Muscle, tendon and bone injuries

Håvard Moksnes, PT PhD

How does load stimulate the tendon?

Mechanotransduction refers to the process by which the body converts mechanical loading into cellular responses. These cellular responses, in turn, promote structural change. A classic example of mechanotransduction in action is bone adapting to load.


Cell communication in mechanotherapy

Intracellular upregulation

Exercise progression model

Rehabilitation
Over the course of one year, 68% of Swedish athletics athletes experienced a performance-limiting overuse injury. (Jacobsson et al. 2013)

23% of participants at the 2014 FINA World Aquatics Championships competed with symptoms of overuse injury. (Mountjoy et al. 2014)

“After four years and hundreds of shots injected into my knee weekly to alleviate swelling and pain, my body is begging me to stop the pounding.”

Former world #2 Li Na retires 2014, age 32
What is an overuse injury?

<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>Common examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>Bone strain/stress reaction/stress fracture</td>
<td>Metatarsal stress fracture in runners</td>
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<tr>
<td></td>
<td>Osteitis, periostitis</td>
<td>Medial tibial stress syndrome in runners and dancers</td>
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<td></td>
<td>Apophysitis</td>
<td>Patellar tendinopathy in jumpers (&quot;jumper's knee&quot;)</td>
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<tr>
<td>Tendon</td>
<td>Tendinopathy (includes paratenonitis, tenosynovitis, tendinitis, tendinosis)</td>
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<td>Labrum injuries</td>
<td>SLAP lesions in throwing athletes</td>
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<td>Chondropathy</td>
<td>Hip Fxi in footballers</td>
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<td>Synovitis</td>
<td>Ulnar collateral ligament injury in baseball pitchers</td>
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<td>Muscle/Fascia</td>
<td>Fasciitis/fasciosis</td>
<td>Iliotibial band syndrome in runners (&quot;runner's knee&quot;)</td>
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<td>Exertional compartment syndromes</td>
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<td>Bursa</td>
<td>Bursitis</td>
<td>Trochanteric bursitis in race walkers</td>
</tr>
<tr>
<td>Nerve</td>
<td>Altered mechanosensitivity</td>
<td>Ulnar neuropathy in cyclists (&quot;handlebar palsy&quot;)</td>
</tr>
<tr>
<td></td>
<td>Entrapment</td>
<td>Ulnar neuropathy in cyclists (&quot;handlebar palsy&quot;)</td>
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</table>

Acute injury

- Caused by instantaneous energy transfer
- MICRO trauma

Overuse injury

- Caused by cumulative energy transfer
- MACRO trauma
Clinical case
The adolescent athlete

Girl 13 years old playing basketball 6 hours per week + weekend matches. Anterior knee pain since May 2015. Ultrasound with neovascularisation @ apex patella

A. Radial shockwave therapy?
B. Injection therapy?
C. Eccentric strength training?
D. Other?

What is a physis?

From Caine et al. (2006)
Overuse injuries

«Demise of the fittest; are we destroying our biggest talents?»

Editorial from Prof Roald Bahr
May 2014

Envelope of load acceptance

Envelope of load acceptance
Adolescents with anterior knee pain

**Diagnosis**
- Mb. Sinding-Larsen
- Mb. Osgood-Schlatter
- PFP
- Patellar instability
- Tendinopathy
- Osteochondritis dissecans
- Osteosarcoma
- Rheumatoid illness

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Adolescents with anterior knee pain

**Diagnosis**
- Mb. Sinding-Larsen
- Mb. Osgood-Schlatter
- PFP
- Patellar instability
- Tendinopathy

**Treatment**
- Main rule:
  - Overload of soft tissue or growth zones
  - Adjust total load!

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Mb. Sinding-Larsen-Johansson

- Occurs during growth spurt
- Resembles “Jumpers knee”
- US helpful?

