Tendinopathy
Does one size fit all?

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Conflict of interest

- Associate Editor for Journal of Orthopaedic and Sports Physical Therapy
- No other conflict of interest

JOSPT

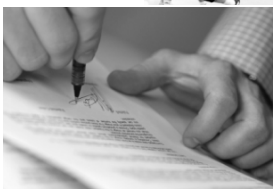
Tendinopathy issue
Volume 45, Issue 11
November 2015, Pages 816-965

Goals and Objectives

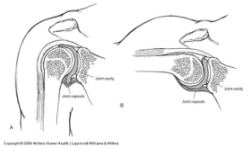
- Describe the purpose of tendons and how this relates to function and injury risk
- Review the pathophysiology of tendinopathy
- Review how tendon injury affect tendon and muscle function
- Describe and review the difference between tendon injury in the midportion versus the osteotendinous junction
- Review the effect of exercise as treatment

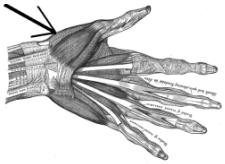
Why tendons?

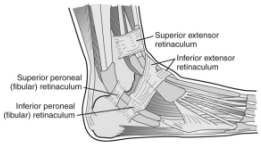
- Tendons saves energy
- Improves explosive power
- Controls movement

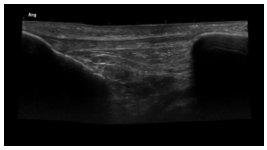


Various types of tendons



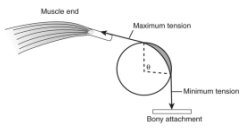


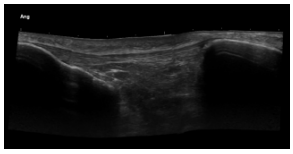




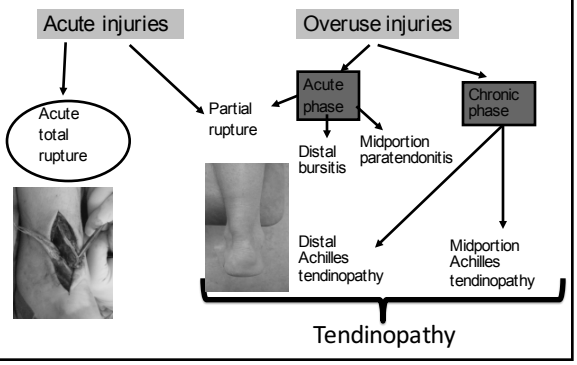
Tendons tolerance to load

- Tolerate tensile forces better than tensile with compressive forces
- Tendon susceptible for injury in areas where compressed around bone





Classification of Achilles tendon injury



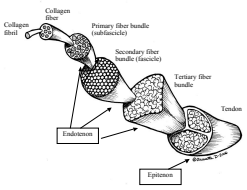
Classification of tendinopathies

Bonar's modification of Clancy's classification of tendinopathies

- Tendinosis
- Tendinitis/ partial rupture
- Paratenonitis
- Paratenonitis with tendinosis

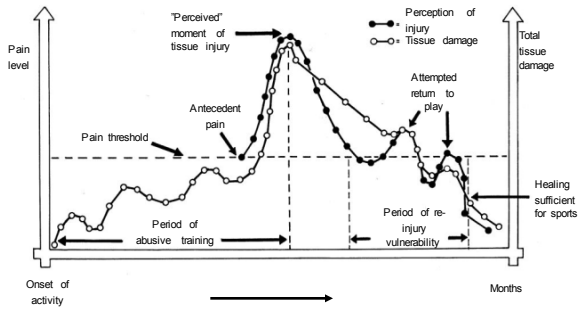
(Puddu et al 1976, Josza & Kannus 1997, Khan et al 1999)

Tendinopathy – tendon structure



Scott et al JOSPT Tendinopathy issue November 2015, and reprinted from Clinical Sports Medicine

