Mass General Brigham
Spaulding Rehabilitation

Shockwave in the Management of Sports Injuries

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HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

Disclosure Statement

Speaker:

Dr. Adam Tenforde

- Disclosed the following financial relationships:
  - StateFarm
    - Consultant
  - Enovis
    - Grant/Research Support Recipient
  - DOD
    - Grant/Research Support Recipient
  - Strava
    - Consultant

Objectives

- To describe the mechanisms for how shockwave may be effective in treatment of musculoskeletal conditions
- To understand the best evidence for use of shockwave treatment for running related injuries
- To apply best practice in application of shockwave in clinical practice

Meeting the challenges for optimal patient-centered treatment

- **Musculoskeletal conditions are common and challenging to treat**
- **Classification of injury may include tendon, fascia, joint and bone**
- **Goals to identify minimally/non-invasive and effective treatments**

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Narrative Review

Effect of Shockwave Treatment for Management of Upper and Lower Extremity Musculoskeletal Conditions: A Narrative Review

Julia M. Reilly, MD, Eric Bluman, MD, PhD, Adam S. Tenforde, MD

PRACTICE MANAGEMENT

PM&R

Best practices for extracorporeal shockwave therapy in musculoskeletal medicine: Clinical application and training consideration

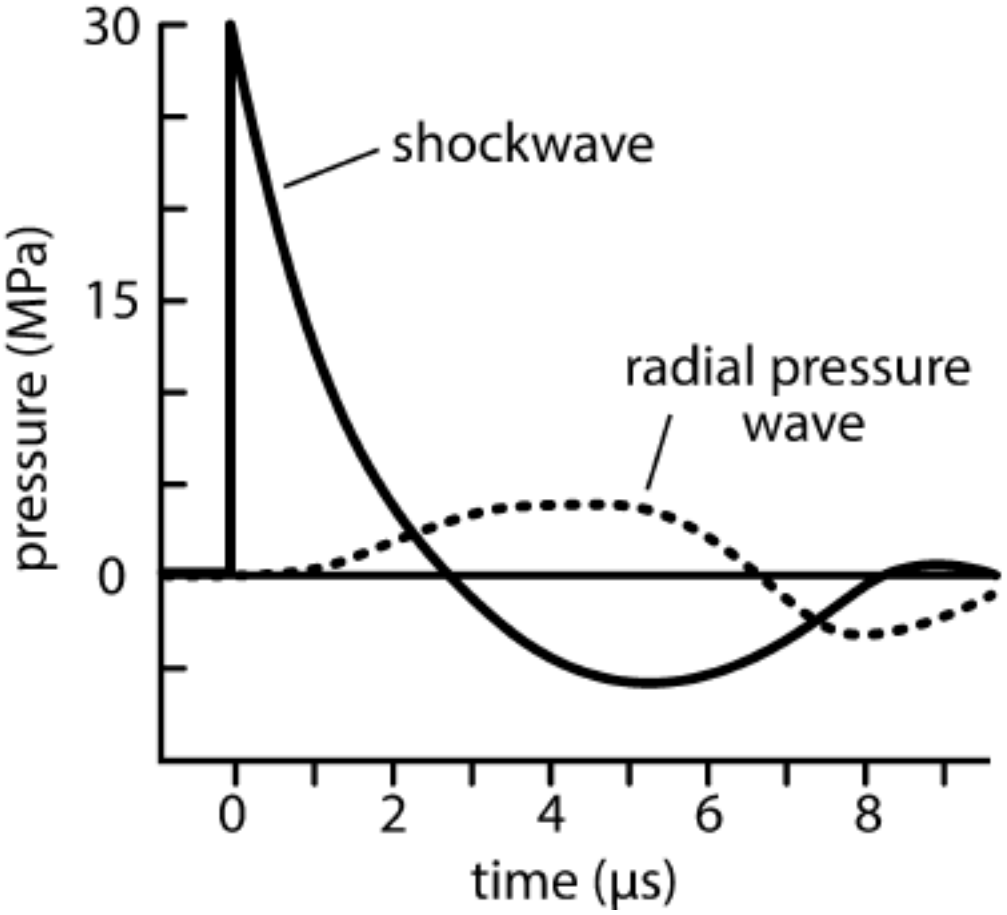
Adam S. Tenforde MD[1] | Haylee E. Borgstrom MD, MS[1] |
Stephanie DeLuca MD[1] | Molly McCormack BA[1] | Mani Singh MD[2] |
Jennifer Soo Hoo MD[3] | Phillip H. Yun MD[4]

What is Shockwave?

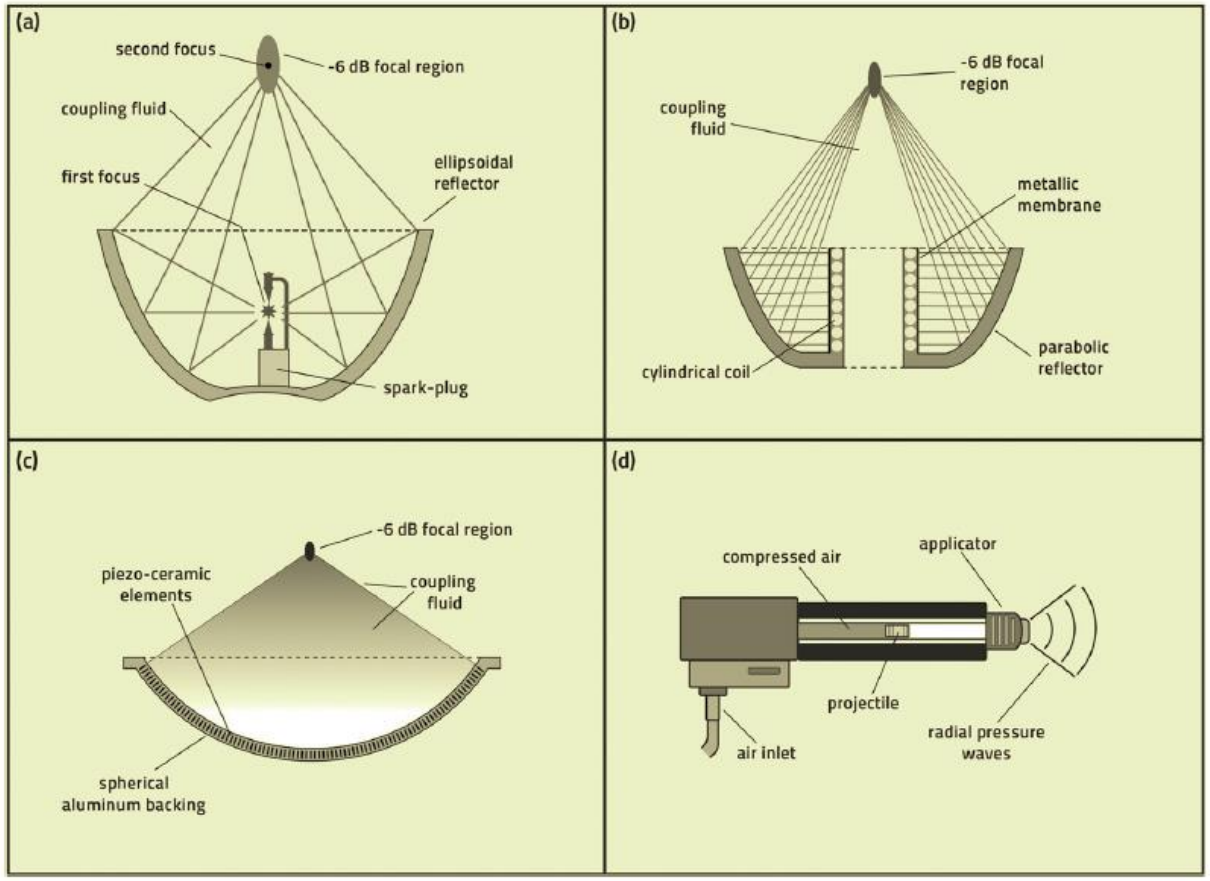
- External source of energy
- Can produce variable energy based on device settings and type of shockwave
- Each may produce different effects on target tissue

What is Shockwave?

