Training Medicine and Training Physiology, Royal Dutch Army, Utrecht, The Netherlands
[2]University of the Uniformed Services of the Health Sciences (USUHS), Bethesda, Maryland, USA

Correspondence to
Lt Col Wes O Zimmermann, Department of Training Medicine and Training Physiology, Royal Dutch Army, Postal address: Stille Steeg West 34, Amersfoort 3823 ZJ, The Netherlands; wozimmermann@mindef.nl, wesselzimmermann@hotmail.com

Received 20 February 2016
Revised 26 May 2016
Accepted 29 May 2016
Published Online First 22 July 2016

To cite: Zimmermann WO, Helmhout PH, Beutler A. *J R Army Med Corps* 2017;**163**:94–103.

ABSTRACT

Overuse injuries of the leg are a common problem for young soldiers. This article reviews the literature concerning the prevention and treatment of exercise related leg pain in military settings and presents the latest developments in proposed mechanisms and treatments. Current practice and treatment protocols from the Dutch Armed Forces are reviewed, with an emphasis on the most prevalent conditions of medial tibial stress syndrome and chronic exertional compartment syndrome. The conclusion is that exercise related leg pain in the military is an occupational problem that deserves further study.

Key messages

- Overuse injuries of the legs are a common problem in occupations that involve repetitive lower limb activities, such as the military.
- The initial medical assessment before employment in the military provides the first opportunity to prevent exercise related leg pain (ERLP)
- The most common diagnoses of young Dutch soldiers with ERLP are medial tibial stress syndrome (MTSS), chronic exertional compartment syndrome (CECS) and a combination of MTSS and CECS.
- New elements in the conservative treatment of ERLP in a secondary care setting are extracorporeal shock wave treatment for MTSS and gait retraining for CECS.
- Despite a growing body of knowledge, overuse injuries of the legs continue to have a high incidence, long recovery time and large impact on military training.

INTRODUCTION

A high prevalence of overuse injuries of the leg is reported in the military, especially in recruits and infantry soldiers.[1–4] Young soldiers tend to develop complaints in the anterior leg, whereas older soldiers are more prone to develop overuse injuries in the posterior leg.[5]

There is a lack of longitudinal epidemiological data regarding leg injuries in the Dutch military, however, several cohort studies have shown that exercise related leg pain (ERLP) is one of the three most common overuse injuries that result in termination of a training course and that soldiers with ERLP remain longer in remedial platoons than those with other overuse injuries.[6 7] A recent study among British recruits reconfirmed that medial tibial stress syndrome (MTSS) has a high incidence and a long rehabilitation time, making it the overuse injury with the greatest impact on military training.[8]

MTSS and chronic exertional compartment syndrome

MTSS and chronic exertional compartment syndrome (CECS) are the two most common types of ERLP of young soldiers in the Dutch military.[7] In contrast to American and British military literature, stress fractures to the tibia are extremely rare in the Dutch armed forces and there is no clear explanation as to why.[9 10] It is assumed that American and British recruits do more running, in shorter training courses, whereas Dutch recruits do more marching and their training courses are, on average, longer. The highest reported incidence of MTSS in a military setting was 35% of 124 naval recruits participating in basic military training (BMT) in Australia;[4] CECS occurred in US Army soldiers at a rate of 0.49 cases per 1000 person-years (4100 cases diagnosed in 5 years).[11] The relative risk for young female soldiers to sustain an overuse injury is 2.5 in the Dutch military[6] and the relative risk for young female soldiers to sustain an overuse injury in the ERLP category has been reported between 1.11 and 3.1 (Table 1).

MTSS is an overuse injury involving the interface of the tibial bone and soft tissue.[31 32] The young soldier reports pain with running and jumping activities over the (posterior) medial tibial border; by definition an area of at least 5 cm or more is tender on palpation. In the early stages of overuse, the pain will disappear after warming up, allowing relatively pain-free participation in the main athletic event, however in later stages of overuse, any walking, running and/or jumping is severely limited by pain, which can last into the next day(s). The natural tendency to heal is favourable. Prolonged rest with targeted stretching and strengthening of leg musculature are associated with activity resumption in most cases.[1]

The definition of CECS is pathologically elevated pressure in a muscular compartment during exercise, which returns to normal with cessation of exercise. Some researchers claim that the increased intracompartmental pressure leads to disrupted local tissue perfusion,[33 34] but others doubt this.[35–37] Pressure in a muscular compartment can rise acutely (acute compartment syndrome, ACS) or repeatedly

Table 1 Risk factors for ERLP in a military setting

Factor	Unfavourable characteristic	Reference	Year	Country	Cohort	Gender of participants	Outcome statistics
Gender	Female	4	2004	Australia	Navy	84 M; 40 F	RR for MTSS 2.03
		11	2013	USA	All forces	4100	RR for CECS 1.11; 95% CI 1.05 to 1.14
		12	2013	NED	Premilitary	1478 M; 115 F	ERLP 9.3% of M; 16.5% of F
		13	2004	Australia	Cadets	122 M; 36 F	OR for medial tibial pain 3.1
		14	2012	Australia	Cadets	288 M; 96 F	OR for MTSS 2.97; 95% CI 1.66 to 5.31
		15	1993	USA	Army BMT	124 M; 186 F	OR for lower extr. 2.1; 95% CI 1.5 to 3.1
Current status	Tenderness to palpation medial tibial border	14	2012	Australia	Cadets	288 M; 96 F	OR for MTSS 4.63; 95% CI 2.5 to 8.5
	Oedema (very unfavourable)	14	2012	Australia	Cadets	288 M; 96 F	OR for MTSS 76.1; 95% CI 9.6 to 602.7
Foot shape	Increased navicular drop >0.5 cm	16	2010	NED	Recruits	35 M	Univariate regr 12.7; 95% CI 1.3 to 121.5
	Reduced navicular drop <0.422 cm	17	2015	Iran	Recruits	181	p=0.015
	Pronated foot (foot posture index≥+6)	4	2004	Australia	Navy	84 M; 40 F	RR for MTSS 1.70
	High foot arch (bony arch index >0.23)	18*	1999	USA	Navy	449 M	RR 1.71; 95% CI 0.74 to 3.95
	>0.27	19	1993	USA	Infantry	246 M	OR 6.12; 95% CI 2.17 to 17.30
	Low foot arch (bony arch index <0.20)	18*	1999	USA	Navy	449 M	RR 1.86; 95% CI 0.82 to 4.25
Hip function	Large exorotation >64°, only in men	13	2004	Australia	Cadets	122 M; 36 F	Right hip p=0.026; Left hip p=0.042
	>60°	20*	1991	Israel	Army	289 M	p<0.001
	Restricted exorotation <41°	17	2015	Iran	Recruits	181	p=0.000
	Large endorotation >48°, only in men	13	2004	Australia	Cadets	122 M; 36 F	Right hip p=0.014; Left hip p=0.000
	Restricted endorotation <40°	16	2010	NED	Recruits	35 M	Univariate regr 1.1; 95% CI 1.0 to 1.2
	<37°	17	2015	Iran	Recruits	181	p=0.004
Leg circumference	Lean calf girth <34 cm, only in men	13	2004	Australia	Cadets	122 M; 36 F	Right leg only, p=0.040
	Narrow tibial bone width <25 mm	20*	1991	Israel	Army	289 M	p<0.001
Ankle function	Dorsal flexion ≥21°	21	2010	USA	Marine Corps	748 F	OR for shin splints 3.4; 95% CI 1.4 to 8.4
	Plantar flexion >52°	16	2010	NED	Recruits	35 M	Univariate regr 0.8; 95% CI 0.7 to 1.0
Other biometrics	Iliospinal height >53 cm	17	2015	Iran	Recruits	181	p=0.017
	Lateral trochanter-tibia height >44.69 cm	17	2015	Iran	Recruits	181	p=0.022
Target job	Soldier (lower rank)	11	2013	USA	All forces	4100	RR for CECS 8.54; 95% CI 7.04 to 10.36
		22	2011	GB	Infantry	660 M	HR officers 0.26; 95% CI 0.14 to 0.49
Target force	Army	11	2013	USA	All forces	4100	RR for CECS 2,72; 95% CI 2.45 to 3.04
Walking technique	Overpronation (foot balance concept)	23	2011	GB	Infantry	468 M	OR for MTSS 9.16; 95% CI 4.32 to 19.42
	Foot pressure measurement barefoot, cavus	18*	1999	USA	Navy	449 M	RR for stress # 1.7; 95% CI 0.59 to 4.89
	Foot pressure measurement barefoot, planus	18*	1999	USA	Navy	449 M	RR for stress # 2.18; 95% CI 0.80 to 3.98
	Foot pressure measurement barefoot	24	2014	GB	Navy officers	200 M	OR for OLLI 5.28; 95% CI 2.88 to 9.70
	Foot pressure measurement shod, cavus	18*	1999	USA	Navy	449 M	RR for stress # 1.82; 95% CI 0.63 to 5.24
	Foot pressure measurement shod, planus	18*	1999	USA	Navy	449 M	RR for stress # 2.45; 95% CI 0.89 to 6.70
	Heavy heel strike	23	2011	GB	Infantry	468 M	OR for MTSS 9.16; 95% CI 4.32 to 19.42
Running technique	Overpronation	25	1993				No statistics
Blood	Low vitamin D intake (<118 IU, <70.0 nmol/L)	26*	2012	Israel	Combat recruits	74 M	Stress # group 59% of DRI (p<0.05)
	Low vitamin D in blood <75.8 nmol/L	27*	2006	Finland	Recruits	756 M	OR for stress # 3.6; 95% CI 1.2 to 11.1
History	Previous lower limb injury	23	2011	GB	Infantry	660 M	HR for all injuries 1.49; 95% CI 1.19 to 1.87
	Menstrual dysfunction >1 year	28*	2006	USA	Marine Corps	2962 F	OR for all stress # 5.64; 95% CI 2.2 to 14.4
	Lower extremity stress fracture	29*	2006	USA	Marine Corps	824 F	OR for stress # 2.1; 95% CI 0.8 to 5.5