- Collagen fibers thinner and loosely arranged
- Increased amount of proteglycans
- Increased water content



Schematic illustration of pain and tissue damage in oversue tendinopathy (Leadbetter 1992)

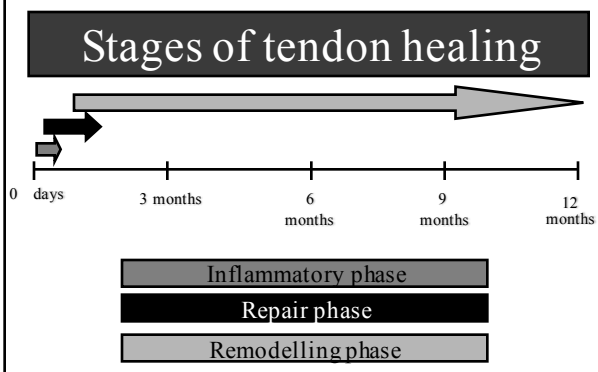
Tendinopathy: Update on Pathophysiology

Scott et al. JOSPT 2015

TABLE 1 CLINICAL FEATURES OF TENDON INJURIES

Clinical Feature	Classification
Time	Acute, less than 4 wk Subacute, 5 to 12 wk Chronic, greater than 12 wk Acute on chronic
Tissue affected (more than 1 can be affected)	Tendon Enthesis Paratendon Tenosynovial sheath
Additional features	Increased color Doppler signal and fluid around (as opposed to within) a tendon suggesting inflammation (tenosynovitis, paratendonitis) Calcification (primary or dystrophic) Bony deformity (eg, subacromial spur, insertional irregularity suggestive of inflammatory enthesitis) Bursitis (some will communicate with tendon sheath) Adjacent structures (eg, underlying joint pathology)
Degree of tissue disruption on cross-section at any site	Grade 1, less than 10% Grade 2, 10% to 50% Grade 3, greater than 50% cross-sectional area (eg, on transverse ultrasound or magnetic resonance imaging)
Underlying (risk) factors	Intrinsic risk factors (biomechanics, family history, sex, age) Extrinsic risk factors (training errors, sport or occupational demands, etc) Medical conditions

Stages of tendon healing



Risk factors – the individual

- Adiposity - ↑ BMI (risk factor for both upper and lower extremity tendinopathies)
- ↑intake of cholesterol result in impaired Type I collagen production
- Smoking – results in worse tendon histology
- Diabetes

TABLE 2 MEDICAL CONDITIONS WITH ASSOCIATED TENDON PATHOLOGY

Site Typically Affected	Examples of Medical Conditions
Mid portion	Dyslipidemias, rheumatoid disease, tumors, infections, storage diseases, gout, pseudogout, heritable connective tissue diseases, hemachromatosis, endocrinopathies (including thyroid disease, Cushing syndrome, hypogonadism, menopause), metabolic diseases including diabetes, hypercalcemia
Enthesis	Psoriasis, gout, pseudogout, spondyloarthropathies, inflammatory bowel disease
Tendon sheath	Rheumatoid arthritis, infections, tumors

Risk factors - Medications

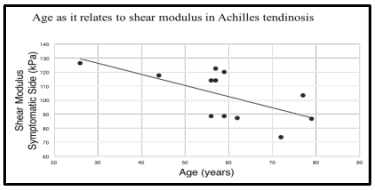
Tendon pathology caused by medications may present similarly to an overuse condition

- Statin-induced tendinopathy
  - Considered fairly rare
  - Main location is Achilles tendon
  - Median time of onset is 10 months
  - 1/3 is rupture
- Corticosteriods
  - Can impair local collagen synthesis
  - Decrease tensile strength

- Fluoroquinolones
  - Ciprofloxacin, levofloxacin
  - Estimated rate of tendinopathy is 0.5-2%
  - Mainly Achilles tendon (40% rupture)
  - Onset is acute (8 days)
  - Greater risk in >60 years

