

Conservative treatment of anterior chronic exertional compartment syndrome in the military, with a mid-term follow-up

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ABSTRACT

Objectives To assess the outcome of conservative treatment for chronic exertional compartment syndrome (CECS) as it relates to the reduction in surgical fasciotomy and return to active duty in a military population.

Methods Historic cohort. From 2015 to 2018, 75 surgically eligible patients with pressure-positive anterior CECS (Group 1), or with positive pressures and associated medial tibial stress syndrome (Group 2), underwent a conservative treatment programme emphasising gait retraining of running and marching. Treatment success was defined as return to duty, without surgery. Fifty patients from 2015 to 2017 were surveyed to assess mid-term outcomes.

Results The average duration of conservative treatment was 144.9 (±59.6) days. Initially, 65% (49/75) were able to return to duty; 28% (21/75) were referred for surgery and 7% (5/75) left the armed forces. There was no difference in outcomes between Group 1 and Group 2. Survey response rate, on average after 742 days (SD 267, range 381–1256), was 84% (42/50); 57% (24/42) had continued duty, without surgery; of them, 43% were at the same military specialty, 57% in a physically less demanding job.

Conclusion A conservative treatment programme for anterior CECS was able to return 65% of patients to active duty, without surgery. At 2 years, the success rate decreased slightly, but remained positive at 57%. In this high-risk group, initiating a conservative treatment protocol with an emphasis on gait retraining can significantly reduce the need for surgical fasciotomy. For those that fail conservative treatment, surgical release may still be indicated.

INTRODUCTION

Chronic exertional compartment syndrome (CECS) is one of the causes of exercise-related leg pain in athletes and service members. A clinical description of CECS is repetitive pain and pathologically elevated pressure in a muscular compartment during physical exercise, which returns to normal with cessation of exercise.¹ CECS can present in any muscular compartment of the human body, but is most prevalent in the anterior compartment of the

What are the new findings?

- This study reports promising results of a special conservative treatment programme for anterior chronic exertional compartment syndrome in the military.
- This study presents the largest case series published until now (n=75).
- This study reports the longest follow-up until now (>2 years).

How might this impact on clinical practice in the future?

- In the military, treatment for anterior chronic exertional compartment syndrome may be initiated with a special conservative approach before fasciotomy.
- The conservative treatment programme should at least contain gait retraining of running and marching, in shoes and boots.
- The number of surgical procedures can be reduced significantly; however, surgery is still indicated when conservative treatment is not effective.

leg (anterior CECS).² The incidence of CECS in the USA armed forces is estimated at 0.49 cases per 1000 person years (4100 cases diagnosed in 5 years).³

Several authors have claimed that non-operative treatment of CECS rarely leads to complete resolution of symptoms or return to previous levels of athletic or military activity; thus, surgery (fasciotomy) has been strongly recommended as first-line treatment and been termed the gold standard of treatment.^{4 5} Unfortunately, it has also been recognised in a number of studies that the results of fasciotomy and return to former activity level are less favourable in the military population.^{1 3 5 6} In the Central Military Hospital, Utrecht, The Netherlands, every patient with anterior CECS and a positive pressure test received fasciotomy without delay for many years.⁷ Unfortunately, the



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occupational prognosis after surgery proved to be poor: A 2-year follow-up of 44 patients with anterior CECS after surgery showed that only 15 patients (34%) had returned to their original military jobs, 28 patients (64%) had left the military and 25 patients (57%) still had symptoms of exercise-related leg pain.⁸ Therefore, the Central Military Hospital changed its policy regarding the protocol of surgical indication. From 2011 onward, patients with clinically proven anterior CECS and a positive pressure test, that is, eligible for surgery, were sent first to a comprehensive conservative treatment programme, either in the Military Rehabilitation Center (Doorn, The Netherlands) or the department of Military Sports Medicine (Utrecht, The Netherlands). Referral was not truly random, and more complicated cases were sent to the Military Rehabilitation Center. This centre offered an inpatient conservative treatment programme containing physical therapy, physical fitness, mental coaching and podiatry. The results were described in two studies: 56% of patients were able to return to base in order to resume military duties without surgery, and the others returned to the surgeon.^{9 10} The results of the conservative treatment programme of the department of Military Sports Medicine were unknown until now. An evaluation is important to determine whether delaying surgery is justified.