- Extracorporeal shockwave therapy (ESWT) is external source of energy
- Can produce variable energy based on device settings and type of shockwave
- Each may produce different effects on target tissue



What is Shockwave?



- **Common Focused Shockwave devices include electrohydraulic, electromagnetic and piezo-electric (Panels A-C)**
- **Radial Shockwave is commonly produced using pneumatic compressive pressure waves (Panel D)**

Moya, et al. Role of extracorporal shockwave in treatment of musculoskeletal disorders. JBJS, 2018.

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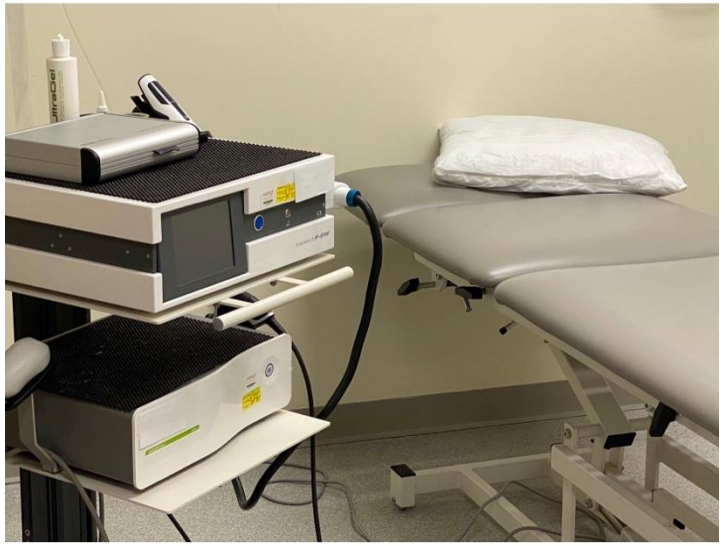
What is Shockwave?

Early devices large and cumbersome



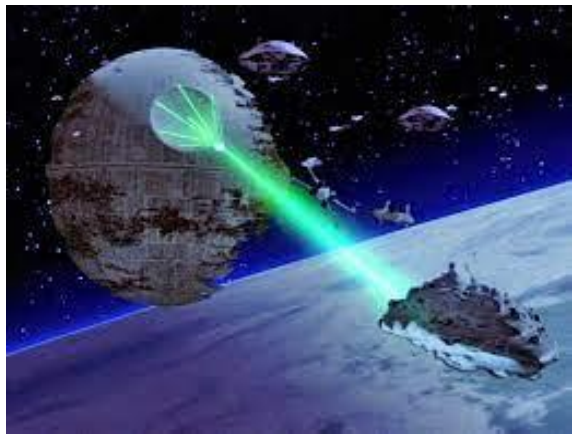
Current Device – size of a desktop computer

What is Shockwave?

Radial Pressure Wave

- Highest energy at surface
- Waves dissipate energy to deeper structures

Focus Shockwave Device



- Highest energy concentrated to one point

Mechanism of Action

Proposed mechanisms of action for shockwave	
Neovascularization at tendon-bone junction	Wang 2002, Wang 2003
Destruction of calcifications	Peters 2004
Increased collagen synthesis/tissue remodeling	Bosch 2007, Vetrano 2011
Leukocyte infiltration	Rompe 1998
Proliferation of tenocytes	Chen 2004
Increased glycosaminoglycan, increased protein synthesis	Bosch 2007
Increased IL-6, IL-8, MMP-2, MMP-9, increased collagen synthesis	Waugh 2015
Increased TGF-β1 and IGF-1, increased collagen synthesis	Wang 2002, Chen 2004
Mechanotransduction, increased collagen synthesis	Bosch 2007
Increased osteoprogenitor differentiation	Wang 2002
Stimulation of nociceptive C-fibers and resulting neuropeptide release	Klonschinski 2011
Nociceptor hyperstimulation/Gate-control theory	Saggini 2015, Wess 2008, Vahdatpour 2013, Zimmerman 2008
Increase in local pain-inhibiting substances	Saggini 2015, Wess 2008, Vahdatpour 2013, Zimmerman 2008
Impaired cell membrane receptor potential	Wess 2008

IL = interleukin; MMP = matrix metalloproteinase; TGF-β1 = transforming growth factor—beta 1; IGF-1 = insulin-like growth factor 1.

Tissue remodeling

Pain modulation

Reilly, Bluman and Tenforde. Narrative Review of Shockwave Treatment. PM&R Journal, 2018

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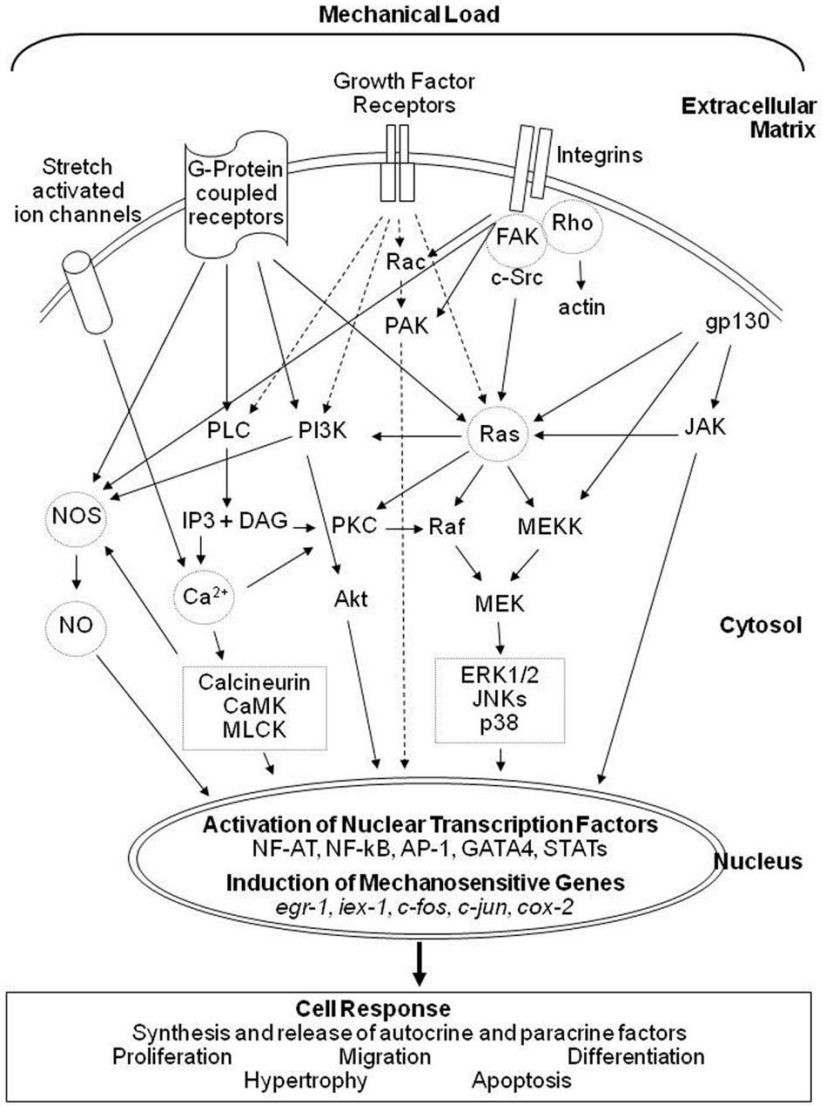
Mechanotransduction



Jaalouk and Lammerding. Mechanotransduction gone awry. Nat Rev Mol Cell Biol, 2009.