Effect of Age – similar to disuse

- Change in mechanical properties with age
- Decreased % water
- Increased risk of tendon rupture after 30y/o
- Turnover rate of collagen decrease with age which has a negative effect on recovery
- Exercise can counteract the changes that occur with age



Tendon injury and Tendon Function

Changes in mechanical properties and performance

In Symptomatic subjects

- Tendinopathic tendons has lower tendon stiffness and elastic modulus (Arya et al JAP 2010, Child et al AJSM 2010)
- Altered Achilles tendon viscoelastic properties affect explosive performance in athletes (Wang et al SJMSS 2012)
- Altered stretch-shortening cycle behavior during submaximal hopping (Debenham et al JSMS 2014)
- Triceps surae activation is altered in runners with Achilles tendinopathy (Wyndow et al. JEK 2013)

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Tendon injury and Tendon Function

Changes in mechanical properties and performance

In Asymptomatic subjects (tendinosis and previous tendinopathy)

- Asymptomatic runners (previous Achilles tendinopathy) exhibit changes in knee kinetics during running, indicating permanent changes in knee biomechanics (Williams et al JOSPT 2008)
- Achilles tendinosis result in a more compliant tendon (Chang & Kulig 2015)
- The compliant tendon elicit a series of neuromechanical adaptations (Chang & Kulig J Physiol 2015)

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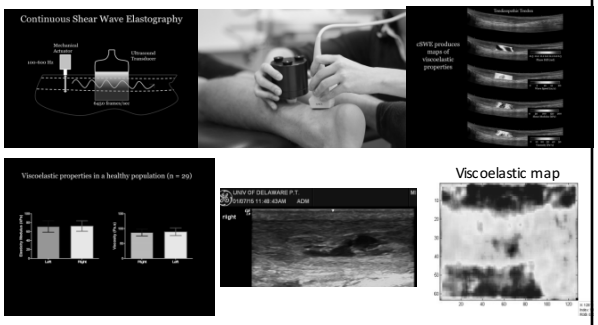
Delaware Tendon Research Lab - Establish Tendon Health



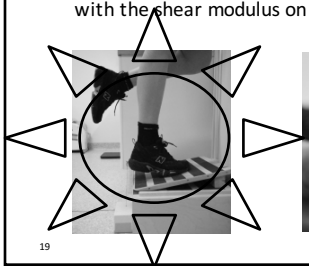
Cortes et al. 2015, Suydam et al 2015

NIH R21 AR067390

Tendon injury and performance

Pilot data

- Mechanical properties evaluated with elastography in patients with Achilles tendinopathy
- Total work done on the heel rise test correlated significantly with the shear modulus on the symptomatic side (r=0.78)



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Tendon injury and Muscle function

J Physiol 593.15 (2015) pp 3373–3387

The neuromechanical adaptations to Achilles tendinosis

Yu-Jen Chang and Kornelia Kulig

Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA, USA

Key points

- Achilles tendinosis is a localized degenerative musculoskeletal disorder that develops over a long period of time and leads to a compliant human Achilles tendon.
- We demonstrate that the compliant Achilles tendon elicited a series of adaptations from different levels of the human movement control system, such as the muscle–tendon interaction, CNS control and other muscles in the lower leg.
- These results illustrate the human body's capacity to adapt to tendon pathology and provide the physiological basis for intervention or prevention strategies.

Tendon injury and Muscle function

Chang & Kulig J Physiol 2015

- Tendinotic group
  - History of unilateral Achilles tendinopathy lasting more than 2 weeks
  - Absence of pain during walking and running
  - Confirmed mid-substance tendinosis, 2mm greater A-P dimension
- Measured tendon structure, mechanical properties (stiffness), electromechanical delay, preactivation and relative muscle activation

Tendon injury and Muscle function

Chang & Kulig J Physiol 2015

On the injured side

- Decreased tendon stiffness
- Increased electromechanical delay
- Greater pre-activation
- Decreased co-contraction

The unilateral Achilles tendon involvement affected the neuromuscular control on the involved side but not the uninvolved side.