The purpose of this study was to determine the initial and mid-term follow-up results of the comprehensive conservative treatment programme in service members with clinically proven anterior CECS and a positive pressure test offered at the department of Military Sports Medicine.

MATERIAL AND METHODS

This study is a historic cohort, involving patients seen by the first author (WZ) in the Central Military Hospital and in the department for Military Sports Medicine, with a follow-up survey, minimally 1 year after completion of a special conservative treatment programme.

Organisation of care

The Royal Netherlands Armed Forces have a diagnostic and treatment protocol for exercise-related leg pain coordinating physicians and physical therapists working in outlying primary care clinics with specialists in the Central Military Hospital. This protocol describes that service members with exercise-related leg pain be referred to the Central Military Hospital if conservative therapy in primary care has not been successful within 6 months.⁸ Since 2013, this hospital has offered a specialty clinic for service members with exercise-related leg pain. A multidisciplinary team of surgery, sports medicine and physiatry evaluates patients in a one-stop shop setting. Diagnostic imaging is ordered if stress fractures, malign or vascular disorders have to be excluded. The latter is in less than 5% of cases. After medical clearance, a sports medicine physician supervises the patient in a standardised running test on a treadmill to pain tolerance and

performs an intracompartmental pressure measurement of compartments suspected for CECS. The standardised running test, the minute-by-minute pain scoring system, the exact execution of the pressure measurement with a Stryker needle manometer and the diagnostic flowchart for exercise-related leg pain were described previously in detail and are available here as online supplementary material 1–3.¹¹ All patient information is stored in an electronic patient record. Based on the evaluations, patients may be referred to conservative treatment in the Military Rehabilitation Center (inpatient) or the Department of Military Sports (outpatient) or to fasciotomy in house. The criteria for surgery for anterior CECS are pain with exertion in the anterior compartment of the leg and pressure ≥ 35 mm Hg in the first minute postexercise and were established locally.⁷

Inclusion

Medical records at the department of Military Sports Medicine were searched for all patients diagnosed with anterior CECS (Group 1) and anterior CECS+medial tibial stress syndrome (MTSS) (Group 2) sent from the Central Military Hospital in the years 2015–2018. The following baseline information was obtained: age (years), sex (male/female), height (m), weight (kg), body mass index, diagnosis (anterior CECS or anterior CECS+MTSS), intracompartmental pressure measurement values, duration of symptoms (months), repeat episode (yes/no), symptoms in first year of service (yes/no), the Single Assessment Numerical Evaluation (SANE) score at intake. This SANE score is a single question instrument evaluating patients' subjective injury status with the following question: 'how would you rate your lower leg today as a percentage of normal, on a 0–100 scale, with 100 being normal'. The SANE score was developed and validated in a military healthcare setting.¹²

Comprehensive conservative outpatient treatment programme

At the department of Military Sports Medicine, each patient received a comprehensive conservative outpatient treatment programme with a selection of interventions described in the literature:^{13 14} stretching and/or strengthening of lower extremity musculature, massage of hypertonic musculature, dry needling of trigger points, extracorporeal shockwave therapy to the medial tibial border, supplementation of vitamin D, evaluation of running shoes, evaluation of shoe inlays, maintaining fitness with a low impact training programme, gait retraining of running and marching and a progressive running schedule. For each of the aforementioned interventions, local protocol describes criteria for application (table 1). If patients received extracorporeal shockwave therapy for MTSS (once per week, four sessions), gait retraining was postponed for the duration of this treatment. Once free of pain in rest, every service member received a 6-week progressive running programme building up to a 15 min uninterrupted run. Some service members with a physically demanding specialty, received

Table 1 Standard care for exercise-related leg pain: criteria for application (version 2018)