Continued

Table 1 Continued

Factor	Unfavourable characteristic	Reference	Year	Country	Cohort	Gender of participants	Outcome statistics
Fitness	>650 s on a 2.4 km run	23	2011	GB	Infantry	468 M	OR for MTSS 3.62; 95% CI 1.77 to 7.38
	Average or lower premilitary activity level	30*	1988	USA	Marine recruits	3025	RR 2.4; 95% CI 1.26 to 4.58
	Low self-rated fitness	29	2006	USA	Marine Corps	824 F	OR for OLLI 1.6; 95% CI 1.1 to 2.5
Smoking	Smoker	23	2011	GB	Infantry	468 M	OR for MTSS 6.54; 95% CI 3.09 to 13.82

*Risk factor specifically for stress fracture.
BMT, basic military training; CECS, chronic exertional compartment syndrome; ERLP, exercise related leg pain; extr, extremity injury; GB, Great Britain; MTSS, medial tibial stress syndrome; NED, Netherlands; OLLI, overuse lower limb injury; OR, odds ratio; regr, regression; RR, relative risk.

with exercise (CECS). ACS is usually caused by trauma and ACS caused by exercise is an extremely rare condition,[38 39] thought to develop in those who already had CECS.[40–42] ACS demands immediate surgical treatment (fasciotomy) to maintain viability of the structures in the muscular compartment.[39 42 43] CECS can present in any muscular compartment of the body, but is most prevalent in the anterior compartment of the leg and the symptoms of CECS depend on the structures located in the affected compartment, particularly nerves.[42 44]

The young soldier with CECS reports a cramping or burning sensation on the anterolateral side of the leg (anterior or lateral compartments) or deep in the calf (deep posterior compartment). The pain is most often related to running or marching, begins at a predictable point after exercise initiation and disappears quickly at cessation of activities, usually within 15 min, although in severe cases the pain can stay on longer. The natural tendency to heal is poor. Without adequate therapy, patients will remain unable to run or march for many years and are forced to permanently reduce their sporting activities.[42 45–47]

METHODS

This article reviews the literature concerning the prevention and treatment of ERLP in military settings and describes the current practice of ERLP care in the Dutch military. A comprehensive search was conducted that included MEDLINE (PubMed) for articles in English that were related to ERLP in the military, using the following (truncated) search terms in different combinations: MTSS, CECS, ERLP and military. The latest consultation of Pubmed was December 2015. The intention of this article is to assist healthcare professionals to better help military patients.

RESULTS

Prevention

Initial medical assessment and intrinsic risk factors

The initial medical assessment before employment in the military provides the first opportunity to prevent ERLP as the screening physician can look for intrinsic risk factors for ERLP (Table 1), although these risk factors are often based on small sample sizes with conflicting results. In a review and meta-analysis, it is suggested that reducing body mass index (BMI), navicular drop, ankle plantar flexion range of motion and hip external rotation range of motion may be a good starting point for preventing and treating MTSS.[1]

There are no prospective studies that determine which of the ERLP risk factors reported in Table 1 are most relevant in the Dutch military. Based on a consensus meeting of senior physicians the following five risk factors are deemed most important in the Dutch military setting: current status (injured at the time of medical examination), a history of ERLP, technique of running and marching, female gender and little prior weight-bearing physical training (defined as: several years of participation in a sport with leg loading such as soccer, track and field, basketball, etc).

If a recruit has several risk factors for the development of ERLP, particularly the five identified above, the physician performing the initial medical assessment can take the following preventative measures: (1) The recruit will be assigned a military job where running and marching is of less importance, (2) The recruit is temporarily denied access to the military to heal and to work on modifiable risk factors or (3) The recruit is denied access to the military permanently when the risk profile for ERLP is particularly unfavourable.

Following the initial medical assessment, the most important factor to prevent injury in military training is a carefully graded increase in physical loading as the literature clearly shows a relationship between weekly training volume (especially running and marching) and the number of injuries to the lower extremity.[48–53] The training load must be compatible with the physical abilities of the recruit.

Changing training programmes and extrinsic risk factors

It is known that incorporating extra rest,[54] incorporating extra stretching exercises[55–57] or assigning running shoes based on plantar shape[58–60] do not reduce the number of overuse leg injuries in military settings. In addition, daily supplementation of calcium or prophylactic treatment with bisphosphonate (risedronate) do not reduce the risk of bone stress injuries to the leg.[61 62] Conversely, there is evidence that calcium plus vitamin D supplementation does reduce the number of lower extremity stress fractures in female recruits with insufficient calcium intake.[63] In contrast to all the negative findings, one recent study showed that gait retraining during BMT, including biofeedback on risk factors and a battery of exercises to improve neuromuscular condition, can reduce the incidence of MTSS.[64]

The role of shoe inlays in the military setting to prevent injury has been controversial for many years. Cushioning insoles in boots can reduce maximal pressure to the heel and forefoot by 37% and 24%, respectively, and users report comfort when wearing them,[5–67] but there is limited evidence that the use of shock-absorbing insoles reduces the number of injuries.[66–70] Providing custom made biomechanical shoe orthoses shows promising results in some studies,[69 71] but three systematic reviews all conclude that more research is necessary to underpin an evidence based policy for providing customised shoe orthoses for asymptomatic military recruits.[68 72 73] To provide every soldier with such orthoses as a prevention strategy is too costly;[69] a possible compromise is providing prefabricated orthoses.[74]

The military instructor plays a key role in the prevention of overuse injuries. Experienced instructors who can prevent overexertion in their training groups have less dropout with injuries and better graduation percentages.[25 75]

Primary care: the medical unit on base

Diagnosis of ERLP

The most common diagnoses in young Dutch soldiers with ERLP are MTSS, CECS and a combination of the two; pain from fascial herniae, tibial stress fractures, peripheral nerve impingement (eg, the superficial peroneal nerve) and ACS caused by exercise are all much rarer.

