Mass General Brigham
Spaulding Rehabilitation

Evaluation of the Injured Runner

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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 review the most common running related injuries
- To discuss the treatment approach of an injured runner
- To identify risk factors for each form of injury to guide management and strategies for chronic/refractory cases

About Me

All-American runner and member of
3 National championship teams at Stanford

Competed in Olympic Trials in 10,000 meters

Enjoy running Boston Marathon

Wife Kate Tenforde Olympian 10,000 meters at Athens 2004

Spaulding National Running Center

Overview

- **Running injuries are common**
- **Injuries can be difficult to treat and often recur**
- **Common injuries include those to tendon, joints and bone**

Common Running Related Injuries

RRMI	Incidence (%)[a]
Medial tibial stress syndrome	13.6–20.0
Achilles tendinopathy	9.1–10.9
Plantar fasciitis	4.5–10.0
Patellar tendinopathy	5.5–22.7
Ankle sprain	10.9–15.0
Iliotibial band syndrome	1.8–9.1
Hamstring muscle injury	10.9
Tibial stress fracture	9.1
Hamstring tendinopathy	7.3
Patellofemoral syndrome[c]	5.5

Lopes, et al. What are the main running-related musculoskeletal injuries? Sports Med, 2012

Challenges in evaluation and treatment of the injured runner

- **Runners have a general distrust of physicians**
- **The cause of most injuries are multifactorial**
- **Developing team-based approach may optimize outcome**

Treatment of the injured runner: a team approach

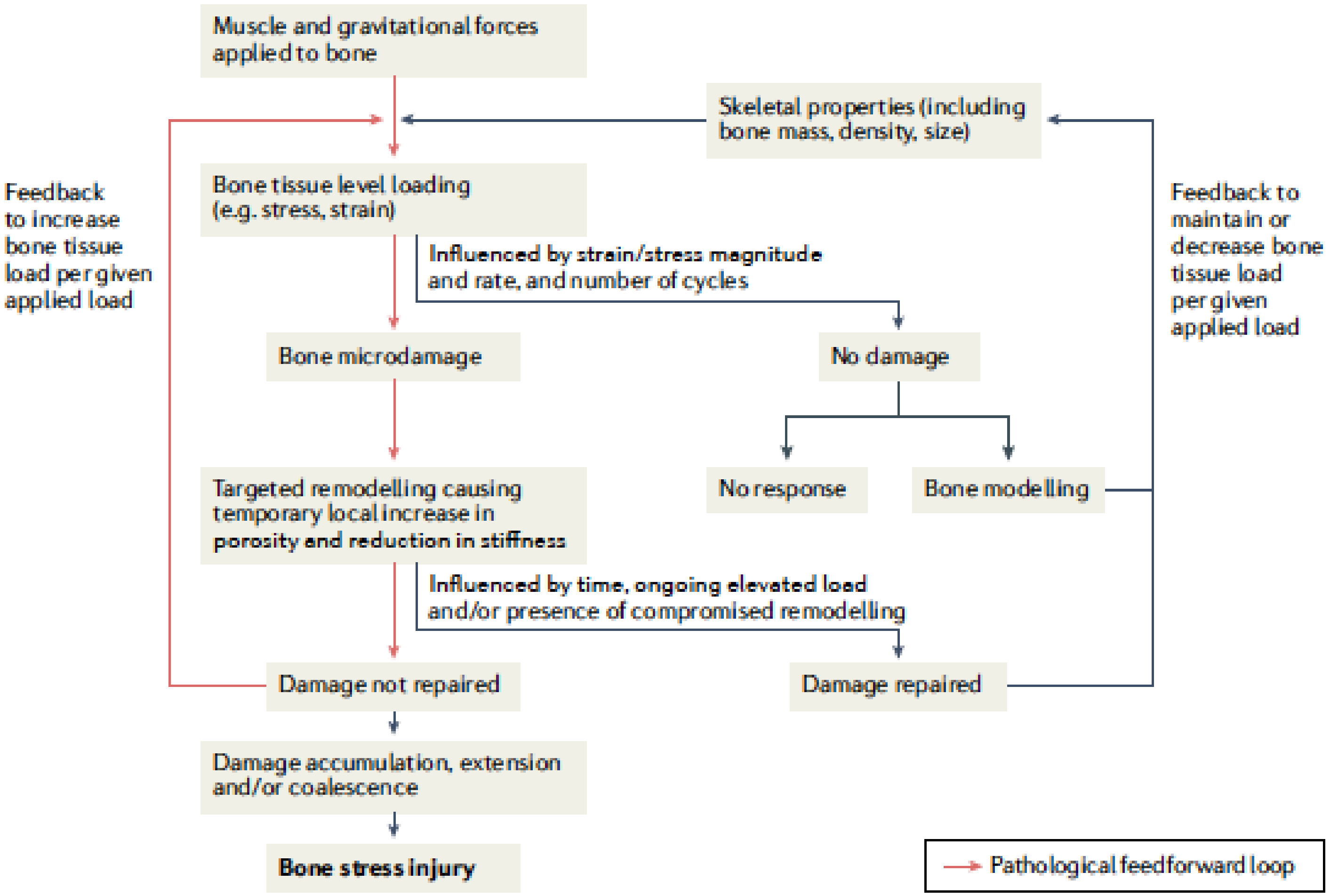
Overview

Three common injuries reviewed:

- **Bone stress injury/Stress fracture**
- **Tendinopathy**
- **Joint related injuries**

Bone Stress Injury - Failure of skeleton to withstand *submaximal* forces acting over *time*

Pathogenesis of Bone Stress Injury



Hoenig, Tenforde et al. Nature Reviews Disease Primers, 2022

Epidemiology

- **Bone stress injuries account for up to 20% of injuries seen in sports medicine clinics.**

Fredericson et al. Stress Fractures in Athletes. Top Mag Reson Imag, 2007.