Intervention	Criterion
Stretching	Gastrocnemius tightness=minimal angle compared with a vertical line: 70° or more. Soleus tightness=maximal distance of the big toe 5 cm from the wall or less. See online supplementary material 4, with two illustrations.
Strengthening	Calve strength insufficient: not able to perform 30 consecutive calve raises on one leg.
Massage hypertonic m. plantaris	m. plantaris palpation painful (patient in prone position).
Dry needling of trigger points	Medial and lateral gastrocnemius: if patient identifies the calve as a pain location.
Compression stockings/sleeves	Not given to patients with proven anterior CECS (ICPM \geq 35 mm Hg).
ESWT	For MTSS only: once a week, 4 sessions; each session 2000 radial shocks, frequency eight per second and intensity 2.5 bar, on the medial tibial border.
Vitamin D supplementation	If MTSS is present: criterion: <50 nmol/L means insufficient, supplementation required; optimal 75 nmol/L.
New running shoes	Every year or 500 miles (800 km). If patient describes a relation between symptoms and shoes. Minimalist shoes are discouraged.
Customised antipronation inlays	If navicular drop is positive (>0.5 cm) and if overpronation is established with slow motion video analysis of barefoot running.
Maintaining fitness with low impact training	Resume three moments of low impact exercise per week. Keep leg pain scores \leq 3 (on a Numeric Pain Rating Scale 0–10).
Gait retraining while running in sports shoes and boots	Four cues for running: 1. Change to a ball-of-foot strike (reduce heel strike), when applicable. 2. 10% reduction of stride length. 3. Strive for cadence 180/min. 4. Increase knee lift 1–2 cm.
Gait retraining while marching in boots	Two cues for marching: 1. 5% increase in cadence from preferred. 2. Reduce force and dorsal flexion angle of heel strike.
Progressive running schedule	Weeks 1–6: run twice a week, end goal=a 15 min uninterrupted run, pain free with new running technique. Weeks 7–12: run twice or three times per week, end goal=a 30 min uninterrupted run, pain free, with new running technique.

CECS, chronic exertional compartment syndrome; ESWT, extracorporeal shockwave therapy; ICPM, intracompartmental pressure measurement; MTSS, medial tibial stress syndrome.

an additional 6-week progressive running schedule to build to a 30 min uninterrupted run, before return to base. Overall, special emphasis was placed on gait retraining of running and marching, in shoes and boots and retention of these newly learnt movement skills. Each patient with anterior CECS received four–six individual gait retraining sessions also described previously in detail.¹⁵

Evaluation of clinical progress was done every time the patient visited the department. If resumption of running and marching with low pain scores was not possible and it was unlikely that treatment success was to be expected, the patient was sent back to the department of surgery in the Central Military Hospital. Patients were allowed to return to base, when they could run at least 12 min pain free and when patient and physician both thought return to base could lead to resumption of military duties. During final evaluation, the SANE score was recorded again (SANE-evaluation).

Follow-up survey

Minimal follow-up was set at 1 year. Therefore, in December 2018 and January 2019, all 2015–2017 patients were contacted by telephone by an instructed medical student. A brief survey with closed questions on military status (active duty, yes/no), less demanding military specialty (yes/no), fasciotomy (yes/no), symptoms (yes/no) and SANE score (0–100) was conducted.

Statistics

Baseline age, biometrics (height in metres, weight in kilograms, body mass index) and disease characteristics that is, duration of symptoms (months), repeat episode of exercise-related leg pain (count), diagnosis and the SANE score at intake (0–100) were described with appropriate measures of central tendency and dispersion for three outcome groups: return to base (treatment success), return to surgeon and exit from the military. Initial treatment success was defined as return to duty, without surgery. The results of the conservative treatment programme were presented with absolute and relative frequencies for the same three outcome groups. For the follow-up survey (minimal follow-up time 1 year), we defined treatment success as continued military service, without surgery. Subsequently, the results of the items of the follow-up survey, that is, military status, less demanding military specialty, fasciotomy, symptoms and SANE score were described appropriately.