The diagnosis of MTSS may be confirmed with history and physical examination alone. When in doubt, other diagnoses can be excluded by additional investigations (eg, stress fracture by advanced imaging).[31] The diagnosis of CECS is confirmed by an intramuscular compartment pressure (IMCP) measurement. Fascial hernia of the anterior and lateral compartments of the leg are often found as a comorbidity of CECS,[5 42 76] but the pathophysiology of CECS and the relationship of CECS to symptomatic and asymptomatic fascial hernia are not fully understood.[2]

MTSS and CECS are two different diseases. However, based on history and physical examination the distinction may be difficult to make, particularly between MTSS and CECS of the deep posterior compartment.[77–79] In addition, many soldiers have complaints compatible with both MTSS and CECS and the clinical presentation may change over time: often initial complaints fit the diagnosis of MTSS, but over time CECS may develop.[10]

To diagnose ERLP correctly, it is necessary to provoke the complaints with an exercise test and repeat the physical examination immediately after exercise.[76 80–84] In the Dutch armed forces the '*Running Leg Pain Profile*' (RLPP) has been developed as a diagnostic tool for ERLP.[80] During a standardised treadmill test (increasing speed and incline) performed in running shoes, a patient is asked to give a pain score of 1–10 for four (or six) regions of their legs (anterior compartment and medial tibial border for both right and left legs and the calves are the two additional two regions) (Figure 1). The test contains running and marching and is designed to reproduce symptoms in the military patient group. CECS symptoms may be reproduced best by marching.[85 86] The RLPP assists in pinpointing an accurate diagnosis and also provides information on the severity of symptoms. In addition, during the test the investigator can judge running biomechanics.[80]

Figure 1 The Running Leg Pain Profile (RLPP): 1. lateral side right leg; 2. medial tibial border right leg; 3. medial tibial border left leg; 4. lateral side left leg (calves, region 5 and 6, optional).

Treatment of ERLP

Table 2 shows the current treatment guideline based on expert consensus for ERLP in the Dutch Armed Forces. It is not necessary to perform an IMCP measurement before starting conservative treatment for ERLP. The treatment must offer the components presented in Box 1.

In the Dutch military, the base physician is responsible for starting the treatment of ERLP and ensuring the timelines are adhered to (Table 2). The physician refers the patient to the physical therapist if the initial actions of the guideline are insufficient to reduce the symptoms and invites the patient to return for monthly visits to discuss treatment progress. The treatment programme on base that should lead to return to full duty is divided into two physical therapy phases, a sports phase and a military-specific phase. The transfer from one phase to the next is based on objective test results, such as a pain-free 12 min run is one of the requirements to enter the sports phase of rehabilitation.

Occupational prognosis for MTSS

The average treatment duration for MTSS, when placed in a remedial platoon in the Dutch military, is 4–5 months.[6 7] This is longer than the 3 months average treatment duration reported in Dutch civilian settings and longer than 82 days, as reported in a large 2015 study of British army recruits.[8 91 107] A possible explanation is that soldiers do not seek medical consultation until their injury has progressed to an advanced stage,[4] or that soldiers are not reported cured until they can return to duty, which requires a high level of fitness. In addition, the 4–5 months in the Dutch remedial platoon placement may include a waiting period. After healing the soldier must wait for an appropriate moment to rejoin a training group. The only factor that has been reported to predict duration of MTSS recovery time is BMI, with a higher BMI predicting a longer recovery time.[16] Wearing a leg brace does not reduce recovery time, the comfort of wear is poor and soldiers find the braces cosmetically displeasing with duty uniform.[108–110]

Referral to secondary care

The physician on base may refer the military patient to secondary care in a regional military hospital if treatment of the soldier with ERLP in accordance with the guideline (Table 2) stagnates. Based on consensus of senior physicians, it is recommended to do this after approximately 3 months of conservative treatment.

Secondary care: a military hospital

Diagnosis

Traditionally Dutch military personnel with overuse injuries of the legs and suspected CECS are sent to the out-patient clinic of the department of general surgery of the Central Military Hospital (CMH). Over the last 20 years, the number of new patients visiting the clinic for ERLP has been constant at 250 per year and until recently approximately 150 fasciotomies per year were performed. In the current protocol the soldier with ERLP meets with three physicians in one hospital visit: a surgeon, a primary care sports medicine physician and a physiatrist. The RLPP is recorded and an IMCP measurement is performed in all compartments where the patient has symptoms, in both legs, even if the patient has unilateral symptoms.

Table 2 Treatment guideline for ERLP in the Dutch Armed Forces[10]

Week	Treatment action	Professional	Treatment phase	Component	References
0	Significant reduction of running, marching, etc	Doctor	Visit 1	1	31
0	Examine ROM of ankle, knee, hip	Doctor	Visit 1	2	
0	Reduce BMI if too much	Doctor	Visit 1	3	
0	Stop creatine supplements	Doctor	Visit 1	3	87,88
0	Stop smoking	Doctor	Visit 1	3	23
0	Vitamin D in blood (goal >78 nmol/L)	Doctor	Visit 1	3	26,27
0–2	NSAID	Doctor	Visit 1	2	57
0–2	Ice	Doctor	Visit 1	2	57,89
2	Send patient to physical therapist on base	Doctor	Visit 2	1	
2	Place in on-base part-time rehab programme	Doctor	Visit 2	1	
2	Place in off-base full-time rehab programme	Doctor	Visit 2	1	6,7
3	Judge running shoes and boots	PT	PT phase 1	3	90
3	Examine/issue orthopaedic inlays	PT	PT phase 1	3	31
3	Judge walking biomechanics	PT	PT phase 1	3	
3	Judge running biomechanics	PT	PT phase 1	3	31,80
3	Compression sleeves (not for CECS)	PT	PT phase 1	4	5,91
3–8	Massage	PT	PT phase 1	2	92,93
3–8	Taping (kinesio)	PT	PT phase 1	2	94,95
3–8	Dry needling, (neural) prolotherapy	PT, doctor	PT phase 1	2	96
3–8	Improve range of motion (stretching)	PT	PT phase 1	3	
3–12	Improve relevant strength	PT	PT phase 1 and 2	3	97–99
3–12	Maintain/improve cardiovascular fitness	PT	PT phase 1 and 2	3	31
6–12	Gradual transfer from low impact to impact	PT	PT phase 1 and 2	4	12,100
6–12	Gait retraining marching (boots)	PT	PT phase 1 and 2	3	PJ Helmhout, *et al*. The effectiveness of a training programme aimed at modifying marching technique in military service members with CECS. A case series with six patients and a 9-month follow-up. In progress.
6–12	Gait retraining running (running shoes)	PT	PT phase 1 and 2	3	101–104
8–12	Extracorporeal shockwave therapy (ESWT)	Sports medicine	PT phase 1	2	105,106
12–20	Gradual increase marching km	Military instructor	Sports- and specific	4	
12–20	Gradual increase running km	Military instructor	Sports- and specific	4	31
12–20	Judge fitness for intended job	Doctor	Evaluation	5	7
8–20	Send to regional military hospital	Doctor	Stagnation	5	

BMI, body mass index; CECS, chronic exertional compartment syndrome; ERLP, exercise related leg pain; ESWT, extracorporeal shockwave therapy; NSAIDs, non-steroidal anti-inflammatory drugs; PT, physical therapist; ROM, range of movement.