Risk factors for bone stress injury

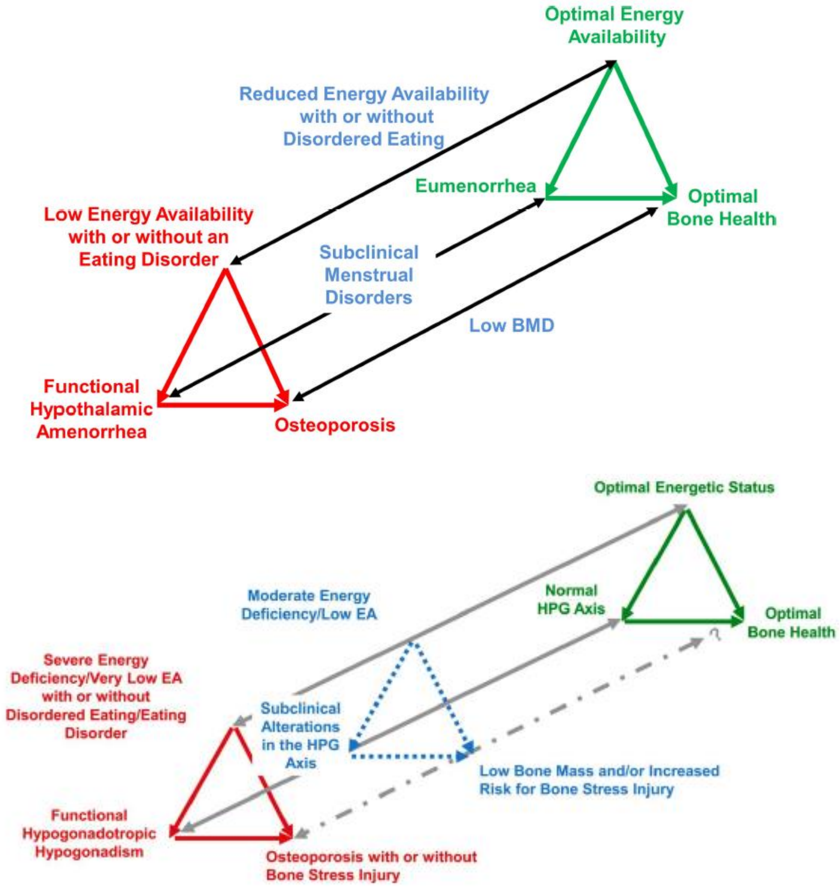
- **Both physical activity and biological factors contribute to overall bone health.**

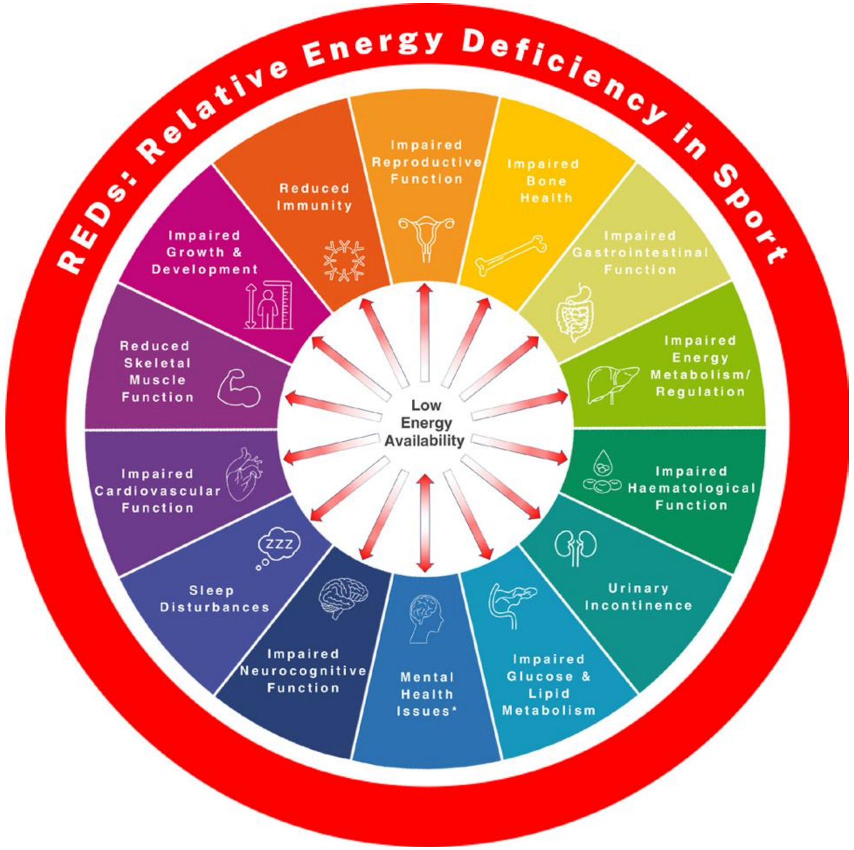
- **Genetics may explain a majority of total bone mass and contribute to risk for injury.**

- **Sex-specific risk factors are important to identify.**

Female and Male Athlete Triad

Relative Energy Deficiency in Sport (REDs)





De Souza, et al. Female Athlete Triad BJSM, 2014
Mountjoy, et al. REDs, BJSM 2023.
Nattiv, et al. Male Athlete Triad CJSM 2021

Low energy availability

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BRAIN / HYPOTHALAMUS

↓ **Sex Hormones**
- **Menstrual dysfunction**
- **Reduced bone mass**
- **Male hypogonadal state**

↓ **Growth Hormone Sensitivity**
- **Loss of muscle**
- **Reduced bone mass**

↓ **Thyroid Hormones**
- **Suppressed metabolism**

↑ **Stress Hormone Levels**
- **Loss of muscle**
- **Reduced bone mass**
- **Menstrual dysfunction**

Chan JL, Mantzoros CS. Lancet 2005;366:74-85.

Adequate energy availability

(+)

BRAIN / HYPOTHALAMUS

Sex Hormones
- Normal menstruation
- Optimal bone mass
- Appropriate testosterone

Growth Hormones
- Build and maintain lean muscle
- Optimal bone mass

Thyroid Hormones
- Normal metabolic function

Normal Stress Hormone Levels

Chan JL, Mantzoros CS. Lancet 2005;366:74-85.