RESULTS

Initial results

In total, 75 patients from the years 2015–2018 with anterior CECS or anterior CECS+MTSS, eligible for surgery, completed the comprehensive conservative treatment programme as described. **Table 2** shows baseline characteristics and initial treatment results for all patients, and also divided in three outcome groups: return to base (treatment success), return to surgeon and exit from the

Table 2 Baseline characteristics and initial treatment results for all patients and three outcome subgroups: (1) return to base 49/75 (65%, treatment success); (2) return to surgeon 21/75 (28%); (3) exit from service 5/75 (7%)

	All	Return to base (success)	Return to surgeon (failure)	Exit from service (failure)
Number of patients (%)	75 (100%)	49	21	5
Male (n; %)	59 (79%)	41	16	2
Female (n; %)	16 (21%)	8	5	3
Age (years)*	21 (4)	21 (4)	22 (5)	22 (2)
Diagnosis anterior CECS (n; %)	37 (49%)	25	11	1
Diagnosis anterior CECS, ICPM R ant, mm Hg	65.6 (24.5)	67.8 (25.1)	61.6 (24.6)	54 (–)
Diagnosis anterior CECS, ICPM L ant, mm Hg	63.1 (19.1)	63.7 (19.8)	62.9 (19.0)	52 (–)
Diagnosis anterior CECS+MTSS (n; %)	38 (51%)	24	10	4
Diagnosis anterior CECS+MTSS, ICPM R ant, mm Hg	65.3 (22.4)	64.6 (19.4)	70.6 (28.0)	56.5 (27.5)
Diagnosis anterior CECS+MTSS, ICPM L ant, mm Hg	61.4 (22.1)	62.6 (21.4)	61.2 (22.2)	54.5 (30.5)
Symptoms (months)	10.5 (7.0)	10.9 (7.7)	10.4 (5.9)	7.2 (3.3)
Repeat episode (yes/no)	32 (43%)	22/49 (45%)	10/21 (48%)	0/5 (0%)
Symptoms in first year of service (yes/no)	51 (68%)	35/49 (71%)	13/21 (62%)	3/5 (60%)
SANE score at intake (0–100)	45.0 (16.0)	47.7 (15.1)	39.5 (15.5)	41.0 (22.2)
Duration of treatment (days)	144.9 (59.6)	153.6 (61.8)	125.6 (49.1)	140.8 (70.0)
SANE score at evaluation (0–100)	74.2 (21.2)	85.7 (8.7)	45.7 (17.1)	81.0 (6.5)

Number of cases (n) and percentage, or average and SD.

*Median and IQR.

CECS, chronic exertional compartment syndrome; ICPM, intracompartmental pressure measurement; MTSS, medial tibial stress syndrome; SANE, Single Assessment Numerical Evaluation.

military. For males, average height was 1.79 m (SD 0.06), average weight 84.0 kg (SD 11.0), average BMI 26.1 (SD 3.0). For females, average height was 1.70 m (SD 0.07), average weight 72.1 kg (SD 7.3), average BMI 25.1 (SD 2.9). Group 1 (n=37) and Group 2 (n=38) were different in duration of treatment 128.4 (\pm 59.8) vs 161.0 (\pm 55.6) days, not in treatment outcome.

Follow-up results

Table 3A and B shows the results of the follow-up survey presented per diagnostic group. Fifty patients from 2015 to 2017 were surveyed by telephone. The response rate was 84% (42/50). The average follow-up time was slightly greater than 2 years, 742 (\pm 267) days. At follow-up: 24/42 patients (57%) were still active duty and without fasciotomy; 18/42 returned to their original military specialty (43%); 15/42 left the military (36%); 20/42 still had symptoms (48%); 5/42 patients received fasciotomy (12%).

DISCUSSION

This study evaluated a comprehensive conservative treatment programme for service members with proven anterior CECS, with and without associated MTSS, eligible for surgery. Almost two-third of patients were able to return to duty without surgery and it was hoped and expected that under supervision of primary care, these patients would recover and maintain their status

on active duty (initial treatment success). Before 2011 all of these patients would have received fasciotomy in the Central Military Hospital without delay. Twenty-one patients were referred back to the department of surgery and five left the armed forces voluntarily (35% initial treatment failure). From the follow-up survey, it was learnt that 24/42 patients were still active duty and did not have surgery (57% follow-up treatment success).