Box 1 Components of the treatment of exercise related leg pain (ERLP) in a military setting

1. Significant reduction of symptom producing activities (running, marching, jumping, etc);
2. Treatment of local pain in soft tissues and reduction of limitations in joint range of motion of ankle, knee and hip;
3. Improvement of modifiable risk factors for ERLP in a military setting (Table 1);
4. Gradual return to leg loading activities;
5. Goal evaluation: is it realistic for this soldier to return to the intended military training and or job?

To confirm the diagnosis of CECS, an IMCP measurement is necessary. A recent survey of American military orthopaedic surgeons showed that 85% of the respondents believed that the diagnosis of CECS should be confirmed with IMCP testing before surgical treatment, but those who were in practice longer and respondents who saw more patients with suspected CECS per year were more likely to recommend surgical treatment based on clinical diagnosis alone.[111] In the Dutch CMH the Stryker measuring device is used to perform IMCP measurements in the 1st minute after exercise according to the RLPP protocol (Figure 2A).[112] The Dutch criteria for surgery have been established by Verleisdonk *et al*,[112] but only for the anterior compartment. Currently in most cases with ERLP, at least four compartments are tested (anterior and deep posterior of both legs) and sometimes more. It is necessary to establish criteria for all compartments separately, both in the resting state and post exercise.[113] For the time being in the Dutch CMH, the criterion for the anterior compartment (35 mm Hg 1 min post exercise) is used for all compartments. With the Stryker pressure monitor the deep posterior compartment can be reached through the anterior compartment. The advantage is that the skin is penetrated only once for measurement of both the anterior and the deep posterior compartments (Figure 2B,C);[77 114] there is however a risk of touching a neurovascular bundle,[115] but in the CMH, there are no reports of serious complications of the Stryker IMCP measurements. In a British paper, one case of bleeding of the arteria tibialis posterior is mentioned

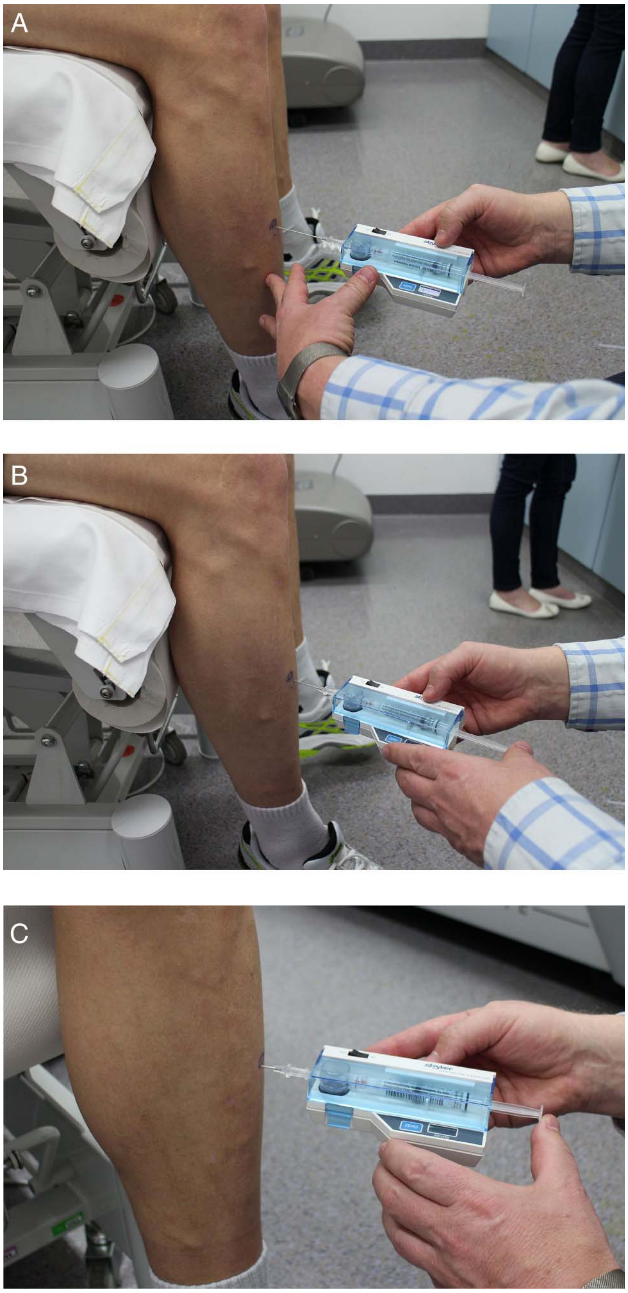

Figure 2 With the Stryker pressure monitor (A) the anterior compartment (B) and the deep posterior compartment (C) can be reached penetrating the skin only once.

after testing 76 patients.[113] Diagnostic utility of the IMCP measurement is improved when measured continuously during exercise[85] which requires insertion of a catheter and one Stryker pressure monitor for each muscle tested. Currently the IMCP is still the accepted standard for CECS diagnostics, if performed with local protocols and local reference values.[116–118]

There is an ongoing search for non-invasive diagnostic procedures. Near-infrared spectrometry[5] and ultrasound immediately after exercise[119] are promising methods which are relatively easy to perform, but not yet accepted as the new standard, because they only reach the anterior compartment. An exercise test inside an MRI machine may be technically possible, but it is not feasible for large numbers of patients per year.[120] The ankle-brachial index (ABI) in the 1st minute post exercise may help to differentiate patients with CECS from normal and ABI in combination with the RLPP may provide an acceptable diagnostic alternative in the military setting.[121]

Conservative treatment of ERLP

Most treatment actions reported in Table 2 have been in use in the Dutch military for many years and are considered '*standard therapy*'. New elements in the conservative treatment of MTSS in a secondary care setting are extracorporeal shockwave treatment (ESWT) and gait retraining. Two studies report that patients with MTSS who receive a standard treatment programme plus ESWT have better outcomes than those who receive the standard treatment only.[91 105] ESWT treatment on the tibia can be quite painful. In the Dutch military setting, ESWT treatment is available in the primary care sports medicine department only, using a protocol adopted from Rompe *et al*[105] (one session per week, 2000 radial shocks, 8 shocks per second, 2.5 bars of pressure, four or five sessions in total). Practical experience has shown that patients strongly prefer self-administration of ESWT on the tibia (Figure 3). Gait retraining to change running biomechanics can reduce the vertical forces of landing significantly[122] with the most important factors in reducing the impact forces of running being a change from a rear-foot to a mid-foot strike[103] and increasing cadence, usually through decreasing stride length.[123] There is no study that reports the results of gait retraining as a treatment for MTSS.

In contrast, gait retraining as a treatment for CECS has been described. Diebal *et al*[102] were the first to report that gait retraining for running was effective in reducing complaints and

Figure 3 Self-application of extracorporeal shockwave treatment, a soldier with medial tibial stress syndrome.