Triad Risk Factors

- BMI (Barrack, Tenforde)
- Elevated dietary restraint (Barrack)
- Late menarche (Barrack, Tenforde)
- History of fracture (Kelsey, Tenforde, Touchy)
- Low BMD (Barrack, Kelsey)
- Triad risk is cumulative (Barrack, Tenforde 2013 and 2017)

Barrack, et al. Higher incidence of bone stress injuries with increasing female athlete triad. AJSM, 2014.
Kelsey, et al. Risk factors for stress fractures among young female cross-country runners. MSSE, 2007.
Tenforde, et al. Sex specific risk factors for stress fractures in young runners. MSSE, 2013.
Tenforde, et al. Association of the Female Athlete Triad Risk Assessment Stratification to the Development of Bone Stress Injuries in Collegiate Athletes, AJSM 2017
Touchy, et al. Prospective analysis of tibial stress fractures. CJSM, 2008.

Male Triad Risk Factors

156 male runners with 307 years of observation over 7 years

- **27% of runners sustained one or more BSI**
- **Each point of CRA was associated with 27% greater risk for BSI**

Risk Factors	Magnitude of Risk		
	Low Risk = 0 points each	**Moderate Risk = 1 point each**	**High Risk = 2 points each**
Low EA with or without DE/ED	☐ No dietary restriction	☐ Some dietary restriction‡; current/past history of DE;	☐ Meets DSM-V criteria for ED*
Low BMI	☐ BMI ≥ 18.5 **or** ≥ 90% EW** or weight stable	☐ BMI 17.5 < 18.5 **or** < 90% EW **or** 5 to < 10% weight loss/month	☐ BMI ≤17.5 **or** < 85% EW **or** ≥ 10% weight loss/month
Delayed Menarche	☐ Menarche < 15 years	☐ Menarche 15 to < 16 years	☐ Menarche ≥16 years
Oligomenorrhea and/or Amenorrhea	☐ > 9 menses in 12 months*	☐ 6-9 menses in 12 months*	☐ < 6 menses in 12 months*
Low BMD	☐ Z-score ≥ -1.0	☐ Z-score -1.0*** < - 2.0	☐ Z-score ≤ -2.0
Stress Reaction/Fracture	☐ None	☐ 1	☐ ≥ 2; ≥ 1 high risk or of trabecular bone sites†
Cumulative Risk (total each column, then add for total score)	**_____ points +**	**_____ points +**	**_____ points = _____Total Score**

Kraus, Tenforde et al. Bone Stress Injury in male distance runners: higher modified Female Athlete Triad Cumulative Risk Assessment scores predict increased risk of injury. BJSM 2019.

Calcium and Vitamin D

In an 8-week trial of supplementation with 2000 mg calcium and 800 IU of vitamin D in female military recruits, there was a 20% reduction in fractures.

Lappe et al. Calcium and vitamin d supplementation decreases incidence of stress fractures in female navy recruits. J Bone Miner Res, 2008.

Higher Total Calcium Protective in Runners

Women who consumed less than 800 mg of calcium per day had nearly *6 times* the rate of stress fracture than women who consumed more than 1500 mg of calcium.

Nieves et al. Nutritional factors that influence change in bone density and stress fracture risk among young female cross-country runners. PMR Journal, 2010.

Milk Consumption May Reduce Injury

Fracture risk decreased by 62% per additional cup of skim milk consumed per day.

Nieves et al. Nutritional factors that influence change in bone density and stress fracture risk among young female cross-country runners. PMR Journal, 2010.

Sleep Quality

- **Inadequate sleep has been found to contribute to increased bone turnover and risk for injury.**
- **18-year old male military recruits were divided into 3 experimental conditions (sleep deprivation 62 hours, 6-hours sleep vertical position, 6-hours sleep horizontally) with measurements of urinary calcium levels and BMD over 7-day period.**

Ben-Sasson, et al. Extended duration of vertical position might impair bone metabolism. Eur J Clin Invest, 1994.

Sleep Quality

- **40% of sleep deprivation (SD) and vertical sleepers (VS) had 170% and 68% increase in urinary calcium excretion and hydroxyproline.**
- **Both SD and VS populations experienced <u>5% reduction in BMD</u> compared to non-responders.**

Ben-Sasson, et al. Extended duration of vertical position might impair bone metabolism. Eur J Clin Invest, 1994.

Biomechanical risk factors

- **Greater vertical center of mass displacement (Joachim)**
- **Lower step rate (Kliethermes)**
- **Free moment (Milner)**
- **Longer Stride length (Pope)**

Joachim, et al. Preseason Vertical Center of Mass Displacement During Running and Bone Mineral Density Z-Score Are Risk Factors for Bone Stress Injury Risk in Collegiate Cross-country Runners. JOSPT 2023
Milner, et al. Free moment as a predictor of tibial stress fractures. J Biomech, 2006.
Pope, et al. Prevention of pelvic stress fractures in female army recruits. Mil Med, 1999.

Kinematic Variables

- **Peak rearfoot eversion**
- **Peak Hip Adduction**

Milner, et al. Is dynamic hip and knee malalignment associated with stress fractures? Med Sci Sport Exerc, 2005.
Pohl, et al. Biomechanical predictors of retrospective tibial stress fractures in runners, J Biomech 2008.

Management

Location and severity of injury guides treatment

- All injuries: calcium 1200 mg daily, vitamin D 1000 IU daily in addition to optimal nutrition intake
- Analgesics rarely needed, avoid NSAIDs
- Activity modification, including boot/crutches in certain high-risk injuries
- Sleep normalization and quality
- Consideration for workup bone density: DXA, medical workup, diet assessment
- Physical therapy and progression to gait retraining
- Refractory cases: consider shockwave or medications

