Mass General Brigham
Spaulding Rehabilitation

Advances in Shockwave for Management of Musculoskeletal Conditions

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HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

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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

Weill Cornell Medicine-Qatar

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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 of musculoskeletal injuries
- To apply best practice in application of shockwave in clinical practice

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My Journey

- **Long-time runner who contributed to three national championship teams at Stanford and was five-time All-American**
- **Olympic Trials qualifier in 10K and 5K distances (my wife is faster and more talented than me)**
- **History of recurrent Achilles tendinopathy**
- **Goal to identify evidence-based and effective treatments for my patients**

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Challenges in clinical practice

- **Musculoskeletal conditions are common**
- **Injuries can be difficult to treat and often recur**
- **Common injuries include soft tissue conditions of tendon, fascia, along with joint and bone**
- **Non-invasive, effective treatments are desirable for both patients and providers**

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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

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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

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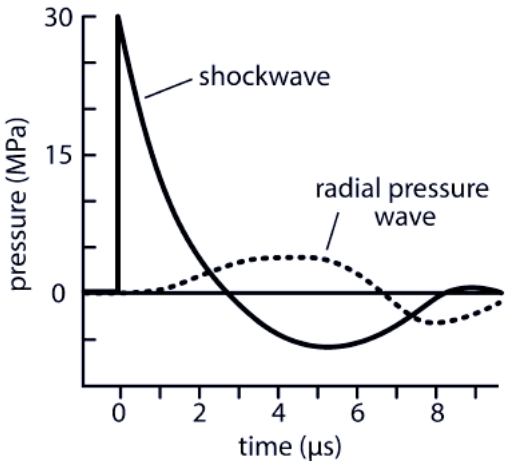
What is Shockwave?



- True shockwave created by focused shockwave device
- Radial shockwave produces a pressure wave that typically has lower amplitude

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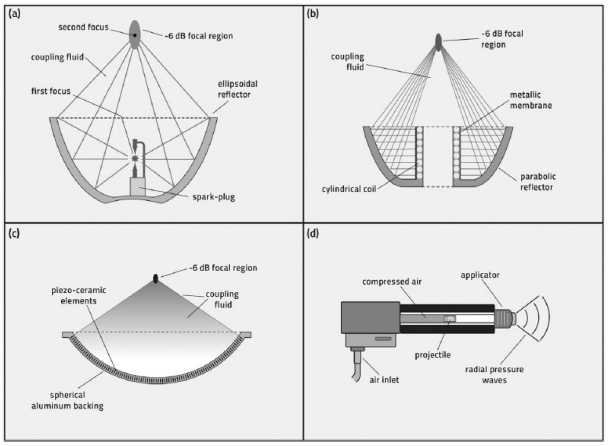
What is Shockwave?



- **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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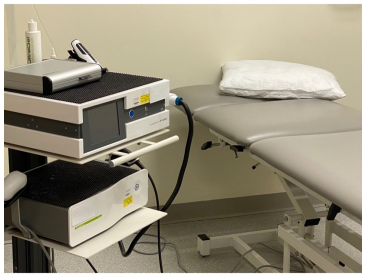
What is Shockwave?

Early devices large and cumbersome



Current Device – size of a desktop computer

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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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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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Advantages of shockwave

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

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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.

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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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Achilles tendinopathy

- 48 patients with >3 mo in double blind, placebo control RCT of 4 treatments radial shockwave
- Greater efficacy in radial shockwave group compared to placebo in AOFAS scales at 4, 8 and 12 weeks

Rasmussen, et al. Shockwave treatment for chronic Achilles tendinopathy. Acad Orthopedics, 2008.

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Insertional Achilles tendinopathy

- 50 patients >6 mo insertional tendinopathy
- Eccentric group: 3x15 rep, twice daily 12 weeks
- Radial shockwave (RSW): 3 weekly sessions
- 64% with RSW and 28% eccentric "complete/very-much" improved, greater VISA-A outcomes RSW at 4 months

Rompe, et al. Eccentric Loading vs Shockwave Treatment Insertional Achilles Tendiopathy. JBJS, 2008

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Eccentric Loading Improves Shockwave Outcomes

- **68 patients >6 mo mid-portion tendinopathy**
- **Radial shockwave (RSW): 3 weekly sessions**
- **RSW + Eccentric group: 3x15 rep, twice daily 12 weeks**
- **4 mo success in 82% RSW + Eccentrics vs 58% with RSW, in addition to greater VISA-A**

Rompe, et al. Eccentric Loading vs Eccentric with Shockwave Treatment Midportion Achilles Tendiopathy. AJSM, 2009

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Does Physical Therapy Work?

