Fasciotomy for Lateral Lower-leg Chronic Exertional Compartment Syndrome

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Fasciotomy for Lateral Lower-leg Chronic Exertional Compartment Syndrome

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ABSTRACT

Exercise-induced lower leg pain may be caused by chronic exertional compartment syndrome (CECS). Anterior or deep posterior compartments are usually affected. Knowledge about CECS of the lateral compartment (lat-CECS) is limited and outcome after fasciotomy is unknown. The purpose of this study is to report on success rates of fasciotomy in patients with lat-CECS. Surgical success rates in patients with lat-CECS diagnosed with a dynamic intracompartmental pressure (ICP) measurement were studied using a questionnaire (success: excellent or good as judged by the patient; unsuccessful: moderate, fair or poor). We conducted ICP measurements in 247 patients for suspected lat-CECS, of whom 78 were positively diagnosed. Following exclusion ($n = 11$), 30 of the eligible 67 patients completed the questionnaire. Bilateral (70 %, $n = 21/30$) exertional pain (97 %, $n = 29$) and a feeling of tightness (93 %, $n = 28$) were the most frequently reported symptoms. Four years after fasciotomy, severity and frequency of symptoms had dropped significantly. Long-term surgical success was reported by 33 % ($n = 10$; excellent $n = 4$, good $n = 6$). Seventy-three percent ($n = 22$) had resumed sports activities (9 same level, 13 lower level). In conclusion, a fasciotomy for lat-CECS was successful in the long term in just one of three operated patients in this retrospective study.

Introduction

One of eight young patients with exercise-provoked leg pain suffers from a chronic exertional compartment syndrome (CECS) [18]. This syndrome is characterized by severe pain and tightness that is located in one or more lower leg compartments [27]. Patients with anterior and deep flexor CECS (ant-CECS, dp-CECS) are most frequently affected [2]. A recent study found that 12 % of all CECS patients had involvement of the third compartment, termed the lateral lower leg compartment (lat-CECS) [24].

In general, results of an invasive, dynamic intracompartmental pressure measurement (ICP) are pivotal in the management of CECS. Pathologically elevated muscle compartment pressures according to predefined cut-off points are used for diagnosis and may support therapeutic measures [17]. If conservative therapy includ-

ing rest and physical therapy fails, a fasciotomy is considered the therapy of choice [3]. Although results of surgery for ant-CECS and dp-CECS are well documented, the surgical literature on lat-CECS is exceedingly scarce. Surgical success rates on a total of only 57 lat-CECS patients were identified from the literature (► **Table 1**) [7, 11–14, 16, 22, 25]. Interestingly, most surgical data were obtained from operations on patients with a combined ant-CECS/lat-CECS syndrome. Conversely, just one case series of small volume ($n = 3$) reported on operative results for isolated lat-CECS [13].

Our department of sports medicine is a referral centre for evaluation of CECS. Since 2001, demographics, baseline characteristics and ICP have been prospectively entered in a digital database. The aim of this study was to evaluate surgical outcomes in patients who were operated on for CECS involving the lateral compartment.

► **Table 1** Literature involving treatment for lat-CECS.

Author, year	Isolated lat-CECS / combined lat-ant-CECS (n/n patients)	Lateral compartments (n)	Population	Treatment	Surgical outcome, (n)
Martens et al., 1984	Not reported (NR)	3	Athletes	Conservative and fasciotomy	NR
Detmer et al., 1985	NR	29	Athletes	Fasciotomy	NR
Turnipseed et al., 1989	NR	245	Predominantly athletes	Fasciotomy and fasciectomy	NR
Verleisdonk et al., 1996	NR	2	Predominantly military	Fasciotomy	NR
Micheli et al., 1999	3 / 16	NR	Female athletes	Fasciotomy	1 excellent, 2 fair
Mouhsine et al., 2005	0 / 4	7	Athletes	Minimal incision fasciotomy	"Good results in all 4 patients at 2 years follow up"
Packer et al., 2013	0 / 26	NR	NR	Conservative and fasciotomy	18 successful (excellent/good), 8 not successful (fair/poor)
Maffulli et al., 2016	0 / 8	11	Athletes	Fasciotomy	All improved EQ-5D and SF-36 scores
Total	3/54	297			