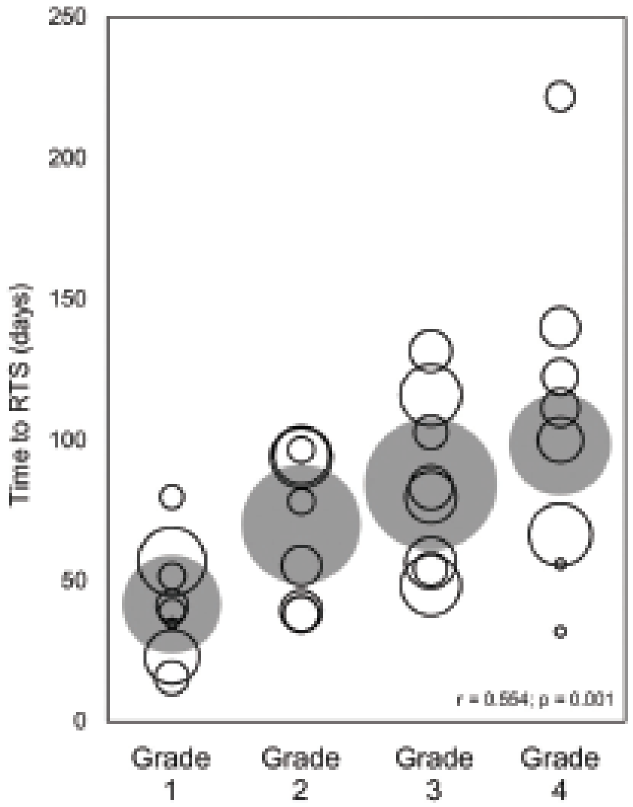
Grading Severity of Injury with MRI

TABLE 1
MRI Grading Scales for Bone Stress Injuries[a]

MRI Grade	Fredericson et al[18]	Arendt et al[2]	Nattiv et al 2013 (Current Study)
1	Mild to moderate periosteal edema on T2; normal marrow on T2 and T1	Positive signal change on STIR	Mild marrow or periosteal edema on T2[b]; T1 normal[c]
2	Moderate to severe periosteal edema on T2; marrow edema on T2 but not T1	Positive STIR plus positive T2	Moderate marrow or periosteal edema plus positive T2; T1 normal
3	Moderate to severe periosteal edema on T2; marrow edema on T2 and T1	Positive STIR plus positive T2 and T1	Severe marrow or periosteal edema on T2 and T1
4	Moderate to severe periosteal edema on T2; marrow edema on T2 and T1; fracture line present	Positive fracture line on T2 or T1	Severe marrow or periosteal edema on T2 and T1 plus fracture line on T2 or T1

Nattiv et al. Correlation of MRI Grading of Bone Stress Injuries With Clinical Risk Factors and Return to Play. Am J Sports Med, 2013

MRI Grade Can Predict Return to Play



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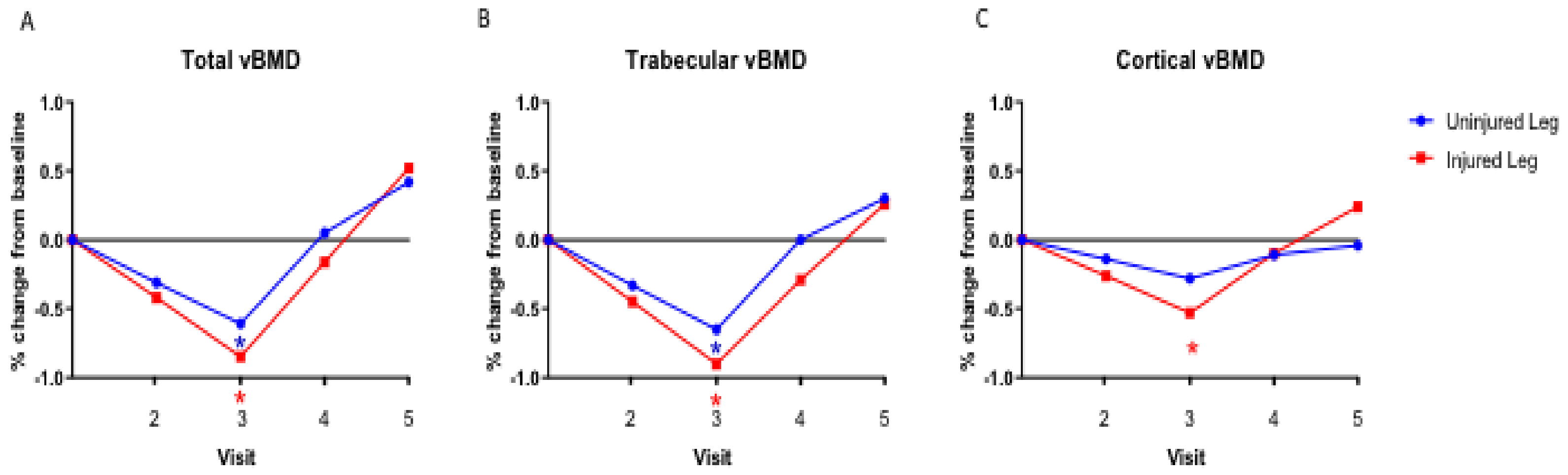
Study or Subgroup	MRI low grade Mean	SD	Total	MRI high grade Mean	SD	Total	Weight
cortical-rich							
Albisetti et al. 2010	37.8	3.6	10	54.5	9.8	9	17.9%
Beck et al. 2012	50	26.1	18	55.2	30.9	19	12.8%
Kijowski et al. 2012	29.9	11.5	20	57.8	26.3	50	17.1%
Maquirriain & Ghisi 2007	56.6	31.4	11	84	20.8	8	10.6%
Nattiv et al. 2013	88.9	11.2	22	131.6	14.7	14	17.0%
Subtotal (95% CI)			**81**			**100**	**75.3%**
Heterogeneity: $Tau^2 = 154.79$; $Chi^2 = 25.45$, $df = 4$ ($P < 0.0001$); $I^2 = 84\%$							
Test for overall effect: $Z = 3.90$ ($P < 0.0001$)							
trabecular-rich							
Harris et al. 2020	74.7	14.6	7	94.3	54.6	3	2.8%
Nattiv et al. 2013	119.7	63.7	3	266.7	44.8	4	1.7%
Ramey et al. 2016	74.2	41.5	10	113.2	45.3	17	7.2%
Rohena-Quinquilla et al. 2018	73.8	43.9	55	114.7	41.6	35	12.9%
Subtotal (95% CI)			**75**			**59**	**24.7%**
Heterogeneity: $Tau^2 = 454.52$; $Chi^2 = 6.47$, $df = 3$ ($P = 0.09$); $I^2 = 54\%$							
Test for overall effect: $Z = 3.13$ ($P = 0.002$)							
Total (95% CI)			**156**			**159**	**100.0%**
Heterogeneity: $Tau^2 = 179.23$; $Chi^2 = 36.55$, $df = 8$ ($P < 0.0001$); $I^2 = 78\%$							
Test for overall effect: $Z = 5.09$ ($P < 0.00001$)							
Test for subgroup differences: $Chi^2 = 1.92$, $df = 1$ ($P = 0.17$), $I^2 = 47.9\%$							

Hoenig, Tenforde et al. Correlation of MRI Grading of Bone Stress Injuries With Clinical Risk Factors and Return to Play. Am J Sports Med, 2021

Time to Full Skeletal Remodeling May Take Longer



Bone strength in both injured and uninjured limb recovered ~6 months!