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Energy Form selection

- **Focused shockwave generates greater energy to target tissue**
- **Radial shockwave often considered lower energy form - this depends on settings!**
- **Animal model suggests lower energy may be better in treatment of tendon disease**
- **Higher energy may be more appropriate for bone/joint applications**

Rompe, et al. Dose-related effects of shock waves on rabbit teno Achilles. JBJS, 1998

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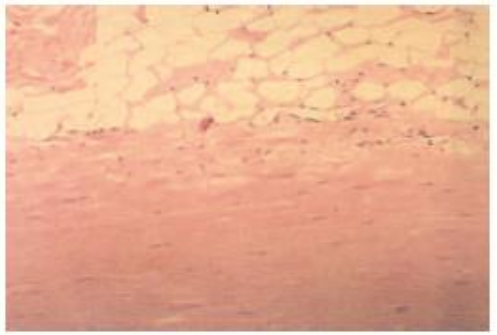
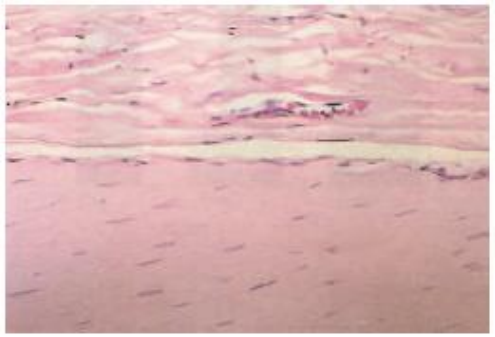
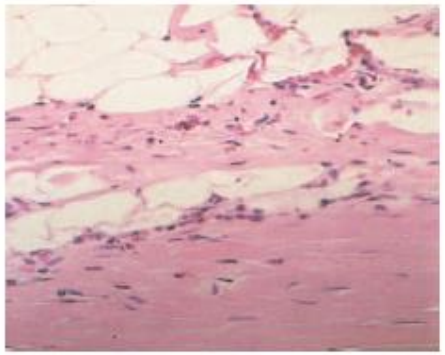
Energy selection: Low to Moderate Energy for soft tissue

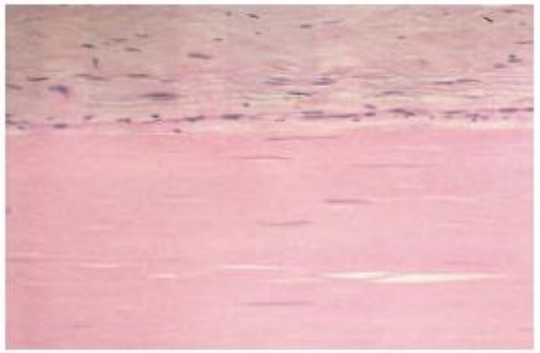
- **Low/moderate energy for soft tissue/tendon application**
  - **Low energy (0.08 mJ):**
    - **H/E with no inflammatory cells at day 1**
    - **Normal tendon appearance day 7**





  - **Moderate energy (0.28 mJ):**
    - **H/E with inflammatory cells (PMNs) day 1**
    - **Regression of inflammatory cells day 7**





Rompe, et al. Dose-related effects of shock waves on rabbit teno Achilles. JBJS, 1998

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Energy selection: High Energy settings reserved for bone

- **High energy (0.60 mJ)**
  - **Excessive inflammatory response day 1**
  - **Progression to fibrinoid necrosis day 7**
  - **Marked fibroblastic proliferation day 14**
  - **Persistent fibrosis and loss of GAG expression within tendon day 28**

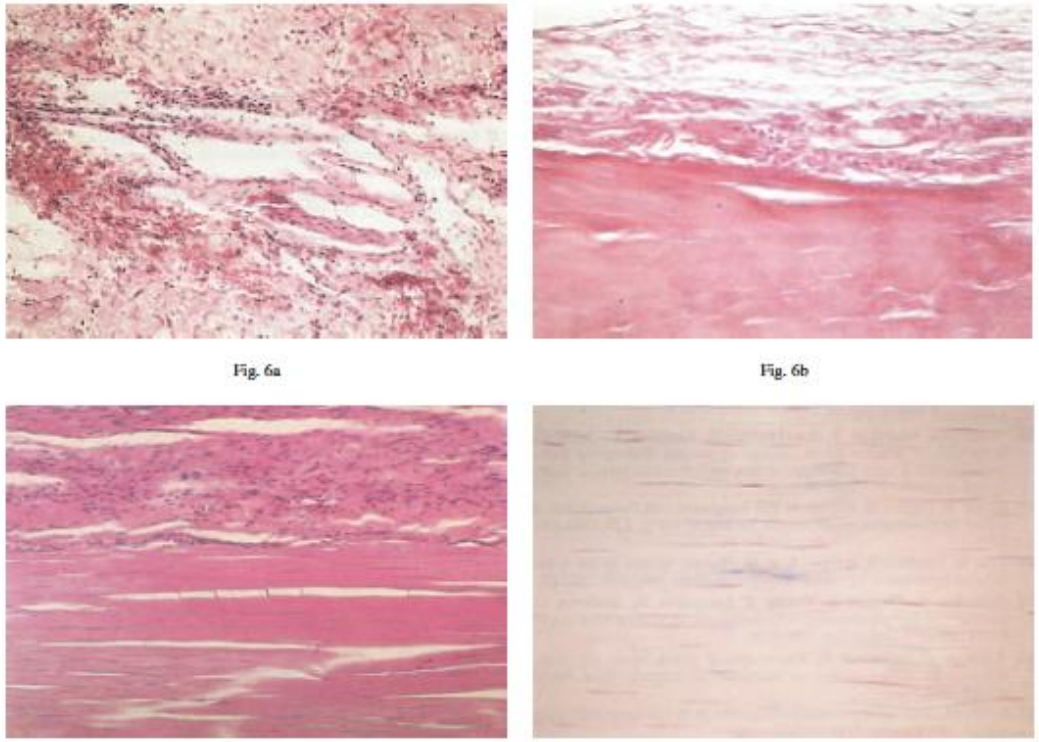

Fig. 6a

Fig. 6b

Rompe, et al. Dose-related effects of shock waves on rabbit teno Achilles. JBJS, 1998

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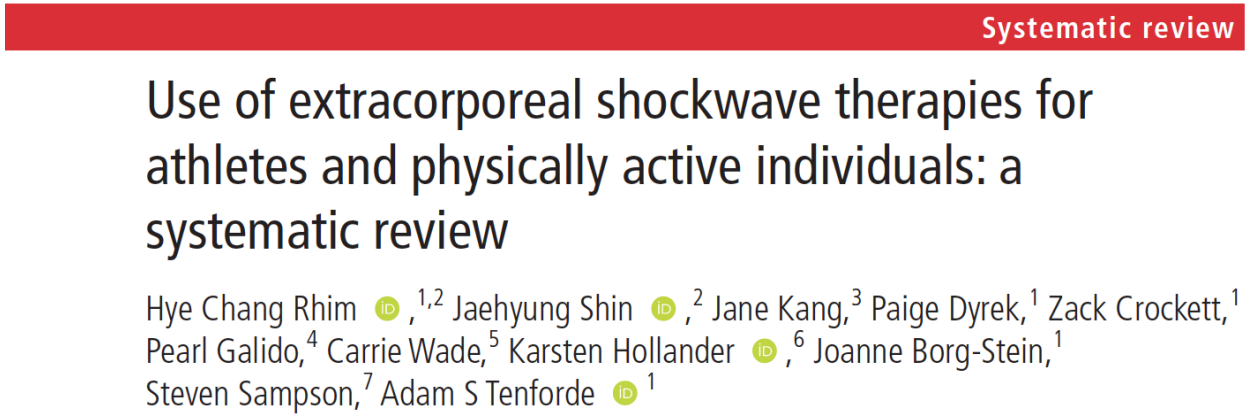
Advantages of shockwave

