Forefoot Running Improves Pain and Disability Associated With Chronic Exertional Compartment Syndrome

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Investigation performed at Keller Army Community Hospital, West Point, New York

Background: Anterior compartment pressures of the leg as well as kinematic and kinetic measures are significantly influenced by running technique. It is unknown whether adopting a forefoot strike technique will decrease the pain and disability associated with chronic exertional compartment syndrome (CECS) in hindfoot strike runners.

Hypothesis: For people who have CECS, adopting a forefoot strike running technique will lead to decreased pain and disability associated with this condition.

Study Design: Case series; Level of evidence, 4.

Methods: Ten patients with CECS indicated for surgical release were prospectively enrolled. Resting and postrunning compartment pressures, kinematic and kinetic measurements, and self-report questionnaires were taken for all patients at baseline and after 6 weeks of a forefoot strike running intervention. Run distance and reported pain levels were recorded. A 15-point global rating of change (GROC) scale was used to measure perceived change after the intervention.

Results: After 6 weeks of forefoot run training, mean postrun anterior compartment pressures significantly decreased from 78.4 ± 32.0 mm Hg to 38.4 ± 11.5 mm Hg. Vertical ground-reaction force and impulse values were significantly reduced. Running distance significantly increased from 1.4 ± 0.6 km before intervention to 4.8 ± 0.5 km 6 weeks after intervention, while reported pain while running significantly decreased. The Single Assessment Numeric Evaluation (SANE) significantly increased from 49.9 ± 21.4 to 90.4 ± 10.3, and the Lower Leg Outcome Survey (LLOS) significantly increased from 67.3 ± 13.7 to 91.5 ± 8.5. The GROC scores at 6 weeks after intervention were between 5 and 7 for all patients. One year after the intervention, the SANE and LLOS scores were greater than reported during the 6-week follow-up. Two-mile run times were also significantly faster than pre-intervention values. No patient required surgery.

Conclusion: In 10 consecutive patients with CECS, a 6-week forefoot strike running intervention led to decreased postrunning lower leg intracompartmental pressures. Pain and disability typically associated with CECS were greatly reduced for up to 1 year after intervention. Surgical intervention was avoided for all patients.

Keywords: chronic exertional compartment syndrome; anterior compartment syndrome; forefoot running; leg pain

Despite nearly 100 years since Dr Edward Wilson wrote one of the first clinical encounters pertaining to chronic exertional compartment syndrome (CECS) of the lower leg during his return trip from the South Pole, the true cause of CECS remains elusive. Chronic exertional compartment syndrome is a well-recognized condition that chiefly affects young, physically active people. While several hypotheses exist that explain the development of tissue ischemia present with CECS, the primary accepted belief is that exercise increases intramuscular pressure, which in turn compromises circulation, prohibits muscular function, and causes pain and disability in the lower leg.5,54

There are 4 distinct compartments located in the lower leg: the anterior, lateral, superficial posterior, and deep posterior. Of these, the anterior compartment is the most commonly reported location of CECS and is the most frequently studied in regard to intramuscular pressure.18,32 The classic symptom of CECS is a complaint of increasing lower leg pain upon physical exertion in conjunction with the absence of other physical signs and symptoms at rest.5 As the problematic exertional activity (typically running) continues, compartment pressures incrementally increase, which presumably causes increasing lower leg pain, sensory abnormalities, and muscle weakness, eventually resulting in a premature cessation of the activity.5

References 3, 18, 19, 23-25, 41, 48, 52, 55, 56.
Upon termination of the activity, the compartment pressures decrease, pain subsides, and the functional examination quickly returns to “normal”.19,25 Eighty-seven percent of patients with CECS participate in sports, and runners account for 69% of these cases.12,50 Despite the prevalence of CECS in athletic populations, a successful long-term nonoperative treatment option does not exist.12,29,36,45,47,49,58 Anti-inflammatory drugs, stretching, prolonged rest, ultrasound, electrical stimulation, orthotics, and massage have resulted in limited success in treating CECS.23,29,48,55 Because none of these nonoperative approaches have yielded consistently positive outcomes, a patient with CECS who does not choose to modify his or her activity level may elect to undergo surgical management in the form of a fasciotomy.29,48 While the majority of patients do well after surgery, approximately 3% to 17% of people who have undergone a fasciotomy experience less than favorable outcomes such as ankle pain, decreased sensation at the incision site, numbness at the lateral lower leg, hypersensitivity to touch, paresthesia in the legs, and recurrence of symptoms.12,29,45,49 In addition, another consequence is the significant hiatus from athletic activity to allow for tissue healing and the gradual return to activity thereafter. An effective nonoperative management approach could eliminate these potential postsurgical complications.

