Intracompartmental Pressure Measurements in 501 Service Members with Exercise-related Leg Pain

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ABSTRACT

Chronic exertional compartment syndrome (CECS) is one of the recalcitrant overuse injuries of the legs. CECS is traditionally diagnosed with an intracompartmental pressure measurement (ICPM). The primary objective of this article was to report the relationship between exertional compartment pain and intracompartmental pressure in young service members. This study is a descriptive analysis of patient records from a central military hospital from 2013 to 2016 (study design: historic cohort; level of evidence, 3). A total of 573 young service members with exercise-related leg pain were evaluated. An ICPM of at least one muscular compartment was performed in 501 patients (87%) 1 min after a standardized running test. CECS (32%), medial tibial stress syndrome (MTSS) + CECS (27%), and MTSS (21%) were the most common diagnoses. In the CECS category, most patients (68%) had ICPM values >35 mm Hg in both anterior and deep posterior compartments, 22% had isolated CECS of the anterior compartments, and the others had combinations of pressures >35 mm Hg in one or more of the four leg compartments (9%). Comparison of exertional pain scores with the ICPM showed a negligible correlation for the anterior compartments (Spearman rank correlation coefficient = 0.257, confidence interval = 0.191–0.327). Service members rated needle pain of the ICPM procedure as moderate: median pain rating 5 out of 10 (range 1–10). This score did not significantly differ between men and women ($P = 0.409$) and was not different if only anterior compartment versus multiple compartments were measured ($P = 0.236$). There is a negligible correlation between exertional compartment pain level and intracompartmental pressure in the leg. Current advice to avoid or minimize ICPM due to needle pain concerns does not appear warranted.

INTRODUCTION

Exercise-related leg pain (ERLP) is a group of recalcitrant overuse injuries in the armed forces and young athletes (1). In the Royal Netherlands Armed Forces, the most prevalent diagnoses in the ERLP group are medial tibial stress syndrome (MTSS), chronic exertional compartment syndrome (CECS), and a combination of these two, whereas stress fractures of the tibia are extremely rare (2). An estimation of CECS in the U.S. military service is that one in every 2000 members is diagnosed with CECS every year (3).

The definition of CECS is repetitive pain and pathologically elevated pressure in a muscular compartment during physical exercise, which returns to normal with cessation of the activity. CECS can present in any muscular compartment of the human body, but it is most prevalent in the anterior compartment of the leg (4). The gold standard for CECS diagnosis is an intracompartmental pressure measurement (ICPM) in the first minute postexercise (5). Previous recommendations to improve the diagnostic accuracy of ICPM include standardization of the preceding exercise test (6) and having the patient exercise to the limit of tolerable pain (7). The accepted criterion for diagnosis and potential surgical treatment of CECS is a pressure of 35 mm Hg 1 min postexercise, measured with a Stryker® pressure measurement device (8).

It has been reported that there is no statistical relationship between severity of symptoms and resting compartment pressures (9). However, although a strongly positive statistical relationship is supposed, no previous studies have reported the relationship between exertional pain and ICPM 1 min postexercise. Finally, ICPM has been reported to be sufficiently uncomfortable to warrant limiting multiple needle insertions (10). However, actual needle pain for the procedure has never been reported numerically.

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The objective of this study was to report the relationship between exertional compartment pain and intracompartmental pressure in young service members suspected of CECS of the legs. In addition, we assessed the needle pain of the ICPM procedure, for both men and women.

METHODS

This study has a historic (retrospective) cohort design. It was performed in the Central Military Hospital (CMH) Department of General Surgery of the Royal Netherlands Armed Forces, Utrecht, the Netherlands. International law does not require approval of an ethical board for this study.

Organization of Care

The Royal Netherlands Armed Forces has a diagnostic and treatment protocol for ERLP coordinating physicians and physical therapists working in outlying primary care clinics with sports medicine and other specialists in the Central Medical Hospital (CMH). This protocol describes that service members with ERLP be referred to the CMH if conservative therapy has not been successful within 6 months (2). Since 2011, the CMH has offered a specialty clinic for service members with ERLP. A multidisciplinary team of surgeon, primary care sports medicine physician, and physiatrist evaluates patients in a one-stop shop setting. Diagnostic imaging is ordered if stress fractures, malign, or vascular disorders are suspected. This is in a small percentage of cases. After medical clearance, a sports medicine physician supervises the patient in a standardized running test on a treadmill to pain tolerance and performs an ICPM of compartments suspected for CECS (see descriptions below). All patient information is stored in an electronic patient record. On the basis of the evaluations, patients may be referred to any of four treatment arms: surgery in the CMH, outpatient conservative treatment in the Military Sports Medicine department, inpatient conservative treatment in the Military Rehabilitation Center, or referral back to their original military base to reengage with primary care.