IMCP measurement in military personnel with CECS. Their study population was homogeneous young, fit, officers in training, with CECS of the anterior compartment only. Recently several studies have confirmed the positive effects of gait retraining on the symptoms of CECS of soldiers.[86 101 124] In addition, shoe type also plays an important role in the amount of force placed on the legs in running. So-called 'low drop/low heel height' shoes can reduce peak forces on the heel by 25%.[90] In earlier studies it was shown that shoes with a negative sole (a slope increase from heel to toe) reduced IMCPs in the anterior compartment during running on average by 20% and that changing shoe type alone may be sufficient therapy to reduce symptoms in patients with CECS.[125 126] Some authors are of the opinion that pain and increased IMCP caused by faulty running biomechanics requires a new diagnostic terminology of 'biomechanical overload syndrome'.[86]

Surgical treatment of ERLP

In the Dutch CMH, no surgical treatment is offered if the diagnosis is MTSS, because the results reported in the literature are poor:[127] patients report reduction of pain after surgery, but only 41% fully return to the presymptom level of sports participation.

Until a few years ago, fasciotomy of the affected compartments seemed the only useful treatment for CECS.[128–130] In the Dutch CMH, Verleisdonk *et al* reported that after minimally invasive fasciotomy of 151 compartments in 81 patients (149 anterior compartments and two lateral compartments) 76% of patients experienced significant reduction of pain 6 months after surgery. The average compartment pressure was reduced from 57 mm Hg preoperatively to 25 mm Hg postoperatively.[131] In 10 cases however, pressures were not reduced postoperatively, four patients (4.9%) had surgical revision and there were four documented complications (three neuromas and one seroma). Complications of fasciotomy reported in the literature include perioperative vascular damage, haematoma, neurological complaints, damage to the superficial peroneal nerve, deep venous thrombosis, delayed wound healing, postsurgical hernia, persistent ankle pain and cosmetically unacceptable scars.[33 132–135] The highest reported rate of complications is 15.7%.[132] The rate of complications in the Dutch CMH is unknown, but the surgeons indicate that the number of complications of surgery rises with the number of compartments opened during one surgical procedure. Long-term complications of fasciotomy are not well documented.

There is limited written information on the rehabilitation after elective fasciotomy of the leg.[136] In some cases it is possible to return to a physically demanding military job.[137] The duration of rehabilitation will be 3 months or more.[34]

Occupational prognosis of CECS after surgery

The prognosis for work in the military is unfavourable after fasciotomy. In a 2010 Dutch analysis of 44 soldiers who underwent fasciotomy of the anterior compartment of the legs in the CMH, 15 patients (34%) returned to their original military jobs, 28 patients left the military (64%) and 25 (57%) still reported symptoms 2 years after surgery (HW Nijhoving. The results of fasciotomy for soldiers. Unpublished paper, Department of Occupational Medicine, Royal Dutch Army, 2013. Dutch.). In an American analysis of 611 soldiers who underwent fasciotomy between 2003 and 2010, 44.7% of patients had symptom recurrence, 27.7% did not return to full duty and 17.3% were referred for medical discharge.[132] A limitation of this study was that it was a retrospective review of a database including 32 treatment centres which did not allow for evaluation of diagnostic criteria, surgical procedures and rehabilitation protocols at the respective centres.[138] Several recent studies confirm that the results of surgical treatment for CECS in the military are inferior to those in civilian athletes.[2 132 138–140]

Based on these insights, the Dutch CMH has changed its policy for surgery for CECS. Fasciotomy is performed only after at least 3 months of conservative treatment, as described in Table 2; preoperatively it is ensured that patients have received gait retraining and that creatine supplementation had been terminated.[87 88] The number of fasciotomies being performed in the Dutch CMH is declining.

CONCLUSIONS

The body of knowledge on ERLP in the military is growing and the number of publications is increasing. Despite these recent developments the occupational problem of ERLP in the military is far from resolved. These overuse injuries continue to have a high incidence, long recovery time and large impact on training. Proactive preventative and rehabilitative management targeting ERLP is necessary to achieve change. The challenge is to convey the current knowledge and the sense of urgency to all physicians and policy makers involved.

Contributors WOZ is the main author and guarantor of this review article. Important contributions in content, grammar and style have been made by PHH and AB.

Competing interests None declared.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Hamstra-Wright KL, Huxel Bliven KC, Bay C. Risk factors for medial tibial stress syndrome in physically active individuals such as runners and military personnel: a systematic review and meta-analysis. *Br J Sports Med* 2015;49:362–9.
2 Dunn JC, Waterman BR. Chronic exertional compartment syndrome of the leg in the military. *Clin Sports Med* 2014;33:693–705.
3 Knapik JJ, Darakjy S, Hauret KG, *et al*. Increasing the physical fitness of low-fit recruits before basic combat training: an evaluation of fitness, injuries and training outcomes. *Mil Med* 2006;171:45–54.
4 Yates B, White S. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *Am J Sports Med* 2004;32:772–80.
5 Zimmermann WO. Compression sleeves 2: the effect on running performance in 100 soldiers with exercise related leg pain. *Nederl Mil Geneesk T* 2013;66:11–17.
6 Zimmermann WO. Evaluation of the rehabilitation of soldiers in basic military training. *Nederl Mil Geneesk T* 2005;58:47–56.
7 Zimmermann WO. The remedial platoon of basic infantry training. *Nederl Mil Geneesk T* 2008;61:21–4.
8 Sharma J, Greeves JP, Byers M, *et al*. Musculoskeletal injuries in British army recruits: a prospective study of diagnosis-specific incidence and rehabilitation times. *BMC Musculoskelet Disord* 2015;16:106.
9 Jacobs JM, Cameron KL, Bojescul JA. Lower extremity stress fractures in the military. *Clin Sports Med* 2014;33:591–613.
10 Zimmermann WO, Harts CC, Helmhout PH. The treatment of soldiers with MTSS and CECS. *Nederl Mil Geneesk T* 2014;67:72–82.
11 Waterman BR, Liu J, Newcomb R, *et al*. Risk factors for chronic exertional compartment syndrome in a physically active military population. *Am J Sports Med* 2013;41:2545–9.
12 Duindam DJL. Prevention of recurrent injuries in pre-military high school students. Masterpiece Sport, Hogeschool Eindhoven, 2013.
13 Burne SG, Khan KM, Boudville PB, *et al*. Risk factors associated with exertional medial tibial pain: a 12 month prospective clinical study. *Br J Sports Med* 2004;38:441–5.
14 Newman P, Adams R, Waddington G. Two simple clinical tests for predicting onset of MTSS medial tibial stress syndrome: shin palpation test and shin oedema test. *Br J Sports Med* 2012;46:861–4.
15 Jones BH, Bovee MW, Harris JM III, *et al*. Intrinsic risk factors for exercise-related injuries among male and female army trainees. *Am J Sports Med* 1993;21:705–10.
16 Moen MH, Bongers T, Bakker EW, *et al*. Risk factors and prognostic indicators for medial tibial stress syndrome. *Scand J Med Sci Sports* 2012;22:34–9.