One nonoperative approach for CECS that has not thoroughly been investigated is the alteration of running technique. It is well known that running technique can significantly influence the kinematic and kinetic measures used to quantify gait biomechanics.2,6,10,11,21,35 A forefoot strike, as opposed to a hindfoot strike, gait pattern leads to decreased ground-reaction forces, stride length, and ground-contact time.51,54 Running technique also influences the anterior compartment pressures of the leg.32,53 Specifically, the anterior compartment pressures are decreased when a forefoot contact pattern is utilized when running.32 Eccentric activity of the tibialis anterior, which is the primary muscle contained within the anterior compartment, is also decreased with a forefoot strike gait pattern.51,54 Theoretically, incorporating the use of a systematic running instructional model (which focuses on landing on the forefoot as opposed to the heel) as part of a nonoperative treatment strategy may buffer the elevation of compartment pressures with running. If successful, this approach could allow those suffering from CECS the ability to increase run duration and intensity without symptoms and greatly reduce the need for fasciotomy for this condition. The purpose of this study was to evaluate the effectiveness of a forefoot running technique intervention on reducing the symptoms associated with CECS. It was hypothesized that this alteration in running technique would result in decreased anterior compartment pressures, decreased pain levels, and increased run duration, thereby reducing the need for surgical intervention for those diagnosed with CECS.

MATERIALS AND METHODS

Patients

On the basis of history and physical examination, all patients diagnosed with CECS by an orthopaedic surgeon and indicated for surgical intervention (fasciotomy) were prospectively enrolled in the study. Common criteria to assist with the diagnosis of CECS include symptom onset within the first 10 to 30 minutes of exercise and symptom resolution or degradation within several minutes after exercise cessation.4,5,14,40,57 To be included in this study, patients had to be military members required to pass the biannual Army Physical Fitness Test, which includes a timed 2-mile run test. They had to report a minimum of a 6-month history of recurrent anterior and/or lateral leg pain and tightness in one or both legs that worsened with running. Pain had to occur within the first 30 minutes of running and lead to cessation of desired exercise. In addition, all symptoms had to completely resolve within 15 minutes upon cessation of running. The physical examination finding had to be “normal” at rest (ie, full ankle and knee range of motion [ROM] and strength, no tenderness or compartment tightness to palpation, and full functional ability to squat and hop without symptoms). Exclusion criteria included previous fasciotomy or other lower extremity surgery, any medical condition that could cause lower extremity swelling, creatine supplementation in the past 2 months, any injury that would affect running tolerance besides CECS, any respiratory issue that could effect running tolerance, and current use of nonsteroidal anti-inflammatory drugs (NSAIDs). Exclusion criteria also included an abnormal finding on any imaging modality (ie, radiographs or magnetic resonance imaging); however, there were no requirements to order imaging studies for screening purposes.

Each participant was given a verbal explanation of the study protocol and provided written informed consent before testing. Approval was granted by the Institutional Review Board at Keller Army Community Hospital.

Preintervention Measurements

Shortly after the clinical diagnosis of CECS and enrollment in the study, baseline measurements were taken for each patient by the same practitioner, which included height, weight, and blood pressure. Baseline kinematic and kinetic measurements as well as anterior compartment pressures were obtained. Self-report questionnaires including the Lower Leg Outcome Survey (LLOS) and the Single Assessment Numeric Evaluation (SANE) for the leg were also completed. Because no validated subjective outcome measures were available to specifically assess orthopaedic conditions of the leg, a team of physical therapists, athletic trainers, and orthopaedic surgeons created the LLOS to evaluate leg conditions such as CECS and tibial stress injuries (Appendix A, available in the online version of this article at http://ajs.sagepub.com/supplemental/). This
12-item survey is patterned after a validated knee outcome survey and uses several questions from that instrument.30 Raw scores are tallied and reported as percentages (100% signifying full function without limitation).