Popp, Tenforde, et al. Changes in volumetric bone mineral density over 12 months after tibial bone stress injury diagnosis: Implications for return to sport and military duty. AJSM: 2021.

Management by Anatomical Location

High risk locations: femoral neck, navicular, anterior tibia, medial malleolus, talus, base of 2nd metatarsal, metaphyseal-diaphyseal junction of 5th metatarsal

Modified weight bearing/non-weight bearing required to ensure healing

Hoenig, Tenforde et al. Nature Reviews Disease Primers, 2022

Ensure Adequate energy availability

+

BRAIN / HYPOTHALAMUS

Sex Hormones
- Normal menstruation
- Optimal bone mass

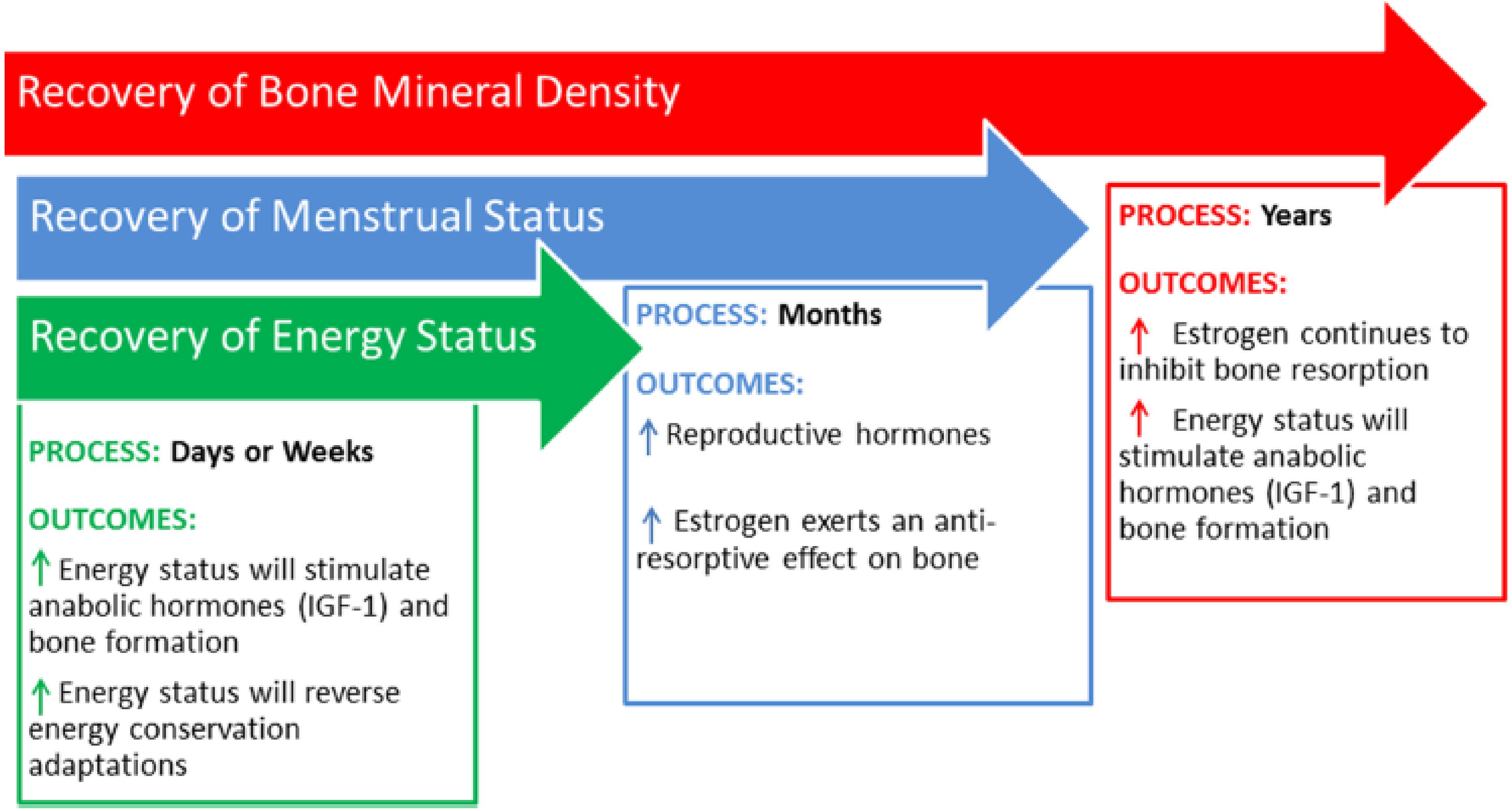
Growth Hormones
- Build and maintain lean muscle
- Optimal bone mass

Thyroid Hormones
- Normal metabolic function

Normal Stress Hormone Levels

Chan JL, Mantzoros CS. Lancet 2005;366:74-85.

Physiological Response to Adequate Energy Availability



De Souza et al, Female Athlete Triad Coalition Consensus Statement BJSM, 2014.