The initial results at the department of Military Sports Medicine with conservative treatment for anterior CECS are comparable to those presented by the Military Rehabilitation Center, return to base 65% vs 56%.¹⁰ Comparison of the programmes must be done with caution; the inpatient treatment programme at the Military Rehabilitation Center was shorter, 6 weeks vs 21 weeks, and our outpatient programme emphasised gait retraining of running and marching to a greater extent. Gait retraining for service members with exercise-related leg pain has been a topic of special interest in our department over the last years. Moreover, several studies showing the importance of training sessions in boots and the effectiveness of combining gait retraining cues have been published.^{15–17} A possible confounder is that the patients sent to the Military Rehabilitation Center had more severe exercise-related leg pain symptoms.

Our 2-year follow-up results compare favourably with the results of fasciotomy in the Central Military Hospital:

Table 3 Results of the follow-up survey, group 1=CECS (A) and group 2=CECS+MTSS (B); 0=no, 1=yes; average and SD, or count and percentage

M/F	Age (years)	Follow-up (days)	Active duty yes/no	Less demanding specialty yes/no	Fasciotomy yes/no	Symptoms now yes/no	SANE now	Treatment success yes/no
(A) Group 1=CECS								
M	30	1102	1	0	1	1	70	0
M	21	1093	0	n.a.	0	1	70	0
M	29	701	1	0	1	1	70	0
M	23	511	0	n.a.	0	0	70	0
F	25	889	0	n.a.	0	1	80	0
M	23	731	0	n.a.	0	1	80	0
M	22	625	0	n.a.	1	0	90	0
M	22	1137	1	1	1	0	100	0
M	25	1098	0	n.a.	0	0	100	0
M	19	408	1	0	0	1	50	1
M	22	653	1	0	0	1	75	1
F	23	827	1	0	0	0	80	1
M	19	801	1	1	0	1	80	1
M	24	556	1	0	0	1	80	1
F	23	434	1	0	0	1	80	1
M	21	907	1	0	0	0	85	1
M	25	961	1	0	0	0	100	1
M	21	731	1	1	0	0	100	1
M	23	445	1	0	0	0	100	1
M	21	497	1	0	0	0	100	1
n=20	23*	755,4	14	3	4	10	83,0	11
	(3,75)	(241,2)	(70%)	3/14=21%	(20%)	(50%)	(13,9)	(55%)
(B) Group 2=CECS+MTSS								
M	21	1026	0	n.a.	0	1	20	0
M	23	1030	0	n.a.	1	1	40	0
F	19	516	0	n.a.	0	1	40	0
M	22	1088	0	n.a.	0	1	60	0
M	22	878	0	n.a.	0	1	60	0
M	19	996	0	n.a.	0	1	70	0
F	22	1256	0	n.a.	0	0	70	0
F	21	839	0	n.a.	0	1	70	0
F	22	381	0	n.a.	0	1	80	0
F	20	477	1	0	0	1	30	1
F	24	433	1	0	0	1	75	1
M	31	1056	1	0	0	0	80	1
M	24	408	1	0	0	0	80	1
M	21	530	1	1	0	0	85	1
M	19	471	1	1	0	0	90	1
M	25	1173	1	1	0	0	90	1
M	21	381	1	0	0	0	95	1
M	21	520	1	1	0	0	95	1

Continued

Table 3 Continued

M/F	Age (years)	Follow-up (days)	Active duty yes/no	Less demanding specialty yes/no	Fasciotomy yes/no	Symptoms now yes/no	SANE now	Treatment success yes/no
M	27	526	1	1	0	0	100	1
M	21	462	1	1	0	0	100	1
M	21	764	1	0	0	0	100	1
M	18	839	1	0	0	0	100	1
n=22	21*	729,5	13	6	1	10	74,1	13
	(2,5)	(293,8)	(59%)	6/12=50%	(5%)	(48%)	(23,8)	(59%)

Note: in total 42/50 patients were reached (84%). At follow-up: 24/42 patients (57%) were still active duty and without fasciotomy; 18/42 returned to their original military specialty (43%); 15/42 left the military (36%); 20/42 still had symptoms (48%); 5/42 patients received fasciotomy (12%).

*Median and IQR.

