Rehabilitation of Hamstring Injuries: We Can Do Better

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  - UW Department of Orthopedics and Rehabilitation
Hamstring Strain Injury

- Most common injury among sprinting athletes
  - Kujala et al. (1997) *Sports Med*

- 2nd most common injury among NFL team, with 8-25 days lost to injury

- Australian Football estimated the cost per hamstring injury in 2012 to be ~$41,000
  - 71% increase over the preceding decade

- 30% re-injury rate
Injury is Likely during Terminal Swing

- Biomechanical data from healthy athletes
- Case studies of injuries during biomechanical experiments

Heiderscheit et al. (2005) *Clin Biomech*
Chumanov et al. (2007) *J Biomech*
Chumanov et al. (2011) *Med Sci Sports Exerc*
Factors Affecting (Re)Injury Risk

Non-Modifiable
- Increased Age
  - 1.3-1.8-fold increase with each year of age (>23yrs)
- Prior HSI
  - 11.6-fold increase

Modifiable
- Decreased flexibility
  - Limited/questionable findings
- Fatigue
- Strength imbalances

Opar et al. (2012) Sports Med
Strength, Age and Prior Injury

 Increased risk associated with history of HSI and age can be mitigated with greater levels of eccentric strength.
Fascicle Length, Age and Prior Injury

- Increased risk associated with age and history of HSI can be mitigated with longer BFllh fascicles

Timmins et al. (2016) Br J Sports Med
Common Eccentric Exercises

- Single leg Deadlift
- Straight-Knee Bridge
- Hip Extension (Glute-Ham Raise)
- Nordic Hamstring Curl

Effects of Eccentric Training

- 30 recreationally active males (22±3.6 yrs)
  - 10-wks eccentric training: Nordic curl (n=10)
  - 10-wks eccentric training: Hip extension (n=10)
  - Control (n=10)

- ~28% increase in strength
- 1-2cm increase in fascicle length

Preventative Effect of Eccentrics

- male professional and amateur soccer teams randomized
  - 10-wk Eccentric training: 23 teams (461 players)
  - Usual training (control): 27 teams (481 players)
  - similar hamstring injury history between groups

- reduced the injury rate of new injuries by >60% and reduced the rate of recurrent injuries by 85%
  - No effect on injury severity

Nordic Hamstring Curl

- Allow 3 min of rest between sets
- If/when the athlete develops sufficient strength to completely stop the movement in the final 10–20° of the range of motion, s/he should hold a weight plate (range 5-45 lbs) to the chest to ensure the exercise is still of supramaximal intensity.

<table>
<thead>
<tr>
<th>Week</th>
<th>Sessions/wk</th>
<th>Sets/Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2 x 5</td>
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<tr>
<td>2</td>
<td>2</td>
<td>2 x 6</td>
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<tr>
<td>3</td>
<td>3</td>
<td>3 x 6-8</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>3 x 8-10</td>
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<tr>
<td>5-10</td>
<td>3</td>
<td>3 x 12-10-8</td>
</tr>
<tr>
<td>10+</td>
<td>1</td>
<td>3 x 12-10-8</td>
</tr>
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</table>

Eccentrics In-Season?

- Gradually introduce in the off-season, prior to time of largest spike in hamstring strain injuries
  - Get past delayed onset muscle soreness
  - Achieve gains in eccentric strength

- Being too aggressive from the start could contribute to injury risk

- Must have maintenance program for remainder of year
  - Do not drop it during the season
Hamstring Muscle Activity

Other Exercise Options
45° Hip Extension

<table>
<thead>
<tr>
<th>Week</th>
<th>Sessions/wk</th>
<th>Sets/Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2 x 6</td>
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<tr>
<td>2</td>
<td>2</td>
<td>3 x 6</td>
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<td>3</td>
<td>2</td>
<td>4 x 8</td>
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<td>4</td>
<td>2</td>
<td>4 x 10</td>
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<tr>
<td>5-8</td>
<td>2</td>
<td>5 x 8-10</td>
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<tr>
<td>9</td>
<td>2</td>
<td>6 x 6</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>5 x 5</td>
</tr>
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</table>

- Train both limbs in alternating fashion; complete a set on one limb, rest 30 s before training the opposite limb, and then recover for 3 min before the next set.
- Load held to the chest in week 1 should represent 60–70% of the estimated 1-RM and progressively increased throughout the training period.