Running Leg Pain Profile

The Running Leg Pain Profile (RLPP) is the pain scoring system used to diagnose military patients with ERLP. Patients are asked every minute to give a pain score of 0–10 for four (or six) regions of the legs (Fig. 1). The RLPP assists in pinpointing an accurate diagnosis and also provides information on the severity of symptoms: MTSS is suspected when pain is reported in regions 2 and 3, and anterior CECS is suspected with pain in regions 1 and 4. Combined symptoms may indicate concurrence of the two diagnoses. The RLPP is performed with a standardized treadmill protocol (Table 1). This protocol comprises running and marching and is designed to reproduce symptoms to the limit of tolerable pain in the military patient group. The test is performed in running shoes, shorts, and a T-shirt (11).

ICPM

Before commencement of the exercise test, all locations indicated for pressure measurement are anesthetized with 1–2 mL xylocaine 1.0%. ICPM is always conducted in the first minute postexercise, with a Stryker® pressure measurement device. Pressures are recorded when the device shows a constant number, approximately 10 s after introduction of the needle in a particular compartment. The patients are supine, with the knees at the edge of the table and the legs hanging vertically toward the floor. Pressure measurements of the deep posterior compartment are done through the anterior compartment. Thereby, the skin is penetrated only once for measurement of both the anterior and the deep posterior compartment. From July 1, 2014, every patient was asked to score ICPM needle pain on a scale of 0–10, immediately after completion of the procedure (see Video, Supplemental Digital Content 1, Intracompartmental pressure measurement, http://links.lww.com/TJACSM/A27).

Figure 1: The RLPP, a pain scoring system used to diagnose patients with ERLP. Patients are asked every minute to give a pain score of 0–10 for four regions of the legs. The vertical line indicates the medial tibial border.

Inclusion

Medical records were searched for all patients with ERLP seen by the CMH from January 1, 2013 through December 31, 2016. From all ERLP patients, the following information was obtained from the medical records: sex (male/female), age (yr), height (m), weight (kg), most symptomatic activity, number of legs involved, previous treatments, ICPM values, diagnosis, proposed treatments, and center of next referral.

Statistics

Demographic characteristics and symptoms were described with appropriate measures of central tendency and dispersion. The measured ICPM values and experienced RLPP were presented graphically by means of a box and whiskers plot. In addition, the Kruskal–Wallis test was used to test if the ICPM values in the different groups of pain scores (0–10) were significantly different from each other during the RLPP. The Spearman rank correlation coefficient (r) was used to determine the correlation between ICPM values and exertional compartment pain. In advance, we decided a correlation of 0.90 to 1.00 is very high, 0.70 to 0.90 is high, 0.50 to 0.70 is moderate, 0.30 to 0.50 is low, and 0.00 to 0.30 is a negligible correlation. Needle pain of the ICPM procedure was described with median interquartile ranges (IQR) and minimum/maximum values, male and female scores were compared with the Mann–Whitney U test. Statistical analysis was performed using SPSS statistical software version 23.0 (IBM Corporation). Alpha level of significance was set at 0.05 for all statistical analyses.

RESULTS

In a period of 4 years, 573 service members with ERLP were seen for a diagnostic intake and treatment suggestions.

TABLE 1.
Treadmill Protocol and Template to Record the RLPP Scores in this Study.

Velocity $km \cdot h^{-1}$	Slope %	Time	Anterior Compartment Right	Medial Tibial Border Right	Medial Tibial Border Left	Anterior Compartment Left	Calve Right (Optional)	Calve Left (Optional)
5	1	0′55″						
6	1	1′55″						
7	1	2′55″						
8	1	3′55″						
9	1	4′55″						
10	1	5′55″						
11	1	6′55″						
12	1	7′55″						
12	5	8′55″						
12	5	9′55″						
7,5	5	10′55″						
7,5	5	11′55″						
12	1	12′55″						
12	1	13′55″						
Finish	Time:							

Table 2 shows selected information from the electronic patient records. Male patients made up 89% (508/573) of the patient group. The median age was 26 years (IQR 7, range 19–58). The average duration of ERLP symptoms upon initial presentation to the CMH was 23.5 months (range 1–240). The most commonly reported exacerbating activity was running (279/452, 62%). The majority of patients (433/533, 78%) reported bilateral symptoms. The most common previously prescribed treatments included rest (397/424, 94%), physical therapy (300/424, 71%), inlays/orthotics (278/424, 66%), a progressive running schedule (206/424, 49%), and compression stockings (125/424, 30%).

