Evaluation of Muscle Injury in Elite Athletes

Steve Kussman
Muscle injury in elite athletes

- Account for 1/3 of all sports related injuries in elite athletes
- Can be from direct trauma or from excessive eccentric contraction along muscle-tendon-bone axis
- **Hamstring** most common injury in soccer, rugby, football
  - Incidence 1/1000 hours of exposure
  - Professional Australian rules football team of 25 players can expect 7 hamstring injuries per season
Muscle injury in elite athletes

- Imaging modalities
  - MRI
    - Fat suppressed fluid sensitive sequences key for detection
    - T1 non fat suppressed for anatomy and blood products
    - Diffusion has been studied, but not routinely used

Muscle injury in elite athletes

• Imaging modalities
  – US
    • Advantages
      – Dynamic imaging
      – Improved spatial resolution
      – Portability
      – Low cost
    • Disadvantages
      – Operator dependent
      – Limited FOV
      – Reduced conspicuity of injury
      – Deep muscles in large athletes

Muscle injury in elite athletes

- Imaging modalities
  - Not routinely used (aside from myositis ossificans)
    - Plain film
    - CT
    - Nuclear medicine

Muscle injury mechanisms

• **Direct muscle injury:** Most common is kneecap to anterior thigh
  - **Mild** contusion = less than 1/3 motion loss
    • 6 day average loss of activity
  - **Moderate** contusion = 1/3 to 2/3 motion loss
    • 56 day average loss of activity
  - **Severe contusion** = more than 2/3 motion loss
    • Greater than 60 day loss of activity
  - **Grading system of indirect muscle injury does not apply**

Muscle injury mechanisms

• **Direct muscle injury:**
  – Return to play difficult to predict, player can often play with severe imaging appearance

Muscle injury mechanisms

• Direct muscle injury:
  – MRI
    • Initial contusion causes edema and interstitial hemorrhage leading to feather-like high signal on fluid sensitive sequences
    • Faint high T1 signal if blood products acutely

Muscle injury mechanisms

• **Direct muscle injury:**
  - MRI
    • Initial contusion causes edema and interstitial hemorrhage leading to feather-like high signal on fluid sensitive sequences
    • Faint high T1 signal if blood products acutely

Muscle injury mechanisms

• **Direct muscle injury:**
  - 2 muscles injured along single vector more common with contusion
  - atypical for eccentric load

Muscle injury mechanisms

• Direct muscle injury:
  – MRI
    • Blood signal will change over time
    • Fibrosis of hematoma margins will contract over time
    • Possible development of myositis ossificans

Muscle injury mechanisms

• **Direct muscle injury:**
  – US
    • *Contusion* usually ill-defined area of hyperechogenicity
    • Muscle may appear swollen but otherwise isoechoic to surrounding muscle

A 27-year-old male elite boxer presenting with pectoralis muscle contusion following punch injury to the chest. Note the generalised reflectivity within the clavicular (CH) and sternocostal (SCH) heads of the pectoralis major muscle.

Muscle injury mechanisms

• **Direct muscle injury:**
  – First 24–48 hours
    • hematoma will appear as an irregularly outlined muscle laceration separated by hypoechoic fluid
    • marked increased reflectivity in the surrounding muscle

Muscle injury mechanisms

- **Direct muscle injury:**
  - After 48–72 hours
    - Hematoma develops into a clearly defined hypoechoic fluid collection with an echogenic margin
    - Echogenic margin gradually enlarges and “fills in” the hematoma in a centripetal fashion

Muscle injury mechanisms

• **Eccentric contraction**
  – Tearing of muscle fibers, usually at myotendinous junction or myofascial interface (weakest points)
  – Sudden onset pain localized to single muscle
  – Most commonly during sprint
Muscle injury mechanisms

• **Eccentric contraction**
  – Athlete related risk factors
    • Age
    • Male sex
    • Improper warm-up
    • Fatigue
Muscle injury mechanisms