Other Exercise Options
Single Leg Roman Chair Holds

<table>
<thead>
<tr>
<th>Week</th>
<th>Sessions/wk</th>
<th>Sets/Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3 x 10s hold</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3 x 10s hold with 20-25lb weight</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3 x 10 plate rows with 20-25lb weight</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Same as prior week</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>3 x 10 rows with 45lb weight</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Same as prior week</td>
</tr>
</tbody>
</table>

- Train both limbs in alternating fashion; after completing a set on one limb, rest 15-30 s before training the opposite limb, and then recover for 2-3 min before the next set

Macdonald et al. (2018) J Strength Cond Res
Badger Athletic Performance dedicates itself to the mission of maximizing student-athlete’s individual on-field performance through the integration of science, training, and injury management.
Gluteus Max Activity in Swing

- Hamstring injuries in running have been associated with reduced G. Maximus activity in 2nd half of swing (front swing)

Influence of Adjacent Muscles on Hamstring Stretch during Running

Running Mechanics: Lumbopelvic Control

- Limited left shoulder motion resulted in increased trunk and pelvic rotation
  - Worse at high speeds
Factors Affecting (Re)Injury Risk

Non-Modifiable
- Increased Age
  - 1.3-1.8-fold increase with each year of age (>23yrs)
- Prior HSI
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Modifiable
- Decreased flexibility
  - Limited/questionable findings
- Fatigue
- Strength imbalances

Initial Strain Injury
- persistent deficits
- Weakness
- Scar tissue
- Altered musculotendon dynamics

Recurrent Strain Injury

Opar et al. (2012) Sports Med
So Many to Choose From...

Sherry-Best-Heiderscheit

- SS
  Stretching and strengthening

- PATS
  Progressive agility and trunk stabilization

- PRES
  Progressive running and eccentric strength

Askling

- C-protocol
  Conventional exercises

- L-protocol
  Lengthening exercises

Mendiguchia

- Rehab Protocol
  L-protocol + progressive running

- Rehab Algorithm
  ECC + core + running + glutes + plyos

Lower re-injury rates
Outcomes from Different Approaches

<table>
<thead>
<tr>
<th>Rehab Approach</th>
<th>Return to Sport (d)</th>
<th>Re-injuries (n)</th>
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</thead>
<tbody>
<tr>
<td>SS</td>
<td>37.4 ± 27.6</td>
<td>7/10 (70%) 12 months</td>
</tr>
<tr>
<td>PATS-1</td>
<td>22.2 ± 8.3</td>
<td>1/13 (8%) 12 months</td>
</tr>
<tr>
<td>PATS-2</td>
<td>25.2 ± 6.3</td>
<td>1/16 (6%) 12 months</td>
</tr>
<tr>
<td>PRES</td>
<td>28.8 ± 11.4</td>
<td>3/13 (23%) 12 months</td>
</tr>
<tr>
<td>C-protocol</td>
<td>51 ± 21</td>
<td>1/38 (2.6%) 12 months</td>
</tr>
<tr>
<td>L-protocol</td>
<td>28 ± 15</td>
<td>0/37 (0%) 12 months</td>
</tr>
<tr>
<td>RP</td>
<td>23.2 ± 11.7</td>
<td>6/24 (25%) 6 months</td>
</tr>
<tr>
<td>RA</td>
<td>25.5 ± 7.8</td>
<td>1/24 (4%) 6 months</td>
</tr>
</tbody>
</table>

- Not just a result of the exercise selection but it chiefly involves the decision making regarding progression and readiness to return to sport.
Hamstring Strain Injuries: Recommendations for Diagnosis, Rehabilitation, and Injury Prevention

RTS Decision Making

**Phase I**

Goals: 1. Normal walking stride without pain
2. Very low speed jog without pain
3. Pain-free isometric contraction against sub-max (50-70%) resistance during prone knee flexion (90°) manual strength test

Protection: Avoid full intensity if pain/stiffness is present

**Phase II**

Goals: 1. Full strength (5/5) without pain during prone knee flexion (90°) manual strength test
2. Pain-free forward and backward jog, moderate intensity

**Phase III**

Goals: Symptom-free during all activities; normal strength through full ROM and speeds; integrate postural control into sport-specific movements

Protection: Avoid full intensity if pain/stiffness is present

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Criteria for Rehab Progression

Progression is largely informed by pain (Hickey et al. Sports Med 2018)
- Are there more objective factors to consider?

