Exertional Leg Pain in the Athlete

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February 13, 2019
Lafayette Sports Medicine Symposium

Leg Pain Case

- 16 year old female XC athlete
- Calf pain with running
- 3 months

Differential Diagnosis

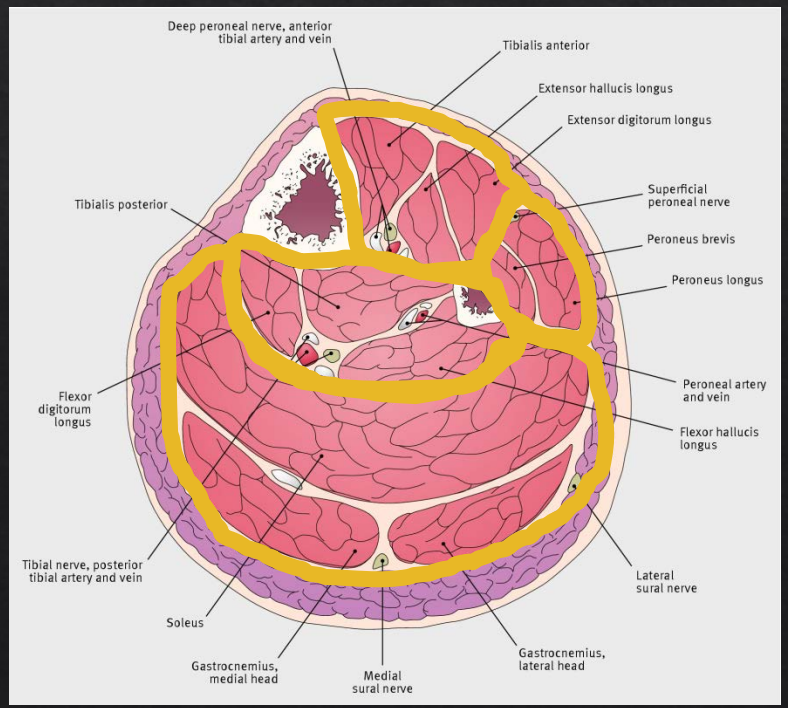
- Stress fracture
- MTSS (periostitis)
- Chronic exertional compartment syndrome
- Tenosynovitis
- Peripheral nerve entrapment
- Deep vein thrombosis
- Radiculopathy
- Arterial vascular disease
- Popliteal artery entrapment syndrome
- CRPS

Chronic exertional compartment syndrome

Background

- “A compartment syndrome is a condition in which increased pressure within a limited space compromises the circulation and function of tissues within that space”
  - Matsen 1981

Compartment	Muscle	Neurovascular Structures
Anterior	Tibialis anterior Extensor digitorum longus Extensor hallucis longus Peroneus tertius	Deep peroneal nerve Anterior tibial vessels
Lateral	Peroneus longus Peroneus brevis	Superficial peroneal nerve
Superficial Posterior	Gastroc-soleus Plantarus	Sural nerve
Deep Posterior	Tibialis posterior Flexor hallucis longus Flexor digitorum longus	Tibial nerve Posterior tibial vessels



Background


Compartment Swelling
Fascia Limits Expansion
Increase in Intra-compartmental Pressure
Elevated Venous Pressure
Decreased Arterio-Venous Gradient
Reduced Blood Flow
Ischemia and Tissue Necrosis

The Seven "P"s of Compartment Syndrome

Severe pain

Elevated compartment pressure, palpably tense

Pain with passive stretch

Paresis/paralysis

Paraesthesia (numbness)

Pulses absent (rare, ominous)

Pallor (rare, ominous)

Types of Compartment Syndrome

- Acute
  - Emergency
  - Football, hockey, rugby
- Chronic (CECS)
  - Running, endurance sports

Acute Compartment Syndrome

- Causes
  - Fracture
  - Muscle bruising/swelling
  - Reperfusion
  - Crush injury
  - Cast/bandage too tight
- Treatment
  - Emergent fasciotomy

CECS-History

- Progressive dull ache
- Localized to affected compartment
- Predicatable, occurs at same time during exercise
- Transient numbness, tingling, or weakness
- Recent increase in training duration or intensity
- Better with rest but not usually immediate

CECS-Physical Examination

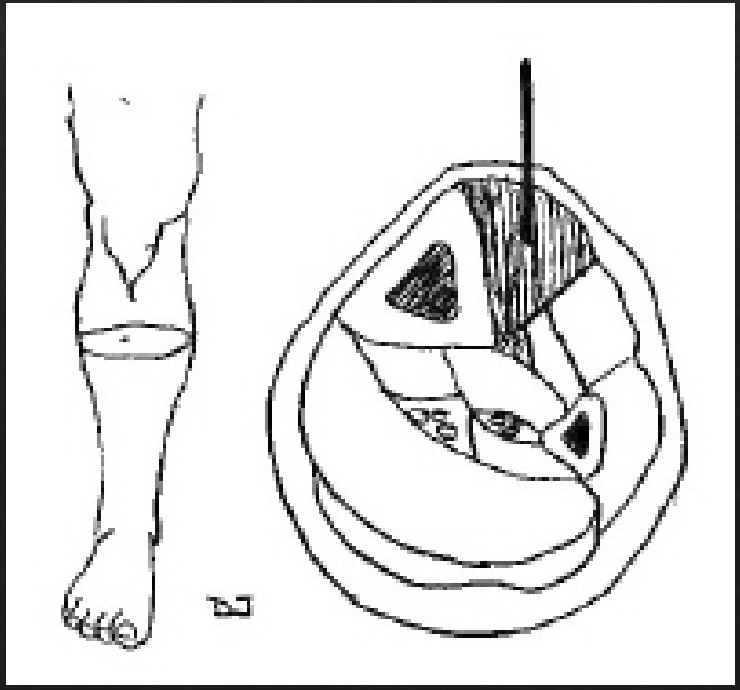
- Typically normal at rest
- Normal distal pulses
- Evidence of muscle hernias in 20-60%
- Post-exertion tenderness and increased tension in the involved compartment
- Post-exertion sensation abnormality or weakness possible in advanced cases

Compartment Testing

- Pre and post exercise measurement of compartment pressure
  - Clean the areas
  - Superficial anesthesia
  - Zero monitor in proper position
  - Enter compartment
  - Inject small amount of saline
  - Record pressure