• **Eccentric contraction**
  – Muscle related risk factors
    • Previous injury to same muscle
      – Re-injury risk high, especially within first 8 weeks.
      – Recurrent strains tend to be larger than initial injury
    • Muscles with high proportion of fast twitch type II fibers
    • Muscles crossing multiple joints
    • Muscles with complex anatomy
    • Most common = biceps femoris, rectus femoris, medial gastrocnemius
Risk factors for eccentric contraction injury

– 114 Australian rules football players studied for 1 season
– 26 players with hamstring muscle injury

Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging

G M Verrall, J P Slavotinek, P G Barnes, G T Fon, A J Spriggins

Table 1 Comparison of anthropometric variables and past clinical history of players from the AFL and SANFL

<table>
<thead>
<tr>
<th>Variable</th>
<th>AFL (n=43)</th>
<th>SANFL (n=71)</th>
<th>Total (n=114)</th>
<th>U, t, or χ²</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22, 21.9 (3.0)</td>
<td>20, 21.4 (3.5)</td>
<td>20.5, 21.6 (3.4)</td>
<td>U=1342</td>
<td>0.276</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>183, 185.0 (7.9)</td>
<td>182, 183.3 (7.0)</td>
<td>183, 183.9 (7.4)</td>
<td>U=1359</td>
<td>0.325</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>86, 85.8 (9.8)</td>
<td>81, 82.5 (9.4)</td>
<td>83, 83.8 (9.6)</td>
<td>t=1.78</td>
<td>0.078</td>
</tr>
<tr>
<td>Aboriginal descent</td>
<td>5</td>
<td>3</td>
<td>8</td>
<td>χ²=2.24</td>
<td>0.112</td>
</tr>
<tr>
<td>PH-PTI</td>
<td>11</td>
<td>15</td>
<td>26</td>
<td>χ²=0.32</td>
<td>0.371</td>
</tr>
<tr>
<td>PH-knee injury</td>
<td>2</td>
<td>8</td>
<td>10</td>
<td>χ²=1.47</td>
<td>0.195</td>
</tr>
<tr>
<td>PH-osteitis pubis</td>
<td>7</td>
<td>10</td>
<td>17</td>
<td>χ²=5.10</td>
<td>0.475</td>
</tr>
<tr>
<td>PH-back injury</td>
<td>9</td>
<td>8</td>
<td>17</td>
<td>χ²=1.97</td>
<td>0.129</td>
</tr>
</tbody>
</table>

Increased risk:

- Increasing age
- Aboriginal descent (higher % type 2 muscle fibers)
- Past history of posterior thigh injury
- Past history of knee injury
- Past history of osteitis pubis

## Muscle injury grading

### Table 1: Overview of previous muscle injury classification systems

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>I</td>
<td>No appreciable tissue tearing, no loss of function or strength, only a low-grade inflammatory response</td>
<td>Tear of a few muscle fibres, fascia remaining intact</td>
<td>No abnormalities or diffuse bleeding with/without focal fibre rupture less than 5% of the muscle involved</td>
<td>MRI-negative=0% structural damage. Hyperintense oedema with or without hemorrhage</td>
</tr>
<tr>
<td>II</td>
<td>Tissue damage, strength of the musculotendinous unit reduced, some residual function</td>
<td>Tear of a moderate number of fibres, fascia remaining intact</td>
<td>Partial rupture: focal fibre rupture more than 5% of the muscle involved with/without fascial injury</td>
<td>MRI-positive with tearing up to 50% of the muscle fibres. Possible hyperintense focal defect and partial retraction of muscle fibres</td>
</tr>
<tr>
<td>III</td>
<td>Complete tear of musculotendinous unit, complete loss of function</td>
<td>Tear of many fibres with partial tearing of the fascia</td>
<td>Complete muscle rupture with retraction, fascial injury</td>
<td>Muscle rupture=100% structural damage. Complete tearing with or without muscle retraction</td>
</tr>
<tr>
<td>IV</td>
<td>X</td>
<td>Complete tear of the muscle and fascia of the muscle-tendon unit</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