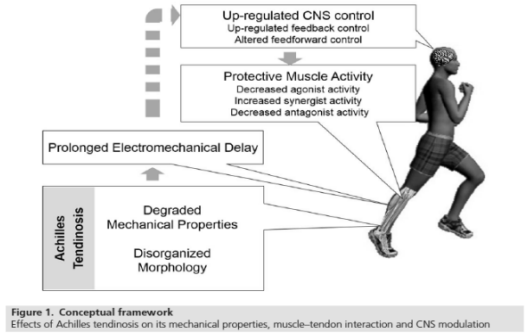

Figure 1. Conceptual framework
Effects of Achilles tendinosis on its mechanical properties, muscle–tendon interaction and CNS modulation

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Chang & Kulig J Physiol 2015

Function and symptoms

ORIGINAL ARTICLE

Full symptomatic recovery does not ensure full recovery of muscle-tendon function in patients with Achilles tendinopathy

Karin Grävare Silbernagel, Roland Thomeé, Bengt I Eriksson, Jon Karlsson

Br J Sports Med 2007;**000**:1–5. doi: 10.1136/bjsm.2006.033464

Relationship between Symptom and Function

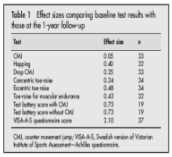


Table 1 Effect sizes comparing baseline test results with those at the 1-year follow-up

Test	Effect size	n
CMJ	0.05	33
Hopping	0.40	32
Drop CMJ	0.25	33
Concentric toe-raise	0.24	34
Eccentric toe-raise	0.48	34
Toe-raise for muscular endurance	0.43	32
Test battery score with CMJ	0.75	19
Test battery score without CMJ	0.73	19
VISA-A-S questionnaire score	2.10	37

CMJ, counter movement jump; VISA-A-S, Swedish version of Victorian Institute of Sports Assessment—Achilles questionnaire.

Function \ Symptom	Fully recovered 90-100 points on VISA-A-S (n=16)
Passed all strength & Jump tests (>89%)	4 patients **25%**
Passed 4 of 5 tests	3 patients **19%**
Passed 3 of 5 tests	9 patients **56%**

Conclusion

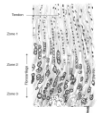
Pain free
Asymptomatic

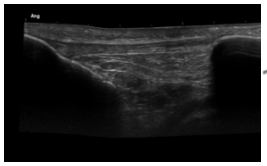
≠

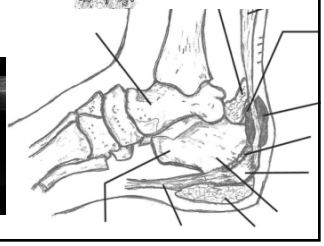
Full recovery of muscle-tendon function

- Continue with tendon exercise even if symptoms have disappeared
- Consider tendon loading exercise for prevention
- Again need measure of tendon health or biomarker for tendon health to continue monitor improvement

Osteotendinous junction

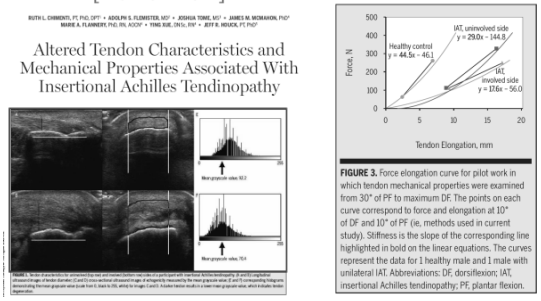






Osteotendinous junction

JOSPT 2014



[RESEARCH REPORT]

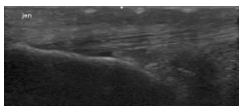
Altered Tendon Characteristics and Mechanical Properties Associated With Insertional Achilles Tendinopathy

FIGURE 3. Force elongation curve for pilot work in which tendon mechanical properties were examined from 30° of PF to maximum DF. The points on each curve correspond to force and elongation at 10° of DF and 10° of PF (ie, methods used in current study). Stiffness is the slope of the corresponding line highlighted in bold on the linear equations. The curves represent the data for 1 healthy male and 1 male with unilateral IAT. Abbreviations: DF, dorsiflexion; IAT, insertional Achilles tendinopathy; PF, plantar flexion.