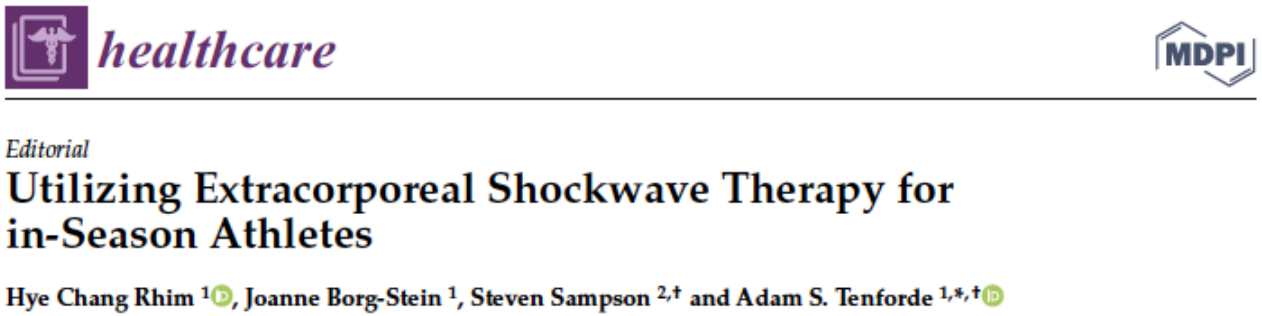
- **Non-invasive**
- **Favorable side effect profile**
- **Activity/sport may continue during treatment**



Systematic review

Use of extracorporeal shockwave therapies for athletes and physically active individuals: a systematic review

Hye Chang Rhim [1,2] Jaehyung Shin [2] Jane Kang,[3] Paige Dyrek,[1] Zack Crockett,[1] Pearl Galido,[4] Carrie Wade,[5] Karsten Hollander [6] Joanne Borg-Stein,[1] Steven Sampson,[7] Adam S Tenforde [1]



healthcare

MDPI

Editorial

Utilizing Extracorporeal Shockwave Therapy for in-Season Athletes

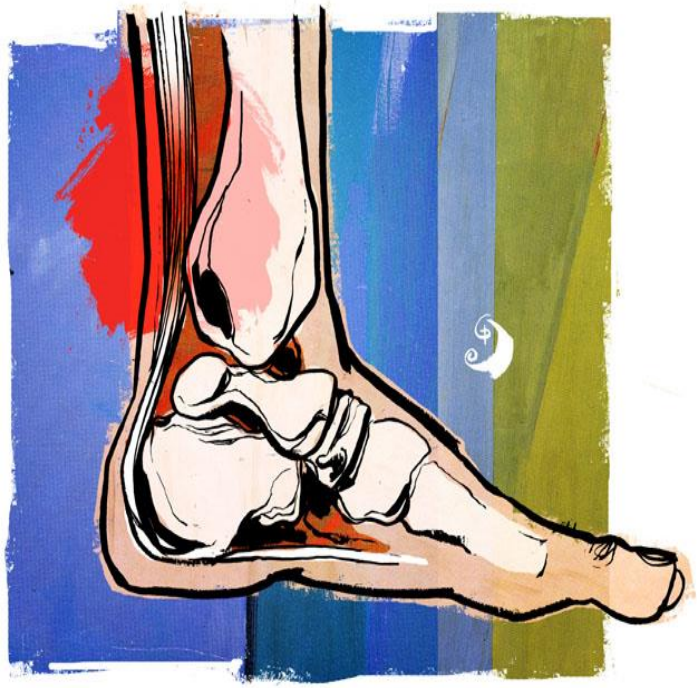
Hye Chang Rhim [1], Joanne Borg-Stein [1], Steven Sampson [2,†] and Adam S. Tenforde [1,*,†]

Tendinopathy – a failed healing response resulting in pain, stiffness and loss of function

Longo UG, Ronga M, Maffulli N. Achilles tendinopathy. Sports Med Arthrosc Rev. 2009;17(2):112-126.

Achilles tendinopathy

- **Growing evidence for shockwave as treatment**
- **Greater efficacy for mid-portion vs insertional, no Haglund deformity**
- **Rare risk of rupture, only reports in clinical trials using focused shockwave in non-athletes at older ages**



Costa, Shock Wave Therapy for Chronic Achilles Pain. Clin Ortho, 2005.

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What treatment works best?

Comparative Efficacy and Tolerability of Nonsurgical Therapies for the Treatment of Midportion Achilles Tendinopathy

A Systematic Review With Network Meta-analysis

Hye Chang Rhim,* MD, Min Seo Kim,† MD, Seungil Choi,‡ BS, and Adam S. Tenforde,§‖ MD
Investigation performed at Korea University College of Medicine, Seoul, Republic of Korea

Rhim, et al. Comparative Efficacy and Tolerability of Nonsurgical Therapies for Treatment of Midportion Achilles Tendinopathy. OJSM, 2020

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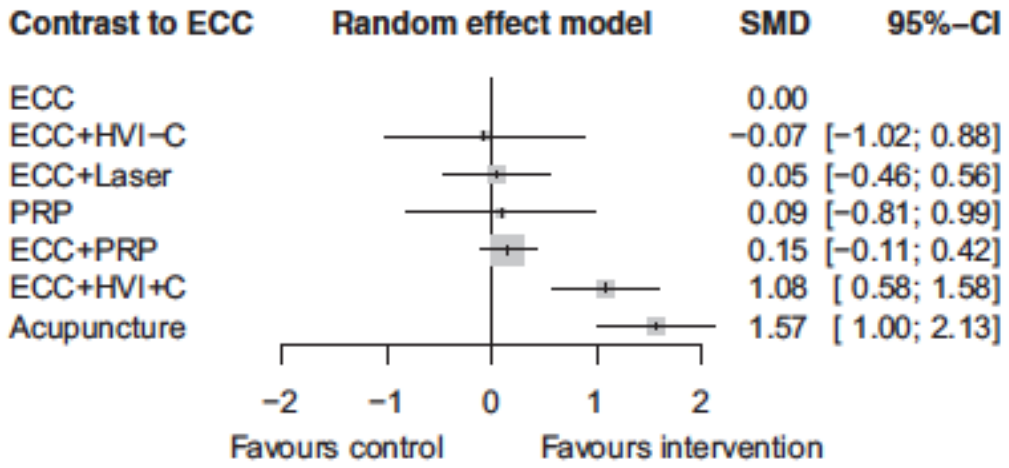
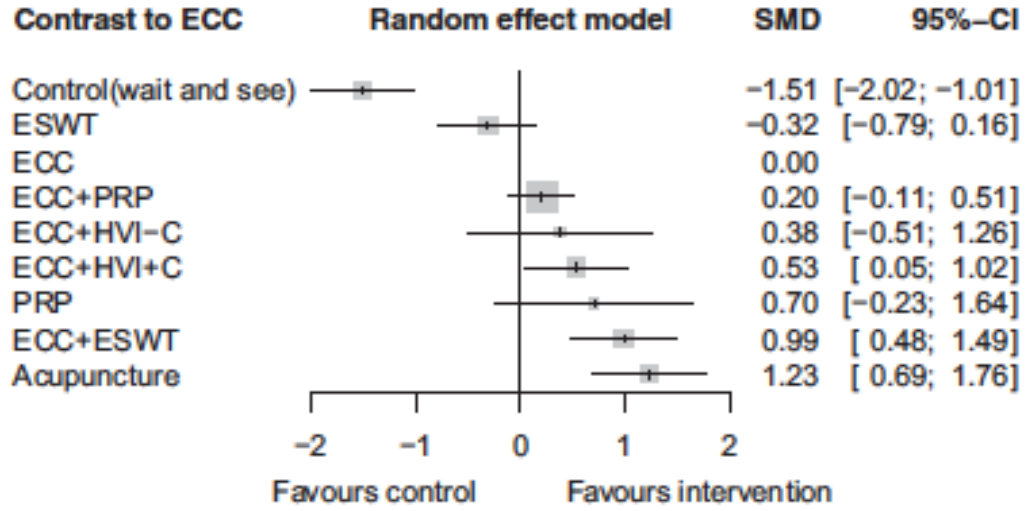
Outcomes favor Eccentric Loading combined with shockwave therapy

Short Term < 12 weeks



Longer Term > 12 weeks



Rhim, et al. Comparative Efficacy and Tolerability of Nonsurgical Therapies for Treatment of Midportion Achilles Tendinopathy. OJSM, 2020