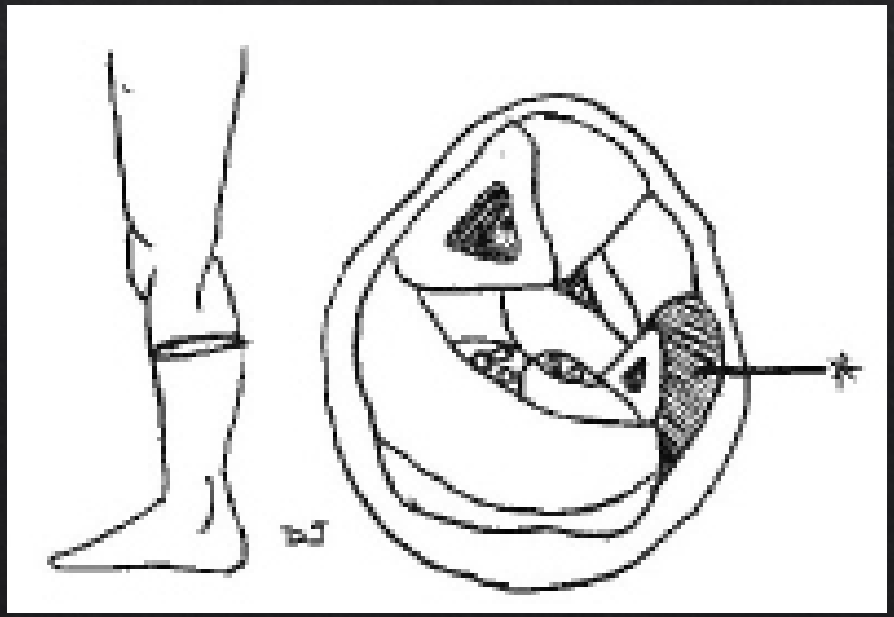
Compartment Testing

- Anterior compartment
  - Junction of proximal and middle third
  - 1cm lateral to anterior border of tibia
  - 1 to 3cm depth



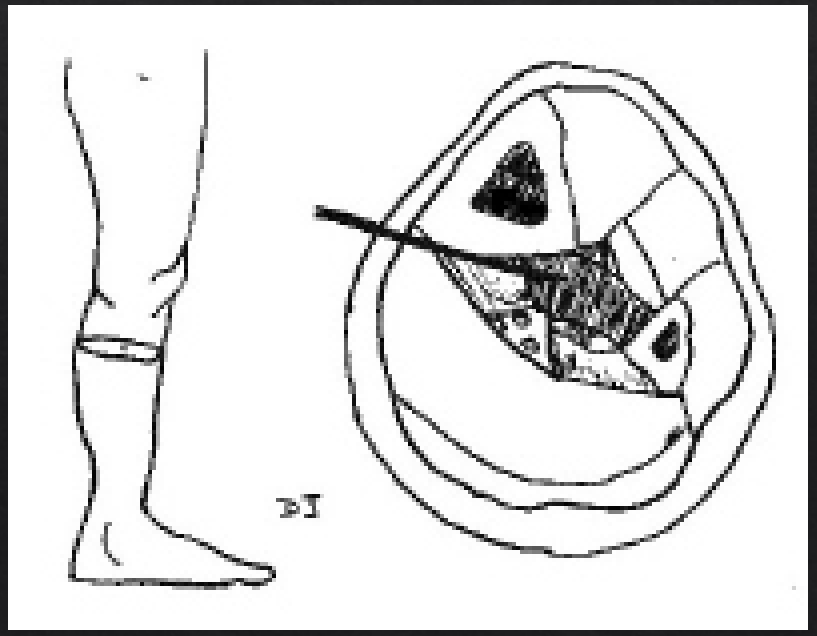
Compartment Testing

- Lateral compartment
  - Junction of proximal and middle third
  - Posterior border of fibula
  - 1 to 1.5cm depth



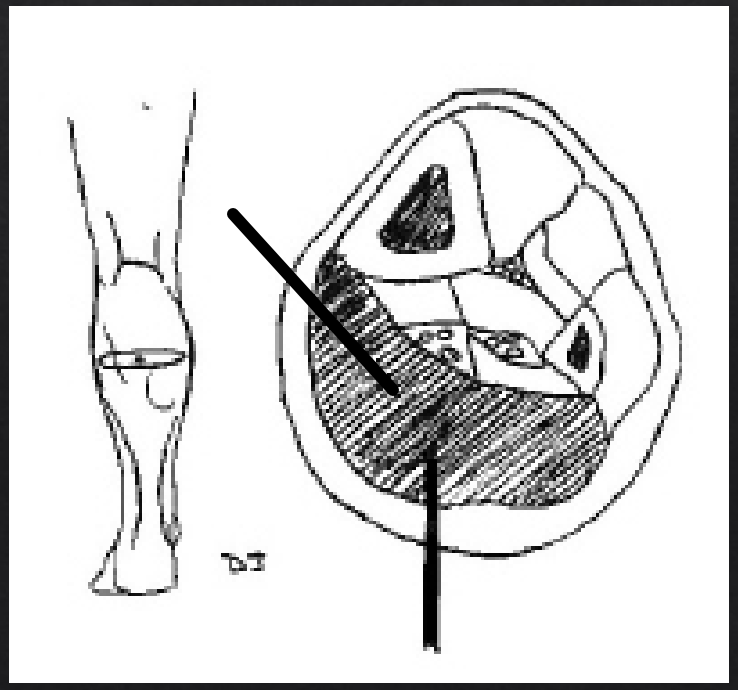
Compartment Testing

- Deep posterior compartment
  - Junction of proximal and middle third
  - Posterior to medial border of tibia
  - 2 to 4cm depth



Compartment Testing

- Superficial posterior compartment
  - Junction of proximal and middle third
  - Directly posterior over calf
  - 2 to 4cm depth



Testing Error

- Proper use of equipment
- Correct needle/catheter placement
- Depth of insertion
- Extremity position during measurement
- Muscle contraction

Pedowitz criteria

- Resting pressure ≥ 15 mmHg
- 1 minute post exercise ≥ 30 mmHg
- 5 minute post exercise ≥ 20 mmHg

Logistical issues with timing

Strength of Recommendation: Weak

Supporting studies level IV and V

Other criteria:

-Styf and Korner (Strength of Recommendation: Weak)

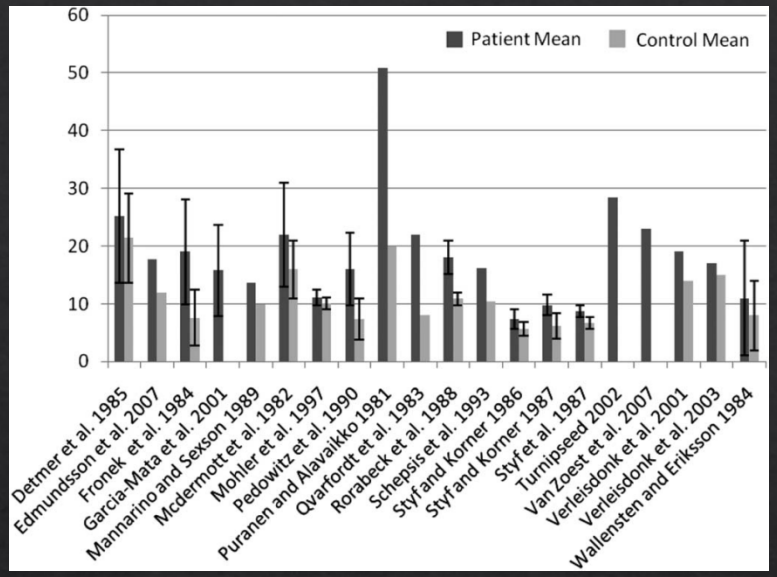
Pain with exercise, post exercise >30 mmHg, >6min to normalize