Consider DXA to Evaluate Bone Density

- One 'high risk' Triad Risk Factor
  - DSM-5 diagnosis of eating disorder
  - BMI ≤ 17.5 kg/m2, <85% estimated weight, OR recent weight loss ≥ 10% in one month
  - Menarche > 16 years of age
  - Current OR history of < 6 menses over 12 month period
  - 2 prior stress reactions/fracture, 1 high risk stress reaction/fracture, or low energy non-traumatic fracture
- Two or more 'moderate risk' Triad Risk Factors
  - Current or history of disordered eating 6 month
  - BMI between 17.5-18.5, <90% estimated weight, or 5-10% weight loss over 1 month
  - Menarche age 15-16
  - Current OR history 6-8 menses in 12 month period
  - Prior Z-score between -1 and -2
- 1+ non-peripheral, 2+ peripheral traumatic fractures with 1 or more moderate/high risk factor or ≥ 6 months on medications that influence bone should also be considered

De Souza et al. 2014 Female Athlete Triad Coalition Statement, Br J Sports Med, 2014.

Pharmacotherapy

- Bisphosphonates should be avoided due to concern for teratogens and have a long-have life
- Forteo (PTH-rP) is anabolic agent that has not been well-studied in athletes
- Consider Transdermal estrogen with micronized progesterone in female athlete with prolonged menstrual dysfunction and bone loss

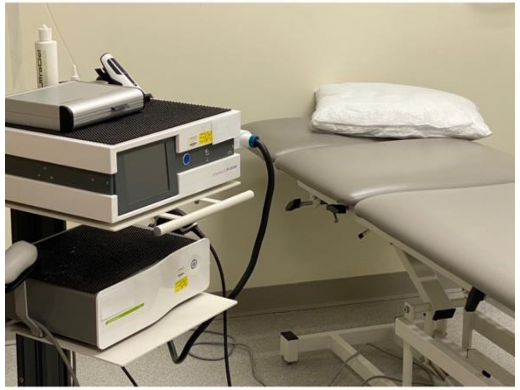
Ackerman, et al. Effects of Estrogen Replacement on Bone Geometry and Microarchitecture in Adolescent and Young Adult Oligoamenorrheic Athletes: A Randomized Trial. JBMR, 2020.

Shockwave Therapy

- **Non-invasive method to stimulate bone healing**

- **Limited evidence in athletes for non-union stress fractures**

- **Athletes: reasonable for predictable healing and to facilitate return to play**

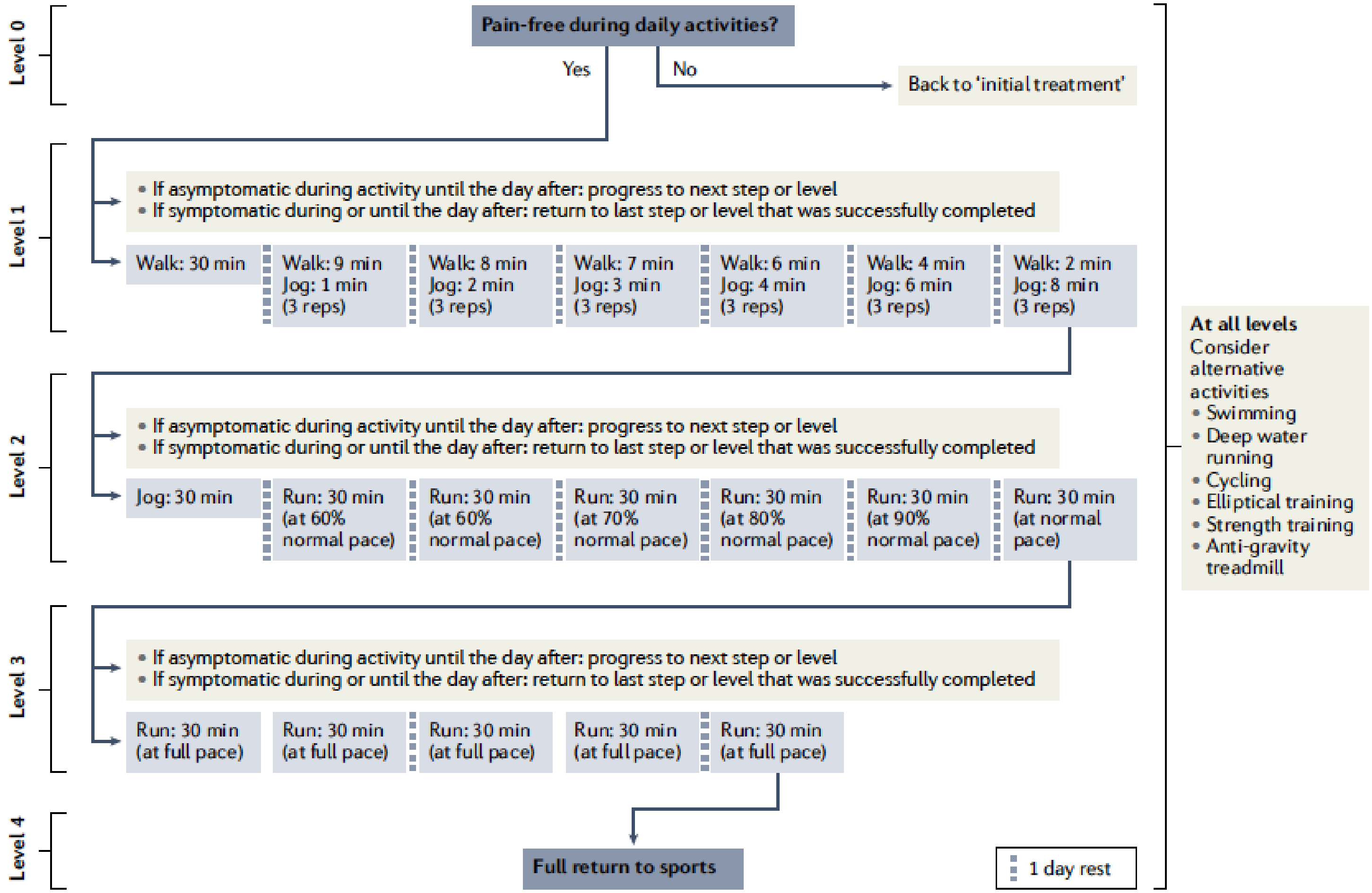


Taki et al. Extracorporeal Shock Wave Therapy for Resistant Stress Fractures. AJSM, 2007.
Moretti, et al. Shock Waves in the Treatment of Stress Fractures. Ultrasound in Med Bio, 2009.
Saxena, et al. Treatment of Medial Tibial Stress Syndrome. JFAS, 2017.