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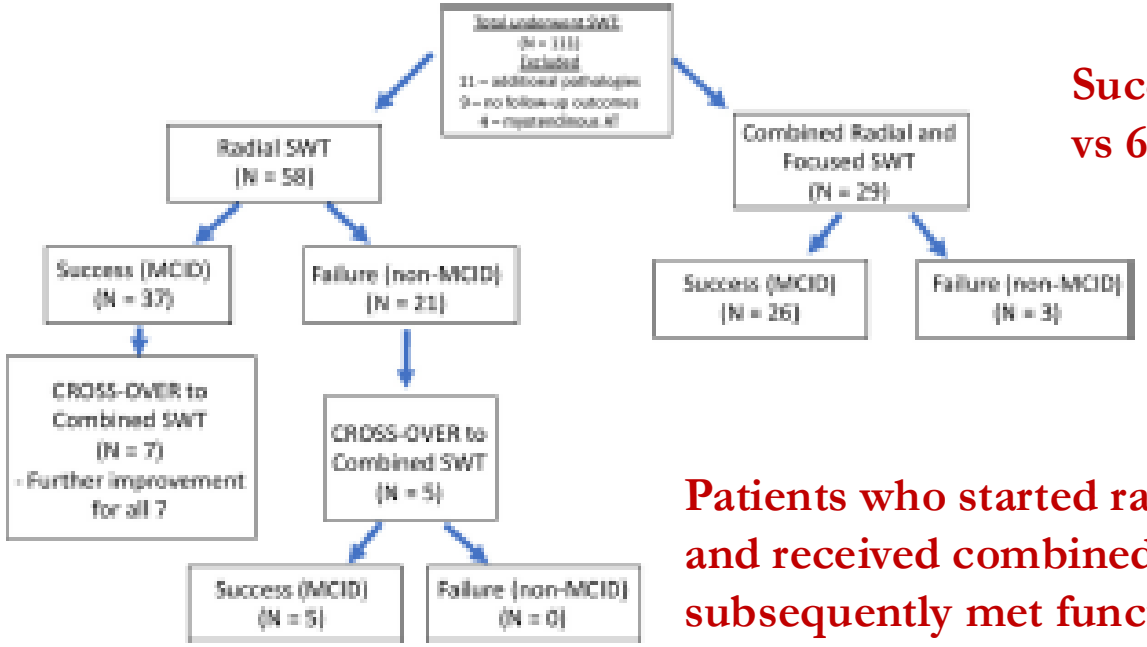
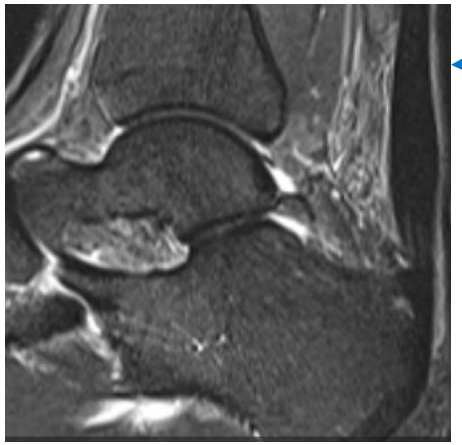
My experience with Achilles Tendinopathy: Combined treatment may be more effective



Success higher for combined shockwave 89.7% vs 63.8% with radial monotherapy

Patients who started radial shockwave and received combined shockwave subsequently met functional gains



Radial Shockwave – Muscle, tendons

Focus Shockwave
- enthesis edema
- calcific lesion(s)

Robinson, et al. Functional Gains Using Radial and Combined Shockwave Therapy in the Management of Achilles Tendinopathy. JFAS, 2021

Proximal Hamstring Tendinopathy

- **40 professional athletes with insertional tendinopathy, equal assignment to 2 treatment groups:**
  - **Radial shockwave (RSW): 4 weekly sessions**
  - **Control: PT + NSAIDs + structured exercise program**
- **Primary outcomes: >50% pain relief and return to sport**

Cacchio, et al. Shockwave Therapy for Treatment of Chronic Proximal Hamstring Tendinopathy. Am J Sports Med, 2011.

.

Proximal Hamstring Tendinopathy

Three Month Outcomes:

- **85% RSW and 10% conventional treatment with >50% pain relief**
- **80% RSW return to sport, none with conventional treatment**

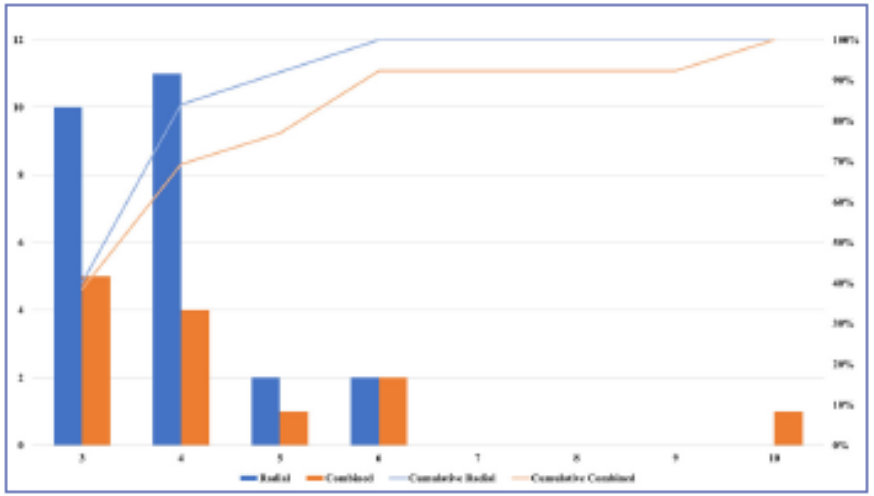
Benefits in shockwave treatment arm sustained at 12 months

Cacchio, et al. Shockwave Therapy for Treatment of Chronic Proximal Hamstring Tendinopathy. Am J Sports Med, 2011.

.

My success treating runners with hamstring tendinopathy

- 63 runners with mean 16 months of symptoms
- Average of 5 sessions of radial or combined shockwave, ceiling effect observed at 6 sessions for nearly all runners
- 62.5% and 56.5% met treatment success using VISA-H outcome measures
- No significant difference in radial or combined shockwave treatment groups



Yun et al. Radial Versus Combined Shockwave Therapy in the Management of Chronic Proximal Hamstring Tendinopathy: Similar Functional Outcomes in Running Cohort. MLTJ: 2022.

Greater Trochanteric Pain Syndrome

- 229 subject randomized to radial shockwave 3 weekly sessions, home program or palpation-guided lateral hip steroid injection
- Superior outcomes for steroid injection at 1 month, greater improvement at 4 and 15 month for RSW group
- Greater response RSW at 4 months but similar to home program at 15 month
- Recent review suggests best outcomes for ESWT at 4 months, particularly using focused shockwaves

Rompe, et al. Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome. Am J Sports Med, 2009.
.Rhim, Et al. Extracorporeal shockwave therapy for greater trochanteric pain syndrome: a systematic review with meta-analysis of randomized clinical trials. JBJS Reviews, i2024.

My technique for treating Tibialis Posterior Tendinopathy

- **Case series of 10 patients with tibialis posterior tendinopathy**
- **All treated with minimum 4 sessions of RSW**
- **Combination of foot core exercises**
- **80-90% met FAAM ADL and sport subscale**

Fig. 2. Three primary exercises of foot core progression: (A) foot doming, (B) toe yoga, and (C) intrinsic foot abduction.

Robinson et al. Nonsurgical Approach in Management of Tibialis Posterior Tendinopathy With Combined Radial Shockwave and Foot Core Exercises: A Case Series. J Foot Ankle Surg, 2020.