-Van den Brand (Strength of Recommendation: Weak)

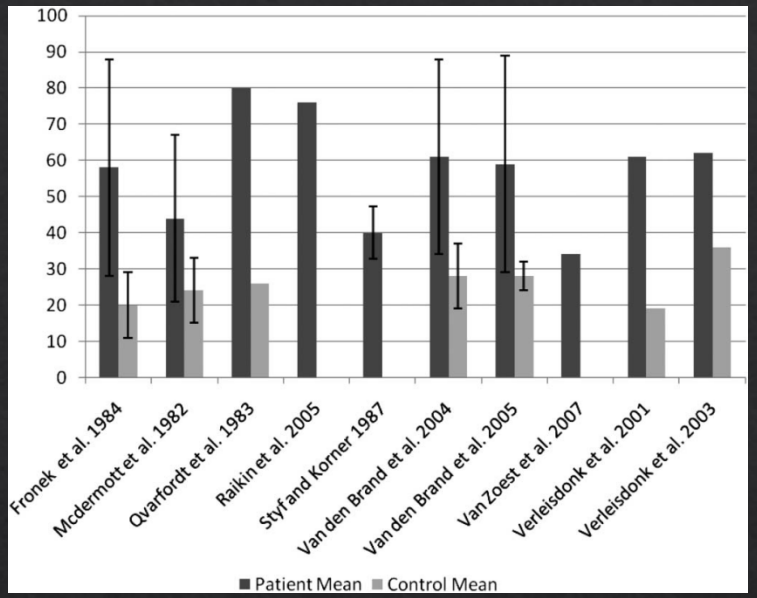
Immediate post exercise >35 mmHg

-Verleisdonk (Strength of Recommendation: Weak)

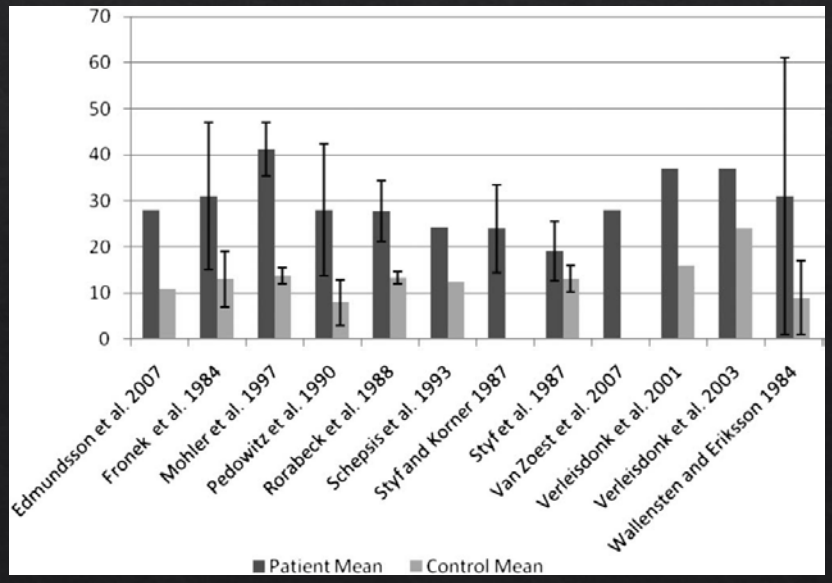
Immediate post exercise >50 mmHg



Pre-exercise



Immediate Post-exercise

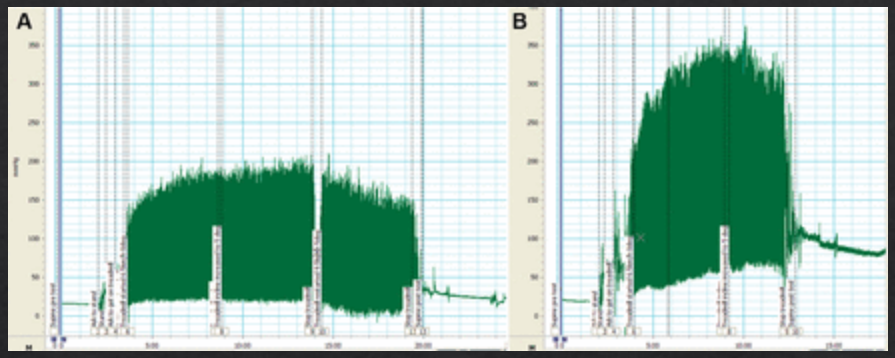


5 min Post-exercise

Aweid 2012

Dynamic Intramuscular Compartment Pressure Measurement

- Study compared dynamic continuous measurement to Pedowitz criteria (Roscoe 2014)
- Cohort study, 20 patients and 20 controls
- Patients IMP > with standing and throughout exercise protocol
- During exercise cut off of 105mmHg (63% sensitive, 95% specific) more accurate than Pedowitz criteria (50-56% sensitive, 70-89% specific)



Representative intramuscular compartment pressure curves: (A) from healthy control subject, (B) from chronic exertional compartment syndrome case.

TABLE 1
Comparisons Between Pressure Variables[a]

	Pre-exercise		Exercise			Postexercise, Supine	
IMCP	Supine	Standing	Phase 1	Phase 2	Phase 3	1 min	5 min
Controls	14.7 ± 4.3	23.8 ± 10.6	61.2 ± 23.4	68.7 ± 22.0	50.2 ± 18.4	18.8 ± 7.9	14.4 ± 6.5
Subjects	15.2 ± 5.2	35.5 ± 14.8	97.1 ± 26.6	114.1 ± 32.2	91.4 ± 40.0	33.9 ± 26.3	26.1 ± 19.9
P	.747	.006	<.001	<.001	<.001[b]	.023[b]	.020[b]

[a]Values are reported as mean ± SD (mm Hg). IMCP, intramuscular compartment pressure.
[b]An adjusted value was used.

Other Diagnostic Tests

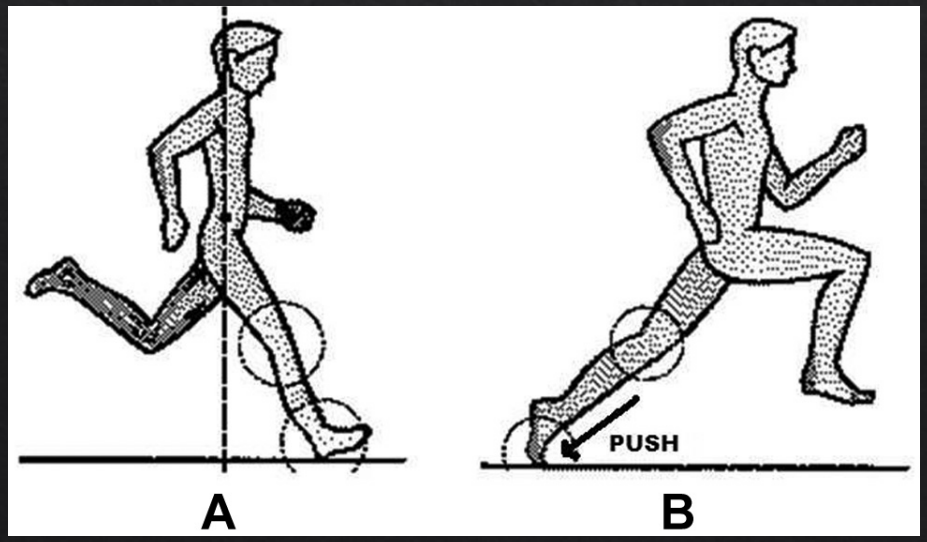
- Near Infrared Spectroscopy
  - Non-invasively measures tissue oxygen saturation
  - Not routinely available
  - Saturation <50%
    - 78% sensitive
    - 67% specific
- Magnetic Resonance Imaging
  - Changes in T2 signal intensity at rest and after exertion
  - Not as good as compartment testing and near infrared spectroscopy although newer studies more promising