Compartment Pressures and Running Performance. To objectify and confirm the clinical diagnosis of CECS, preexercise and postexercise intracompartmental pressures of the anterior compartments were measured by the same orthopaedic surgeon using a side-port needle (Intra-Compartmental Pressure Monitor, Stryker, Kalamazoo, Michigan). This device has been shown to demonstrate acceptable levels of accuracy and precision.7,47 During intracompartmental measurements, the patient was positioned in a long seated position (knee fully extended, with both the knee and ankle completely relaxed). Because the entry point for the anterior compartment is located anterolaterally to the midtibia and over the anterior tibialis muscle belly, measurements of the leg were taken to find the location of the midtibia on each patient; the needle was then inserted 3 cm lateral to the midtibial crest. The pressure monitor was zeroed at a 90° angle, and the skin was penetrated at a 45° angle through the fascia until a “pop” was felt, which represented entry into the fascia. The compartment pressures were obtained after the injection of 0.3 to 0.5 mL of saline into the compartment to allow equilibration with the interstitial fluids.

Postexercise measurements were collected after a run at a self-selected speed using a treadmill (Life Fitness 97Ti, Franklin Park, Illinois). All patients ran until they reported a pain level of 7 of 10 on a verbal rating scale. Ratings of perceived exertion and pain levels were also collected immediately after the run using the Borg rating of perceived exertion (RPE) scale8 and visual analog scale for pain, respectively. Postexercise anterior compartment pressure measurements were taken within 1 minute after run cessation. Average running speed and total run distance were documented after completion of the treadmill running test.

Kinematic and Kinetic Measurements. Kinematic (step length, step rate, and support time) and kinetic (vertical ground-reaction force, impulse, and weight acceptance rate) data were collected utilizing an instrumented treadmill (Kistler Gaitway, Winterthur, Switzerland) within 2 days after the pressure measurements. Patients ran at the same self-selected speed that was established during baseline testing. Ground-reaction force (GRF) data were sampled at 250 Hz and filtered using a zero-lag, fourth-order low-pass Butterworth filter with a cutoff frequency of 10 Hz. Kinematic and kinetic data were collected for 50 strides before running termination occurred (after symptoms reached 7/10 on a verbal rating scale).

Self-Report Questionnaires. Self-report questionnaires included the LLOS and the SANE. The LLOS specifically evaluates conditions of the leg such as CECS and tibial stress injuries (Appendix A, available online). The SANE is a global question that asked patients in this study the following: “On a scale from 0-100, how would you rate your lower leg with 100 being normal?”

Intervention

The intervention in this study was instruction and training to adopt a forefoot strike running technique. The aim was to eliminate the initial hindfoot strike, which would presumably reduce the eccentric activity of the anterior compartment musculature of the leg. Additional emphasis included increasing the running step rate to 3 steps per second and using the hamstrings muscle group to pull the foot from the ground versus push the foot off the ground using the gastrocnemius and soleus muscles (Figures 1 and 2).41,42 Specific training drills and exercises designed to teach forefoot striking consisted of weight shifting, falling forward, foot tapping, high hopping, and running with the EZ run belt (Pose Tech Corp, Miami, Florida) and are described previously.14,42,43 The patients also practiced running barefoot and were provided with verbal cueing to “run quietly” to eliminate the tendency to heel strike upon ground contact. A digital metronome was utilized to stabilize step cadence at 180 steps per minute. A video camera was used to record individual running form to allow the physical therapist to demonstrate forefoot technique running errors (ie, overstriding, heel striking). Exercise instruction was conducted 3 times per week for approximately 45 minutes each session and took place over the course of 6 weeks. A typical training session during the first 3 weeks consisted of approximately 15 to 20 minutes of the specific training drills followed by forefoot running practice intervals for distances of 0.25 km with a 2-minute walking period between intervals. The verbal cueing, digital metronome, and video camera were used during the running practice time. During the last 3 weeks of training, the focus was on gradually progressing running speed and endurance as patients were able to maintain proper running form for longer distances between walking bouts. The online video demonstrates the transition of one patient from a hindfoot striking gait pattern to a forefoot striking pattern.