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Medial Tibial Stress Syndrome

- **Case-control of 94 runners with >6 mo MTSS, radiograph to exclude bone pathology**
- **Radial shockwave (RSW) of 3 weekly sessions vs standard care**
- **Outcomes of improved pain at 1, 4 and 15 months**
- **40 of 47 returned to running, 23 of 47 controls at study conclusion**

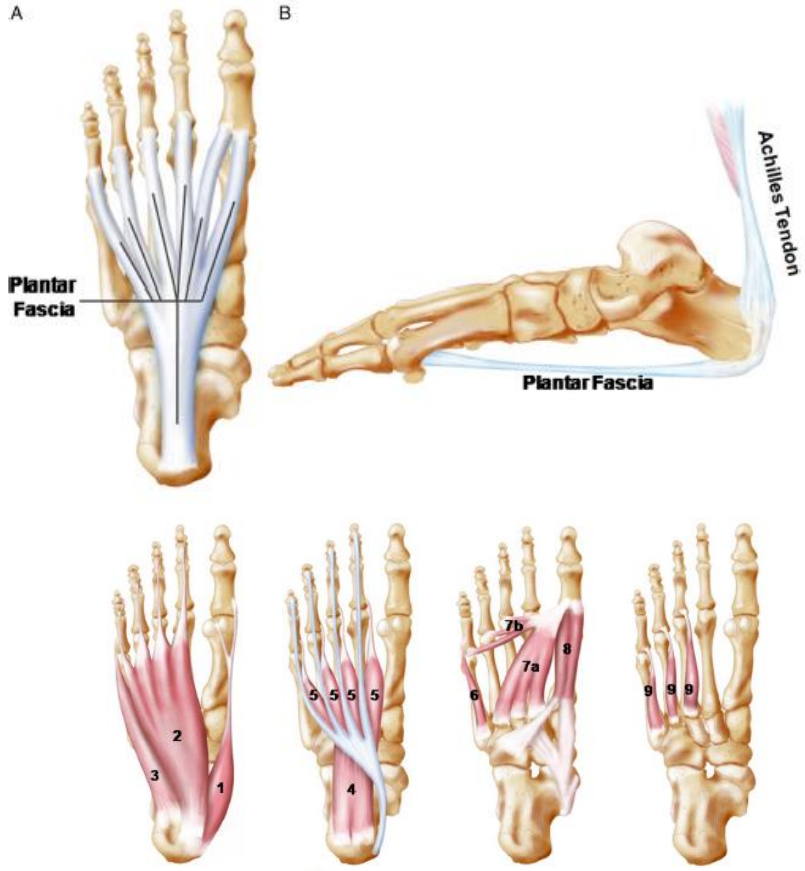
Rompe, et al. Low-energy extracorporal shock wave therapy as a treatment for medial tibial stress syndrome. Am J Sports Med, 2010

.

Plantar fasciitis - Degenerative condition of the fascia overlying plantar aspect of foot

Plantar Fascia

- Plantar fascia is both static and dynamic stabilizer of the foot
- 3 bands originating from calcaneus, 5 slips from central band to each toe
- Portion of Achilles tendon fibers in continuity with plantar fascia
- Preservation of fascia is key in active individuals



Hicks. Mechanics of the foot. Plantar aponeurosis and arch. J Anat 1954

McKeon, et al. The foot core system: a new paradigm for understanding intrinsic foot muscle function. Br J Sports Med, 2014

Plantar Fasciitis

- 250 subjects >6 months plantar foot pain
- 5 academic center, blinded RCT of 3 sessions of focused shockwave vs placebo
- Heel pain reduction higher ESWT 69% vs 34% for placebo group at 12 weeks after last treatment

Gollwitzer, et al. Clinical relevant effectiveness of focused ESWT plantar fasciitis. JBJS, 2015.

Local anesthesia may reduce efficacy

- **Subject randomization to receive plantar heel injection with shockwave**
- **All subjects received 3 weekly radial shockwave treatments**
- **Group with local anesthesia with reduced pain relief at 3 months**

Rompe, et al. Repetitive low-energy shock wave application without local anesthesia is more efficient than repetitive low-energy shock wave application with local anesthesia in the treatment of chronic plantar fasciitis. JOR, 2005.

.

Meta-analysis of Shockwave Treatment for Plantar Fasciitis

- **Included 1174 participants from 9 RCT that included blinding and use of placebo, no local anesthesia**

- **40-60% experienced reduction in heel pain, 41-61% with reduced first step pain, 49-60% with improved heel pain during ADLs**

Lou, et al. Effectiveness of Extracorporeal Shock Wave Therapy Without Local Anesthesia in Patients With Recalcitrant Plantar Fasciitis. Am J Phy Med Rehabil, 2017.

.

Systematic Review of Systematic Reviews: Plantar Fasciitis

Systematic Review

A Systematic Review of Systematic Reviews on the Epidemiology, Evaluation, and Treatment of Plantar Fasciitis

Hye Chang Rhim [1,†], Jangwon Kwon [2,†], Jewel Park [3], Joanne Borg-Stein [4,5] and Adam S. Tenforde [4,5,*]

- **Reviews concluded longer-term outcomes improved with both PRP and shockwave therapy over corticosteroid**
- **Limited head-to-head comparisons to draw conclusions PRP vs shockwave**

Rhim et al. Life, 2021.

.

My Experience with Plantar Fasciitis

- **38 patients (31 runners) with chronic plantar fasciitis**
- **Radial treatment or combined (radial + focus shockwave) with physical therapy**
- **Outcome of interest Foot and Ankle Ability Measure (FAAM)**

DeLuca, et al. Similar Functional Gains Using Radial and Combined Shockwave Therapy in the Management of Plantar Fasciitis. JFAS, 2021

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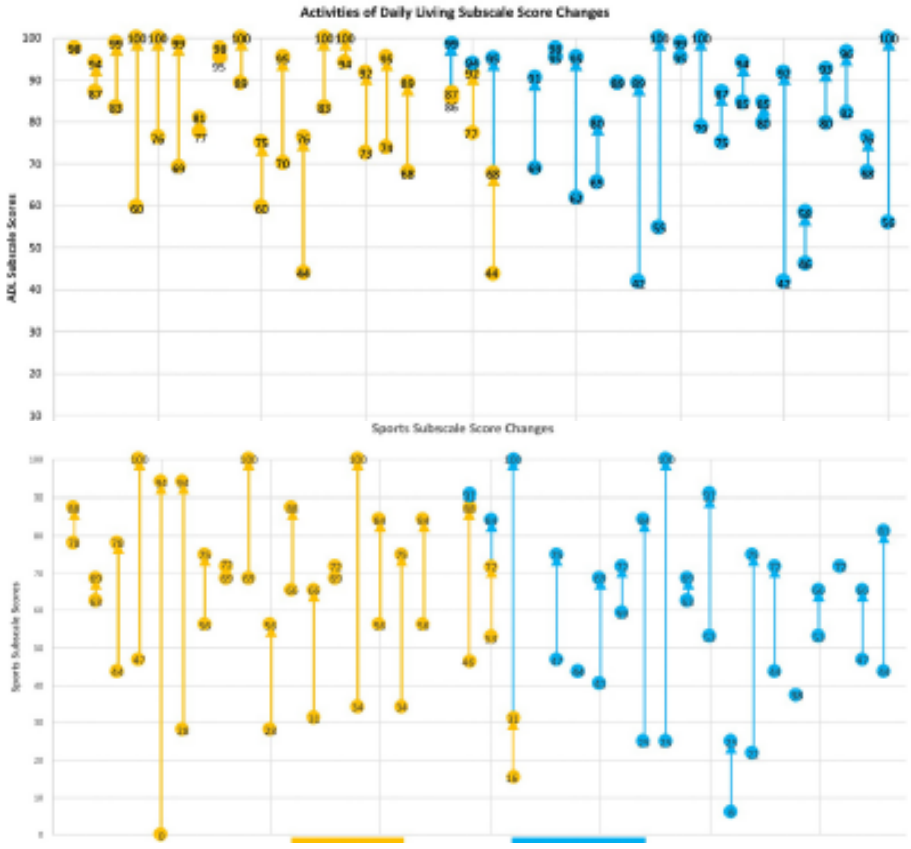
My Experience with Plantar Fasciitis



70% vs 77.8% met success for ADL

75% vs 85% success sports subscale

DeLuca, et al. Similar Functional Gains Using Radial and Combined Shockwave Therapy in the Management of Plantar Fasciitis. JFAS, 2021

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PRP with ESWT for plantar fasciitis

- Cases of 69 yo F and 70 yo M
- Combined (Focus with Radial) ESWT with functional improvement
- Addition of PRP allowed return to running