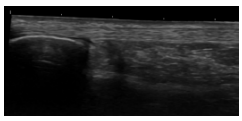
Greater echogenicity related to symptom severity

Insertional considerations

Standing plantar flexion



Standing neutral



Standing dorsiflexion

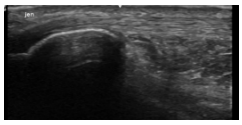
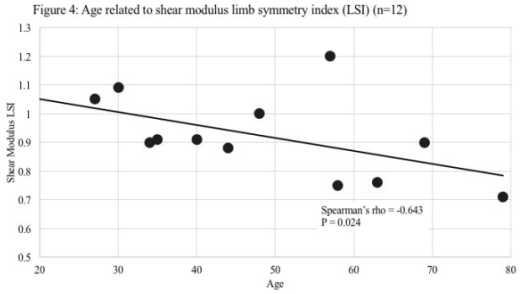
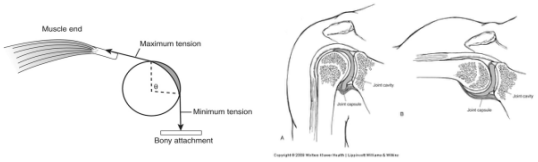


Figure 4: Age related to shear modulus limb symmetry index (LSI) (n=12)



Bone - tendon

- Increased compression of tendon with increased dorsiflexion (both achieved with ankle movement and squatting).
- Decreased with heel lift
- Consider exercise which minimize excessive stretch and compression
- Gait training often beneficial in insertional Achilles tendinopathy



Exercise - The effect of loading and on tendon

- Responds by becoming larger, stronger more resistant to injury (Kannus et al 1997)
- Exercise increases circulation and increases collagen synthesis in tendon (Langberg et al. 1998, 1999, 2000, 2001, Kjaer 2004)
- Adaptive response slower than muscle

Effects of Immobilization

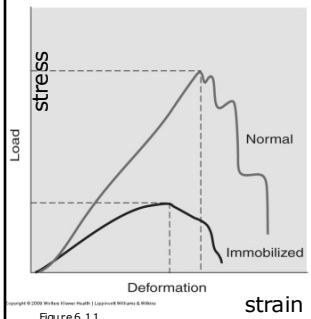
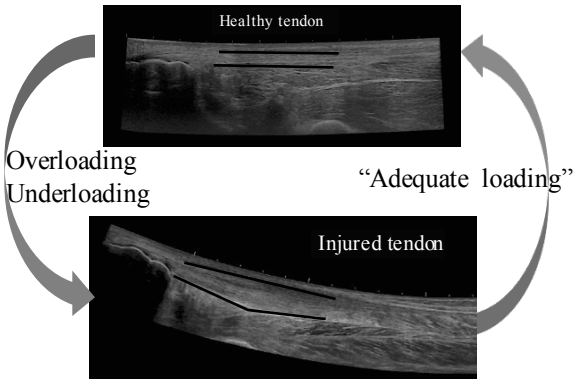


Figure 6.11

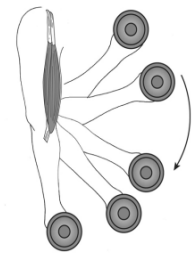
Effects of immobilization

- SAID principle: specific adaptation to imposed demand
- immobilization:
  - decreases tensile strength and stiffness
  - causes contractures
- effects of immobilization can be minimized if tendon/ligament is elongated when immobilized



Eccentric exercise treatment

- Systematic reviews indicate that eccentric exercise have the most evidence of effectiveness
  (Kingma et al 2007, Magnussen et al 2009, Woodley et al 2007)
- Consensus that all patients should initially be treated with an exercise program for 3 months
  (Alfredson & Lorentzon 2000, Kader et al. 2002, Alfredson 2003, Rompe et al. 2007)



Does the tendon know the difference between eccentric and concentric exercise?