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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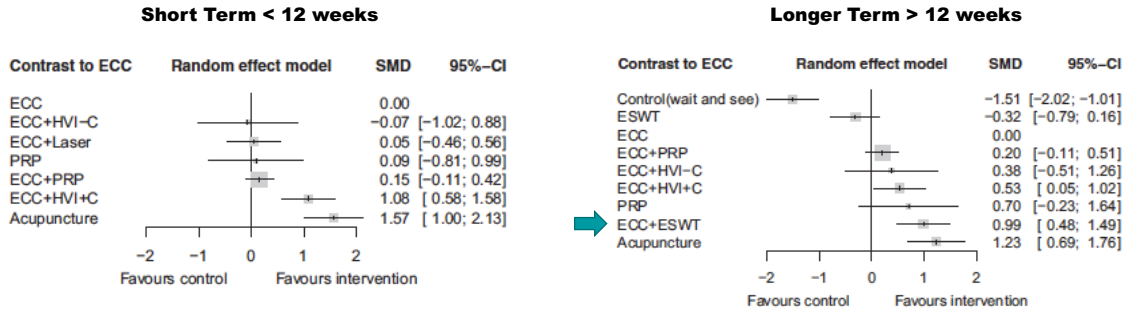
Outcomes favor Eccentric Loading combined with interventions



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

- **Cohort of 87 patients (63 runners) with Achilles tendinopathy Aug 2017-Oct 2020**
- **Radial treatment or combined (radial + focus shockwave) with eccentric loading and formal physical therapy**
- **Outcome of interest VISA-A**

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

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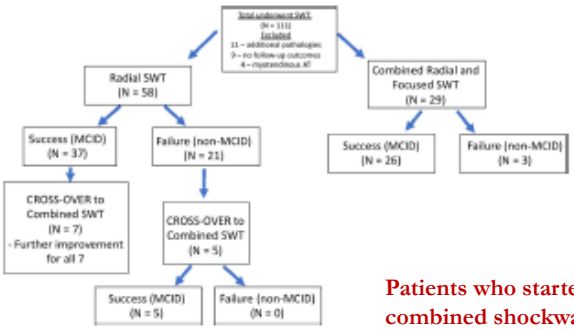
My experience with Achilles Tendinopathy



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

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

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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.

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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.

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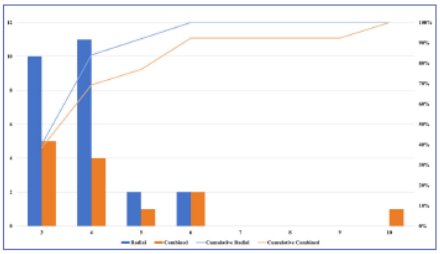
My success treating runners with hamstring tendinopathy

- 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

Rompe, et al. Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome. Am J Sports Med, 2009.

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**
- **Outcomes: FAAM ADL and sport subscale**

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.

Tibialis Posterior Tendinopathy

80-90% success in meeting 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.

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

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

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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

- Earliest evidence in plantar foot pain
- 36 subjects with > 12 mo pain and radiograph calcaneal heel spur
- Single blind RCT to 3 weekly radial shockwave (RSW) treatments using local anethetic vs placebo
- 72% with pain reduction in RSW at 24 weeks

Rompe, et al. Low-energy extracorporeal shockwave for the painful heel. Arch Orthop Trauma Surg, 1996.

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.

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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.

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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.

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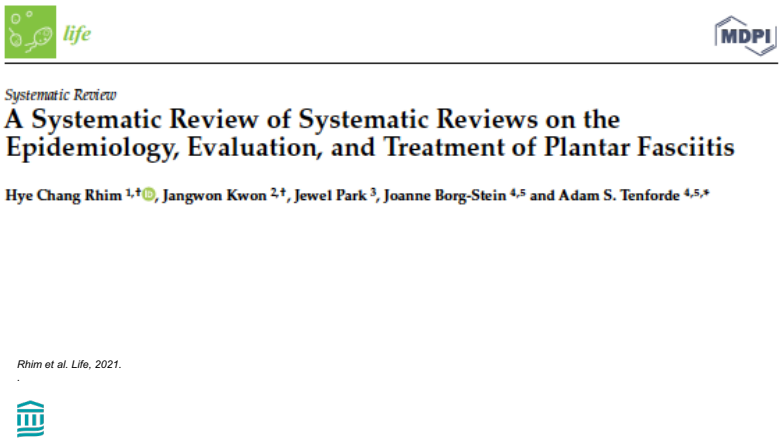
Systematic Review of Systematic Reviews: Plantar Fasciitis


life

MDPI

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,*]

Rhim et al. Life, 2021.