Postintervention Measurements

Six-Week Follow-up. At 6 weeks after the intervention, the physical examination, intracompartmental pressures, kinematic and kinetic measurements using the instrumented treadmill, and self-report questionnaires were repeated; the protocol was identical to that used to obtain the baseline measurements. The primary purpose of collecting kinematic and kinetic data was to substantiate that a treatment effect occurred or that running form had indeed changed compared with baseline from implementing the forefoot running intervention. For the treadmill running test and postexercise pressure measurements, patients ran until they reported a pain level of 7 of 10. If a pain level of 7 of 10 was not reached during the posttest, the running test was terminated at 5 km or if the patient requested to stop.

In addition to the repeated measures, a 15-point global rating of change (GROC) scale was included at the completion of the study to measure the patients’ perceived change and overall improvement.31 The scale allowed the patient to rate his or her change from “a very great deal worse”
to “a very great deal better.” The minimal clinically important difference for the GROC scale is a 3-point change from baseline.31

One-Year Follow-up. At a minimum of 1 year after the intervention, participants were contacted to complete an activity questionnaire, the LLOS, and the SANE. In addition, the military requires a biannual physical fitness test that includes a timed 2-mile run. The performance on this test before entering the study and 1 year after intervention was gathered from institutional records.

Statistical Analysis

Descriptive statistics for variables and measures of central tendency for continuous variables were calculated to summarize the data. Because this study did not use a random sampling technique and the sample size was small, nonparametric tests were utilized for statistical analysis. To evaluate the primary outcome variables (intracompartmental pressures, running time and distance, and pain) and the biomechanical variables (step length, step rate, vertical GRF, impulse, and rate of loading), a Wilcoxon signed–rank test was used to analyze differences between baseline and at 6 weeks postintervention. A Wilcoxon signed–rank test was also used to evaluate the secondary outcome variables (LLOS and SANE) between baseline and at 6 weeks and at 1 year (after intervention) as well as the 2-mile run time between baseline and at 1 year after intervention. The level of significance was set at $P < .05$. All statistical analyses were performed using SPSS statistics software (Version 11.5, SPSS Inc, Chicago, Illinois).

RESULTS

Ten consecutive patients (8 male, 2 female) accepted enrollment into the study. Baseline patient characteristics are included in Table 1. All patients reported a history of CECS symptoms for a minimum of 10 months. All patients participated in self-selected athletic activities as required by the United States Military Academy, which included sports such as football, basketball, crew, equestrian, and grappling. Patients reported that participation in these sports did not increase CECS symptoms; however, one patient elected to participate in grappling instead of soccer because of leg pain experienced during soccer. All patients were required to run 2 miles for their biannual physical fitness test. Training for and attempting to pass this event during testing was reportedly the primary symptom-producing activity. Patients reported not being able to complete the 2-mile run test because of pain or reported being able to complete the run only through immense pain in order to pass the event.

The initial physical examination at rest was unremarkable in all cases (ie, full ankle, knee, and hip ROM and strength, no tenderness or compartment tightness to palpation, and full functional ability to squat and hop without symptoms). No excessive wear pattern was evident for any of the running shoes, and one patient in the study wore custom orthotics (several years’ history of use).

During the initial running examination, all patients demonstrated a hindfoot striking gait pattern. All patients

![Figure 1. A hindfoot striking runner at ground contact (A) and toe off (B). Notice the extended knee and dorsiflexed ankle at ground contact (muscular activity is increased in the tibialis anterior). The ankle is plantarflexed, and the runner is pushing off from the ground, which increases the activity of the gastrocnemius/soleus muscles. Reprinted with permission from the Pose Tech Corporation.](image1)

![Figure 2. A forefoot striking runner at ground contact (A) and toe off (B). The ankle is in a more neutral position at ground contact, therefore decreasing the activity of the tibialis anterior. At toe off, the foot is pulled from the ground by the hamstring muscles, and no push off occurs. Reprinted with permission from the Pose Tech Corporation.](image2)