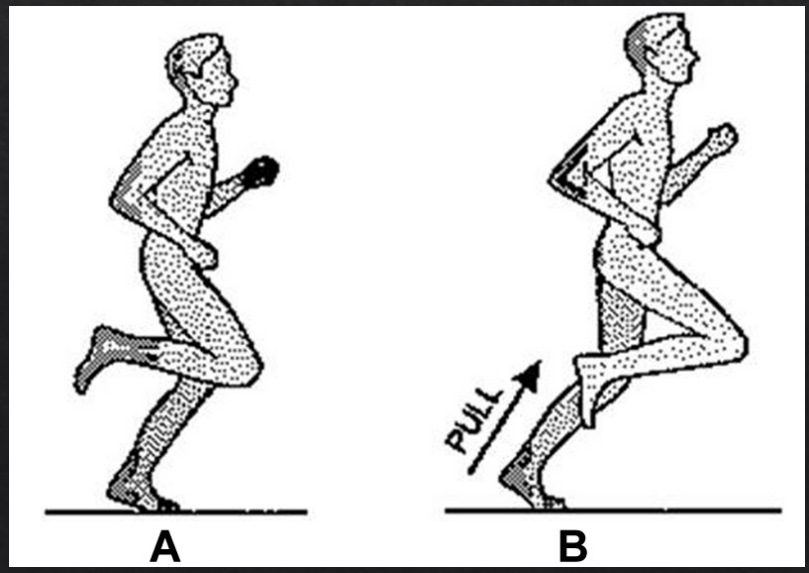
Treatment

- Non-operative
  - NSAIDs
  - Stretching
  - Rest
  - Ultrasound
  - Electrical stimulation
  - Orthotics
  - Massage
  - Gait alteration
  - Chemodenervation
  - Ultrasound guided needle fenestration
- Operative
  - Red Flags?

Gait Alteration

- Forefoot strike
  - Decreased eccentric activity of the tibialis anterior
  - Lower anterior compartment pressure in healthy subjects





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

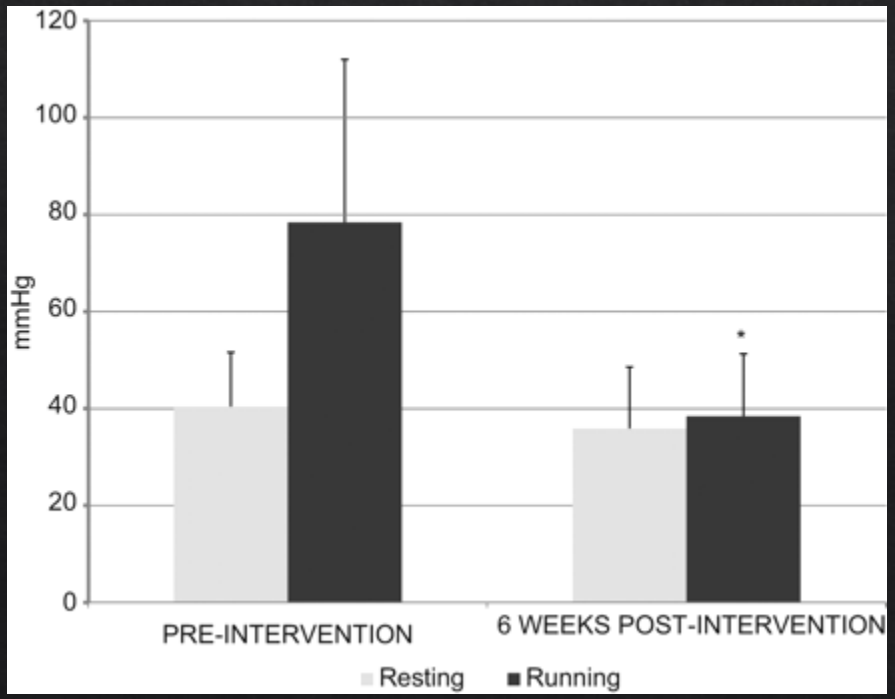
- American Journal of Sports Medicine, 2012
- Case series, 10 subjects diagnosed with CECS
- Intervention: 6 weeks of forefoot run training

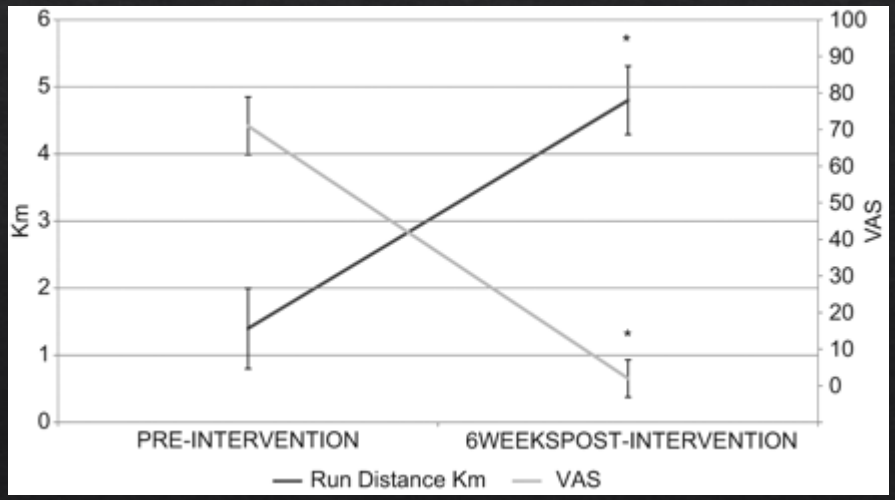
Study Intervention

- Eliminate hindfoot strike to reduce eccentric activity in anterior compartment musculature
- Increase step rate to 3 steps per second
- Use hamstrings to “pull the foot from the ground”
- Verbal cueing to “run quietly”
- Video taping to demonstrate errors

Study Results

- Decreased mean post-exercise anterior compartment pressures
- Increased running distance until pain = 7/10
- Decreased pain with running





The Effectiveness of a 6-Week Intervention Program Aimed at Modifying Running Style in Patients with Chronic Exertional Compartment Syndrome