CECS, chronic exertional compartment syndrome; F, female; M, male; MTSS, medial tibial stress syndrome; n.a., not applicable; SANE, Single Assessment Numerical Evaluation.

return to the original military specialty 43% vs 34%, leaving the military 36% vs 64%, still exercise-related leg pain symptoms 48% vs 57%. A randomised study directly comparing the results of a conservative approach versus fasciotomy would be valuable to determine which pathway is most beneficial for the individual patient.

Including the current study, there are now at least five case series on the conservative treatment of anterior CECS available.^{10 18–20} In addition, one case study also presents promising results.²¹ While admittedly the quality of level of evidence remains low (poor control groups, primarily retrospective studies with small number case series and potential observer bias), this growing body of evidence on the effectiveness of comprehensive conservative treatment for anterior CECS can no longer be ignored, certainly not for military patients. It is reasonable and perhaps safer and more cost-effective to follow a protocol in which surgery for exercise-related leg pain is offered only after ‘optimal’ conservative treatment has been attempted. It appears that comprehensive conservative treatment for anterior CECS should be at least a 6-week programme and should include gait retraining of running and, in a military setting, retraining of marching and running while in boots. Fortunately, the same gait retraining cues are beneficial to treat the other overuse injuries in the exercise-related leg pain group including MTSS and overuse stress injuries.^{15 16}

In this study, the average duration of treatment for all patients was 144,9 days. Group 2 patients needed 32 days longer than Group 1. This is not surprising, but reflects the treatment protocol. Group 2 patients received 4 weeks of extracorporeal shockwave, before gait retraining was started. Average duration of treatment for those patients referred back to a surgeon was 125.6 days. This reflects that if patients were not experiencing sufficient relief with the comprehensive conservative treatment programme, unnecessary surgical treatment delay was prevented.

One subgroup that requires additional focus and analysis is the group of five patients who chose not to have surgery and left the services. They were all patients with first episode anterior CECS, the duration of symptoms was relatively short and they left the programme with high SANE scores. It could be argued that these patients represented treatment success, their goals were different, they had no intention of returning to active duty and were granted dismissal by request.

From the follow-up survey, it was learnt that not all patients referred back to the Central Military Hospital received fasciotomy. At retesting, some no longer qualified for surgery, intracompartmental pressure measurement values were now below 35 mm Hg. For these patients, conservative treatment failed and surgery was not offered. Currently, reduction of activity is the only treatment option offered for these patients, which is unsatisfactory. Future research must explore other treatment options for this group of patients, such as intramuscular injection with botulinum toxin.

This study illustrates the impact of anterior CECS on service members and the military organisation. It also demonstrates the diversity of possible treatment outcomes, active duty, with or without transfer to a less physically demanding specialty, and continuing work with different levels of exercise-related leg pain symptoms, as reflected by the follow-up SANE scores. In a time where recruiting and retaining young men and women in the military is very difficult, efforts in primary prevention of exercise-related leg pain are paramount, with continuing emphasis on developing efficient and durable early-stage treatment strategies to prevent chronic and recurrent symptoms.⁸

The authors must acknowledge limitations in the research approach and design. This historic cohort design in the absence of a defined control group introduces the potential of observer bias, the outcome pathways of reduced surgical risk and exposure using this protocol

are based on defined numbers of surgeries performed in the primary military hospital for a single country. Those numbers and the reduction in surgical procedures in this cohort are not subject to such bias. A separate area of concern might target the specifics of diagnosis and definitions of success of outcomes as defined as return to active duty. Patients received individualised treatment plans and had two different diagnostic categories (anterior CECS with and without associated MTSS). The follow-up survey was not a validated questionnaire. Be that as it may, the study is enormously valuable in demonstrating that a comprehensive conservative first protocol can be effective in returning military patients to duty, and it can significantly decrease the number of surgical procedures and associated risks and costs for this population.

CONCLUSION

In conclusion, for patients with anterior CECS in the military population, initiating care with a comprehensive conservative treatment protocol can have a two-third return to duty rate while avoiding surgery and reduce the total number of fasciotomies required. At follow-up, on average more than 2 years later, 57% of patients surveyed were active duty, without surgery (follow-up treatment success). Surgical fasciotomy may still be effective and reasonable in patients who fail the comprehensive conservative first protocol.

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