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Original Research

Association Between Intracompartmental Pressures in the Anterior Compartment of the Leg and Conservative Treatment Outcome for Exercise-Related Leg Pain in Military Service Members

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KEYWORDS
Chronic exertional compartment syndrome;
Conservative treatment;
Medial tibial stress syndrome;

Abstract *Objective:* To explore the relationship between a single the intracompartmental pressure (ICP) value in the anterior compartment of the leg 1 minute after provocative exercise and the outcome of a conservative treatment program in a cohort of military service members with chronic exercise-related leg pain.
Design: Retrospective cohort study.
Setting: Department of military sports medicine at a secondary care facility.

List of abbreviations: ant-CECS, anterior chronic exertional compartment syndrome; CECS, chronic exertional compartment syndrome; ERLP, exercise-related leg pain; GPE, Global Perceived Effect; ICP, intracompartmental pressure; SANE, Single Assessment Numeric Evaluation.
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Military personnel;
Rehabilitation

Participants: In the years 2015 through 2019, the conservative treatment program was completed by 231 service members with chronic exercise-related leg pain, of whom 108 patients with 200 affected legs met all inclusion criteria (N=108).
Interventions: All patients completed a comprehensive conservative treatment program, consisting of 4-6 individual gait retraining sessions during a period of 6-12 weeks. In addition, patients received uniform homework assignments, emphasizing acquisition of the new running technique.
Main Outcome Measures: The primary treatment outcome was return to active duty. The duration of treatment, occurrence of acute on chronic compartment syndrome, and patient-reported outcome measures were considered secondary treatment outcomes. Potential risk factors for the primary treatment outcome were identified with a generalized logistic mixed model.
Results: Return to active duty was possible for 74 (69%) patients, whereas 34 (31%) needed further treatment. The multivariable analysis showed that the absolute values of ICP in the anterior compartment were not associated with the treatment outcome (odds ratio, 1.01; *P*=.64). A lower Single Assessment Numeric Evaluation score at intake was negatively associated with the potential to successfully return to active duty (odds ratio, 0.95; *P*=.01). No acute on chronic compartment syndromes were reported.
Conclusions: A single postexercise ICP value in the anterior compartments of the lower leg of military service members with chronic exercise-related leg pain was not associated with the outcome of a secondary care conservative treatment program and can be safely postponed.

Repetitive leg loading as commonly encountered in sports, recreation, and work may lead to several overuse injuries that are characterized by pain between the knee and ankle and are frequently identified in the literature by the term exercise-related leg pain (ERLP).[1] Within this group of pain syndromes, medial tibial stress syndrome and chronic exertional compartment syndrome (CECS), in particular the subtype with elevated intracompartmental pressure (ICP) of the anterior compartment (ant-CECS), are most prevalent.[2] In 2014, the term "biomechanical overload syndrome" was introduced and later used for a syndrome that clinically mimics ant-CECS without pathologically elevated ICPs values.[2,3]

ERLP has a manifest effect on young active duty service members in the armed forces.[4] In the Netherlands, ERLP is consistently in the top 3 of overuse injuries and constitutes a significant portion of the 25% attrition rate from musculoskeletal injuries during both basic and elite military training.[5,6] When ERLP symptoms in the military become chronic, commonly reported diagnoses are medial tibial stress syndrome (21%), ant-CECS (32%), or a combination of these 2 (31%).[2] Traditionally treatment for medial tibial stress syndrome focusses on rest, whereas treatment for ant-CECS is surgical with modest occupational success rates.[7] Current treatment regimens for these diagnoses in the ERLP group have shifted focus to a conservative treatment first approach, with great emphasis on gait retraining during running and marching.[8-10]

Conservative treatment is initiated in all patients with ERLP, regardless of the specific diagnosis or ICP value measured at intake. Nevertheless, ICP measurements are still performed as part of standard care to determine a possible indication for early surgical treatment and to estimate the risk of developing an acute on chronic compartment syndrome.[11-13] However, the invasive nature of ICP measurements is associated with a risk of (asymptomatic) hematoma formation and the possibility to penetrate nerves or arteries.[14,15] Therefore, the need to measure ICP prior to conservative treatment for service members suspected of ant-CECS should be evaluated.