CASE REPORT

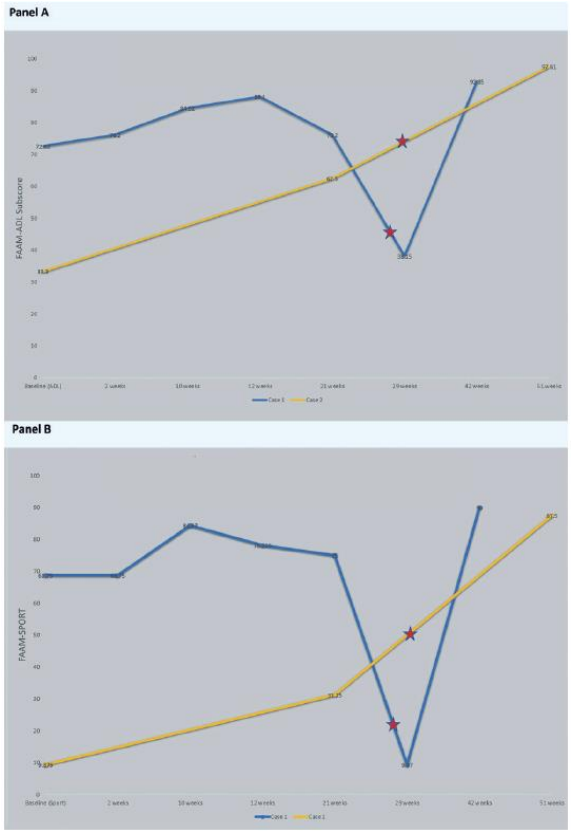
ACCEPTED: March 2023

PUBLISHED ONLINE: April 2023

Jarnagin JJ, McCormack M, McInnis KC, Borg-Stein J, Tenforde AS. Use of combined shockwave therapy and platelet-rich plasma injection for management of chronic plantar fasciitis in runners: two case reports. Dtsch Z Sportmed. 2023; 74: 52-56.

Jarnagin JJ[1], McCormack M[1], McInnis KC[1], Borg-Stein J[1], Tenforde AS[1]

Use of Combined Shockwave Therapy and Platelet-Rich Plasma Injection for Management of Chronic Plantar Fasciitis in Runners: Two Case Reports



FAAM ADL

FAAM Sport

Bone Stress Injury Management

Taki: Series of 5 athletes with non-union stress fractures (mean 1 yr), treatment of tibia (2), 5th metatarsal (1), inferior pubic ramus (1) and medial malleolus of ankle (1) treated with one session focused shockwave (OssaTron 2000-4000 shocks at 0.29-0.40 mJ) with local anesthesia: all with bone consolidation and return to sport 3-6 months (mean 4 months) following one treatment

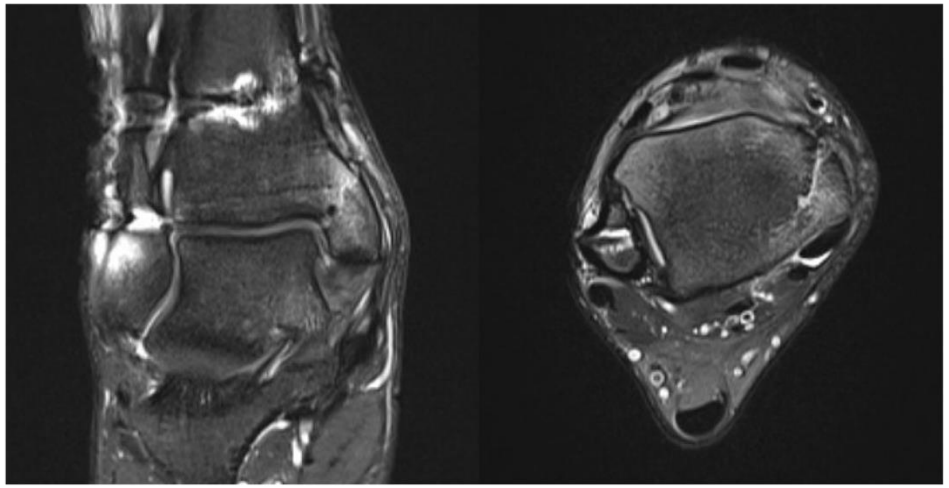
Moretti: 10 athletes with Jones fracture or anterior tibial diaphysis fracture, each received 3-4 sessions of focused shockwave (Electromagnetic Storz Minilith) for 3-4 treatments every 2-3 days. Bone fusion seen in all within 6-14 weeks, return to sports 3-10 mo (most within 3-4 mo)

Taki., et al. Extracorporeal Shock Wave Therapy for Resistant Stress Fracture in Athletes: A report of 5 Cases. AJSM 2007.
Moretti et al. Shock Waves in the Treatment of Stress Fractures. Ultrasound Med and Biol, 2009.

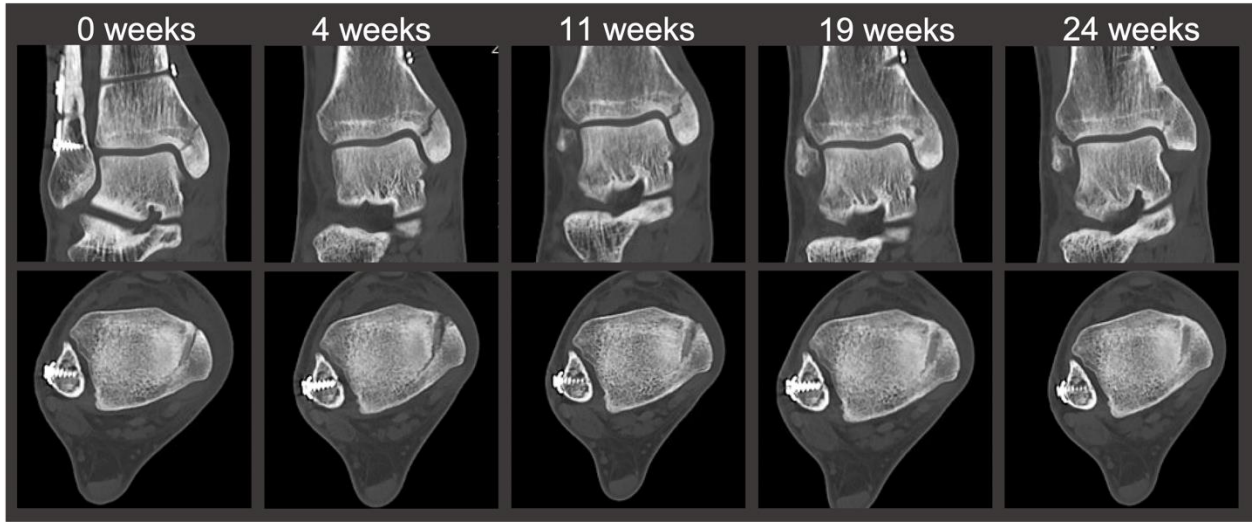
My Observations Treating Bone Stress Injuries in Runners

- **40 patients with 41 total bone stress injuries based on exam and graded using MRI**
- **Average of 5 sessions of focus shockwave therapy (electromagnetic device, minimum 0.30 mJ ~3000 shocks per session)**
- **Nearly all (98%, 39 of 40 runners) returned to pain-free running:**
  - **Return to run at median 12 weeks for acute injuries, 18 weeks for delayed/non-union**
  - **One athlete Saxena class II navicular stress fracture required ORIF**