Physical Therapy

- Critical for addressing movement impairments
- Goal to address full kinetic chain
- Gait Retraining with prior bone stress injuries or failure to see improvements with traditional PT program

Return to Sport: Pain-Free Progressive Skeletal Loading



Hoenig, Tenforde et al. Nature Reviews Disease Primers, 2022
Warden et al. JOSPT, 2014

Prevention: Optimize Skeletal Health by Lifestyle

Strategies to optimize skeletal health include:

- **Screening and treatment of the Triad/REDs**
- **Promote bone loading activities at an early age**
- **Ensuring adequate and high-quality sleep**
- **Appropriate nutrition, including adequate energy availability, calcium and vitamin D**

Patellofemoral Pain - *A common cause of anterior knee pain resulting from abnormal stress to the patellofemoral joint*

Risk Factors

Local Joint Impairments	Altered Lower Extremity Biomechanics	Training Errors/Overuse
Quadriceps weakness	Hip abductor weakness	Increasing exercise too quickly
Impaired VM function	Hip external rotator weakness	Inadequate time for recovery
Soft tissue inflexibility	Excessive foot pronation	Excessive hill work
Quadriceps	Pes planus	
Gastrocnemius	Excessive impact shock with heel strike	
Iliotibial band		
Hamstring		

Dutton et al. Update on the rehabilitation of patellofemoral pain. Curr Sports Med Reports, 2014

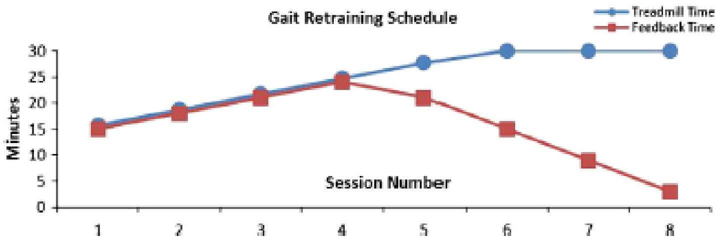
Risk Factors

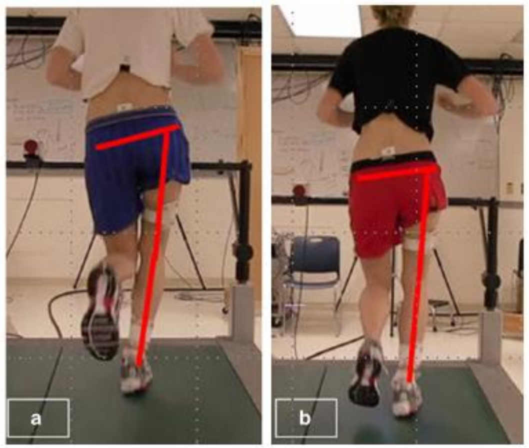
- **Pain relief**
- **Activity modification**
- **Physical therapy**
- **Gradual return to running**
- **Bracing, injection treatments refractory cases**
- **Surgery rarely indicated**

Dutton et al. Update on the rehabilitation of patellofemoral pain. Curr Sports Med Reports, 2014

Gait Retraining

- mirror therapy with faded feedback design reduced knee pain and improved alignment, durable benefits at 3 months!





Willy, et al. Mirror gait retraining for the treatment of patellofemoral pain in female runners. Clin Biomech, 2012

Gait Retraining

- Protocol using faded feedback resulted greatest pain reduction and persistent changes
- Studies ranged 8-18 sessions over 2-6 weeks and most exceeded 3 hours of retraining

Cheung and Davis, 2011

Bonacci 2018

Davis, Tenforde et al. Gait Retraining for Patellofemoral Pain. Curr Review Musculoskeletal Medicine 2020.

Tendinopathy - *A term used to describe the spectrum of tendon disease*

It's not all inflammation!

- **Tendinitis** refers to an active inflammatory process

- **Tendinosis** describes a more chronic form of tendon injury, devoid of inflammation and considered a "failed healing response"

- **Tendinopathy** encompasses tendon diseases, defined as tendon pain, stiffness and loss of function associated with mechanical loading

It's not all inflammation!

Intrinsic Risk Factors

- Older age
- Male sex
- Genetics
- Limb mechanics

Extrinsic Risk Factors

- Activity Level
- Training factors
- Footwear
- Loading characteristics
- Medications

Joseph and Denegar. Treating Tendinopathy. Clin Sports Med, 2015

Management of Tendinopathy

- **Initial Management**
  - Activity Modification
  - heel lift/taping
  - Trial of ice/heat
  - NSAIDs controversial
- **Address biomechanical/strength deficits**
- **Chronic/refractory cases**
  - shockwave therapy
  - Interventional treatments: Biologics, tenotomy
  - Surgery (rarely!)

Does Physical Therapy Work?

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

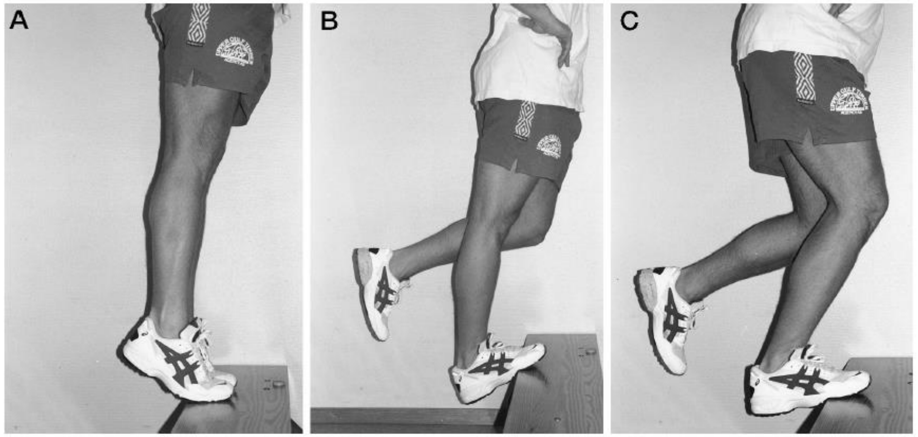
A Systematic Review With Network Meta-analysis

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
.