<table>
<thead>
<tr>
<th>Table 1: Patient Characteristics (n = 10)</th>
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<td>Characteristic</td>
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<td>Age, y</td>
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<tr>
<td>Weight, kg</td>
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<td>Height, cm</td>
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<td>Body mass index, kg/m²</td>
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<td>Baseline systolic blood pressure, mm Hg</td>
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<td>Baseline diastolic blood pressure, mm Hg</td>
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*All values are means ± standard deviations.*
reported the onset of leg pain within the first 5 minutes of running, which progressively worsened while running. Physical examination findings immediately upon running cessation in all cases included increased pain with passive ankle plantar flexion, increased pain with resisted dorsiflexion, and increased tightness and tenderness to palpation in the anterior compartment of the leg. Other findings that occurred infrequently (fewer than 3 cases for each) included paresthesia, weakness with resisted dorsiflexion, pain with passive inversion or eversion, and pain with resisted plantar flexion, inversion, or eversion. Symptoms resolved in all cases within 15 minutes of running cessation.

Of the 10 patients enrolled, 8 had bilateral symptoms, while 2 had unilateral symptoms. For those patients with bilateral symptoms, there were no significant differences in compartment pressures between the right and left legs at baseline resting ($P = .78$), baseline after running ($P = .81$), postintervention resting ($P = .49$), or postintervention after running ($P = .71$). For the statistical analysis of compartment pressures, the mean value was taken for the patients with bilateral leg symptoms.

Intracompartmental Pressures

There was a significant difference ($P = .001$) in intracompartment pressures between preintervention resting (40.4 $\pm$ 11.4 mm Hg) and preintervention after running (78.4 $\pm$ 32.0 mm Hg). There was no significant difference ($P = .33$) in intracompartment pressures between 6 weeks after intervention resting (35.9 $\pm$ 11.7 mm Hg) and 6 weeks after intervention postrunning (38.4 $\pm$ 11.5 mm Hg). There was a significant difference ($P = .002$) between preintervention after running (78.4 $\pm$ 32.0 mm Hg) and 6 weeks postintervention after running (38.4 $\pm$ 11.5 mm Hg) (Figure 3). The increase in postrunning intracompartmental pressure compared with resting pressure 6 weeks after intervention (3.7 $\pm$ 6.9 mm Hg) was significantly less ($P = .002$) than the increase in postrunning pressure preintervention (38.0 $\pm$ 24.7 mm Hg).

Running Performance

Running distance increased significantly ($P < .001$) from preintervention (1.4 $\pm$ 0.6 km) to 6 weeks after intervention (4.8 $\pm$ 0.5 km) (Figure 4). Reported pain on the visual analog scale while running significantly decreased ($P < .001$) from preintervention (71.3 $\pm$ 7.9 mm) to 6 weeks after intervention (2.7 $\pm$ 5.1 mm) (Figure 4). The Borg RPE also increased significantly ($P < .001$) from baseline (13 $\pm$ 1.9) to 6 weeks after intervention (16.7 $\pm$ 1.6). No patient had to withdraw from the study because of complications or an inability to tolerate the running technique over the duration of the 6-week instructional period. The GROC scores at 6 weeks after the intervention were between 5 and 7 (quite a bit better to a very great deal better) for all patients.

Reported running distance at 1 year after intervention revealed that 8 of the 10 patients were running a minimum of 5 km 2 to 3 times per week. Regarding the 2 patients who were not running 5 km, one reported recently tearing his anterior cruciate ligament while playing soccer, and the other had sprained her ankle. Neither of these 2 patients reported running limitations before their recent injuries. Two patients reported that they completed half-marathons since their 6-week follow-up. Compared with the 2-mile run time on the Army Physical Fitness Test before beginning the study, patients completed the 2-mile run significantly faster 1 year after intervention ($P < .01$). All patients recorded a faster 2-mile run time, while 5 of 10 patients ran at least 30 seconds faster. All of the patients reported being able to return to sports participation without limitation, and no patient required a fasciotomy.