In 451 (79%) of 573 cases, all diagnostic procedures were completed on the same day. Figure 2 shows the clinical diagnoses assigned to these chronic ERLP patients, of which CECS (145/451, 32%), MTSS + CECS (121/451, 27%), and MTSS (95/451, 21%) were the most common diagnoses. In the CECS category, most patients (98/145, 68%) had ICPM values >35 mm Hg 1 min after exercise in both the anterior and the deep posterior compartments, 22% (32/145) had isolated CECS of the anterior compartments, the others (13/145, 9%) had combinations of pressures >35 mm Hg in one or more of the four leg compartments. Isolated CECS of the deep compartments or the lateral (peroneal) compartments was very rare, accounting for ~1% of all CECS cases (2/145). After diagnosis in the CMH, most patients were referred to the Military Sports Medicine Department for additional outpatient conservative treatment (274/376, 73%). Gait analysis and gait retraining (218/320, 68%), a progressive running schedule (174/320, 54%), and extracorporeal shockwave therapy of the medial tibial border (152/320, 48%) were the therapeutic modalities most often suggested by the multidisciplinary clinic.

Figures 3A and 3B show the relationship between the pain score in the last minute of the RLPP versus the pressure measured immediately after exercise in anterior compartments and deep posterior compartments, respectively. Figure 3A shows a statistical relationship between increasing median ICPM value (thick black lines) and increased RLPP anterior compartment pain. The Kruskal–Wallis test ($P = 0.000$) revealed that the median pressure values in at least one group varies from the rest. However, Figure 3A also illustrates that some individuals with zero or low compartmental pain scores had intracompartmental pressures far above 35 mm Hg (open circles top left). Other individuals had high compartment pain scores (e.g., 8 or above on the RLPP locations 1 and 4) but low intracompartmental pressures (e.g., below 20 mm Hg). Additional statistical evaluation with the Spearman rank correlation coefficient produced a negligible correlation between ICPM scores and compartment pain scores ($r = 0.257$, with a confidence interval of 0.191–0.327). Figure 3B shows that there is no correlation between pain scores and pressures in the deep posterior compartments (Kruskal–Wallis test, $P = 0.115$).

An ICPM of at least one muscular compartment of one leg was performed in 501 (87%) of 573 patients. A score for ICPM

TABLE 2.
Patient Characteristics.

	No.	%	Average SD
All ERLP patients (N = 573)	573	100	
Sex (male)	508	89	
Sex (female)	65	11	
Age, all	573		28.2 ± 6.7
Height (male), cm	495		181.9 ± 6.7
Height (female), cm	62		169.8 ± 6.3
Weight (male), kg	499		82.8 ± 16.4
Weight (female), kg	63		71.4 ± 10.0
BMI (male)	471		25.7 ± 3.0
BMI (female)	61		24.7 ± 3.2
Duration of symptoms in months	546		23.8 ± 31.5
ICPM in at least one compartment	501	87	
Most symptomatic activity (n = 452)			
Running	279	62	
Fast marching	57	13	
Walking	44	10	
Running and marching	13	3	
Other	59	13	
Number of legs involved (n = 553)			
Both legs	433	78	
Left leg	52	9	
Right leg	68	12	
Previous treatments, top 5 (n = 424)			
Rest	397	94	
Physical therapy	300	71	
Inlays	278	66	
Progressive running schedule	206	49	
Compression stockings	125	30	
Pain scores of ICPM (n = 316)			
Anterior compartment only (M + F)	13		6.0 ± 2.2
Anterior + deep compartments (M + F)	303		5.2 ± 2.4*
Clinical diagnosis in first visit (n = 451)			
CECS (ICPM >35 mm Hg)	145	32	
MTSS + CECS (ICPM > 35 mm Hg)	121	27	
MTSS	95	21	
Other, e.g., myogenic calve pain, Achilles tendon	44	10	
Compartment pain (ICPM < 35 mm Hg)	26	6	
MTSS + compartment pain (ICPM < 35 mm Hg)	20	4	
Proposed treatments, top 5 (n = 320)			
Observational gait analysis + gait retraining	218	68	
Progressive running schedule	174	54	
Shockwave	152	48	
Evaluate/renew running shoes	133	42	
Video gait analysis + gait retraining	98	31	
Referred to (n = 376)			
Military sports medicine (outpatient)	274	73	
Military rehabilitation clinic (inpatient)	42	11	
Return for treatment on base	34	9	
CMH, surgery	26	7	

*No significant difference between men and women; P = 0.418.
BMI, body mass index; M + F = male + female.

needle pain was obtained in 316 patients; in the majority of cases (303/316, 96%), an ICPM of both the anterior and deep compartment was performed. The median score for needle pain of the ICPM procedure was 5 (IQR 4, range 1–10). This score did not significantly differ between men and women (P = 0.409) and was not different if only the anterior compartments were measured (P = 0.236).