Materials and Methods

Since January 2001, characteristics including history, physical examination and ICP-measurements of patients referred to our facility for suspected CECS have been recorded in an electronic database. At the end of 2012, this database contained 1,384 patients. The first patient with a possible lat-CECS was evaluated in November 2001. For inclusion in the present study, patients were required to have at least one ICP above one of 3 threshold levels associated with CECS (Pedowitz criteria; ≥ 15 mmHg at rest, ≥ 30 mmHg 1 min after provocative exercise, or ≥ 20 mmHg 5 min after provocative exercise) [17]. Details of our dynamic intracompartmental pressure measurement procedure were recently published [24]. All included patients had undergone a fasciotomy of the lateral compartment. A history of vascular claudication, significant lower leg trauma or surgery of the lower leg other than for CECS were considered exclusion criteria. The study was conducted according to the Declaration of Helsinki. The local ethics committee judged that evaluation of the study protocol was not required because this effort was considered a normal evaluation of the patient-related outcome (PRO) and an audit of the results. The hospital's medical ethical committee judged that the regulations specified in the Medical Research Involving Human Subjects Act (WMO) did not apply to the study protocol [8].

If history, physical examination and ICP were consistent with lat-CECS, the patient was informed of the diagnosis and management options. A portion of the patients decided on conservative therapy including rest, cooling, inlays or physical therapy. If the patient preferred an operation, he/she was offered the option to undergo the procedure in their referring facility or in our hospital. They were informed of the specifics of an operation and possible complications including hematoma, superficial peroneal nerve damage and wound infection.

If patients decided to undergo an operation in our hospital, they underwent an outpatient procedure under general or spinal anaesthesia. One hour before the operation, they received 2500 IU of a low-molecular heparin subcutaneously. Outlines of the lateral com-

partment including bony landmarks (fibular head, lateral malleolus) were identified by palpation and marked on the skin with a skin marker. The area of pain was determined by palpation. After sterile exposure, access to the fascia was obtained using two to three 4–5 cm longitudinal incisions. The length and number of incisions depended on the length of the leg and area of pain following pre-operative palpation. The peroneal fascia was freed bluntly and opened in a longitudinal manner using a knife and scissors beyond the area of pain (► **Fig. 1a**). The superficial peroneal nerve that runs underneath ventral portions of this fascia was usually identified, thus preventing accidental damage. The skin incisions were closed intracutaneously (► **Fig. 1b**) followed by a one-day compressive bandage that was replaced by compressive stockings thereafter, 24 h a day for 2 weeks. A bilateral lat-CECS was surgically treated in a one-stage procedure. If a patient was diagnosed with a combined lateral and anterior CECS, an anterior tibialis muscle fasciotomy was performed simultaneously via a separate one-inch incision as reported [6]. If a patient suffered from a combined lat/dp-CECS, a fasciotomy of the lateral and deep flexor compartment was performed on one side. If successful, and if the patient suffered from a bilateral CECS, the contralateral side followed 6 weeks later. After one day, normal daily activities were allowed except for sports activities or jumping. If wound recovery was satisfactory at the 2-week postoperative outpatient check-up, patients were instructed to start bicycling and light jogging. Between week 4 and 8 post-operatively, the patient was allowed to intensify the exercise regimen to maximal levels.

In December 2013 and January 2014, efforts were made to contact all eligible patients by telephone. Once they were given study information and had provided verbal consent, they were asked to complete a set of questions that was sent later that day by mail or email. The questionnaire was developed to investigate the severity and frequency of 5 cardinal symptoms including pain, muscle weakness, cramps, a feeling of tightness and paraesthesia as experienced before surgery and at present using a verbal rating scale [10]. Terms such as "all the time", "most of the time", "half of the time", "sometimes" and "never" were used to quantify frequency whereas the

► **Fig. 1** **a** The peroneal fascia is opened in a longitudinal manner using knife and scissors. **b** The skin incisions are closed intracutaneously.

terms “not at all”, “mild”, “moderate”, “severe” and “very severe” were used to grade severity. Patients also judged outcome at present using the adjectives “excellent”, “good”, “fair” or “poor”. If patients had undergone a two-staged bilateral surgical procedure, they were instructed to report the outcome after completion of both operations. If patients had undergone an additional operation for ant-CECS or dp-CECS at a later time point, they were instructed to report on residual symptoms in the lateral aspect of the lower leg, being the area reflecting the lateral compartment. Non-responders received two reminders by telephone, mail or email.