Kinematics and Kinetics

Both kinematic and kinetic changes were noted after the 6-week instructional program. As compared with the
preintervention values, step length and contact time significantly decreased ($P < .05$), while step rate significantly increased ($P < .05$) 6 weeks after intervention (Table 2). In addition, peak vertical GRF, impulse, and weight acceptance rate all significantly decreased ($P < .05$) from preintervention to postintervention (Table 2).

### Self-Report Questionnaires

The SANE was significantly greater ($P < .001$) from before intervention (49.9 ± 21.4) to both 6 weeks after intervention (90.4 ± 10.3) and 1 year after intervention (93.8 ± 11.0). Likewise, the LLOS was significantly greater ($P < .001$) from before intervention (67.3 ± 13.7) to both 6 weeks after intervention (91.5 ± 8.5) and 1 year after intervention (94.2 ± 8.2) (Figure 5). With the exception of the 2 patients who sustained unrelated injuries, all other patients reported 98 or better on the SANE and 92 or better on the LLOS at 1 year after intervention.

### DISCUSSION

After a 6-week intervention focused on forefoot strike running instruction, postrunning intracompartamental pressures of the leg were significantly reduced in 10 patients diagnosed with CECS. In addition, running distance increased over 300%, while reported pain decreased dramatically. The SANE and LLOS self-report questionnaires were both significantly improved (Figure 5). All patients after the 6-week intervention reported quite a bit better (+5) to a very great deal better (+7) on GROC scores. One year after the intervention, the SANE and LLOS self-report questionnaires were overall greater than reported during the 6-week follow-up. Two-mile run times were also significantly faster compared with preintervention values. Perhaps most importantly, surgical intervention was avoided for all patients.

The results of this study provide preliminary evidence that this nonoperative treatment approach of forefoot strike running instruction for those who have CECS can yield positive outcomes. A potential rationale for the reduction in pain and intracompartamental pressures and the resulting increase in running tolerance is the difference in foot and knee position at ground contact during a forefoot running style compared to a hindfoot running style. Kirby and McDermott found that anterior compartment pressures were significantly influenced by running style, reporting that anterior compartment pressures were increased when a hindfoot striking gait pattern was utilized. Gershuni et al found a significant increase in the anterior compartment pressures of healthy patients in the full ankle dorsiflexion and full knee extension positions. Full knee extension coupled with full ankle dorsiflexion is the exact position of a hindfoot striking runner at ground contact. This may explain the finding of increased anterior compartment pressures when using a hindfoot landing running style. In addition to a more favorable foot position (less ankle dorsiflexion) at initial ground contact, eliminating the heel strike upon ground contact by replacing it with a forefoot strike may reduce the eccentric activity of the anterior leg compartment muscles and therefore curtail the increase of anterior compartment pressures and symptoms of CECS with running.

Further research using motion analysis and muscle electromyography is necessary to substantiate this hypothesis.

The importance of intracompartamental pressure measurements to confirm the diagnosis of CECS or to make surgical determinations is debatable. While Pedowitz et al published “normal” intracompartamental pressure values, only 35% of surgeons use this criteria to diagnose people with CECS. Pressure measurements vary in some cases up to 500% potentially because of operator experience, catheter type, volume of instilled fluid, and the depth of catheter placement. Obviously, measurement reliability is enhanced by using a single experienced tester and following standardized procedures as employed in this study (intraclass correlation coefficient, .86). Regardless of whether

### Table 2

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<thead>
<tr>
<th>Kinematics</th>
<th>Preintervention</th>
<th>Postintervention</th>
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<tbody>
<tr>
<td>Step length, m</td>
<td>1.18 ± 0.08</td>
<td>1.12 ± 0.10b</td>
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<tr>
<td>Step rate, steps/s</td>
<td>2.71 ± 0.11</td>
<td>2.86 ± 0.17b</td>
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<tr>
<td>Support time, s</td>
<td>0.30 ± 0.03</td>
<td>0.28 ± 0.02b</td>
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<tr>
<td>Kinetics</td>
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<tr>
<td>Peak $v_{GRF}$, BW</td>
<td>2.40 ± 0.18</td>
<td>2.34 ± 0.22b</td>
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<tr>
<td>Impulse, BW/s</td>
<td>0.38 ± 0.02</td>
<td>0.36 ± 0.02b</td>
</tr>
<tr>
<td>Weight acceptance rate, BW/s</td>
<td>29.66 ± 5.54</td>
<td>26.43 ± 5.71b</td>
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$v_{GRF}$, vertical ground-reaction force; BW, body weight.

