Load Progression for Lower Extremity Tendinopathy Recovery

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  - UW Department of Orthopedics and Rehabilitation
Objectives

1. Identify the principles (intensity, position, frequency) of progressive loading of tendinopathies to promote recovery

2. Differentiate effective load progression strategies for mid-portion vs insertional tendinopathy
Tendinopathies

- Among the most common of running injuries
  - Achilles

- Prolonged, unpredictable recovery

- Risk increases with age
  - > 35 y/o

- Interaction of tissue mechanics and running mechanics
Tendon Pathology

Normal Tendon

Reactive Tendinopathy

Tendon Dysrepair

Degenerative Tendinopathy

Results from a failed healing process that causes degenerative changes of the tendon structure, neovascularization, and nerve ingrowth:

- Cells activated and increased
- Proteoglycans (PG) increased
- ECM disruption from PGs
- Vascular ingrowth
- Cell death
- ECM degeneration
- Neovascularization

Common Clinical Presentations

- Acute episode of increased training or activity levels
  - Likely a degenerative lesion with some reactive aspects
  - Mismatch between load applied and tendon capacity

- Reactive episode after period of time off
  - Injury or off-season followed by (rapid) return to previous level of training
  - Unloading period decrease tendon mechanical properties and tendon capacity to tolerate load
Resistance Exercise

- Resistance exercise is a positive stimulus for tendon cell activity and matrix restructuring
  - increase collagen production in abnormal tendons
  - improve tendon structure in both the short term and the longer term
  - decrease tendon vessels
  - reduce pain

- Mechanical loading causes biochemical response through a process called mechanotransduction

Mechanotransduction

- Mechanotransduction
- Mechanocoupling
- Cell-to-cell communication
- Effector response

Heavy Load Eccentric Exercise

- Strong clinical evidence that eccentric strengthening can be effective in promoting healing of tendinopathies

- Basic Program
  - 3 x 15 reps with knee straight
  - 3 x 15 reps with knee bent
  - 1-2x daily exercise
  - 12-week program
  - + 10-20% BW as tolerated

Refining the Program

- What aspects of the Alfredson’s protocol are the key to success?
  - Eccentrics
  - Full motion
  - 2x/d for 12 wks
  - Knee straight (gastroc) and knee bent (soleus)

- Concerns with patient adherence (painful)
  - Subsequent risk of recurrence

- Mid-portion vs insertional
Heavy Load Eccentrics

Insertional

Progress to step as pain allows

Midsubstance

Full motion as pain allows

Pain Monitoring

Pain Monitoring Model

Numerical Pain Rating Scale (NPRS)

Safe zone  Acceptable zone  High risk zone

0  2  5  10

No pain  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.
Pain and Tendon Load Management

- **Tendon load reduction**
  - Reduce running volume and load (increase step rate, avoid hills) to avoid exacerbation of symptoms
  - May need to temporarily avoid over-ground running and substitute other exercise options (cycling, deep water running)
  - Address trigger points, joint mobility, and posture as needed

- **Pain management**
  - Isometric exercises of the involved tendon: 30–60s holds, 3–5 reps, 1–3 sets; start with lower volume if tendon is highly reactive/irritable

Kountouris and Cook (2007) *Best Pract Res Clin Rheumatol*
Isometrics and Pain Modulation

Table 2 Loading protocols in the study

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Prescription</th>
<th>Recovery (min)</th>
<th>Loading bolus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric</td>
<td>Biodex Pro 5×45 s at 60°</td>
<td>2</td>
<td>70% MVC</td>
</tr>
<tr>
<td>Isotonic</td>
<td>Leg extension machine 4×8 repetitions 4 s eccentric phase 3 s concentric phase</td>
<td>2</td>
<td>100% 8RM</td>
</tr>
</tbody>
</table>

Heavy Load Isometrics

- 30-60s holds
- 3-5 reps, 1-3 sets
- start with lower volume if tendon is highly reactive/irritable
- near maximal effort

- Joint position
  - start near neutral to avoid wrapping tendon over bone
    - Achilles – avoid dorsiflexion
    - Hamstring – avoid hip flexion
  - gradually increase tendon wrapping as pain allows
Tendon Load Adaptation

**Step 1**
- Continue isometric exercises and ice for pain management; increase dorsiflexion angle as able
- Improve muscle strength (higher load, 3 sets of 8–15 reps, 3–4 d/wk) and endurance (lower load, 3 sets of 20–30 reps, 5–7 d/wk) based on individual impairments and needs
  - Constrain range of motion to minimize tendon wrapping
  - Emphasis on the eccentric phase initially but not exclusively