Combination of Bone Marrow Aspirate and Shockwave



Medial malleolar stress fracture after high ankle sprain with stabilization



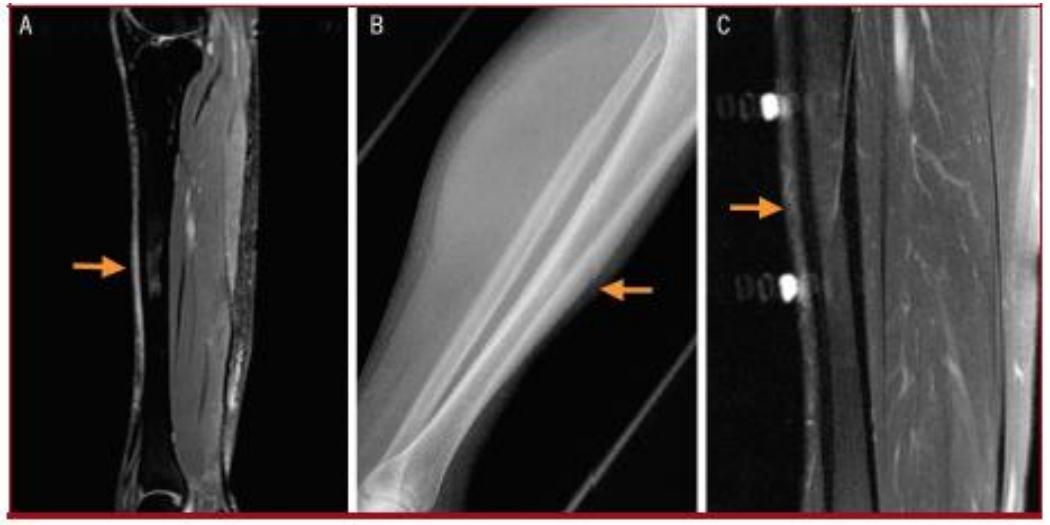
Shockwave therapy performed starting week 12, BMAC week 14, serial CT healing

”Can I run while doing shockwave therapy?”

- 25 year-old F runner with 3 months of mid-portion Achilles tendon pain
- Five sessions of radial shockwave applied over 6 weeks leading to Chicago Marathon
- Completed event pain free and qualified for Boston Marathon by time
- Similar high performance within female runner with proximal hamstring tendinopathy -> pain free and 100k ultra-marathon completed 4 months after treatement

Shockwave in Combination with Gait Retraining

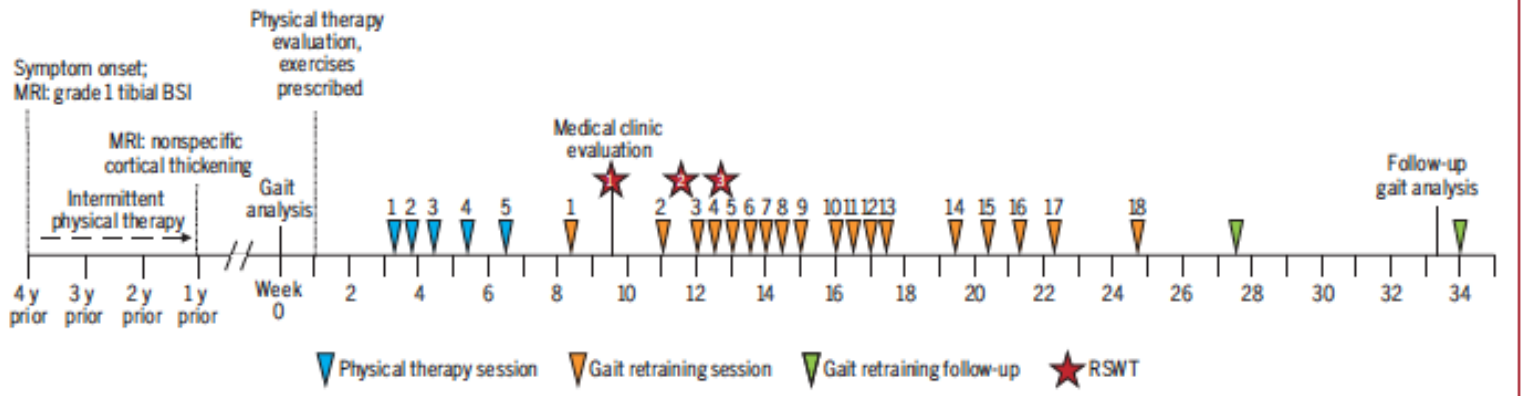
- 34 year-old F runner with 7 years of leg pain with running
- Initial MRI grade 1 BSI, subsequent studies over 3 years with diffuse cortical thickening
- Prior PT with refractory pain
- Goal to return to running



Shockwave in Combination with Gait Retraining

- Pain when initiating gait retraining on attempts to run
- 3 (painful!) radial shockwave treatments
- Full progression to pain free status

FIGURE 1
Timeline showing chronicity of symptoms and progression through RSWT, physical therapy, and gait retraining interventions.



Abbreviations: BSI, bone stress injury; MRI, magnetic resonance imaging; RSWT, radial extracorporeal shock wave therapy.

Douglas, Posilkin and Tenforde. Chronic Periostitis of the Anterior Tibia Treated with Combination of Shockwave Therapy andGait Retraining: A Case Report. JOSPT Cases, 2021

Shockwave in Combination with Gait Retraining

"I really didn't see running as a possibility for me anymore, between the physical pain and how emotionally draining and discouraging it was to start every running season knowing the issues I was undoubtedly going to run into and the dread of waiting for it to happen. Between the shockwave therapy and my physical therapist's guidance, I am now following a run plan that allows me to run 3 to 6 miles four times a week"

Treatment dose: Radial Shockwave

- Radial shockwave applied for 3000 strikes using smaller diameter applicator head to enthesis/tendon and 3000 strikes with larger diameter to the myotendinous and muscle region using clinical focusing
- Effective treatment typically at 2-4.5 bars of air pressure with radial shockwave for soft tissue conditions

Mitchkash et al. Efficacy of Extracorporeal Pulse-Activated Therapy in the Management of Lower-Extremity Running-Related Injuries: Findings From a Large Case Cohort JFAS, 2020.
Yun et al. Radial versus Combined Shockwave Therapy in the Management of Proximal Hamstring Tendinopathy: Similar Functional Outcomes in Running Cohort. MLTJ, 2021.
DeLuca et al. Similar Functional Gains Using Radial Versus Combined Shockwave Therapy in Management of Plantar Fasciitis. JFAS, 2021.

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Treatment dose: Focused Shockwave

- Moderate energy (0.10 to 0.25 mJ) to enthesis/tendon for 1500-2000 shocks using clinical focusing
- High energy (titrate to goal threshold 0.30 mJ) to bone for 3000-4000 shocks for 3-4 sessions, may consider "booster" treatments during return to sport

Robinson, et al. Functional Gains Using Radial and Combined Shockwave Therapy in the Management of Achilles Tendinopathy. JFAS, 2020.
Yun et al. Radial versus Combined Shockwave Therapy in the Management of Proximal Hamstring Tendinopathy: Similar Functional Outcomes in Running Cohort. MLTJ, 2021.
DeLuca et al. Similar Functional Gains Using Radial Versus Combined Shockwave Therapy in Management of Plantar Fasciitis. JFAS, 2021.
Beling, et al. Outcomes Using Focused Shockwave for Treatment of Bone Stress Injury in Runners. Bioengineering, 2023.

Inform on appropriate load management

- Post-procedure – caution on hyperstimulation analgesic effect
- Counsel on limited evidence with tendon rupture following focused shockwave
- Principles of green/yellow/red for tendon/fascia healing
- Apply standard guidelines for bone healing

1. The pain is allowed to reach 5 on the NPRS during the activity.
2. The pain after completion of the activity is allowed to reach 5 on the NPRS.
3. The pain the morning after the activity should not exceed a 5 on the NPRS.
4. Pain and stiffness are not allowed to increase from week to week.

Silbernagel and Crossley, A Proposed return to sport for Achilles tendinopathy. JOSPT, 2015

Clinical outcomes

- Most clinical trials identify outcomes at 3-4 months after initiating **3-4 sessions of treatment**
- PROMs are best to quantify response to treatment
- Imaging has limited value outside monitor fracture healing

Patient Considerations

- Recommendations to avoid NSAIDs for 6 weeks during treatment
- Contraindicated with cardiac pacemaker/electronic implants
- Relative contraindication treatment in skeletal immaturity (use radial pressure waves!), pregnancy, malignancy, or localized infections
- In rheumatological disease -> unknown pro-inflammatory response

Summary

- Shockwave is a safe, non-invasive treatment for sports injuries
- Treatment should be combined with physical therapy and appropriate load management
- Full outcomes observed at 3 months


Mass General Brigham