We calculated the area under the 4-point pressure curve in each patient having a complete set of 4 ICP measurements as suggested ($0.5 \times \text{resting pressure} + \text{pressure immediately after exercise} + \text{pressure 1 min after exercise} + 0.5 \times \text{pressure 5 min after exercise}$) [27].

In order to approximate the overall effect of surgery, VRS scores of symptom frequency and symptom severity were converted into a numerical scale (symptom frequency: all the time = 5 points, most of the time = 4, half of the time = 3, sometimes = 2, never = 1; symptom severity: very severe = 5 points, severe = 4, moderate = 3, mild = 2, not at all = 1). For instance, if a patient experienced pain

before the operation “most of the time” (4 points) as “severe” (4 points), his preoperative pain symptom score was $16 (4 \times 4)$. Conversely, if he judged his pain after the operation as “sometimes” (2 points) “severe” (4 points), he received a postoperative score of 8 (2×4). The outcome after surgical treatment was defined as a success if patients reported the end result as excellent or good. In contrast, the outcome was unsuccessful if an average, fair or a poor result was achieved.

Statistical analysis was performed using SPSS statistics 22.0.0.0 (SPSS Inc. Chicago, IL, USA). Normality of distribution was determined using the Shapiro-Wilk test. If normal, data were expressed as mean $\pm$ standard deviation (SD). If not, median and range were used. Differences between groups with respect to patient characteristics were analysed using Pearson’s chi-squared test, or by Fisher’s exact test if expected values in more than one cell of the cross table were below 5. A Mann-Whitney U test was used to compare differences between two independent groups (either responders versus non-responders, or lat-CECS only versus combined lat-CECS) and to compare not normally distributed dependent variables that were either ordinal or continuous. An independent samples t-test was used to determine if there was a statistically significant improvement in symptom score after operation. A Kruskal-Wallis H test was used to determine if there was a relation between preoperative area under the ICP curve and postoperative outcome. Similarity of the shape of distribution was assessed by visual inspection of a boxplot. If distribution was similarly shaped, differences in medians were investigated. If distribution was not similarly shaped, differences in mean rank were investigated. A $p \leq 0.05$ was considered significant for all tests.

Results

In our facility, a total of 1,384 ICP measurements for suspected CECS were performed during the 12-year study period and 247 (18 %) were related to an ICP of the lateral lower leg compartment (► **Fig. 2**). Based on the Pedowitz criteria, 78 patients were diagnosed with lat-CECS (12 % of all positive ICPs, 78/678). Two-thirds of this patient group (64 %, $n = 50$) had a combination of a lat-CECS with a CECS of the anterior (ant-CECS; 42 %, 33/78), deep posterior (dp-CECS; 9 %, 7/78) or both compartments (13 %, 10/78). In contrast, an isolated lat-CECS was detected in the remaining 36 % ($n = 28$). After exclusion of 11 patients for reasons depicted in the flow diagram, 67 patients were eligible for the long-term follow-up via questionnaire. A total of 30 patients responded to this questionnaire (45 % response rate). Questionnaires from the nonresponding patients were not available because their current whereabouts were unknown ($n = 11$) or repetitive requests were not acknowledged for unknown reasons ($n = 26$).

Sex distribution among patients undergoing a fasciotomy for lat-CECS ($n = 30$) was almost equal (53 % female, ► **Table 2**). The median age at the time of diagnosis was 25 years (range 17–65), and follow-up was conducted at 4 years (median, range 1–11 years). Ten patients had an isolated lat-CECS. If lat-CECS patients suffered from a combined CECS ($n = 20$), the anterior compartment was frequently involved (90 %, 18/20). The combination dp-CECS with lat CECS was determined in just 4 patients (20 %).

► **Fig. 2** Flow chart of patients undergoing an intracompartmental pressure measurement (ICP) for suspected chronic exertional compartment syndrome (CECS) of the lateral lower-leg compartment.