Accordingly, the purpose of this study was to explore the relationship between absolute ICP values in the anterior compartment of the leg and the outcome of a comprehensive conservative treatment program in a cohort of military service members with chronic ERLP. The study's primary outcome variable was a successful return to active duty. In addition patient safety was evaluated, with particular attention to the development of acute on chronic compartment syndrome.

Methods

Study design

A retrospective cohort study was performed at the Department of Military Sports Medicine of the Royal Netherlands Army (Utrecht, The Netherlands). At this institute for secondary care, all service members with chronic ERLP receive a comprehensive conservative rehabilitation program first, before surgical treatment is offered. For this study design, if an evaluation of standard care is provided, national law does not require permission from an ethical committee. All patients provided written consent for aggregated and encoded use of their treatment data.

Study population

Military service members with ERLP symptoms longer than 6 months who completed the secondary care outpatient treatment program (see 'Standard care, outpatient treatment

program') in the years 2015 through 2019 were eligible. All patients were screened prior to initiation of the comprehensive treatment program, using a detailed template for history and physical examination. Additionally, ICP measurement of the anterior compartment was performed in patients suspected of ant-CECS.

All patients were subjected to a standardized symptom provocation test and a locally developed pain scoring system, both described previously (text box 1).[2] This diagnostic methodology has been in use in military sports medicine in the Netherlands since 2012 and has been described in multiple publications.[2,5] It has not been validated formally.

Patients were included if subjective exertional pain scores over the anterolateral side of the leg were ≥2 on a 0-10 scale in at least 1 leg. Patients with concomitant presence of posteromedial tibial pain (medial tibial stress syndrome), unilateral or bilateral, were eligible for inclusion. In addition, for inclusion, number of treatment days, outcome of treatment, and ICP values of the anterior compartment of both legs had to be available in the medical records. Reasons for exclusion were missing data in medical records, a fasciotomy in the history, or the concurrent presence of other lower extremity injuries (eg, Achilles' tendinopathy, etc).

ICP measurement

ICP measurements were performed in all symptomatic compartments of both legs by a single senior sports medicine physician (W.Z.) using a previously described and published protocol.[2] Symptom provocation was achieved using a locally standardized test, encompassing running and marching on a treadmill. This test was designed to reproduce symptoms to the limit of tolerable pain in the military patient group. The single ICP measurement was performed with a hand-held device[a] connected to a side-port needle, in the first minute post exercise.[16,17] All measurements were completed in approximately 1 minute. Patients were supine, with the knees at the edge of the table and the legs hanging vertically toward the floor. The local criterion for the diagnosis of ant-CECS was 35 mmHg or above, measured in the first minute post exercise.[2]

Standard care, outpatient treatment program

All patients completed a comprehensive conservative treatment program. The treatment program was individualized, based on patient characteristics and military occupational specialty (absolute ICP values were not taken into account). However, the part for gait retraining was standardized for all patients. Patients received at least 4 and maximally 6 individual gait retraining sessions during a period of 6-12 weeks. Three common gait retraining cues were repeated at each training session: (1) change from a heel strike landing to a fore foot strike landing; (2) increase cadence to 180 steps/min; and (3) stand up taller, do not bend over at the waist (trunk and pelvic position). In addition, patients received uniform homework assignments, increasing running time and distance gradually, with 2-3 sessions per week, emphasizing acquisition of the new running technique.

All patients were interviewed for ERLP symptoms at every visit to the department. In addition, all patients were instructed to contact the emergency department of the Central Military Hospital immediately in case recognizable ERLP symptoms were persistent after cessation of provocative exercise (possible development of acute on chronic compartment syndrome).

Data collection

For this study, an encoded database was created. Demographic data were collected and included: age, sex (female=0/male=1), height (m), weight (kg), body mass index (interval-level), duration of symptoms (months), recurrent ERLP episode (no=0/yes=1), laterality of anterolateral complaints (unilateral=0/bilateral=1), concomitant presence of posteromedial pain (suspected for medial tibial stress syndrome; not=0, unilateral=1, bilateral=2), and the military job category before and after treatment (category 1-6; category 1 are the physically least demanding jobs and category 6 the physically most demanding jobs). The ICP values of the anterior compartments were retrieved, as well as the Single Assessment Numeric Evaluation (SANE) score at intake and after completion of the treatment program. The 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," and it was validated in a military health care setting.[18] A SANE score ≥70 usually coincides with the moment the military sports medicine physician and the patient feel return to base, to resume active duty in several weeks, is opportune.[10]

The primary treatment outcome was defined as return to active duty (yes=0, ie, treatment success/no=1, ie, treatment failure). Secondary outcome measures were duration of treatment (days), development of acute on chronic compartment syndrome, the change in SANE score, and the Global Perceived Effect (GPE) scale[19] after completion of the conservative treatment program.