17 Sobhani V, Shakibaee A, Khatibi Aghda A, *et al*. Studying the relationship between medial tibial stress syndrome and anatomic and anthropometric characteristics of military male personnel. *Asian J Sports Med* 2016;6:e23811.
18 Kaufman KR, Brodine SK, Shaffer RA, *et al*. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 1999;27:585–93.
19 Cowan DN, Jones BH, Robinson JR. Foot morphologic characteristics and risk of exercise-related injury. *Arch Fam Med* 1993;2:773–7.
20 Giladi M, Milgrom C, Simkin A, *et al*. Stress fractures. Identifiable risk factors. *Am J Sports Med* 1991;19:647–52.
21 Rauh MJ, Macera CA, Trone DW, *et al*. Selected static anatomic measures predict overuse injuries in female recruits. *Mil Med* 2010;175:329–35.
22 Wilkinson DM, Blacker SD, Richmond VL, *et al*. Injuries and injury risk factors among British army infantry soldiers during predeployment training. *Br J Sports Med* 2011;17:381–7.
23 Sharma J, Golby J, Greeves J, *et al*. Biomechanical and lifestyle risk factors for medial tibia stress syndrome in army recruits: a prospective study. *Gait Posture* 2011;33:361–5.
24 Franlyn-Miller A, Bilzon J, Wilson C, *et al*. Can RSScan footscan(®) D3D™ software predict injury in a military population following plantar pressure assessment? A prospective cohort study. *Foot* 2014;24:6–10.
25 Ross J. A review of lower limb overuse injuries during basic military training. *Mil Med* 1993;158:410–20.
26 Moran DS, Heled Y, Arbel Y, *et al*. Dietary intake and stress fractures among elite Male combat recruits. *J Int Soc Sports Nutr* 2012;9:6.
27 Ruohola JP, Laaksi I, Ylikomi T, *et al*. Association between serum 25(OH)D concentrations and bone stress fractures in Finnish young men. *J Bone Min Res* 2006;21:1483–8.
28 Shaffer RA, Rauh MJ, Brodine SK, *et al*. Predictors of stress fracture susceptibility in young female recruits. *Am J Sports Med* 2006;34:108–15.
29 Rauh MJ, Macera CA, Trone DW, *et al*. Epidemiology of stress fracture and lower extremity overuse injury in female recruits. *Med Sci Sports Exerc* 2006;38;1571–7.
30 Gardner LI, Dziados JE, Jones BH, *et al*. Prevention of lower extremity stress fractures: a controlled trial of a shock absorbent insole. *AJPH* 1988;78:1563–7.
31 Moen MH, Tol JL, Weir A, *et al*. Medial tibial stress syndrome: a critical review. *Sports Med* 2009;39:523–46.
32 Franklyn M, Oakes B. Aetiology and mechanisms of injury in medial tibial stress syndrome: current and future developments. *World J Orthop* 2015;6:577–89.
33 George CA, Hutchinson MR. Chronic exertional compartment syndrome. *Clin Sports Med* 2012;31:307–19.
34 Wilder RP, Magrum E. Exertional compartment syndrome. *Clin Sports Med* 2010;29:429–35.
35 Trease L, van Every B, Bennell K. A prospective blinded evaluation of exercise thallium-201 SPET in patients with suspected chronic exertional compartment syndrome of the leg. *Eur J Nucl Med* 2001;28:688–95.
36 Balduini FC, Shenton DW, O'Connor KH, *et al*. Chronic exertional compartment syndrome: correlation of compartment pressure and muscle ischaemia utilizing 31P-NMR spectroscopy. *Clin Sports Med* 1993;12:151–65.
37 Amendola A, Rorabeck CH, Vellett D. The use of magnetic resonance imaging in exertional compartment syndromes. *Am J Sports Med* 1990;18:29–34.
38 Gore R, Mallory R, Sullenberger L. Bilateral lower extremity compartment syndrome and anterior tibial stress fractures following an Army physical fitness test. *Medscape J Med* 2008;10:82.
39 McHale KM, Prahinski JR. Acute exertional compartment syndrome occurring after performance of the army physical fitness test. *Orthop Rev* 1994;23:749–53.
40 Martens MA, Backaert M, Vermaut G, *et al*. Chronic leg pain in athletes due to a recurrent compartment syndrome. *Am J Sports Med* 1984;12:148–51.
41 Reneman RS. The anterior and the lateral compartmental syndrome of the leg due to intensive use of muscles. *Clin Orthop Rel Res* 1975;113:69–80.
42 Reneman RS. The anterior and the lateral compartment syndrome of the leg. PhD Thesis, Utrecht, 1968.
43 Archbold HA, Wilson L, Barr RJ. Acute exertional compartment syndrome of the leg: consequences of a delay in diagnosis: a report of 2 cases. *Clin J Sport Med* 2004;14:98–100.
44 Paik RS, Pepples D, Hutchinson MR. Chronic exertional compartment syndrome. *BMJ* 2013;346:f33.
45 van den Brand JHG. Clinical aspects of lower leg compartment syndrome. PhD Thesis. Utrecht, 2004.
46 Fronek J, Mubarak SJ, Hargens AR, *et al*. Management of chronic exertional anterior compartment syndrome of the lower extremity. *Clin Orthop Rel Res* 1987;(220):217–27.
47 Van der Wal WA, Heesterbeek PJ, Van den, *et al*. The natural course of chronic exertional compartment syndrome of the lower leg. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2136–41.
48 Knapik JJ, Hauret KG, Canada S, *et al*. Association between ambulatory physical activity and injuries during United States Army basic combat training. *J Phys Act Health* 2011;8:496–502.
49 Finestone A, Milgrom C. How stress fracture incidence was lowered in the Israeli army: a 25 year struggle. *Med Sci Sports Exerc* 2008;40:S623–9.
50 Almeida SA, Williams KM, Shaffer RA, *et al*. Epidemiological patterns of musculoskeletal injuries and physical training. *Med Sci Sports Exerc* 1999;31:1176–82.
51 Jordaan G, Schwellnus MP. The incidence of overuse injuries in military recruits during basic military training. *Mil Med* 1994;159:421–6.
52 Jones BH, Cowan DN, Tomlinson JP, *et al*. Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc* 1993;25:197–203.
53 Friedl KE, Evans RK, Moran DS. Stress fracture and military medical readiness: bridging basic and applied research. *Med Sci Sports Exerc* 2008;40(Suppl 11); S609–22.
54 Popovich RM, Gardner JW, Potter R, *et al*. Effect of rest from running on overuse injuries in army basic training. *Am J Prev Med* 2008;18(Suppl 3):147–55.
55 Brushøj C, Larsen K, Albrecht-Beste E, *et al*. Prevention of overuse injuries by a concurrent exercise program in subjects exposed to an increase in training load: a randomized controlled trial of 1020 army recruits. *Am J Sports Med* 2008;36:663–70.
56 Pope RP, Herbert RD, Kirwan JD, *et al*. A randomized trial of preexercise stretching for prevention of lower-limb injury. *Med Sci Sports Exerc* 2000;32:272–7.
57 Andrish JT, Bergfeld JA, Walheim J. A prospective study on the management of shin splints. *J Bone Joint Surg Am* 1974;56:1697–700.
58 Knapik JJ, Swedler DI, Grier TL, *et al*. Injury reduction effectiveness of selecting running shoes based on plantar shape. *J Strength Con Res* 2009;23:685–97.
59 Knapik JJ, Trone DW, Swedler DI, *et al*. Injury reduction effectiveness of assigning running shoes based on plantar shape in marine corps basic training. *Am J Sports Med* 2010;38:1759–67.
60 Knapik JJ, Brosch LC, Venuto M, *et al*. Effect on injuries of assigning shoes based on foot shape in air force basic training. *Am J Prev Med* 2010;38:S197–211.
61 Schwellnus MP, Jordaan G. Does calcium supplementation prevent bone stress injuries? A clinical trial. *Int J Sport Nutr* 1992;2:165–74.
62 Milgrom C, Finestone A, Novack V, *et al*. The effect of prophylactic treatment with risedronate on stress fracture incidence among infantry recruits. *Bone* 2004;35:418–24.
63 Lappe J, Cullen D, Haynatzki G, *et al*. Calcium and vitamin D supplementation decreases incidence of stress fractures in female navy recruits. *J Bone Miner Res* 2008;23:741–9.
64 Sharma J, Weston M, Batterham AM, *et al*. Gait retraining and incidence of medial tibial stress syndrome in army recruits. *Med Sci Sports Exerc* 2014;46:1684–92.
65 House CM, Waterworth C, Allsopp AJ, *et al*. The influence of simulated wear upon the ability of insoles to reduce peak pressures during running when wearing military boots. *Gait Posture* 2002;16:297–303.
66 Windle CM, Gregory SM, Dixon SJ. The shock attenuation characteristics of four different insoles when worn in a military boot during running and marching. *Gait Posture* 1999;9:31–7.
67 Rome K, Handoll HH, Ashford R. Interventions for preventing and treating stress fractures and stress reactions of bone of the lower limbs in young adults (review). *Cochrane Database Syst Rev* 2005;(2):CD000450
68 Craig DI. Medial Tibial Stress Syndrome: evidence based prevention. *J Athl Trai* 2008;43:316–18.
69 Larsen K, Weidich F, Leboeuf-Yde C. Can custom-made biomechanic shoe orthoses prevent problems in the back and lower extremities? *J Manipulative Physiol Ther* 2002;25:326–31.
70 Schwellnus MP, Jordaan G, Noakes TD. Prevention of common overuse injuries by the use of shock absorbing insoles. *Am J Sports Med* 1990;18:636–41.
71 Franklyn-Miller A, Wilson C, Bilzon J, *et al*. Foot orthoses in the prevention of injury in initial military training: a randomized controlled trial. *Am J Sports Med* 2011;39:30–7.
72 Yeung SS, Yeung EW, Gillespie LD. Interventions for preventing lower limb soft-tissue running injuries. *Cochrane Database Syst Rev* 2011;(7):CD001256.
73 Thacker SB, Gilchrist J, Stroup DF, *et al*. The prevention of shin splints in sports: a systematic review of literature. *Med Sci Sports Exerc* 2002;34:32–40.
74 Dixon SJ. Influence of a commercially available orthotic device on rearfoot eversion and vertical ground reaction force when running in military footwear. *Mil Med* 2007;172:446–50.
75 Bullock SH, Jones BH, Gilchrist J, *et al*. Prevention of physical training-related injuries recommendations for the military and other active populations based on expedited systematic reviews. *Am J Prev Med* 2010;38 (Suppl 1):S156–81.
76 Blackman PG. A review of chronic exertional compartment syndrome in the lower leg. *Med Sci Sports Exerc* 2000;32(Suppl 3):S4–S10.
77 Davey JR, Rorabeck CH, Fowler PJ. The tibialis posterior muscle compartment. An unrecognized cause of exertional compartment syndrome. *Am J Sports Med* 1984;12:391–7.
78 Mubarak SJ, Gould RN, Lee YF, *et al*. The medial tibial stress syndrome. A cause of shin splints. *Am J Sports Med* 1982;10:201–5.