Denotes significant difference compared to preintervention values at $P < .05$ for all measures.
a clinician uses pressure measurements, a positive pressure test result alone is not sufficient to make a diagnosis of CECS and should never replace a meticulous history and comprehensive physical examination.22 As an interesting addendum, the results of this study suggest that there may be limited benefit in measuring pressures bilaterally for those who have bilateral symptoms of CECS. It appears that measuring intracompartmental pressure on one leg may be sufficient as there were no significant pressure differences between legs in these people at rest or after running. Future research should be conducted to examine whether pressure differences exist in the legs of those who have unilateral symptoms.

Performance outcomes were impressive in this study. With the exception of one patient, all were able to run 5 km after 6 weeks of the forefoot strike running intervention with reported verbal rating scale pain levels of <1 of 10; the single patient who was unable to complete the pre-determined running distance (ran 3.4 km) stopped because of a pre-existing patellofemoral problem. Not only did run distance increase and pain levels decrease, but also the RPE values during exercise increased. Patients were able to run harder, as demonstrated by their RPE values, without an increase in their compartment symptoms. The Borg RPE scale has been shown to be a good indicator of physical stress during aerobic training.22 Lagally et al34 found that a correlation exists between a person’s RPE and his or her heart rate, blood lactate levels, percentage of \( \text{VO}_2 \) max, and respiration rate. Given that run distance, pain levels, and RPE values all demonstrated positive outcomes, it is not surprising that the GROC score improved substantially as well. While it may be unclear how a forefoot strike running style resulted in these notable changes, this study is the first to provide evidence of a viable nonoperative treatment option for CECS. Certainly, future research is needed to support the findings of this investigation.

Future research may also be performed to examine the effects of forefoot running on other musculoskeletal conditions. Similar to our findings, many studies have demonstrated reductions in impulse, GRF, and stride length as well as an increase in step rate when adopting a forefoot versus a hindfoot strike running technique.8 It is possible that implementing a similar forefoot running intervention could improve other lower extremity stress injuries such as stress fractures or medial tibial stress syndrome. The ideal length of intervention needed to change a person’s running style is also unknown. We are not aware of any clinical trials pertaining to this topic. Based on experience and opinion, Arendse et al2 reported that 7.5 hours of training over 5 consecutive days was required to learn forefoot landing, while Dallam et al10 reported a 1-hour session for 12 weeks was necessary. We chose 6 weeks based on a pilot work of 2 previous cases.14 Anecdotally, it appeared that the majority of patients in this study had changed running style reasonably well by 3 to 4 weeks. However, running style research is in its infancy, and thus, further research is required to address these areas.

One limitation in this study is the small sample size without having a control group with which to compare treatment effects. A large randomized clinical trial is needed to confirm these findings, and planning is underway. However, anecdotal experience at our institution suggests that the majority of these patients would have elected to undergo fasciotomy for symptomatic relief with running. The fact that 10 consecutive patients dramatically improved in running performance and all avoided fasciotomy is noteworthy.

Another potential limitation is that we did not utilize motion analysis to definitively demonstrate that patients were truly employing a forefoot strike at ground contact while running. Direct visualization of patients and indirect evidence of decreased impulse and GRF, however, are consistent with the elimination of the hindfoot strike pattern and the adaptation of a forefoot strike technique.1,13,15,17,35,39,44

CONCLUSION

In 10 patients with diagnosed CECS, a 6-week forefoot running intervention performed 3 times per week for 45 minutes led to decreased postrunning lower leg intracompartmental pressures. The pain and disability typically associated with CECS were greatly decreased. All patients demonstrated large improvements on self-report questionnaires including GROC scores following the 6-week intervention. One year after the intervention, running speed and distance as well as self-report questionnaires were greater than reported during the 6-week follow-up, and surgical intervention was avoided for all cases.

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44. Romano N, Fletcher G. Runners do not push off the ground but fall forwards via a gravitational torque. Sports Biomech. 2007;6(3):434-452.