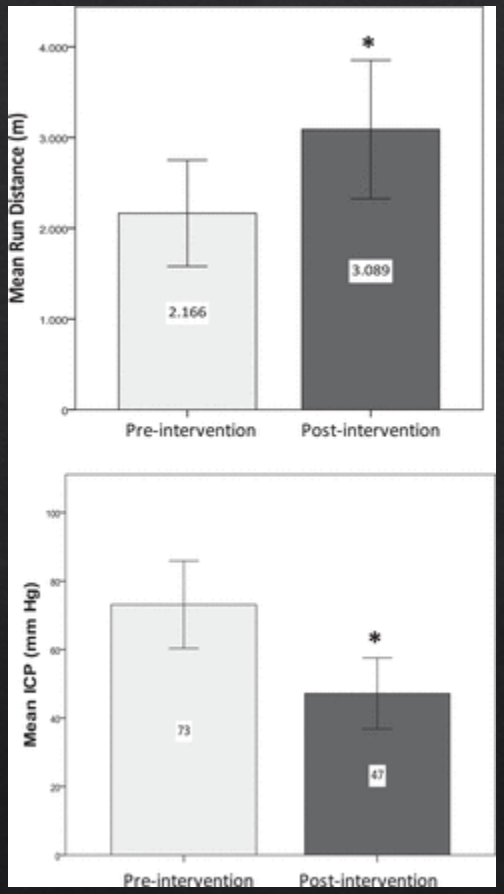
- The Orthopedic Journal of Sports Medicine, 2015
- Cohort study, 19 patients with CECS
- Intervention: 6 weeks of forefoot running intervention with PT (n=13) vs less frequent PT plus home program (n=6)

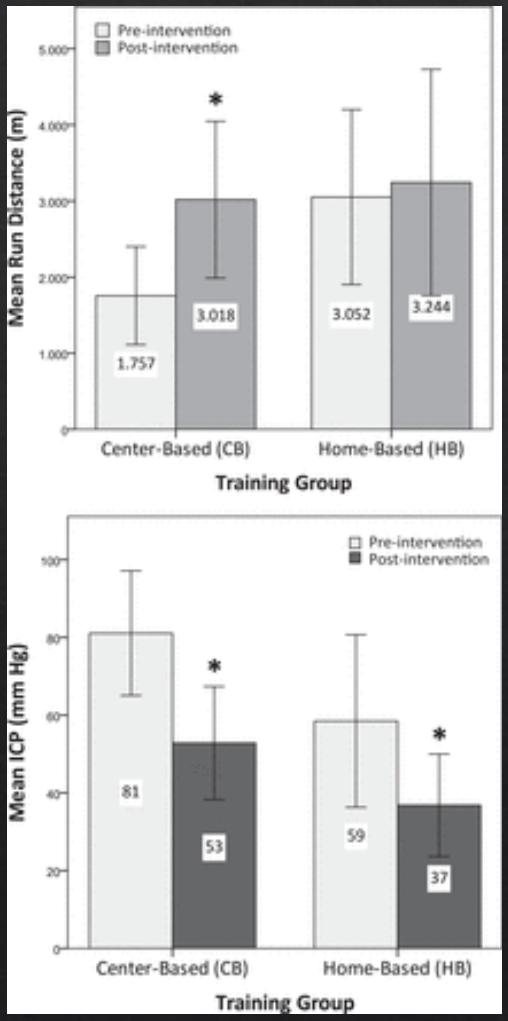
Study Details

- Members of Royal Netherlands Army w/ CECS
- Post-exercise anterior ICP, questionnaire, running performance before and after intervention
- Running strategy: forefoot strike, >180 steps/min, shorten stride, actively use hamstring to pull foot from ground

Study Results

- Improved:
  - Running distance
  - ICP
  - Survey scores
    - Pain
    - Function
- No statistical significance between groups



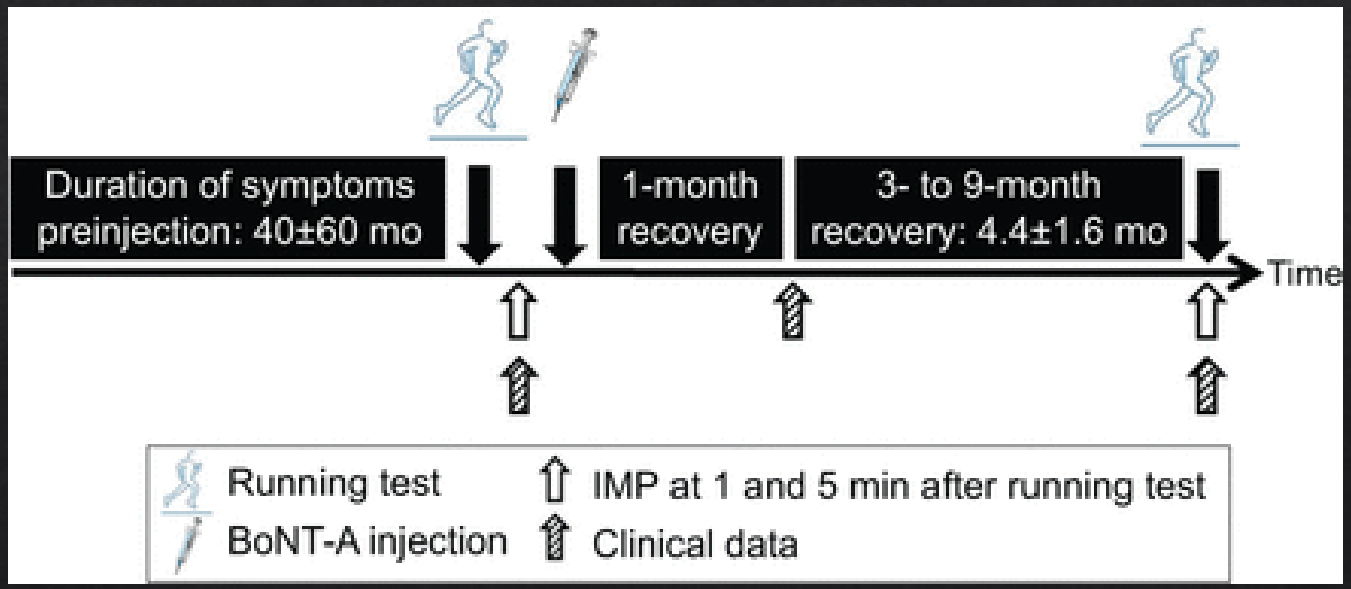


Intramuscular Pressure Before and After Botulinum Toxin in Chronic Exertional Compartment Syndrome of the Leg

- The American Journal of Sports Medicine, 2013
- Case series, 16 patients with CECS
- Intervention: Botulinum toxin injection into affected compartments (ant, lat, ant/lat)