The majority of the 30 lat-CECS patients reported bilateral symptoms (80 %, 24/30). Two frequently reported symptoms were exertional pain (97 %, 29/30) and a feeling of tightness (93 %, 28/30). Patients also often experienced exertional muscle weakness (73 %, 22/30), paresthesias (70 %, 21/30) and/or cramps (70 %, 21/30). Except for one patient, all patients participated in sports activities. Prior to the operation, half (52 %, 15/29, 1 missing value) of the patients had to completely terminate sports activities, 24 % (7/29) pursued sport at a lower level, 10 % (3/29) pursued sport with complaints and 14 % had changed sports activities due to lat-CECS. No statistically significant differences in baseline characteristics were found between patients with an isolated lat-CECS or a combined compartment syndrome (age $U = 77.0$, $z = 1.015$, $p = 0.328$; BMI $U = 106.5$, $z = 0.540$, $p = 0.599$; rest ICP $U = 137.5$, $z = 1.652$, $p = 0.100$; ICP 1 min after exertion $U = 65$, $z = 0.617$, $p = 0.570$; ICP 5 min $U = 108.5$, $z = 1.505$, $p = 0.135$).

Sixty percent (18/30) received surgery in referring institutions and 40 % (12/30) in our facility. Decrease in severity of symptoms after a median 4 years after surgery are depicted in ► **Fig. 3**. Pain, muscle weakness, cramps, feeling of tightness and paraesthesia all

showed a significant decrease in mean pain score after fasciotomy (minimal 50 %). Long-term surgical success was attained in 33 % of cases ($n = 10$; excellent $n = 4$, good $n = 6$; 30 % of all lat-CECS patients (3/10), 35 % of all combined CECS patients (7/20)). Conversely, the operation was deemed unsuccessful in 67 % ($n = 20$; moderate $n = 10$, fair $n = 7$, poor = 3). A total of 73 % (22/30) had resumed sports activities (9/30 same level, 13/30 lower level). There was no significant difference in outcome between isolated lat-CECS or combined syndrome ($p = 0.768$, $\chi^2(1) = 0.087$). Moreover, there was no significant difference in symptom relief between both groups ($p > 0.05$). Also, no statistically significant associations between outcome and sex ($p = 0.442$), uni- or bilaterality ($p = 0.372$), operating hospital (Máxima Medical Center, 42 % successful, referral hospital 28 % successful; $p = 0.461$) or level of sports ($p = 1.00$) were present. Lastly, there was no statistically significant difference in preoperative “area under the ICP curve” between the five postoperative outcome groups at long-term follow-up (“excellent”, “good”, “moderate”, “fair”, “poor”; $\chi^2(4) = 3.918$, $p = 0.417$). Nevertheless, mean rank increased from “poor” (7.00), “fair” (9.50), “moderate” (11.31), “good” (12.25), to “excellent” (17.33). This

► **Table 2** Characteristics of questionnaire responders.

N°	Affected compartment *	Sex (f/m)	Age at baseline (y)	BMI (kg/m ²)	Unilateral/Bilateral	Level of sport baseline	Outcome operation
1	Lat	F	49	21	Unilateral	Social	Good
2	Lat	F	30	24	Bilateral	Social	Poor
3	Lat	F	35	28	Bilateral	Social	Average
4	Lat	M	28	21	Bilateral	Local	Fair
5	Lat	F	23	31	Bilateral	National	Good
6	Lat	M	25	25	Bilateral	International	Average
7	Lat	F	65	32	Bilateral	Social	Poor
8	Lat	F	22	30	Bilateral	National	Average
9	Lat	M	18	22	Bilateral	International	Average
10	Lat	M	25	27	Bilateral	Local	Excellent
11	Dp-lat	F	19	21	Bilateral	National	Excellent
12	Ant-dp-lat	F	43	33	Unilateral	Social	Average
13	Ant-lat	M	22	26	Unilateral	Social	Excellent
14	Ant-lat	F	30	33	Unilateral	Social	Average
15	Ant-lat	M	21	23	Bilateral	Local	Average
16	Ant-lat	F	30	34	Bilateral	Social	Fair
17	Ant-dp-lat	F	19	27	Bilateral	Local	Fair
18	Ant-lat	F	23	23	Bilateral	Social	Fair
19	Ant-dp-lat	F	40	38	Bilateral	No	Poor
20	Ant-lat	F	17	25	Bilateral	International	Fair
21	Ant-lat	F	23	26	Bilateral	Local	Fair
22	Ant-lat	M	23	26	Bilateral	National	Average
23	Ant-lat	M	18	24	Bilateral	Local	Good
24	Ant-lat	M	48	26	Bilateral	Social	Average
25	Ant-lat	M	26	24	Bilateral	Local	Average
26	Ant-lat	M	36	35	Bilateral	Local	Excellent
27	Ant-lat	M	50	26	Bilateral	Social	Good
28	Dp-lat	F	23	24	Bilateral	Local	Good
29	Ant-lat	M	17	24	Unilateral	National	Fair
30	Ant-dp-lat	M	24	28	Unilateral	National	Good
(* lat = lateral, ant = anterior, dp = deep posterior)							