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Patellar tendinopathy
Plantar fasciopathy
Lateral epicondylopathy
Active rehab is well documented

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

M. Kokkinos1, V. Koivamäki2, P. Augard2, N. Broshy1, P. Huson1, L. H. Laurora2, N. C. Kähkö2, M. Kjær1, N. P. Thorsen2

➢ Lack of acute inflammatory cells
➢ Typical features of earlier injury-repair cycles
➢ Active angiogenesis with increased presence of mast cells
➢ Both proliferation and apoptosis of fibroblasts
❖ Generally indicative of failed, but ongoing, cycles of tissue repair and adaptation

Scott et al 2007

Patellar tendon biopsy

Supervised exercise program

Starting 1 week following injection
➢ 12 weeks with 3 sessions per week
➢ One supervised session each week
➢ No running during the 1st 6 weeks
➢ Return to Sport after 12 weeks
➢ Compliance and progression monitored with exercise diary

Rehabilitation algorithm

1. Review training/match exposure past 6 months
2. Review weekly schedule
3. Remove «unnecessary» load
4. Implement symptom coping strategies
5. Active rehab aimed at impairments
6. Graded increased exposure
1. Review training/match exposure past 6 months
   - Increased frequency?
   - Increased intensity?
   - Changed environment?
   - Playing several teams?
   - “Did you have a holiday this summer?”

2. Review weekly schedule
   - Write it down on paper!
   - When do you rest?
   - Which sessions can be removed?

3. Remove «unnecessary» load
   - Remove “unnecessary” runs and hops
   - Change from running to cycling
   - School sessions vs club sessions
   - Leisure time activities

4. Implement symptom coping strategies
   - RICE after loading
   - Pain monitoring model
   - Rest days
   - Less playing time
   - One game per week
   - Play and train with only one team!
5. Active rehab aimed at impairments
- Increase the size of the envelope
- Shock absorption
- Hip, hamstring and kinetic chain

6. Graded increased exposure
- Stabilize load with symptom control
- Alternate days team and rehab
- Increase frequency OR intensity
- Continue coping strategies

Plantar fasciopathy

http://blogs.bmj.com/bjsm/2014/09/15/plantar-fasciitis-important-new-research-by-michael-rathleff/

Effect of Corticosteroid Injection, Physiotherapy, or Both on Clinical Outcomes in Patients With Unilateral Lateral Epicondylalgia A RCT

**Conclusion and Relevance**
Among patients with chronic unilateral lateral epicondylalgia, the use of corticosteroid injection vs placebo injection resulted in worse clinical outcomes after 1 year, and physiotherapy did not result in any significant differences
Take home messages RTP with overuse injuries

- Assess and tweak total load
- Include the parents and coaches
- Removal from play may be necessary
- Agree on a structured progression plan

Hamstring injuries - injury types and rehabilitation

Håvard Moksnes
Sports Physiotherapist
Hamstring injuries
- Different types of injuries
  - High-speed running
  - Slow-speed stretching
  - High-speed stretching
  - Overuse (proximal)

Two distinct acute injuries

Askling 2007, Heiderschneit 2010

van der Made et al 2016

van der Made et al 2016
Hamstring muscle group

- Semitendinosus
- Semimembranosus
- Biceps Femoris

Biceps Femoris – short head

Semitendinosus
Semimembranosus
Biceps Femoris

Muscle injuries in football

- Hamstring 37%
- Adductor 23%
- Quadriceps 19%
- Calf 13%

van der Made et al 2016

Ekstrand et al 2011
Hamstring injuries

Rehabilitation exercises matter
- Lengthening exercises are more effective than conventional exercises!

Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols

Br J Sports Med
2013;47:953-959
Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols

Involvement of the proximal tendon significantly increases time to return to sport

Do not forget apophyseal avulsions!