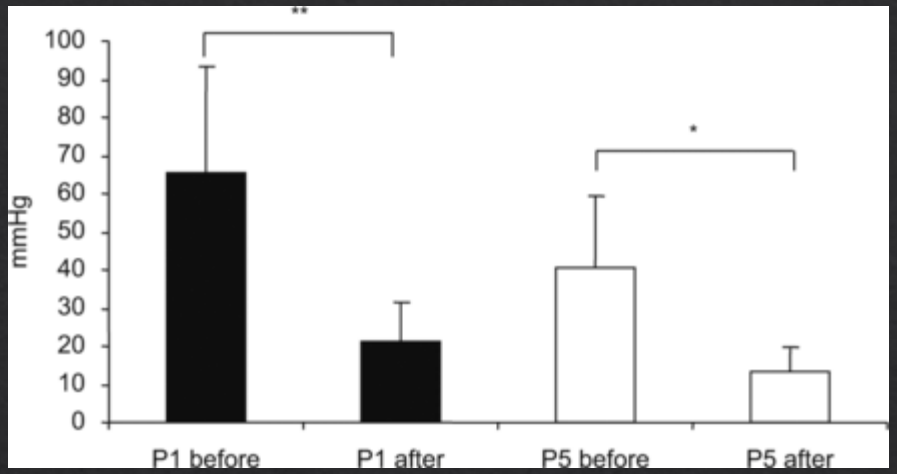
Study Details

- 16 patients: total of 25 anterior and 17 lateral compartments injected with botulinum toxin

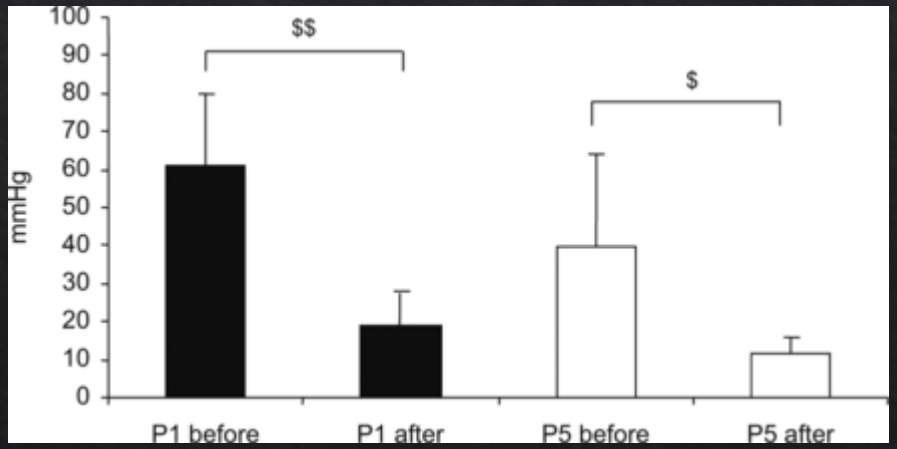


Study Results

- P1=1 min post exercise, P5=5 min post exercise
- IMP Anterior
  - P1↓63%
  - P5↓59%
- IMP Lateral
  - P1↓68%
  - P5↓63%
- Exertional pain eliminated in 15/16 (94%)
- Strength decrease in 11/16 (69%) without functional consequences
- No overt safety issues (flulike sx, breathing and swallowing issues, etc)



Anterior Compartment



Lateral Compartment

Botulinum Toxin for Chronic Exertional Compartment Syndrome: A Case Report With 14 Month Follow-Up

Michael R. Baria, MD and Jacob L. Sellon, MD
Clin J Sport Med Volume 26, Number 6, November 2016

- 20yo runner, 1 year h/o symptoms
- Positive compartment testing
- Using ultrasound and electric stimulation to guide needle placement, botulinum toxin (onabotulinum toxin A) was injected into the tibialis anterior, extensor hallucis longus, extensor digitorum longus, fibularis longus, and fibularis brevis. Each muscle was injected with 20 units proximally and 20 units distally.
- Return to shorter distances (2 miles) at 2 weeks and longer distances at 1 month
- No return of symptoms at 14 month follow up and no weakness on exam

PM R 8 (2016) 286-290

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Case Presentation

Ultrasound-Guided, Percutaneous Needle Fascial Fenestration for the Treatment of Chronic Exertional Compartment Syndrome: A Case Report

Jonathan T. Finnoff, DO, Sathish Rajasekaran, MD

-18yo collegiate lacrosse player
-Symptoms for 2 years with positive compartment pressure testing
-Full return to sport 1 week after procedure
-No symptoms at 18 month follow up

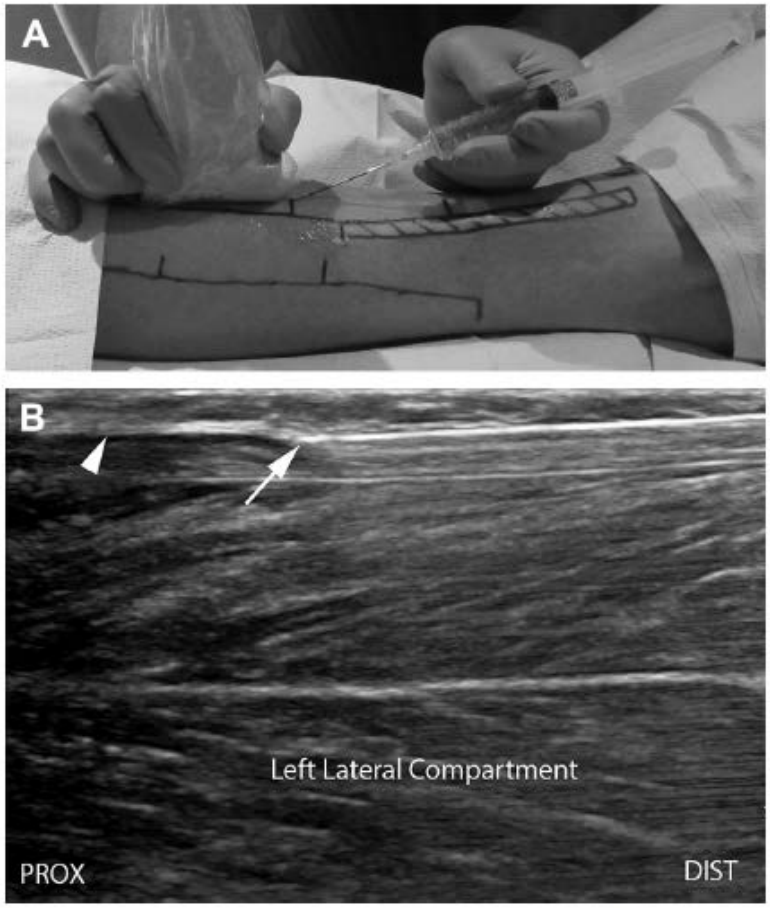


Figure 3. (A) An 18-gauge needle entering the skin under sonographic guidance to fenestrate a segment of the lower leg anterior compartment. Proximal = left side of the figure; distal = right side of the figure; anterior = top of picture; posterior = bottom of picture. (B) Long-axis ultrasound image of the needle fenestrating the left lateral compartment of the lower leg. Arrow = needle tip; arrowhead = fascia; PROX = proximal; DIST = distal.