suggestive trend was not observed 3 months after surgery ($\chi^2(4) = 1.066$, $p = 0.900$; “poor” (7.50), “fair” (11.92), “moderate” (12.10), “good” (12.50), “excellent” (10.33)).

Discussion

The aim of this study was to report on outcome in patients with lower leg lat-CECS undergoing a fasciotomy. The present report is the first large case series evaluating results of surgery for isolated lat-CECS or for a combined CECS including the lateral lower leg compartment. Four years after surgery, the severity and frequency of CECS-specific symptoms such as pain and tightness had dropped by at least 50 %. However, just one third of the patients rated the outcome as excellent or good even though most patients (73 %) had resumed sports activities.

Chronic exertional compartment syndrome is most common in young healthy athletes with a predisposition in women [5, 7, 19, 20, 26]. Patients in our study population diagnosed with

lat-CECS were 25 years old (median, range 17–65). The vast majority participated in sports activities and suffered from bilateral (80 %) exertional pain (97 %, 29/30) and a feeling of lower leg tightness (93 %, 28/30). Sex distribution was almost equal (53 % female). A striking 60 % of all patients with lat-CECS also had an ant-CECS. Therefore each patient with exertional complaints of the antero-lateral lower leg may suffer from a lat-CECS justifying a low threshold for ICP testing.

The Pedowitz criteria are the gold standard for diagnosing CECS. These generally used cut-off points were arbitrarily determined and a correlation with treatment outcome was never attained. Also, the Pedowitz criteria were never specified for the 3 different lower leg compartments [17]. Moreover, a recent study showed significant improvement of symptoms after fasciotomy in patients with normal ICP measurements who were treated surgically based on clinical examination only [15]. Therefore, the diagnostic value of the Pedowitz criteria is questionable. Overestimating the number of lat-CECS patients using this diagnostic tool may partially explain

the present suboptimal outcome. We did not find a statistically significant correlation between preoperative ICP (area under the ICP curve) and surgical outcome for CECS in the lateral compartment. However, mean rank associated with degree of result increased substantially (poor, (7.0) to excellent (17.33)), possibly suggesting an improved outcome in patients with higher preoperative ICP. From January 2013 onwards we initiated a prospective study analysing surgical outcome in lat-CECS that may possibly allow us to determine whether ICP values predict surgical outcome.

There is some controversy regarding the exact frequency of the three types of lower leg CECS. Some studies suggest that the lateral compartment is second after the anterior compartment [5, 9, 23]. One study reported an up to 35 % lat-CECS rate [2]. It is therefore somewhat strange why published results on surgery for this supposedly frequent type of lower leg CECS are scarce [11, 13, 14, 16]. To date, the outcome of isolated CECS of the lateral compartment is reported in just 3 individuals, one with an excellent and 2 with a fair postoperative result [13]. In the largest population of combined lat-CECS patients ($n = 26$, all ant/lat-CECS), 73 % were satisfied with the results of surgery [16]. Our population is the largest to date, consisting of 30 lat-CECS patients of whom 10 had an isolated lat-CECS. Even though all preoperative symptoms showed a significant decrease in mean pain score after fasciotomy, only a disappointing one of three patients undergoing fasciotomy rated their overall postoperative improvement 4 years later as excellent or good. In two patients with a failed operation (fair and poor, respectively), ICP measurements were again conducted demonstrating normality. Clinical reassessment did not provide an alternative diagnosis. The possibility of a condition other than CECS causing the symptoms such as neurovascular entrapments or medial tibial stress syndrome must always be considered, because the differential diagnosis of persisting exertional leg pain is rather extensive [1, 4].