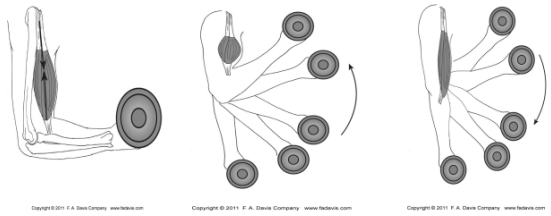
Exercise for tendinopathy

Many different explanations for successful treatment with eccentric exercise

Are these explanations for the effect of the mechanical load produced by any exercise or just eccentric exercise?

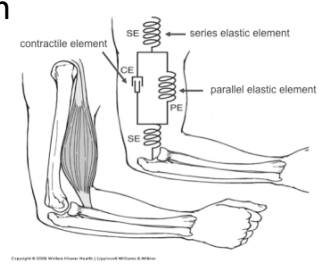
What is the difference between concentric and eccentric muscle contraction?

Isometric Concentric Eccentric



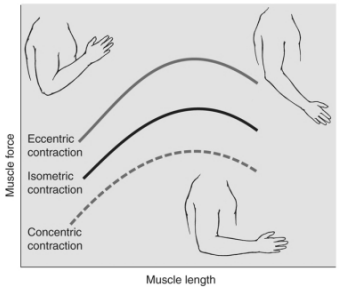
Muscle tension

- **Total muscle tension/force**
  - **Passive tension**
    Tension developed in passive elastic component
  - **Active tension**
    Tension developed by the contractile components



The total amount of musde tension is then transmitted to the tendon

Muscle length-tension relationship



Muscle has **the ability** to generate greater force in eccentric contraction for the same muscle length (use the passive elastic components)

This is not the same as to say just because you are contracting eccentrically the force produced is greater

Exercise – Concentric compared to Eccentric loading

- No differences in peak tendon force (at same loads) (Rees et al 2008, Henriksen et al 2009)
- No difference in tendon length (at same loads) (Rees et al 2008)
- Reduced EMG activity during eccentric contraction compared to concentric but patients with tendinopathy relatively greater % (Henriksen et al 2009, Hebert-Losier et at 2012, Reid et al 2012)

Exercise – Concentric compared to Eccentric loading

- An increase in tendon vibration at high frequencies with eccentric loading which was not found with concentric loading (Rees et al 2008, Henriksen et al 2009)
- Deficits in both concentric and eccentric strength (Silbernagel et al 2006)
- **Time to focus on adjusting loading dosage to the specific tendon/injury and individual patient**

Exercise for tendon injury

The goal of the exercise treatment

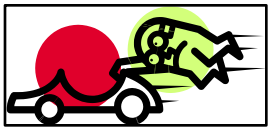
- Reduce symptoms
- Improve strength, endurance and function
- Promote tendon healing

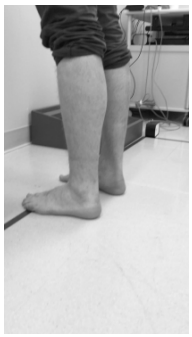
Rehabilitation of tendons

The tendon load can be increased two ways:

- Increase the external load

- Increase the speed of movement



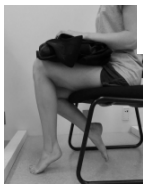


Type of exercise

Muscle contraction

- Isometric
- Isotonic
  - Concentric
  - Eccentric
- Isokinetic
  - Concentric
  - Eccentric

Beyer et al 2015



Exercise - Treat tendon injury and functional deficits

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SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

Eccentric overload training for patients with chronic Achilles tendon pain – a randomised controlled study with reliability testing of the evaluation methods