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Muscle injury grading

• **Eccentric contraction**
  
  – Traditional Clinical Grading System
    • Grade 1 (stretch) = small tear, less than 5% loss of function
    • Grade 2 (partial tear) = 5-50% loss of function
    • Grade 3 (near complete/complete tear) = >50% loss of function
Muscle injury grading

- **Eccentric contraction**
  - Imaging Based Grading system
  - US Grade 1:
  - Normal or Focal areas of increased echogenicity occupying less than 5% of muscle


Grade 1 rectus femoris injury
Muscle injury grading

- **Eccentric contraction**
  - Imaging Based Grading system
  - MRI Grade 1:
  - Feathery high signal within muscle, often at MTJ
  - Less than 5% cross sectional area

Muscle injury grading

• **Eccentric contraction**
  – Imaging Based Grading system
  – **US Grade 2:**
  – greater than 5% of muscle, less than 100%
  – Discontinuity of muscle striations, +/- intramuscular fluid collections

Muscle injury grading

• **Eccentric contraction**
  - Imaging Based Grading system
  - **MRI Grade 2:**
  - Discontinuity of muscle striations, +/- intramuscular fluid collections
  - Often laxity in central tendon

Muscle injury grading

- **Eccentric contraction**
  - Imaging Based Grading system
  - **US Grade 3:**
  - Complete discontinuity at myotendinous junction, often with intermuscular, perifascial, and subcutaneous collections

Muscle injury grading

- **Eccentric contraction**
  - Imaging Based Grading system
  - MRI Grade 3:
    - Complete discontinuity at myotendinous junction, often with intermuscular, perifascial, and subcutaneous collections

Muscle injury grading

- Munich consensus

- 30 English speaking scientists and team doctors of national and first division professional sports teams completed questionnaire on currently used terminology
- Word “strain” with most significant variability
- New comprehensive classification system developed with this data by group of 15 “experts”

Muscle injury grading

• Munich consensus
  – Terms not recommended
    • Strain: biomechanical term which is not defined and is used indiscriminately for anatomic and functionally different injuries
    • Pulled-muscle
    • Hardening
    • Hypertonus
Muscle injury grading

• Munich consensus
  – **Functional** muscle disorders (no macroscopic evidence of fiber tearing)
    • Type 1: overexertion related
    • Type 2: neuromuscular disorders
  – **Structural** muscle disorders
    • Type 3: partial tear
    • Type 4: (sub) total tears/tendon avulsion
**Muscle injury**

- **Delayed onset muscle soreness (DOMS)**
  - 12-24 hours after strenuous exercise
  - Often non-elite athletes or with increase in training
  - Soreness peaks 24-72 hours, subsides by 5-7 days (grade 1 strain usually about 2 weeks)
  - Similar to grade 1 muscle strain, but more than 1 muscle, and often more than 1 compartment
  - US normal or hyperechogenicity in more than 1 compartment

www.radiologyassistant.nl
Muscle injury grading

• Munich Consensus: location of injuries
Muscle injury grading

• Type 3A vs 3B
  – Moderate = greater than diameter of muscle fascicle or bundle