DISCUSSION

This study reports on the relationship between exertional leg pain and intracompartmental pressures in a group of young service members with recalcitrant ERLP, suspected for CECS.

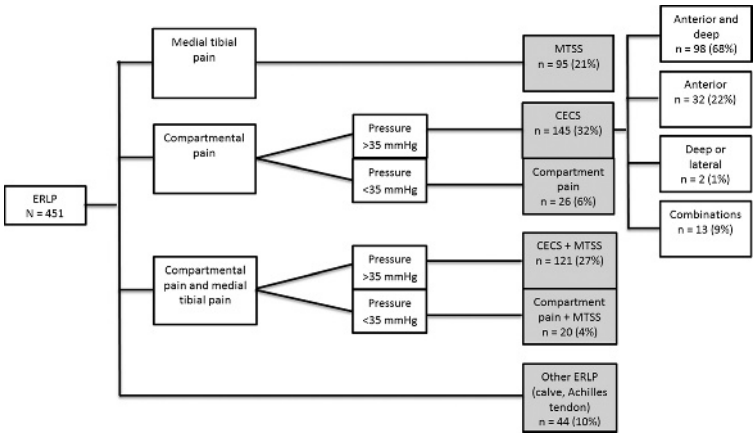

Figure 2: Clinical diagnoses assigned to the chronic ERLP patients (n = 451).

The most important findings are that there is no direct correlation between exertional compartment pain level and intracompartmental pressure in the leg. Patients with high compartment pain may have high or low intracompartmental pressures, and patients without symptoms may have very high pressures. A further finding is that current advice to avoid or minimize ICPM due to needle pain concerns does not appear warranted.

ICPM, a standardized pain assessment tool (i.e., RLPP), and a standardized running protocol are useful in subcategorizing patients with exertional leg pain (Fig. 2). In particular, the patient group with high anterior compartment pain but low anterior compartment pressures 1 min after exercise (Fig. 3A) has not been described before. The patient group with high medial tibial pain but low deep posterior compartment pressures (Fig. 3B) has been described earlier (12). However, medial tibial scores (2 and 3 of the RLPP) may not reflect pain in the deep compartment but could also represent pain originating from the medial tibial border, caused by MTSS. The anterior tibial scores (1 and 4 of the RLPP) most likely do reflect pain in the anterior compartment because of anatomical proximity. Although there is a statistical relationship between the RLPP pain scores of the anterior compartments and the ICPM measurements at group level (Fig. 3A, P = 0.000), this does not mean that the physician confronted with an individual patient with exertional anterior compartment pain can assume high intracompartmental pressures. Patients with high anterior pain scores but low anterior compartment pressures are described as "compartment pain" patients in our five subcategory scale. These findings further challenge our current understanding of CECS. CECS is a multifactorial problem and involves more than just increased ICPM (13). New diagnostic terminology, such as "Biomechanical Overload Syndrome," may be appropriate for those patients with high compartment pain and low pressures (14). Patients with very high pressures