MRI does not add value over and above patient history and clinical examination in predicting time to return to sport after acute hamstring injuries: a prospective cohort of 180 male athletes

Prediction RTS with MRI

- **Grade I**
  - Mean 18 days (±19)
  - 70% = 0 -> 37 days
  - 95% = 0 -> 56 days

- **Grade III**
  - Mean 24 days (±13)
  - 70% = 11 -> 37 days
  - 95% = 0 -> 50 days
Hamstring muscle group

Sprinting type injury
- Long head of biceps femoris

Sprinting type injury
- Intramuscular tendon involvement
  - Yes = longer recovery time
- Secondary problems
  - Biceps femoris short head
The intramuscular tendon

Reurink
2016

Stretching type injury

Askling
2007

Hamstring muscle group
Proximal Hamstring Tendinopathy: A Real Pain in The Butt For Runners!

- Pain during high intensity running
- Pain with prolonged sitting
- Pain with increased stride length
- Pain during uphill running
- Must reduce running volume!

**Regional Muscle Use During Hamstring Strengthening Exercises**


**Sport specific RTS**
The results of the present study demonstrate that stable surgical repair with accelerated tendon loading could be performed in all (n = 49) patients without reruptures and major soft tissue–related complications.

Olsson et al AJSM 2013
TREATMENT PROTOCOL – ACHILLES TENDON RUPTURE NON-SURGICALLY TREATED

**Week 0**
- Treatment: Walker brace with 3 heel pads, weight-bearing through the heel as tolerated, use of crutches. Referral to Orthopedic technician for shoe heel-lift (use on affected heel side)
- Stitches: Allowed to take off the walker brace for washing and changing the foot. When the walker brace is removed, an orthopedic technician/physical therapist will assist with the exercise program.
- Exercise program: Foot flexion exercises daily.
- After a week:
  - Treatment: Walker brace with 2 heel pads (take off the upper pad), full weight-bearing, use of 2 crutches if needed.
- Exercise program: Home exercises daily as described above.

**After 2 weeks**
- Treatment: Walker brace with 1 heel pad, full weight-bearing.
- Exercise program: Home exercises daily as described above.

**After 4 weeks**
- Treatment: Walker brace without heel pad, full weight-bearing.
- Exercise program: Home exercises daily as described above.

**After 6 weeks**
- Visit orthopaedic surgeon.
- Treatment: Wean off walker brace. Use of shoes with heel-lift (until 14 weeks after injury), compression stocking to prevent swelling.
- Exercise program: Important that all exercises are performed slowly and carefully.

**Side 83**

The first 6-8 weeks

- Biological healing
- No stretching!
- Controlled loading in plantar flexion to stimulate tendon healing
- Maintain muscle activation
- Maintain physical fitness
  - Strength, bike and eliptical trainer

**Side 84**

Systematic measurement of tendon length

**Side 85**

Post-operative weeks 7 - 12

- Build calf muscle strength
- Develop neuromuscular strategies
- Develop neuromuscular endurance
- Avoid tendon elongation
  - heel-wedge
- Minimize lower leg effusion
  - Compression stocking + crutches/brace longer distances

**Side 86**
Build calf muscle strength

Standing heel-raises
  Bilateral
  Extended knee

✓ Seated heel raises
  ➢ 90° knee flexion

✓ Leg press machine
  ➢ Extended knee
  ➢ Avoid tendon stretch!

Develop neuromuscular endurance

Single & double leg stance
  ➢ Extended knee!
  ➢ Sagittal sway
  ➢ Closed eyes
  ➢ Perturbation?