Primary Strategy is Loading Program

- "Alfredson protocol" consists of 3 sets of 15 repetitions with both knees straight and bent, performed twice daily



- Theoretical benefits of eccentric loading include collagen reorganization and disrupting neovascularization

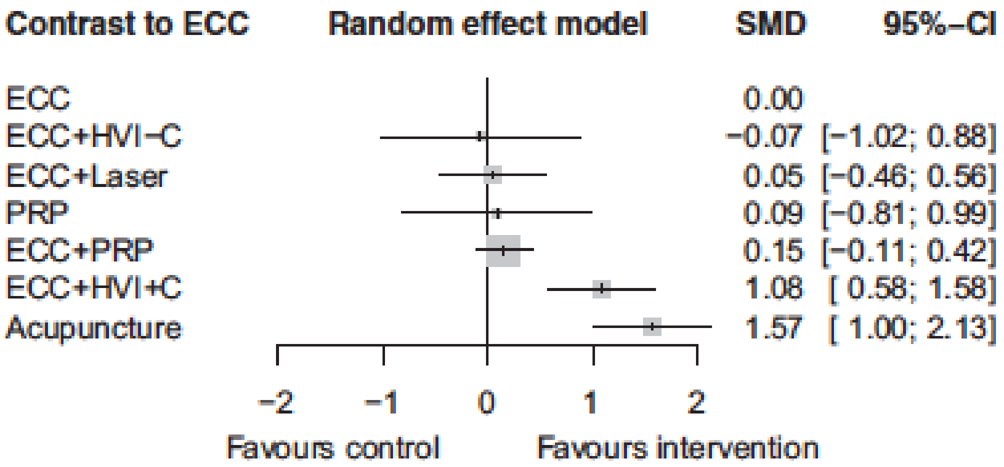
- Results demonstrate comparable efficacy to surgery

Alfredson, et al. Heavy-Load Eccentric Calf Training Achilles Tendinosis. AJSM, 1998

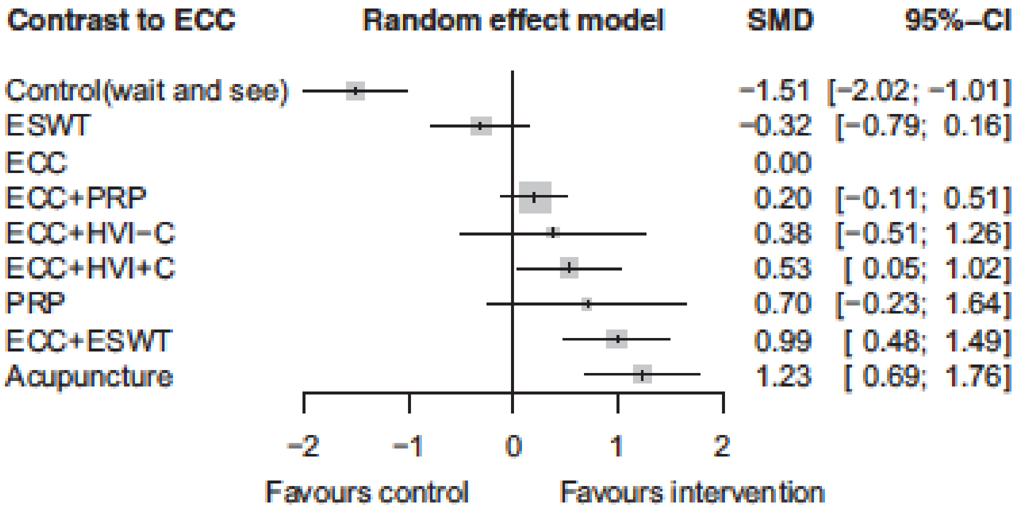
Jonsson, et al. New regimen for eccentric calf muscle training in patients with chronic insertional Achilles tendinopathy. BJSM, 2008

Outcomes favor Eccentric Loading combined with interventions

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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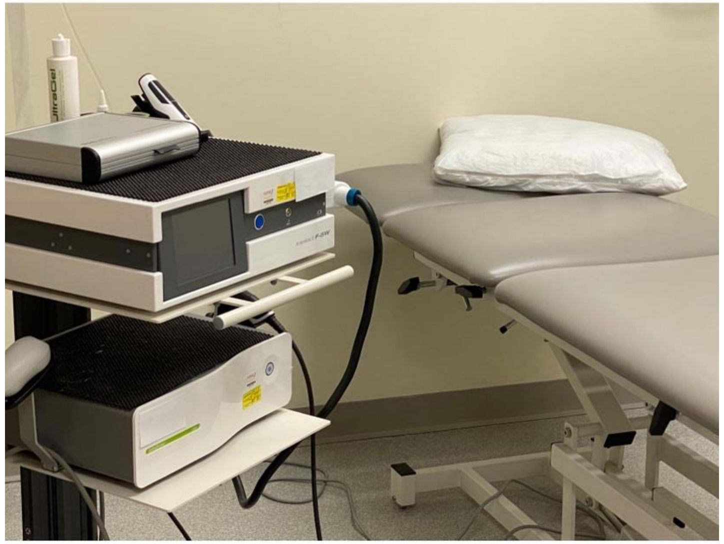
Advantages of shockwave

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



Return to Running

- Management guided by pain control
- Graded return to activity
- Goals specific to runner and time in season

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.

Silbernagal et al. Conservative Management of Achilles Tendinopathy. J Ath Train, 2020
Silbernagel and Crossley. Proposed return to sport model RTP Midportion Achilles Tendinopathy. JOSPT, 2015

Summary

- **Running injuries are common!**
- **Effective management requires comprehensive approach to reduce recurrence**
- **Biomechanics, biology and other risk factors require exploration for management**

Summary

- **Treatment should include multidisciplinary team**

- **Lifestyle factors (sleep, nutrition) are critical**

- **Communication builds trust within team and optimizes outcomes**

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