**Step 2**
- Improve muscle power; increase speed and range of exercises
- Progress to plyometric training, such as jump squats, skipping, jumping rope, double-leg progressing to single-leg hopping (30–60s reps, 4–6 sets with 60s rest between sets, 2–3 d/wk)
High-Magnitude Loading Elicits Tendon Adaptations

- Achilles tendon training program
  - High strain (90%MVC) vs low strain (55%)
    - Randomized between legs
  - 5 sets of isometric plantarflexion (knee straight)
    - Equal total exercise volume
  - 14wk duration; 4d/wk

- Both groups showed increased plantarflexor strength (20-32%)

- High magnitude loading (90% MVC) caused
  - Reduced tendon strain
  - Increased tendon CSA

- Training at 55% MVC had no effect on the tendon

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Heavy Slow Resistance

- Compared to typical heavy load eccentric
  - Similar clinical improvements (VAS, VISA-A)
  - Similar reductions in tendon thickness and neovascularization
  - Greater patient adherence and satisfaction
    - Less total loading time

<table>
<thead>
<tr>
<th>Week</th>
<th>Load</th>
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<tbody>
<tr>
<td>1</td>
<td>3x15RM</td>
</tr>
<tr>
<td>2-3</td>
<td>3x12RM</td>
</tr>
<tr>
<td>4-5</td>
<td>4x10RM</td>
</tr>
<tr>
<td>6-8</td>
<td>4x8RM</td>
</tr>
<tr>
<td>9-12</td>
<td>4x6RM</td>
</tr>
</tbody>
</table>

- 6 s/rep, 3x/wk
- Bilateral, equal weight bearing

Basic Achilles Program

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate duration</td>
<td>1-2 wks</td>
<td>2-4 wks</td>
<td>4-12 wks</td>
</tr>
<tr>
<td>Repetitions</td>
<td>1-3 x 3-5</td>
<td>3 x 15</td>
<td>3 x 15</td>
</tr>
<tr>
<td>Range of motion</td>
<td>fixed</td>
<td>limited</td>
<td>full</td>
</tr>
<tr>
<td>Exercises:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isometric (5 x 30-60s holds)</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2-legged heel raises standing</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-legged heel raises standing</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>2-legged heel raises sitting</td>
<td></td>
<td>●</td>
<td>+10-20% BW</td>
</tr>
<tr>
<td>2-up/1-down heel raises standing</td>
<td>●</td>
<td></td>
<td>+10-20% BW</td>
</tr>
<tr>
<td>Plyometrics</td>
<td></td>
<td></td>
<td>●</td>
</tr>
</tbody>
</table>

-pain < 5/10 is allowable during and after exercise
- subside by next day
- participate in usual activities only if mild discomfort or no pain
Bent Knee Strengthening

- Soleus (deep Achilles) is often not adequately emphasized during the rehabilitation process
- Restrict dorsiflexion during exercise as needed
Mild Plyometrics

2-leg

1-leg
Increased Compliance of Gastrocnemius Aponeurosis with Age

- Middle age and older runners may be more predisposed based on a reduced tendon vasculature and altered tendon compliance.
Achilles Tendinopathy
Provocative Running Mechanics

- Pain is typically during propulsive phase of stance (50-100%)
  - Generally not during loading response

- Excessive ankle dorsiflexion during midstance
  - Should be assessed relative to ankle dorsiflexion observed in weightbearing
  - Excessive strain and wrapping prior to initiation of concentric contraction

- If medial insertional pain, look for high rate of pronation during contact
How to Reduce Dorsiflexion Angle?

- Increased ankle dorsiflexion is related to increased knee flexion

- Reduce both by increasing lower extremity stiffness
  - Spend less time on the ground

Morin et al. (2007) J Biomechanics
Farley and Gonzalez (1996) J Biomechanics
Goal: Reduce Ankle Dorsiflexion

- Increase step rate → reduces ground contact time → reduces ankle dorsiflexion

9:30 min/mile; 150 steps/min
9:30 min/mile; 160 steps/min
Proximal Hamstring Tendinopathy

- related to wrapping of tendon around ischial tuberosity
  - Creates compression and shearing on tendon and possibly bursa

- Presentation
  - No specific mechanism of injury
  - Pain localized on or adjacent to ischial tuberosity
  - No radiating pain
  - Pain may reduce during running
    - Aggravated by speed work and uphill
  - Pain is provoked near end-range hip flexion and with resisted hip extension in a hip flexed position
Provocative Running Mechanics