Develop neuromuscular strategies and strength
Develop neuromuscular endurance

Develop neuromuscular strategies and strength

*Post-operative weeks 12 ➔*

- Rebuild energy storage and release
- Increase velocity in movements
  - Reduce frequency and reps
- Slowly increase hopping and running
  - Think reps – not time or distance!
- Running, hopping and single-leg hopping
Post-operative weeks 12 →

Physical function tests

✓ Single leg CMJ jump
✓ 25 consecutive single leg hops
✓ Heel-raise exhaustion

Average hop height
Jump coefficient (contact/flight time)
Evaluate flow and quality
**Hopping; jump coefficient**

Contact time/flight time

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Non-injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.96</td>
<td>0.88</td>
<td>0.83</td>
</tr>
<tr>
<td>0.83</td>
<td>0.74</td>
<td></td>
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</tbody>
</table>

- 4 months
- 5 months

**Single leg CMJ (cm)**

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Non-injured</th>
<th>Both</th>
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</thead>
<tbody>
<tr>
<td>4 months</td>
<td>19.5</td>
<td>22.5</td>
<td>24.5</td>
</tr>
<tr>
<td>5 months</td>
<td>42.3</td>
<td>44.7</td>
<td></td>
</tr>
</tbody>
</table>

**Heel-raise exhaustion (work)**

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Non-injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.912</td>
<td>2280</td>
<td>2714</td>
</tr>
<tr>
<td>3096</td>
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</tbody>
</table>

- 4 months
- 5 months

**Clinical update**

**Bone stress injuries**
Bone stress injury continuum

- **Stress reaction**: Increased bone turnover, periosteal ± marrow oedema
- **Stress fracture**: Discernable fracture line
- **Complete fracture**: Structural instability

**BSI pathophysiology**

Warden et al. 2015
**Epidemiology**

- Extremely common in distance runners
  - 33-66% have a history of stress fracture
  - 8-21% per year affected
  - Up to 20% of all athletics injuries
- More common in females
  - 1.5 to 3 times greater risk
- Endurance, aesthetic and weight-class sports a particular problem
- High rate of recurrence

<table>
<thead>
<tr>
<th>Bone</th>
<th>Sport(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humerus</td>
<td>Throwing and racquet sports</td>
</tr>
<tr>
<td>Rib</td>
<td>Rowing and kayak</td>
</tr>
<tr>
<td>Pars interarticularis</td>
<td>Cricket, diving, gymnastics, ballet</td>
</tr>
<tr>
<td>Femur</td>
<td>Distance running, jumping, ballet</td>
</tr>
<tr>
<td>Tibia</td>
<td>Distance running, ballet</td>
</tr>
<tr>
<td>Navicular</td>
<td>Sprinting, jumping, football</td>
</tr>
<tr>
<td>Metatarsal</td>
<td>Sprinting, jumping, marching ballet</td>
</tr>
</tbody>
</table>

**Risk factors**

- Internal risk factors
  - Age
  - Sex
  - Anatomy
  - Body composition
  - Health & Injury history
  - Physical Characteristics
    - Fitness
    - Muscle strength
    - Joint ROM
    - Skill level
  - Psychological factors
- Susceptible Athlete

A comprehensive model of injury causation
Meeuwisse, 1994

**Factors affecting bone loading**

- Bone loading

**Factors affecting bone load tolerance**

- Bone strain

Risk factors for bone stress injuries
Warden, 2015
Factors affecting bone loading

- Training factors
  - Magnitude of load
  - Rate of load application
  - Number of loading cycles
  - Training frequency (recovery)

- Intrinsic anatomy/biomechanics
  - Excessive or inadequate subtalar pronation
  - Increased hip external rotation
  - Leg length difference
  - Low muscle strength or endurance

Sullivan 1984, Simkin 1989

Factors affecting bone loading

- Training surface
  - Hard or cambered surfaces
  - Changes to normal surface

- Equipment
  - Shoes
  - Orthotic inserts

Milgrom 2003, Brukner & Khan, 2012

Factors affecting bone loading

- Technique factors
  - Forefoot/rearfoot strike pattern
  - Stride length
  - Mixed bowling action in cricket

Elliot 2000
Factors affecting load tolerance

- Genetics
  - Maternal family history of osteopenia/osteoporosis
- Physical activity history
- Nutrition
  - Energy balance (intake vs. expenditure)
  - Calcium and Vitamin D status

Factors affecting load tolerance

- Endocrine status
  - Older age at menarche
- Disease
- Medication use
  - Glucocorticoids
  - Anticonvulsants

Factors affecting bone loading

- Bone loading
- Factors affecting bone load tolerance

Diagnosis of BSI

- Gradual onset of pain
- Recent change in training
- Pain does not “warm up” with continued training
- Pain resolves with rest in early phases
- Later stages - pain with ADLs, at rest and at night

Risk factors for bone stress injuries

Warden 2015
Diagnosis of BSI - Examination

- Localised bony tenderness
- Signs of inflammation may or may not be present
- Sometimes possible to palpate callus formation
- Special tests?