- **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**

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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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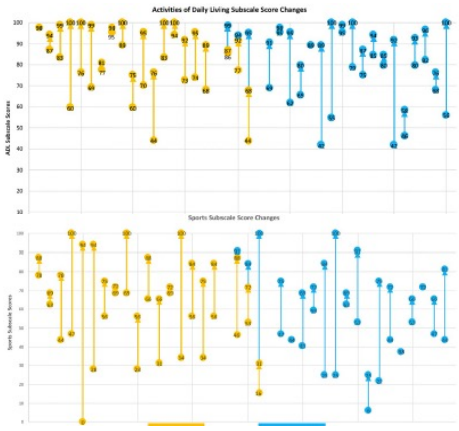
My Experience with Plantar Fasciitis



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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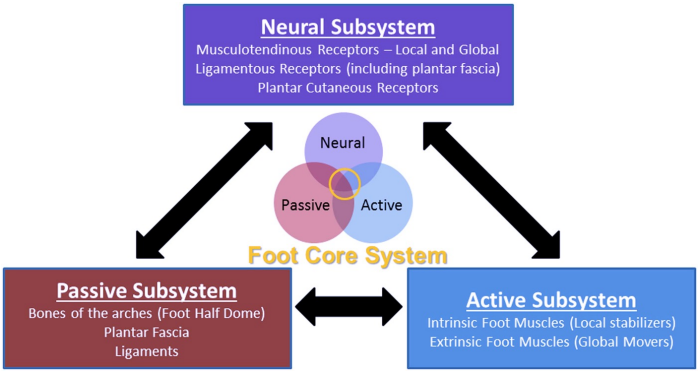
Foot Core Paradigm



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

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Foot Core Paradigm: short foot or 'doming'

Stiffen your toes, press into the ground

Squeeze your arch, drawing the ball of your foot towards your heel, making your foot shorter, creating an arch

Hold for 10 seconds then relax

Slide courtesy of Lindsay Wasserman, PhD PT

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Foot Core Paradigm: foot intrinsic exercises

Toe spreads

Toe Yoga

Foot Intrinsic Strengthening

Slide courtesy of Lindsay Wasserman, PhD PT

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 Stress Fractures in Runners

- 45 cases in four years of runners treated with high energy focused shockwave therapy, including 15 with grade 4 BSI (stress fracture) and delayed/non-union in 7 runners
- Standard protocol of 3-4 sessions typically once per week, treatment 3000-4000 shocks with goal minimum threshold of 0.30 mJ energy
- Clinical follow-up at 6 weeks to advance rehabilitation program and determine return to sport
- Additional shockwave performed during return to running progression

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My Observations Treating Stress Fractures in Runners

- 14 of 15 runners achieved pain free status and returned to running
- One patient had non-union observed on CT of navicular bone (Saxena II) and elected surgery
- Patients treated included both those without markers of low energy availability and runners with Triad risk categories in moderate to high risk

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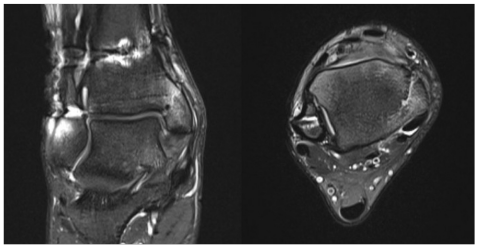
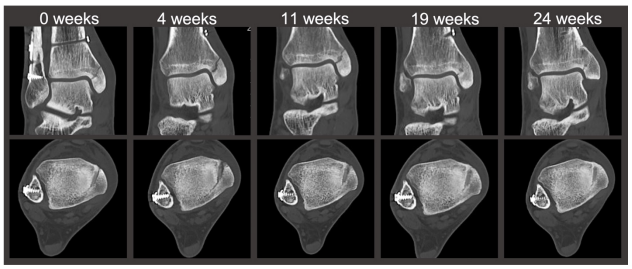
Combination of Bone Marrow Aspirate and Shockwave



Medial malleolar stress fracture after high ankle sprain with stabilization



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

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Observations in Rheumatological Disease

- Case series of 17 patients who received shockwave for musculoskeletal pain
  - 8 of 17 reported clinical improvement following treatment
  - Disease flair in 4 of 17, including 3 with known rheumatoid disease but not on stable medication regimen

Yun, Tenforde, et al. Extracorporeal shockwave therapy for a focal musculoskeletal complaint in patients with rheumatic disease: a cases series. In Press

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"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

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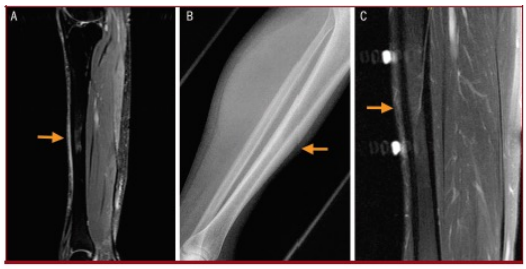
Shockwave in Combination with Gait Retraining