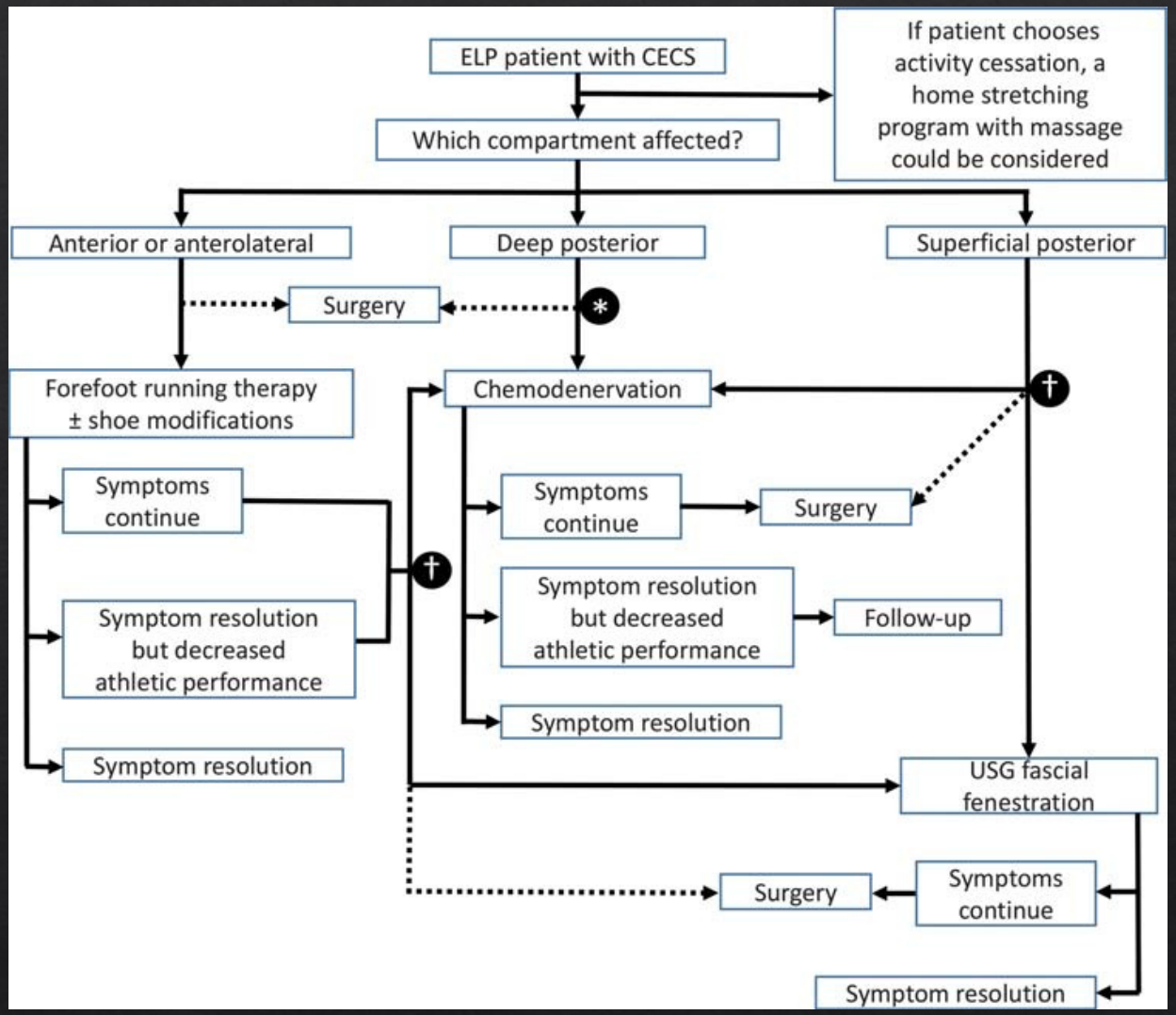
Surgical Treatment

- Fasciotomy
- Complications
  - 4.5-13%
  - Hematoma, nerve/artery injury, DVT
  - Symptom recurrence in 7-17%
    - Recent military study has higher rates
- Postoperative Care
  - Ice/elevation for 3-5 days
  - WBAT, prn crutches
  - Light activities allowed early
  - Full activities as soon as tolerated, often 3-4 weeks after surgery

Surgical Treatment

- Surgical Treatment of Chronic Exertional Compartment Syndrome of the Leg (Waterman 2013)
  - Military study
- 611 patients, 754 surgical procedures
  - Average age 28.0 years
  - 91.8% male
  - 77.4% ant/lat, 19.4% ant/lat/post, 2.2% post
- Surgical results
  - 44.7% reported recurrent symptoms, 5.9% underwent revision
  - 15.7% surgical complications
  - 17.3% referred for medical discharge due to CECS

Treatment Algorithm



Rajasekaran S, Hall MM. Nonoperative management of chronic exertional compartment syndrome: A systematic review. Curr Sports Med Rep. 2016;15(3):191-198.

Popliteal artery entrapment syndrome (PAES)

PAES-Definition

- Symptomatic extrinsic compression of the popliteal artery by the surrounding musculotendinous structures
  - Most frequently the medial head of the gastrocnemius muscle
- Can be in isolation or in conjunction with popliteal vein and/or tibial nerve compression

PAES-Types

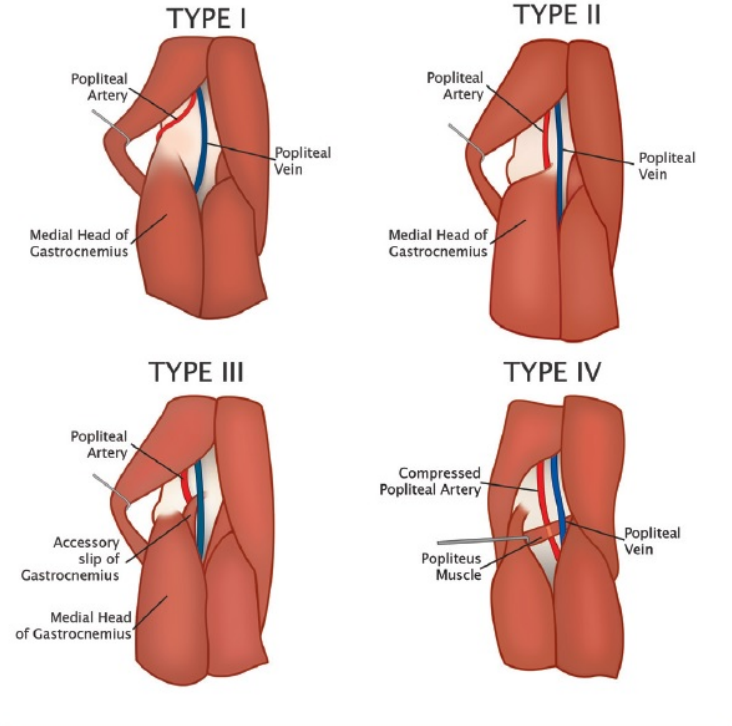


Figure 6. Illustration of four anatomical anomalies that can lead to popliteal artery entrapment syndrome.