### Muscle injury grading

<table>
<thead>
<tr>
<th>Type</th>
<th>Classification</th>
<th>Definition</th>
<th>Symptoms</th>
<th>Clinical signs</th>
<th>Location</th>
<th>Ultrasound/MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Circumferential muscle disorder</td>
<td>Circumferential increase of muscle tone (muscle firmness) due to overexertion, change of playing surface or change in training patterns.</td>
<td>Aching muscle firmness, increasing with continued activity. Can provoke pain at rest. During or after activity.</td>
<td>Dull, diffuse, tolerable pain in involved muscles, circumscribed increase of tone. Athlete reports of 'muscle tightness'.</td>
<td>Focal involvement up to entire length of muscle</td>
<td>Negative</td>
</tr>
<tr>
<td>1B</td>
<td>Delayed-onset muscle soreness (DOMS)</td>
<td>More generalized muscle pain following unaccustomed, eccentric muscular activity.</td>
<td>Acute inflammatory pain. Pain at rest. Hours after activity.</td>
<td>Oedematous swelling, stiff muscles. Limited range of motion of adjacent joints. Pain on isometric contraction. Therapeutic stretching leads to relief.</td>
<td>Mostly entire muscle or muscle group</td>
<td>Negative or oedema only</td>
</tr>
<tr>
<td>2A</td>
<td>Spine-related neuromuscular muscle disorder</td>
<td>Circumferential increase of muscle tone (muscle firmness) due to functional or structural spinal/humeralis disorder.</td>
<td>Aching muscle firmness, increasing with continued activity. No pain at rest.</td>
<td>Circumscribed (longitudinal) increase of muscle tone. Discrete oedema between muscle and fascia. Occasional skin sensitivity, defensive reaction to muscle stretching. Pressure pain.</td>
<td>Muscle bundle or larger muscle group along entire length of muscle</td>
<td>Negative or oedema only</td>
</tr>
<tr>
<td>2B</td>
<td>Muscle-related neuromuscular muscle disorder</td>
<td>Circumferential (spindle-shaped) area of increased muscle tone (muscle firmness). May result from dysfunctional neuromuscular control such as reciprocal inhibition.</td>
<td>Aching, gradually increasing muscle firmness and tension. Cramp-like pain</td>
<td>Circumscribed (spindle-shaped) area of increased muscle tone, oedematous swelling. Therapeutic stretching leads to relief. Pressure pain.</td>
<td>Mostly along the entire length of the muscle belly</td>
<td>Negative or oedema only</td>
</tr>
<tr>
<td>3A</td>
<td>Minor partial muscle tear</td>
<td>Tear with a maximum diameter of less than muscle fasciculus.</td>
<td>Sharp, needle-like or stabbing pain at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain.</td>
<td>Well-defined localised pain. Probably palpable defect in fibre structure within a firm muscle band. Stretch-induced pain aggravation.</td>
<td>Primarily muscle-tendon junction</td>
<td>Positive for fibre disruption on high resolution MRI*. Intramuscular haematoma</td>
</tr>
<tr>
<td>3B</td>
<td>Moderate partial muscle tear</td>
<td>Tear with a diameter of greater than a fasciculus</td>
<td>Stabbing, sharp pain, often noticeable tearing at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain.</td>
<td>Well-defined localised pain. Palpable defect in muscle structure, often haematoma, fascial injury. Stretch-induced pain aggravation.</td>
<td>Primarily muscle-tendon junction</td>
<td>Positive for significant fibre disruption, probably including some retraction. With fascial injury and intramuscular haematoma</td>
</tr>
<tr>
<td>4</td>
<td>(Sub)total muscle tear/tendinous avulsion</td>
<td>Tear involving the subtotal/complete muscle diameter/tendinous injury involving the bone-tendon junction.</td>
<td>Dull pain at time of injury. Noticeable tearing. Athlete experiences a 'snap' followed by a sudden onset of localised pain. Often toll.</td>
<td>Large defect in muscle, haematoma, palpable gap, haematoma, muscle retraction, pain with movement, loss of function, haematoma.</td>
<td>Primarily muscle-tendon junction or bone-tendon junction</td>
<td>Subtotal-complete discontinuity of muscle/ tendon. Possible wavy tendon morphology and retraction. With fascial injury and intramuscular haematoma</td>
</tr>
<tr>
<td>Contusion</td>
<td>Direct injury</td>
<td>Direct muscle trauma, caused by blunt external force. Leading to diffuse or circumscribed haematoma within the muscle causing pain and loss of motion.</td>
<td>Dull pain at time of injury, possibly increasing due to increased tone. Athlete often reports diffuse external mechanism.</td>
<td>Dull, diffuse pain, haematoma. Pain on movement, swelling, decreased range of motion, tenderness to palpation depending on the severity of impact. Athlete may be able to continue sport activity rather than in indirect structural injury.</td>
<td>Any muscle, mostly vastus intermedius and rectus femoris</td>
<td>Diffuse or circumscribed haematoma in varying dimensions</td>
</tr>
</tbody>
</table>