The presence of untreated CECS is often very incapacitating for active individuals and negatively affects quality of life [11, 14]. Up to 85 % of CECS patients are unable to practice sports activities at the desired level before surgery [11, 21]. The aim of the operation is to facilitate a return to a desired level of sports activity, but success is not always achieved. Just half of all operated CECS patients returned to sports practice in one study [14]. One other study of operated dp-CECS patients reported that only 38 % returned to pre-injury levels and 41 % performed at lower levels [28]. The present study found that only 30 % were able to resume sports activities at a similar level compared to their preoperative condition, whereas the remaining 70 % performed at a lower level than previously. The profound effect of the presence of CECS on quality of life should not be underestimated in these active individuals. Therefore more prospective research is needed to improve surgical outcome and return to desired level of sports.

The retrospective nature of this study is associated with several limitations. The response rate was only 45 %. Moreover, there is a risk of both recall bias and information bias because patients were asked to recall severity and frequency of preoperative symptoms, sometimes even up to 10 years after the operation. Furthermore, documentation of baseline characteristics was occasionally incomplete and operations were done at various institutions. Therefore, a prospective study concisely monitoring patient characteristics and surgical results for lat-CECS was set up from January 2013 on-

wards. Results of this prospective study will determine whether outcome of fasciotomy for lat-CECS is indeed inferior compared to other types of lower leg CECS.

Conclusion

Four years after surgery, just one in three patients who underwent a fasciotomy for lateral lower-leg chronic exertional compartment syndrome rated their outcome as excellent or good.

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Conflict of interest

The authors declare no conflict of interest.

References

- [1] Apigian AK, Landry GJ. Basic data underlying decision making in nonatherosclerotic causes of intermittent claudication. *Ann Vasc Surg* 2015; 29: 138–153
- [2] Bong MR, Polatsch DB, Jazrawi LM, Rokito AS. Chronic exertional compartment syndrome: Diagnosis and management. *Bull Hosp Jt Dis* 2005; 62: 77–84
- [3] Brennan FH Jr., Kane SF. Diagnosis, treatment options, and rehabilitation of chronic lower leg exertional compartment syndrome. *Curr Sports Med Rep* 2003; 2: 247–250
- [4] Burrus MT, Werner BC, Starman JS, Gwathmey FW, Carson EW, Wilder RP, Diduch DR. Chronic leg pain in athletes. *Am J Sports Med* 2015; 43: 1538–1547
- [5] Davis DE, Raikin S, Garras DN, Vitanzo P, Labrador H, Espandar R. Characteristics of patients with chronic exertional compartment syndrome. *Foot Ankle Int* 2013; 34: 1349–1354
- [6] de Bruijn JA, van Zantvoort AP, Winkes MB, Raaymakers L, van der Cruysen-Raaijmakers M, Hoogeveen AR, Scheltinga MR. Feasibility and safety of an operative tool for anterior chronic exertional compartment syndrome treatment. *Foot Ankle Int* 2015; 1475–1482
- [7] Detmer DE, Sharpe K, Sufit RL, Girdley FM. Chronic compartment syndrome: Diagnosis, management, and outcomes. *Am J Sports Med* 1985; 13: 162–170
- [8] Harriss DJ, Macsween A, Atkinson G. Standards for ethics in sport and exercise science research: 2018 update. *Int J Sports Med* 2017; 38: 1126–1131
- [9] 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: 176–184
- [10] Loos MJ, Houterman S, Scheltinga MR, Roumen RM. Evaluating postherniorrhaphy groin pain: Visual Analogue or Verbal Rating Scale? *Hernia* 2008; 12: 147–151
- [11] Maffulli N, Loppini M, Spiezia F, D'Addona A, Maffulli GD. Single minimal incision fasciotomy for chronic exertional compartment syndrome of the lower leg. *J Orthop Surg Res* 2016; 11: 61