79 D'Ambrosia RD, Zelis RF, Chuinard RG, *et al*. Interstitial pressure measurements in the anterior and posterior compartments in athletes with shin splints. *Am J Sports Med* 1977;5:127–31.
80 Godefrooij DA, Zimmermann WO. Developments in the treatment of chronic exertional compartment syndrome. *Nederl Mil Geneesk T* 2012;65:160–2.
81 McCrory P. Exercise related leg pain: neurological perspective. *Med Sci Sports Exerc* 2000;32(Suppl 3):S11–14.
82 Schepsis AA, Lynch G. Exertional compartment syndromes of the lower extremity. *Curr Opin Rheumatol* 1996;8:143–7.
83 Styf J. Chronic exercise-induced pain in the anterior aspect of the lower leg. An overview of diagnosis. *Sports Med* 1989;7:331–9.
84 Styf J. Diagnosis of exercise-induced pain in the anterior aspect of the lower leg. *Am J Sports Med* 1988;16:165–9.
85 Roscoe D, Roberts AJ, Hulse D. Intramuscular compartment pressure measurement in chronic exertional compartment syndrome: new and improved diagnostic criteria. *Am J Sports Med* 2015;43:392–8.
86 Franklyn-Miller A, Roberts A, Hulse D, *et al*. Biomechanical overload syndrome: defining a new diagnosis. *BMJ* 2014;48:415–16.
87 Potteiger JA, Carper MJ, Randall JC, *et al*. Changes in lower leg anterior compartment pressure before, during and after creatine supplementation. *J Athl Trai* 2002;37:157–63.
88 Schroeder C, Potteiger J, Randall J, *et al*. The effects of creatine dietary supplementation on anterior compartment pressure in the lower leg during rest and following exercise. *Clin J Sport Med* 2001;11:87–95.
89 Smith W, Winn F, Parette R. Comparative study using four modalities in shinsplint treatments. *J Orthop Sports Phys Ther* 1986;8:77–80.
90 Giandolini M, Horvais N, Farges Y, *et al*. Impact reduction through long-term intervention in recreational runners: midfoot strike pattern versus low-drop/low-heel height footwear. *Eur J Appl Physiol* 2013;113:2077–90.
91 Moen MH, Holtslag L, Bakker E, *et al*. The treatment of medial tibial stress syndrome in athletes; a randomized clinical trial. *Sports Med Arthrosc Rehabil Ther Technol* 2012;4:12.
92 Alsemgeest MAM. Exercise related leg pain caused by plantar hypertonia. *Sport Geneesk* 2012;2:22–5.
93 Blackman PG, Simmons LR, Crossley KM. Treatment of chronic exertional anterior compartment syndrome with massage: a pilot study. *Clin J Sport Med* 1998;8:14–17.
94 Griebert MC, Needle AR, McConnell J, *et al*. Lower-leg kinesio tape reduces rate of loading in participants with medial tibial stress syndrome. *Phys Ther Sport* 2016;18:62–7.
95 Franettovich M, Chapman AR, Blanch P, *et al*. Augmented low-dye tape alters foot mobility and neuromotor control of gait in individuals with and without exercise related leg pain. *J Foot Ankle Res* 2010;3:5.
96 Zimmermann WO, Willeboordse E. Chronic exercise related leg pain in soldiers: new findings in the soft tissues? *Nederl Mil Geneesk T* 2013;66:92–9.
97 Muller C, Honselaar B. Strenghtening the dorsal flexors in MTSS. *Nederl Mil Geneesk T* 2011;64:146–51.
98 Raaijmakers B, Honselaar B, Rehorst J. Core-stability training for MTSS. *Sportgericht* 2010;64:31–7.
99 Madeley LT, Munteanu SE, Bonanno DR. Endurance of the ankle joint plantar flexor muscles in athletes with medial tibial stress syndrome: a case-control study. *J Sci Med Sport* 2007;10:356–62.
100 Huisman A. Jumping ahead! Building up jumps in MTSS. *Sportgericht* 2010;64:10–15.
101 Helmhout PH, Diebal AR, van der Kaaden L, *et al*. The effectiveness of a 6 week intervention program aimed at modifying running style in patients with chronic exertional compartment syndrome: results from a series of case studies. *Orthop J Sports Med* 2015;3:2325967115575691.
102 Diebal AR, Gregory R, Alitz C, *et al*. Forefoot running improves pain and disability associated with chronic exertional compartment syndrome. *Am J Sports Med* 2012;40:1060–7.
103 Giandolini M, Arnal PJ, Millet GY, *et al*. Impact reduction during running: efficiency of simple acute interventions in recreational runners. *Eur J appl physiol* 2013;113:599–609.
104 IJzerman JC, Kuipers H. Tibial stress syndrome. *Geneesk Sport* 1978;11:56–68.
105 Rompe JD, Cacchio A, Furia JP, *et al*. Low-energy extracorporeal shock wave therapy as a treatment for medial tibial stress syndrome. *Am J Sports Med* 2010;38:125–32.
106 Moen MH, Rayer S, Schipper M, *et al*. Shockwave treatment for medial tibial stress syndrome in athletes; a prospective controlled study. *Br J Sports Med* 2012;46:253–7.
107 Moen MH, Schmikli SL, Weir A, *et al*. A prospective study on MRI findings and prognostic factors in athletes with MTSS. *Scand J Sci Sport* 2014;24:204–10.
108 Moen MH, Bongers T, Bakker EW, *et al*. The additional value of a pneumatic leg brace in the treatment of recruits with medial tibial stress syndrome; a randomized study. *J R Army Med Corps* 2010;156:236–40.
109 Johnston E, Flynn T, Bean M, *et al*. Randomized controlled trial of a leg orthosis versus traditional treatment for soldiers with shin splints: a pilot study. *Mil Med* 2006;171:40–4.
110 Allen CS, Flynn TW, Kardouni JR, *et al*. The use of a pneumatic leg brace in soldiers with tibial stress fractures—a randomized clinical trial. *Mil Med* 2004;169:880–4.
111 Cruz AI Jr, Laidlaw MS. Invasive compartment pressure testing for chronic exertional compartment syndrome: a survey of clinical practice among military orthopedic surgeons. *Am J Orthop* 2015;44:E384–389.
112 Verleisdonk EJ. Chronic exertional compartment syndrome. PhD thesis. Utrecht, 2000.
113 Dharm-Datta S, Minden DF, Rosell PA, *et al*. Dynamic pressure testing for chronic exertional compartment syndrome in the UK military population. *J R Army Med Corps* 2013;159:114–18.
114 Rorabeck CH. Exertional tibialis posterior compartment syndrome. *Clin Orthop Rel Res* 1986;(208):61–64.
115 Turnipseed W, Detmer DE, Girdley F. Chronic compartment syndrome. An unusual cause for claudication. *Ann Surg* 1989;210:557–62; discussion 562–3.
116 Roberts A, Franklyn-Miller A. The validity of the diagnostic criteria used in chronic exertional compartment syndrome: a systematic review. *Scand J Med Sci Sports* 2012;22:585–95.
117 Aweid O, Del Buono A, Malliaras P, *et al*. Systematic review and recommendations for intracompartmental pressure monitoring in diagnosing chronic exertional compartment syndrome of the leg. *Clin J Sport Med* 2012;22:356–70.
118 Hislop M, Tierney P. Intracompartmental pressure testing: results of an international survey of current clinical practice, highlighting the need for standardised protocols. *Br J Sports Med* 2011;45:956–8.
119 Rajasekaran S, Beavis C, Aly AR, *et al*. The utility of ultrasound in detecting anterior compartment thickness changes in chronic exertional compartment syndrome: a pilot study. *Clin J Sport Med* 2013;23:305–11.
120 Ringler MD, Litwiller DV, Felmlee JP, *et al*. MRI accurately detects chronic exertional compartment syndrome: a validation study. *Skeletal Radiol* 2013;42:385–92.
121 Zimmermann WO, Helmhout PH, Noest R. The ankle-arm index before and after exercise in normals and soldiers with exercise related leg pain. *Nederl Mil Geneesk T* 2015;68:44–9.
122 Crowell HP, Davis IS. Gait retraining to reduce lower extremity loading in runners. *Clin Biomech* 2011;26:78–83.
123 Wellenkotter J, Kernozek TW, Meardon S, *et al*. The effects of running cadence manipulation on plantar loading in healthy runners. *Int J Sports Med* 2014;35:779–84.
124 Breen DT, Foster J, Falvey E, *et al*. Gait re-training to alleviate the symptoms of anterior exertional lower leg pain: a case series. *Int J Sports Phys Ther* 2015;10:85–94.
125 Jerosch J, Castro WHM, Halm H, *et al*. Influence of the running shoe sole on the pressure in the anterior tibial compartment. *Acta Orthop Belg* 1995;61:190–8.
126 Cunningham A, Spears IR. A successful conservative approach to managing lower leg pain in a university sports injury clinic: a two patient case study. *Br J Sports Med* 2004;38:233–4.
127 Yates B, Allen M, Barnes MR. Outcome of surgical treatment of medial tibial stress syndrome. *J Bone Joint Surg Am* 2003;85A:1974–80.
128 Cook S, Bruce G. Fasciotomy for chronic compartment syndrome in the lower limb. *ANZ J Surg* 2002;72:720–3.
129 Howard JL, Mohtadi NG, Wiley JP. Evaluation of outcomes in patients following surgical treatment of chronic exertional compartment syndrome in the leg. *Clin J Sport Med* 2000;10:176–84.
130 Almdahl SM, Samdal F. Fasciotomy for chronic compartment syndrome. *Acta Orthop Scand* 1989;60:210–11.
131 Verleisdonk EJ, van den Helder CJ, Hoogendoorn HA, *et al*. Goede resultaten van fasciotomie bij het chronisch compartimentsyndroom van het onderbeen. *Ned Tijdschr Geneesk* 1996;140:2513–17.
132 Waterman BR, Laughlin M, Kilcoyne K, *et al*. Surgical treatment of chronic exertional compartment syndrome of the leg: failure rates and postoperative disability in an active patient population. *J Bone Joint Surg Am* 2013;95:592–6.
133 Kramer DE, Pace JL, Jarrett DY, *et al*. Diagnosis and management of symptomatic muscle herniation of the extremities: a retrospective review. *Am J Sports Med* 2013;41:2174–80.
134 de Fijter WM, Scheltinga MR, Luiting MG. Minimally invasive fasciotomy in chronic exertional compartment syndrome and fascial hernias of the anterior lower leg: short- and long-term results. *Mil Med* 2006;171:399–403.
135 Mouhsine E, Garofalo R, Moretti B, *et al*. Two minimal incision fasciotomy for chronic exertional compartment syndrome of the lower leg. *Knee Surg Sports Traumatol Arthrosc* 2006;14:193–7.
136 Schubert AG. Exertional compartment syndrome: review of the literature and proposed rehabilitation guidelines following surgical release. *Int J Sports Phys Ther* 2011;6:126–41.