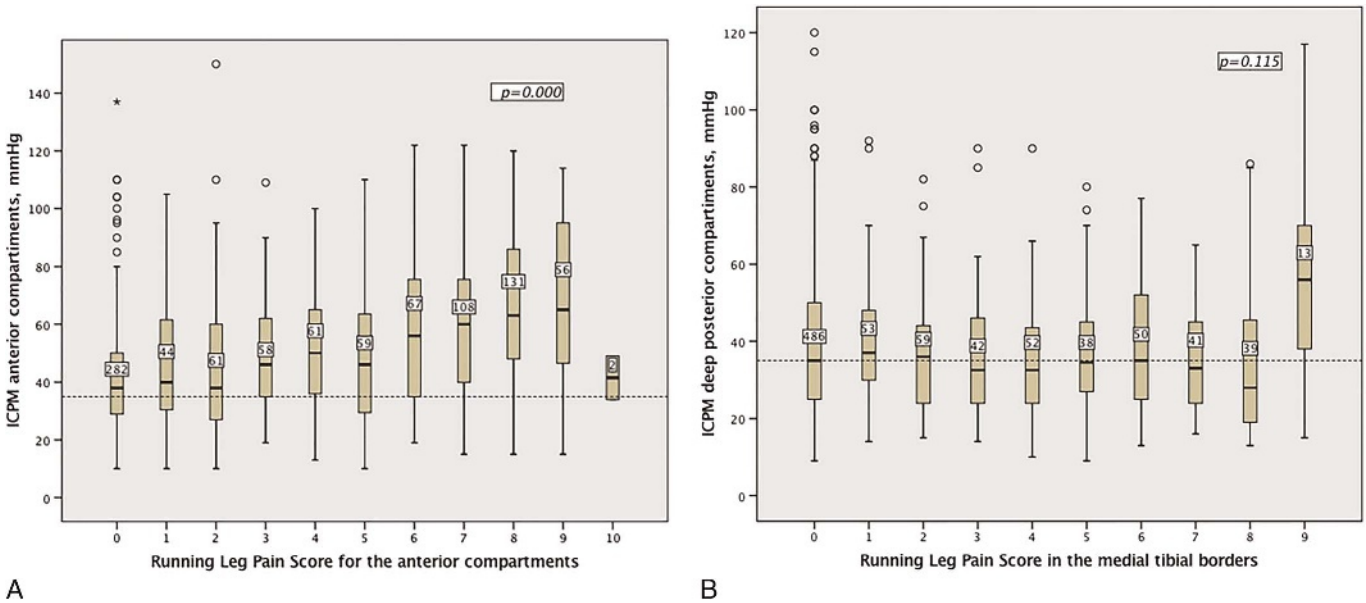

Figure 3: A, Pain scores of patients with ERLP during running (RLPP locations 1 and 4) versus pressure in the anterior compartments in 929 legs. Open circles on top left indicate individuals with very high pressure measurements, but no (zero) or low anterior compartment pain; 35 mm Hg is the diagnostic threshold for CECS. Kruskal–Wallis test P = 0.000. B, Pain score of patients with ERLP during running (RLPP locations 2 and 3) versus pressure in the posterior deep compartments in 873 legs. Note the lack of correlation between median pressure (dark lines) and pain score (Kruskal–Wallis test P = 0.115); 35 mm Hg is the diagnostic threshold for CECS.

(e.g., >100 mm Hg), but no pain at all, bring into question whether we actually know what "normal" values are (11, 15).

This study is the first to report scores on ICPM needle pain. On a scale of 0–10, 303 patients scored pain from ICPM of the anterior and deep compartments combined with a median: 5 (range 1–10). This score can be interpreted as "moderate" pain. Hence, the common practice of limiting ICPM to one leg and as few compartments as possible to reduce patient discomfort would seem unjustified (10).

In 4 years' time, 501 service members underwent ICPM in one or more compartments of the leg. This large number of cases establishes the CMH as a major center for CECS care. Other centers with similar reported cohort sizes include the Maxima Medisch Centrum (Veldhoven, The Netherlands), which frequently publishes research on CECS in civilian patients and has an electronic patient database starting in 2001 (16). In a military setting, the British Defense Medical Rehabilitation Centre near Epsom in Surrey specializes in treating service members with ERLP (17).

A distinct finding from this study is that the average duration of symptoms for ERLP patients initially presenting to the CMH was nearly two years, despite local military medical protocols dictating that service members with ERLP be referred to the CMH if conservative therapy has not been successful within 6 months. More effort is necessary to educate base physicians about the ERLP protocol to avoid diagnosis and treatment delay.

The strength of this study is that it reports on a large number of ERLP patients and a large number of ICPMs. In addition, according to our clinical experience, this article presents an accurate description of the current state of affairs in the treatment of young service members with ERLP in the Royal Netherlands Armed Forces, and it adds information that may help to unravel the pathophysiological mechanism of CECS. Limitations of this study include its single center source and the queried database with incomplete records resulting in slightly different numbers for each analysis (see Table 1).

Future studies could further examine the best treatment options for patients with high exertional compartment pain but low intracompartmental pressures. For example, surgical fasciotomy, long considered the gold standard for exertional compartment syndrome, would not seem warranted in this subgroup of patients.

CONCLUSION

In 4 years' time, 573 Dutch service members were referred to secondary care for evaluation of chronic ERLP and treatment suggestions. Almost 59% of these service members were diagnosed with CECS or CECS + MTSS. ICPM, a standardized pain assessment tool (i.e., the RLPP), and a standardized running protocol are useful in subcategorizing patients with exertional leg pain. Subsets of patients with ERLP may have high compartment pressures and low compartment pain scores, or vice versa. The clinical treatment ramifications of these categories is still evolving and further research into optimal treatment strategies for all subgroups of patients is warranted. Current advice to avoid or minimize ICPM due to needle pain concerns does not appear warranted.

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