Statistical analysis

Statistical analysis was performed using statistical software.[b] Normally distributed data were presented using a mean with corresponding SD, whereas medians with IQRs were used for data without a normal distribution. A univariate logistic regression was used to test differences between the 2 outcome groups formed, using the primary treatment outcome (ie, return to duty yes/no). Next to ICP values of affected anterior compartments at intake, other covariates were elected based on established prognostic markers (age, sex, recurrent episode, duration of symptoms, laterality of symptoms), statistical considerations (SANE score at intake), or clinical relevance (body mass index, presence of a fascial hernia). The change in SANE score was determined by subtracting the SANE score at intake from the SANE score after completion of the conservative treatment program.

Given the multilevel structure of the data (ICP values of the anterior compartments nested in patients), a generalized linear mixed model was used to determine if baseline ICP values were associated with the primary treatment

outcome (return to duty yes/no). The model was built with the previously mentioned fixed-effects estimates (see 'Data collection') and a random intercept and slope. Presence of multicollinearity was evaluated, and robust covariances were used to handle violations of model assumptions. The (adjusted) odds ratio with 95% confidence limits of this analysis was used to report the strength of the associations. Significance was set at *P* values (2-sided) $\leq$.05.

The secondary treatment outcomes were analyzed by comparing the duration of treatment, the change in SANE scores, and the GPE scale after treatment for the 2 outcome groups, using an independent samples *t* test (duration of treatment and change in SANE score) or a chi-square test (GPE scale).

Results

Patient demographics of the study population

During the 5-year study period (2015-2019), the conservative treatment program was completed by 231 patients with ERLP, of whom 108 patients with 200 affected legs met all inclusion criteria (table 1). The other 123 patients were excluded for the following reasons: only exertional pain in the posteromedial region (n=49), a fasciotomy in the history (n=16), missing ICP values (n=53), or missing treatment outcome parameters (n=5).

Absolute ICP values in the anterior compartment of all affected legs at intake ranged from 12-126 mmHg. Patients who did and did not return to active duty had comparable ICP values in the anterior compartment (table 1). Yet, patients not returning to active duty reported significantly lower SANE scores at intake. All other characteristics were similar in both outcome groups.

Primary treatment outcome

After completion of the comprehensive conservative treatment program, 74 (69%) of the included service members returned to base to resume active duty, whereas 34 (31%) were not recovered sufficiently and needed further treatment. Of the 74 service members who could return to active duty, 60 (81%) could resume their previous occupational specialty. Twelve patients (16%) were allocated a physically less demanding position. Two patients (3%) were able to pursue physically more demanding position.

The multivariable analysis evaluating the potential risk factors for this primary treatment outcome showed a random effect (*P*<.001) (see table 1). The model revealed that the absolute values of ICP in the anterior compartment were not associated with the treatment outcome. For 2 participants with a difference in ICP of 1 mmHg, the odds to leave duty was 1.01 (95% CI, 0.98-1.03). A lower SANE score at intake was negatively associated with the potential to successfully return to active duty; for 2 participants with a difference of 1 point in SANE score at intake, the odds to leave duty was 0.95 (95% CI, 0.91-0.99).

Table 1 Study characteristics and multilevel logistic regression analysis for successful treatment outcome of the comprehensive conservative treatment program for service members with chronic exercise-related leg pain in the anterolateral region of the leg