137 Flautt W, Miller J. Post-surgical rehabilitation following fasciotomies for bilateral chronic exertional compartment syndrome in a special forces soldier: a case report. *Int J Sports Phys Ther* 2013;8:701–15.
138 Baumgarten KM. Chronic exertional compartment syndrome: are surgical outcomes worse on soldiers compared with civilians?: Commentary on an article by CPT Brian R. Waterman, MD, *et al*.: "Surgical treatment of chronic exertional compartment syndrome of the leg: failure rates and postoperative disability in an active patient population". *J Bone Joint Surg Am* 2013;95:e48.
139 McCallum JR, Cook JB, Hines AC, *et al*. Return to duty after elective fasciotomy for chronic exertional compartment syndrome. *Foot Ankle Int* 2014;35:871–5.
140 Roberts AJ, Krishnasamy P, Quayle JM, *et al*. Outcomes of surgery for chronic exertional compartment syndrome in a military population. *J R Army Med Corps* 2015;161:42–5.

JRAMC

Prevention and treatment of exercise related leg pain in young soldiers; a review of the literature and current practice in the Dutch Armed Forces

Wes O Zimmermann, P H Helmhout and A Beutler

*J R Army Med Corps*2017 163: 94-103 originally published online July 22, 2016
doi: 10.1136/jramc-2016-000635