- [12] Martens MA, Backaert M, Vermaut G, Mulier JC. Chronic leg pain in athletes due to a recurrent compartment syndrome. *Am J Sports Med* 1984; 12: 148–151
- [13] Micheli LJ, Solomon R, Solomon J, Plasschaert VF, Mitchell R. Surgical treatment for chronic lower-leg compartment syndrome in young female athletes. *Am J Sports Med* 1999; 27: 197–201
- [14] Mouhsine E, Garofalo R, Moretti B, Gremion G, Akiki A. Two minimal incision fasciotomy for chronic exertional compartment syndrome of the lower leg. *Knee Surg Sports Traumatol Arthrosc* 2006; 14: 193–197
- [15] Orlin JR, Oen J, Andersen JR. Changes in leg pain after bilateral fasciotomy to treat chronic compartment syndrome: A case series study. *J Orthop Surg Res* 2013; 8: 193
- [16] Packer JD, Day MS, Nguyen JT, Hobart SJ, Hannafin JA, Metzl JD. Functional outcomes and patient satisfaction after fasciotomy for chronic exertional compartment syndrome. *Am J Sports Med* 2013; 41: 430–436
- [17] Pedowitz RA, Hargens AR, Mubarak SJ, Gershuni DH. Modified criteria for the objective diagnosis of chronic compartment syndrome of the leg. *Am J Sports Med* 1990; 18: 35–40
- [18] Qvarfordt P, Christenson JT, Eklof B, Ohlin P, Saltin B. Intramuscular pressure, muscle blood flow, and skeletal muscle metabolism in chronic anterior tibial compartment syndrome. *Clin Orthop Relat Res* 1983; (179): 284–290
- [19] Raikin SM, Rapuri VR, Vitanzo P. Bilateral simultaneous fasciotomy for chronic exertional compartment syndrome. *Foot Ankle Int* 2005; 26: 1007–1011
- [20] Reneman RS, Wieberdink J, Strackee J. [Chronic anterior and chronic lateral compartment syndrome of the lower leg; a frequently not recognized syndrome?]. *Ned Tijdschr Geneesk* 1971; 115: 543–551
- [21] Slimmon D, Bennell K, Brukner P, Crossley K, Bell SN. Long-term outcome of fasciotomy with partial fasciectomy for chronic exertional compartment syndrome of the lower leg. *Am J Sports Med* 2002; 30: 581–588
- [22] Turnipseed W, Detmer DE, Girdley F. Chronic compartment syndrome. An unusual cause for claudication. *Ann Surg* 1989; 210: 557–563
- [23] Turnipseed WD. Diagnosis and management of chronic compartment syndrome. *Surgery* 2002; 132: 613–619
- [24] van Zantvoort AP, de Bruijn JA, Winkes MB, Dielemans JP, van der Cruijssen-Raaijmakers M, Hoogveen AR, Scheltinga MR. Isolated chronic exertional compartment syndrome of the lateral lower leg: a case series. *Orthop J Sports Med* 2015; 3: 2325967115617728
- [25] Verleisdonk E, van den Helder CJ, Hoogendoorn HA, van der Werken C. [Good results of fasciotomy in chronic compartment syndrome of the lower leg]. *Ned Tijdschr Geneesk* 1996; 140: 2513–2517
- [26] Waterman BR, Liu J, Newcomb R, Schoenfeld AJ, Orr JD, Belmont PJ Jr. Risk factors for chronic exertional compartment syndrome in a physically active military population. *Am J Sports Med* 2013; 41: 2545–2549
- [27] Winkes MB, Hoogveen AR, Houterman S, Giesberts A, Wijn PF, Scheltinga MR. Compartment pressure curves predict surgical outcome in chronic deep posterior compartment syndrome. *Am J Sports Med* 2012; 40: 1899–1905
- [28] Winkes MB, van Zantvoort AP, de Bruijn JA, Smeets SJ, van der Cruijssen-Raaijmakers M, Hoogveen AR, Scheltinga MR. Fasciotomy for deep posterior compartment syndrome in the lower leg: A prospective study. *Am J Sports Med* 2016; 44: 1309–1316