Characteristic	All Patients (N=108)	Return to Active Duty (n=74)	No Return to Active Duty (n=34)	Unadjusted Model		Adjusted Model	
				P Value	OR (95% CI)	*P* Value	OR (95% CI)
Age (y), median (IQR min-max)	22 (20-24)	21 (20-24)	23 (20-24)	.82	1.01 (0.92-1.11)	.52	1.05 (0.90-1.23)
Sex, male, n (%)	88 (82)	62 (84)	26 (76)	.37	1.59 (0.58-4.34)	.57	0.65 (0.14-2.91)
BMI, mean ± SD	26±3	26±3	27±3	.59	1.04 (0.91-1.17)	.83	1.02 (0.84-1.25)
Recurrent episode, n (%)	44 (41)	31 (42)	13 (38)	.72	1.17 (0.51-2.68)	.63	0.74 (0.22-2.50)
Fascial hernia, n (%)	10 (9)	6 (8)	4 (12)	.55	0.66 (0.17-2.52)	.59	1.81 (0.21-15.30)
Duration of symptoms (mo), median (IQR min-max)	8 (6-12)	8 (6-13)	9 (6-12)	.92	1.00 (0.96-1.05)	.83	1.01 (0.95-1.07)
Laterality of anterolateral complaints, n (%)				.26	1.87 (0.63-5.54)	.77	1.38 (0.16-12.34)
Unilateral	8 (8)	6 (8)	2 (6)				
Bilateral	92 (92)	68 (92)	32 (94)				
Concomitant presence of posteromedial tibial pain, n (%)							
None	48 (44)	34 (46)	14 (41)	ref	-	ref	-
Unilateral	10 (9)	7 (9)	3 (9)	.61	0.80 (0.34-1.88)	.30	3.53 (0.32-38.50)
Bilateral	50 (46)	33 (45)	17 (50)	.81	0.83 (0.19-3.63)	.34	0.49 (0.11-2.14)
ICP affected anterior compartments at intake (mmHg), mean ± SD	60±24	58±24	64±24	.19	1.01 (1.00-1.02)	.64	1.01 (0.98-1.03)
SANE score at intake, mean ± SD	47±16	49±16	40±16	.01	0.96 (0.94-0.99)	.01	0.95 (0.91-0.99)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); max, maximum; min, minimum; OR, odds ratio; ref, reference.

Secondary treatment outcomes

The median duration of the treatment program was 137 days, ranging from 21-351 days. Treatment time was comparable for both groups (return to duty 158±67, no return to duty 143±71; P=.16). During the treatment program, none of the participants developed an acute on chronic compartment syndrome.

The average improvement in SANE score was 27±22 points, which was significantly higher for patients returning to active duty (return to active duty 37±18, no return to active duty 12±22; P<.01). After completion of the conservative treatment program the average SANE scores were 83±13 for the group that returned active duty and 52±19 for the group of patients that did not return to active duty (P<.01). Improvement of symptoms on the GPE scale was reported by 95 patients (88%), of whom 73 returned to active duty and 22 did not. Worsening of symptoms was reported by 3 patients (3%), all not returning to active duty. No change was reported by the remaining 10 patients (9%), although 1 of these patients did return to active duty.

Discussion

This retrospective study aimed to evaluate the relationship between a single ICP value of the anterior compartments 1 minute after exercise in the legs of military service members with chronic ERLP and the outcome of a comprehensive conservative treatment program. These absolute ICP values were shown not to be associated with the potential to return to active duty. In addition, the development of acute on chronic compartment syndrome was not reported. The execution of a single ICP measurement after provocative exercise and prior to initiation of a comprehensive conservative treatment program in this military patient group with chronic ERLP appears to have no added value and can be safely postponed.

The role of ICP values in the anterior compartment of the leg is an ongoing debate, especially in patients with chronic ERLP. The relationship between absolute ICPs values in the anterior compartment and treatment outcome for patients with ant-CECS has been investigated, and so far no significant correlation was found for conservative treatment in the military[20] or for surgical treatment in both civilian and military populations.[21-24] In current clinical practice these ICP values are mainly used to discriminate between the subdiagnosis ant-CECS and biomechanical overload syndrome, unfortunately in the absence of an evidence-based, globally accepted ICP protocol, cutoff values, or standardized provocation tests.[16,17,25] Clinical studies use ICP values to evaluate treatment outcome after conservative[8,9,26] or surgical[21,27] interventions. Conservative interventions have been demonstrated to lower elevated ICPs in the anterior compartment in patients with ERLP, although the predictive value was not reported.[8,9,25,26] Moreover, a few cohort studies examined whether ICPs could play a prognostic role in either conservative or surgical treatment, but none of these identified the pressure values as a prognostic factor.[20,22-24]