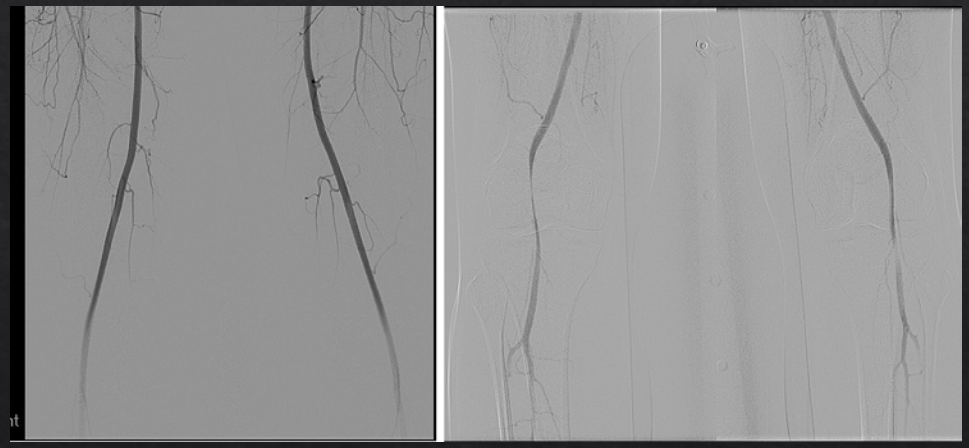
Musthpa 2017

PAES-Presentation

- Calf pain with exercise
- Young athlete, male > female
- 40% bilateral
- Lower limb pulses often normal on exam

PAES-Diagnosis

- Lack of consensus on optimal imaging
- Lower limb arterial angiography most common, better with provocation maneuvers



Lower-limb arterial angiogram at rest (left) and during forced plantar flexion demonstrating bilateral popliteal artery occlusion (right).

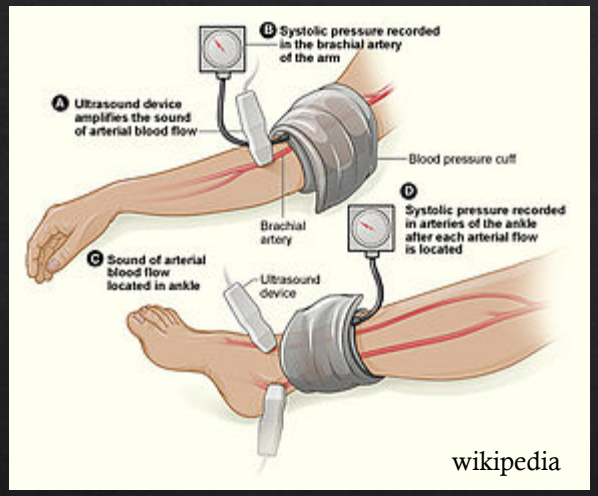
Hameed (2018)

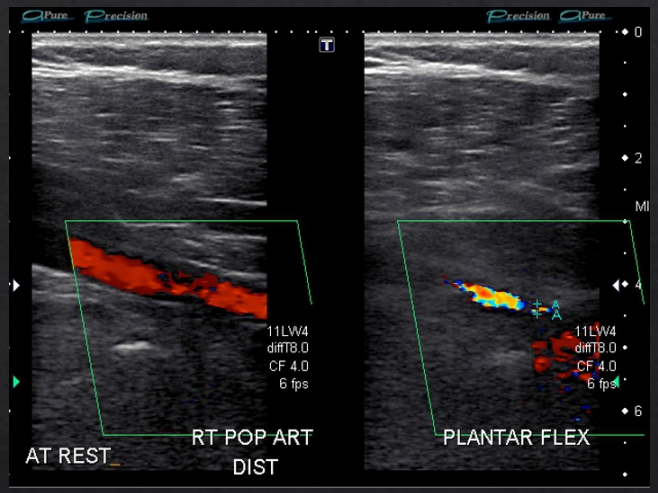
PAES-Diagnosis

Ankle-brachial pressure index with provocation

Duplex ultrasound with provocation

MRI or CT angiography



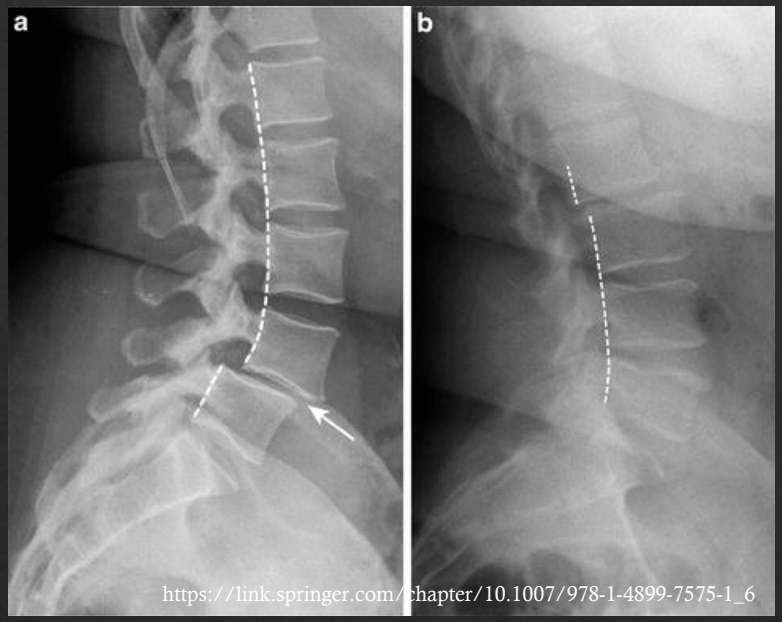


PAES

- Median delay before diagnosis is 12 months
- Many instances of people undergoing surgery for CECS without benefit later found to have PAES
- Treatment: surgery
- No consensus on return to sport
- Recent case reports on ultrasound guided botulinum toxin

Leg Pain Case

- 16 year old female XC athlete
- Calf pain with running
- 3 months



-Discussion of past issues revealed she was a gymnast but had to stop due to low back issues.

-X-ray of lumbar spine demonstrated bilateral spondylolysis with grade 1 spondylolisthesis

-Symptoms resolved with lumbar spine rehabilitation

Diagnosis	Findings	Testing
Stress fracture	Localized tenderness Pain with torsion/bending	X-ray, Bone scan, MRI
MTSS (periostitis)	Diffuse tenderness Resisted PF/inv causes pain	Bone scan, MRI
CRPS	Allodynia Trophic skin changes	Bone scan, thermography, sympathetic block
Chronic exertional compartment syndrome	Swollen, tense compartments, visible herniations	Compartment testing
Tenosynovitis	Tenderness along tendon Pain with resisted strength	MRI
Peripheral nerve entrapment	Positive Tinel's	EMG
Deep vein thrombosis	Pain with plantarflexion, swelling, palpable cords	Duplex ultrasound
Radiculopathy	Sensory changes, weakness	EMG, spine MRI
Arterial vascular disease	Pain, paresthesia, cold	Ankle-brachial index
Popliteal artery entrapment syndrome	Pain and coolness Paradoxical claudication	Ultrasound, arteriogram

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Thank You!