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Continued Sports Activity, Using a Pain-Monitoring Model, During Rehabilitation in Patients With Achilles Tendinopathy

A Randomized Controlled Study

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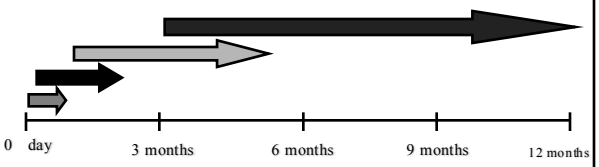
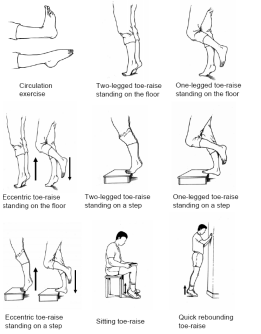
2nd European Conference of Sports Rehabilitation

Rehabilitation phases



Acute phase
Recovery phase
Rebuilding phase
Return to activity

Exercise – Comprehensive treatment protocol



Exercise program

- Concentric and eccentric loading
- Divided into 4 phases
- Increasing speed of movement

Heavy slow resistance training

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Corticosteroid injections, eccentric decline squat training and heavy slow resistance training in patellar tendinopathy

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Slow eccentric-concentric contractions in HSR
Pain was acceptable

Exercise – Pain monitoring model

PAIN-MONITORING MODEL

Numerical Pain Rating Scale (NPRS)

Safe zone	Acceptable zone	High risk zone

0 (No pain) 2 5 10 (Worst pain imaginable)

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 is not allowed to increase from week to week.

Has been evaluated in two randomized trials with good outcome

The protective mechanism of pain

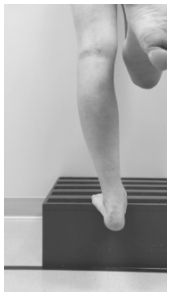
Training Diary

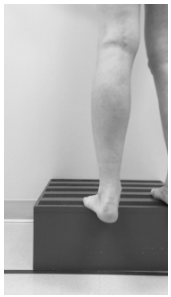
Name:_____
Physical Therapist:_____
Startdate:_____

Week #____	Home exercises	Physical activity	Comments
Day 1			
Day 2			

Muscular control

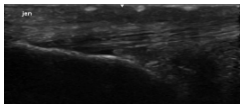
Eccentric drop exercise or eccentric stretch exercise



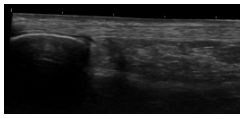


Insertional considerations

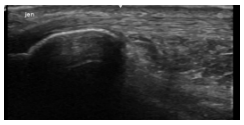
Standing plantar flexion



Standing neutral



Standing dorsiflexion



What about the foot?

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Intrinsic musculature

- Stabilize the toes
- Dynamic supporters of the arches
- Important to activate/exercise intrinsic muscle when foot injuries
- Lumbricals and interossei help flex MTP and extend IP joints

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How should exercise delivery be modified?

- Load consideration
  - Consider total load during the week
  - Heavy less often or lighter more often
- Response to exercise
  - Pain monitoring model
  - Important how the response is the next day
  - Training diary
- Consider joints above and below
- Adjust starting and end position of exercise depending on injury and response
- NMES to stimulate muscle activity

Summary – Clinical aspects

- Not all tendons are the same
- Not all overuse tendon injuries are the same
- Consider individual risk factors (age, disease, meds)
- Stiffness in tendinopathy is a sensation not a change in mechanical properties
- Stretching might not be of relevance unless limitation in ROM (need to know if joint, muscle or tendon limiting ROM)
- Exercise has an effect but takes time
- Changes in tendon mechanical properties affect function even if no symptoms

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The Team!

Delaware Tendon Research Group
STAR Campus, University of Delaware

Thank you!

Tendinopathy – Does one size fit all?
Karin Grävare Silbernagel PT, ATC,PhD

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