- 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



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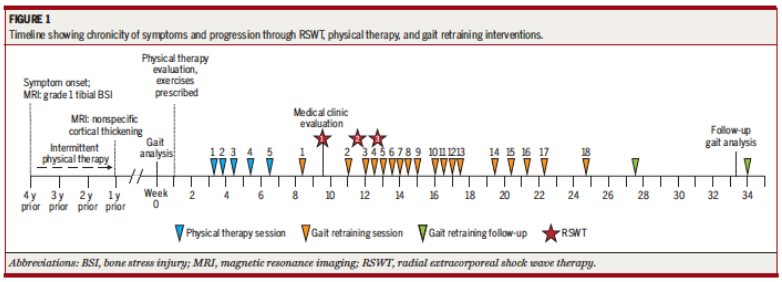
Shockwave in Combination with Gait Retraining

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



Douglas, Posilkin and Tenforde. Chronic Periostitis of the Anterior Tibia Treated with Combination of Shockwave Therapy and Gait 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"

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

Developing Best Practices

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]

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ESWT core curriculum components	
Didactic	
Lectures	Principles of ESWT: Introduction to physics, knobology, safety protocols/ techniques, ergonomics, informed consent (risks, benefits, side effects), time-out protocols, and basic ESWT applications
Hands-on demonstration sessions	Led by senior residents, fellows, and/or attendings
Trainee practice sessions	Direct supervision and feedback from senior residents, fellows, and/or attendings
Clinical	
Rotation orientation	Review of milestones, competencies, and rotation goals
Faculty observation	Preprocedural, procedural, and postprocedural protocols
Progressive trainee performance	Direct faculty supervision with procedural involvement based on current milestone achievement
Feedback sessions	Both formal sessions at specific time points during rotation (ie, midpoint), as well as informal/immediate feedback during procedure or debriefing session afterward to allow for focused practice aligned with milestone goals
Procedural documentation	Review of necessary elements and/or billing procedure if applicable
Competency assessment	Based on outlined ESWT milestones in Table 8

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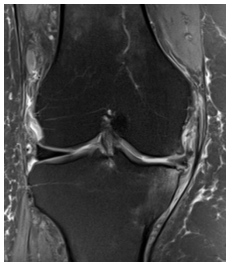
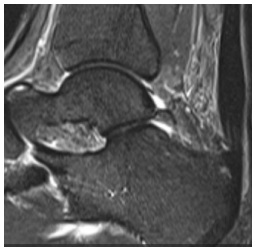
Developing Best Practices: Ergonomics

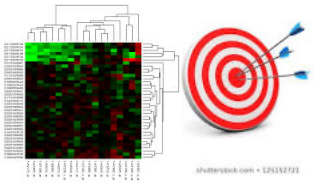
Future Directions: Phenotyping Pain

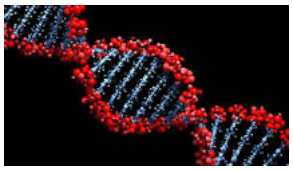


Osteoarthritis:
-joint space narrowing
-extraarticular bone edema
-tendon and ligamentous injury

Tendon injury:
-degenerative changes
-muscle injury
-adjacent bone traction and joint disease





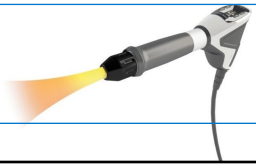


New Model to approach Osteoarthritis of the Knee

Platelet Rich Plasma
– joint space

Focus Shockwave
– Bone Marrow Lesion

Radial Shockwave
– Muscle, tendons



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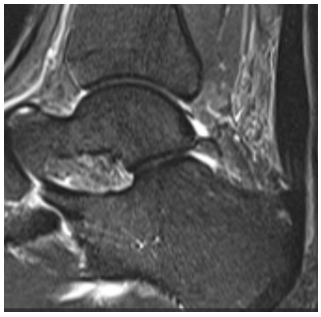
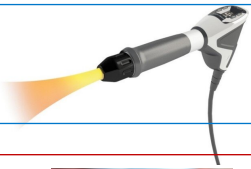
Re-imagine Management of Tendinopathy with Interstitial tearing or larger defect



Radial Shockwave
– Muscle, tendons



Platelet Rich Plasma
- primary tendon defect
- articular structures

Focus Shockwave
- enthesis edema
- calcific lesion(s)

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Patient Considerations

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

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Outcomes

- Full effects may be seen 12 weeks or longer after last treatment
- Comparative efficacy to other interventions is needed
- Outcome measures are collected to document success

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