- Positions of increased hip flexion
  - Increased wrapping of tendon against ischial tuberosity
  - Examples
    - Uphill running
    - Speed work
    - Foot well ahead of center of mass at contact
    - Excessive anterior pelvic tilt
Pain Management

- **Isometric exercises of the involved tendon:** 30–60s holds, 3–5 reps, 1–3 sets; start with lower volume if tendon is highly reactive/irritable

- **Tendon load reduction**
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  - Address trigger points, joint mobility, and posture as needed

Kountouris and Cook (2007) *Best Pract Res Clin Rheumatol*
Tendon Load Progression

- **Isometric**
  - Limited hip flexion

- **Isotonic**
  - Progressing hip flexion

- **Plyometric**

**FIGURE 2.** Examples of stage 1 exercises: (A) single-leg bridge hold, (B) long-lever bridge hold, (C) straight-leg pull-down, and (D) trunk extension.
Tendon Load Progression

**Isometric**
Limited hip flexion

**Isotonic**
Progressing hip flexion

**Plyometric**

**Limited Hip Flexion**

*FIGURE 3. Examples of stage 2 exercises: (A) Nordic hamstring exercise, (B) prone leg curl, (C) supine leg curl, and (D) bridging progressions (e.g., adding weight).*

Bridged Knee Curls on Physioball

2-leg

1-leg
Modified Nordic Curls
### Tendon Load Progression

<table>
<thead>
<tr>
<th>Isometric</th>
<th>Isotonic</th>
<th>Plyometric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited hip flexion</td>
<td>Progressing hip flexion</td>
<td></td>
</tr>
</tbody>
</table>

**Increased Hip Flexion**


**Figure 4.** Examples of stage 3 exercises: (A) Romanian deadlift, (B) step-ups, (C) walking lunges, (D) hip thrusts (weights can be added to the bar to increase resistance), and (E) single-leg deadlift.
Resisted Terminal Swing
Exercise Progression

- **Isometric**
  - Limited hip flexion
- **Isotonic**
  - Progressing hip flexion
- **Plyometric**

*Figure 5. Examples of stage 4 exercises: (A) bounding, (B) alternate-leg split squats, (C) A-skips, (D) cutting, and (E) sprinter leg curl.*

# Tendon Load Progression

**Example Plan**

<table>
<thead>
<tr>
<th>Week</th>
<th>Type</th>
<th>Hip Angle</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Isometrics</td>
<td>0°</td>
<td>1-2x/d</td>
</tr>
<tr>
<td>2</td>
<td>Isometrics</td>
<td>20°</td>
<td>1-2x/d</td>
</tr>
<tr>
<td>3-4</td>
<td>Isometrics</td>
<td>Up to 30°</td>
<td>Alternate days</td>
</tr>
<tr>
<td></td>
<td>Isotonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-6</td>
<td>Isometrics</td>
<td>Up to 50°</td>
<td>Alternate days</td>
</tr>
<tr>
<td></td>
<td>Isotonics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7+</td>
<td>Plyometrics</td>
<td>Progress to full</td>
<td>3 day cycle</td>
</tr>
<tr>
<td></td>
<td>Isometrics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Isotonics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Isometric**
- Limited hip flexion

**Isotonic**
- Progressing hip flexion

**Plyometric**
Passive Tension of Muscle

- Increased passive muscle stiffness (shear wave imaging) of the vastus lateralis in BB and VB players with patellar tendinopathy
  - No difference in RF stiffness
- VL muscle stiffness correlated with proximal patellar tendon stiffness

Stretching: More Harm than Good?

- End range stretching may provoke symptoms due to compressive loading
  - Better to manage restrictions in muscle mobility with massage techniques rather than stretching

Too much tendon wrapping at end range, i.e., increased compression

Practice and Research Gaps

1. Optimal dosage, frequency and intensity of tendon loading has yet to be defined, and is likely highly individual
   - Principles vs protocol

2. Pain model of load progression has not been evaluated with rigorous clinical trials
   - Several are ongoing

3. The application of these loading concepts to older, degenerated tendons is premature
Take Home Points

1. Identify provocative running/movement mechanics and training habits, and modify

2. Minimize tendon wrapping
   - i.e., limit ankle dorsiflexion, hip flexion

3. Use isometrics at start and throughout rehab to modify pain and condition tendon

4. Progress as tolerated: Motion, Intensity, Volume
Thank You

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Athletic Performance

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