Diagnosis of BSI - Imaging

<table>
<thead>
<tr>
<th>Modality</th>
<th>Cost</th>
<th>Radiation</th>
<th>Sensitivity</th>
<th>Specificity</th>
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</thead>
<tbody>
<tr>
<td>X-ray</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>CT</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
<td>High</td>
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Diagnosis Accuracy of Various Imaging Modalities for Suspected Lower Extremity Stress Fractures

Wright 2015
## Diagnosis of BSI - Imaging

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<tr>
<td>Bone scan</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
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<tr>
<td>Bone scan</td>
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<td>High</td>
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<td>Moderate</td>
</tr>
<tr>
<td>MRI</td>
<td>High</td>
<td>None</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

## High-risk BSIs
- More likely to progress to complete fracture, delayed union or non-union
- Those that require surgical repair
- Those that require assisted or non-weightbearing
- Often located on the tension side of the bone's biomechanical axis

## Low-risk
- Femoral shaft
- Posteromedial tibia
- Tibia
- Calcaneus
- 2nd-4th metatarsal diaphysis

## High-risk
- Femoral neck
- Anterior cortex of tibia
- Medial malleolus
- Talus (lateral process)
- Navicular
- Proximal 5th metatarsal
- Base of 2nd metatarsal
- Great toe sesamoids
MRI grading

1. Periosteal surface - mild to moderate oedema (T2 images)
   Bone marrow normal (T1 & T2 images)

2. Periosteal surface - moderate to severe oedema (T2 images)
   Bone marrow oedema (T2 images)

3. Periosteal surface - moderate to severe oedema (T2 images)
   Bone marrow oedema (T1 & T2 images)

4. Periosteal surface - moderate to severe oedema (T2 images)
   Bone marrow oedema (T1 & T2 images)
   Clearly visible fracture line

Management - key principles

- Unload, then systematically reintroduce loading
- Address all potential causes
  - Factors affecting bone loading
  - Factors affecting load tolerance
- Avoid NSAIDs - they may affect bone healing
- Is there a role for adjunct treatments?
  - Electrotherapies
  - Pharmaceutical agents

Loading stress fractures

- Unloading necessary for all stress fractures
- There is probably an "optimal load"
  - Maximise speed of recovery
  - Maximise strength of repair
  - Reduce risk of recurrence
- Unfortunately, we don't know what that is
  - Little research
  - Large individual variability
- Practical solution - use pain as a guide

Low-risk fractures

- If pain-free gait, full weight bearing is permitted
- If gait painful, partial weight bearing with boot/brace
- Maintain conditioning with low-weight-bearing activities
  - Swimming
  - Deep-water running
  - Antigravity treadmill (when gait is pain-free)
**Osteoclast inhibitors**
- Bisphosphates often used to treat osteoporosis, Paget’s disease, & bone tumors
- Used by some for stress fractures, but no evidence it accelerates recovery
- No evidence that it prevents stress fractures
- Side effects - nausea, fatigue, gastrointestinal symptoms, joint & muscle pain
- Not recommended

**Parathyroid hormone and antiscardosin antibody therapy**
- Both have anabolic effect on bone production
- Promote osteogenesis, osteoblast proliferation and survival
- Laboratory studies promising
- Effect unknown in vivo
- Routine use not advised
Finally, when is a BSI healed?

Brukner & Khan 2012