Daily physical measures may be useful to inform the progression (Whiteley et al. Br J Sports Med 2018):
- length of palpation pain
- knee flexion strength at long muscle lengths
- active knee extension in maximum hip flexion
- reported pain during daily activity

### Phase I
1. Normal walking stride without pain
2. Very low speed jog without pain
3. Pain-free isometric contraction against sub-max (50-70%) resistance during prone knee flexion (90°) manual strength test

### Phase II
1. Full strength (5/5) without pain during prone knee flexion (90°) manual strength test
2. Pain-free forward and backward jog, moderate intensity

### Phase III
RTS Decision Making

Hamstring Muscle Activation

- Intensity of muscle activation should be part of exercise selection

- Also consider:
  - Hamstring muscle length
  - Lumbopelvic position
  - Strictly sagittal (?)

Return to Sport Decision Making

- Full strength without pain
  - 4 reps of max manual strength test in prone knee flexion position (90° & 15°)
  - Isokinetic torque ratios
  - Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque
  - Eccentric knee flexion strength (?)

- Full range of motion without pain

- Replication of sport specific movements near maximal speed without pain
  - Incremental sprint test for running athletes
  - Body posture replication

- Apprehension & fear of re-injury
## Return to Sport Factor Comparison

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sherry-Best-Heiderscheit</th>
<th>Askling</th>
<th>Mendiguchia</th>
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<tr>
<td>Pain</td>
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<tr>
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<td>Quality</td>
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<tr>
<td>Speed</td>
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<tr>
<td>Apprehension</td>
<td></td>
<td>x</td>
<td>x</td>
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- Re-injuries most often occur:
  - same location as the index injury
  - early after RTS [median 24 days (IQR, 140 days); 50% within 4wks]
  - radiologically greater severity

Post-Injury Remodeling

- 7 days post-injury:
  - Persistent edema; (~20%) of muscle
  - Evidence of scar tissue

- 2 mo. post-injury:
  - Edema resolved
  - Fully formed scar tissue
    - 92% increase in biceps tendon volume

- 7 mo. post-injury:
  - Persistent edema; (~20%) of muscle
  - Evidence of scar tissue

Silder et al. (2008) *Skeletal Radiology*
Connell et al. (2004) *AJR*
Muscle Volume Changes

Injured

Healthy

<table>
<thead>
<tr>
<th>BFLH</th>
<th>BFSH</th>
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</thead>
<tbody>
<tr>
<td>-12%</td>
<td>+22%</td>
</tr>
</tbody>
</table>

**p<0.01 **p=0.06

**Compared to healthy controls**

Silder et al. (2008) *Skel Radiol*
Strength Deficits at Long Muscle Length

- Strength loss at longer muscle lengths may contribute to re-injury risk
- Residual deficits in torque-angle relationship addressed with eccentric training

Silder et al. (2013) J Orthop Sports Phys Ther
Dynamic Deficits and Fascicle Strain

No significant bilateral differences in peak musculotendon stretch

| Strains greater for injured subjects adjacent to injury site |

Silder et al. (2010) Clin Biomech
What are Hamstring Loads during Sprinting?

- 80% to 100% running speed:
  - Force increases by ~50%
  - Negative work increases by ~70%

Measured Kinematics  Forward Dynamics

Chumanov et al. (2007) *J Biomech*
Chumanov et al. (2011) *Med Sci Sports Exerc*
Hamstring Load during Sprinting

- 25% ↑ Speed
- 30% ↑ Muscle Force
- 50% ↑ Eccentric Load

265 lbs

335 lbs

25% ↑ Speed
30% ↑ Muscle Force
50% ↑ Eccentric Load
Summary

- Progression-based rehabilitation approaches
  - Phase 1: protect scar development and minimize atrophy
  - Phase 2: build strength and neuromuscular control of trunk and pelvis
  - Phase 3: symptom-free, normal strength, sport-specific movements

- Even with effective rehabilitation approaches, at return to sport
  - On average, 20% of muscle shows evidence of injury
  - Clear evidence of scar tissue formation
  - On average, 10% strength deficit

- Suggestive of needing better return to play criteria

- Eccentric strength and progressive high speed running are critical components to mitigate re-injury risk
Thank You

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