The current study is the first to analyze the association of a single ICP value in the anterior compartment of the leg with the return to active duty after conservative treatment, using a multivariable logistic model for a cohort of military service members. With this model, these single, postexercise ICP values were not associated with the outcome of the conservative treatment program. This study substantiates the proposal by Dharm-Datta et al[25] to start all military patients with suspected ant-CECS on a comprehensive conservative approach without ICP measurements. In the Dutch military health care system this may lead to a 70% reduction of the number of ICP measurements performed. Next to saving costs, such a reduction of ICP measurements may be advantageous in terms of reducing potential complications of the procedure, such as pain and hematoma formation.[14,15]

Further research will be necessary to determine whether these results also apply to the outcome of surgical treatment because the scope of the current study is limited to ICP measurement before commencement of a conservative treatment program. If, however, at a later stage symptoms of ERLP persist despite conservative treatment and surgical therapy is considered, measurement of ICP of the anterior compartments might still be warranted, depending on locally applied surgical protocols.[25] However, several studies have indicated that ICP values of the anterior compartment are of limited importance for surgical outcome.[21,23,28] Extending the current research question to military patients who were treated surgically could aid further understanding of the relationship between ICPs in the anterior compartment and ERLP treatment.

Contrary to the ICP value 1 minute after provocative exercise, the patient reported SANE score at intake was identified as a significant factor predicting primary treatment outcome (ie, return to active duty) in the presented multivariable model (P=.01) (see table 1). This SANE score was negatively associated with the primary treatment outcome. In other words, a low SANE score at intake reduced the chance of return to active duty after completion of the conservative treatment program. More extensive research is warranted to validate the SANE score as predictor of conservative treatment.

Next to providing more insights in absolute ICP values in the anterior compartment of patients with anterolateral leg pain, this study adds to the growing body of evidence that conservative treatment for chronic ERLP can be effective and safe. Earlier it was thought no form of conservative treatment was helpful for ant-CECS, but now several articles show positive and promising results for gait retraining programs, especially in the military.[8-10,29,30] Diebal et al[8] were the first to report positive effects of gait retraining for ant-CECS; all 10 participants (100%) were able to return to base for active duty, without surgery. In our current study, 74 of 108 service members (69%) were able to return to active duty. This discrepancy is probably best explained by differences in patient selection because the current study included all referred military service members with ERLP and Diebal included only young, male, very fit cadets from officer training. In a group of 10 civilian runners with anterior exertional lower leg pain, Breen et al[29] reported that 70% were able to run 30 minutes without pain 1 year after a 6-week gait retraining program. In the 2 previous studies and current data, no conversion from chronic to acute compartment syndrome was reported. This

is a rare, but potentially devastating condition, described in several case reports.[11-13]

Study limitations

This study performed with a historic cohort in a military health care setting is subject to typical limitations. Clearly, generalization of findings to civilian athletes must be done with caution because the current study population has a clear defined priority of approaching ERLP with a nonoperative treatment. Also, like other military studies, female patients were underrepresented in the current cohort. Bias might have been introduced in this study by the use of nonvalidated means of diagnosis, namely a single absolute ICP measurement rather than the change of ICP pressures before and after exertion. Also, ICP measurements are currently performed in the absence of a globally accepted evidence-based ICP protocol and cutoff values. However, in the absence of a validated criterion standard, the use of measurements taken 1 minute after exercise is considered an acceptable diagnostic approach.[16] The use of "return to active duty" as primary treatment outcome might have added additional bias. With this outcome measure, the presence of residual symptoms, the necessity for activity modifications, or the subjective experience of limitations are not clearly defined. Nevertheless, retaining service members in active duty is very relevant for armed forces in a time when many units are challenged to keep the ranks filled. With these drawbacks in mind, the authors are of the opinion that the current study, expanding on earlier work in the military,[20] substantiates a change in clinical care for service members with ERLP in the Netherlands and possibly other military care organizations around the world.

Conclusions

In military service members with chronic ERLP, a single ICP value in the anterior compartments of the legs 1 minute after exercise was not associated with the outcome of a comprehensive conservative treatment program. Conservative treatment did not lead to any case of acute on chronic exertional compartment syndrome. In this group of patients ICP measurement of the anterior compartment can be safely postponed until conservative treatment has failed and surgical treatment is considered.

Suppliers

a. Stryker Intracompartmental Pressure Monitor System; Stryker.
b. IBM SPSS Statistics, version 26; IBM Corporation.

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