*Recommendations for high-resolution MRI: high field strength (minimum 1.5 or 3.0 T), high spatial resolution (use of surface coils), limited field of view (according to clinical examination/ultrasound), use of skin marker at centre of injury location and multiplanar slice orientation.
Muscle injury grading

• Type 3A vs 3B
  – Moderate = greater than diameter of muscle fascicle or bundle
  – “clinically challenging to differentiate”
  – Type 3A usually no scar formation
  – Type 3B often with scar formation

Muscle injury grading


**British athletics muscle injury classification: a new grading system**

Noel Pollock, Steven L J James, Justin C Lee, Robin Chakraverty

- Problems with Munich
  - Functional injuries most likely structural
  - Only the structural part of the grading system had prognostic value
  - Neglects recent evidence about site, length, tendon involvement, and MRI negative presentations
Muscle injury grading

- Grade 0 = normal MRI or DOMS
- Grade 1 = small tear
- Grade 2 = moderate tear
- Grade 3 = extensive tear
- Grade 4 = complete tear
- Some groups subdivided into 3 categories (a, b, or c)
Muscle injury grading


Figure 1 Letter classification dependent on anatomical site of muscle injury. (a) Myofascial, (b) musculo-tendinous, (c) intratendinous.
Muscle injury grading

- **Grade 0 = normal MRI or DOMS**
  - 0a = focal neuromuscular injury with normal MRI
  - 0b = generalized muscle soreness with normal MRI or DOMS
Muscle injury grading

- **Grade 1 = small tear**
  - Athlete will present with pain during or after activity
  - Range of motion normal
Muscle injury grading


• **Grade 1** = small tear
  
  – 1a:
    
    • extends from fascia
    • high signal within periphery of muscle
    • no greater than 10% into muscle and length less than 5 cm
    • frank muscle fiber disruption not usually seen
Muscle injury grading


• **Grade 1** = small tear
  - 1b:
    • within muscle or myotendinous junction
    • less than 5 cm length
    • less than 10% cross sectional area

Grade 1b injury to long head of biceps femoris
Muscle injury grading

- **Grade 2 = moderate tear**
  - Pain causing athlete to stop activity
  - Decreased range of motion at 24 hours
  - Weakness
Muscle injury grading

- **Grade 2 = moderate tear**
  - 2a:
    - Extend from peripheral fascia into the muscle
    - Clinical experience suggests from pain during change of direction
    - Less reduction in strength compared to other grade 2 injuries

Grade 2a injury to lateral aspect of long head of biceps femoris.
Muscle injury grading


• **Grade 2** = moderate tear
  – 2a:
    • Signal abnormality
      – between 10-50% cross sectional area
      – extends between 5-15 cm
    • Fiber distortion <5 cm

Grade 2a injury to lateral aspect of long head of biceps femoris.
Muscle injury grading


• **Grade 2** = moderate tear
  – 2b:
    • Within muscle or more commonly, MTJ
    • Signal abnormality
      – 10-50% cross sectional area
      – Length of abnormal signal 5-15 cm
    • Fiber distortion less than 5 cm

Grade 2b injury to long head of biceps femoris
Muscle injury grading


- **Grade 2** = moderate tear
  - 2c:
    - Injury extends into tendon
    - Injury of tendon less than 5 cm and less than 50% tendon thickness
    - 2c rather than 3c based on these measurements, even if loss of normal tendon tension

Grade 2c injury to long head of biceps femoris
Muscle injury grading


• **Grade 3 = extensive tear**
  – Sudden onset pain and athlete falls to ground
  – Significantly reduced range of motion at 24 hours
  – Obvious weakness with contraction
  – Pain with walking
Muscle injury grading

• **Grade 3** = extensive tear
• **Grade 3a (myofascial)** and **3b (myotendinious)**
  — Signal abnormality
    • Greater than 50% cross sectional area
    • Or greater than 15 cm length
  — Fiber distortion
    • greater than 5 cm
Muscle injury grading


**Grade 3** = extensive tear

- **3c:**
  - *Intratendinuous injury*
  - Greater than 5 cm length of tendon involved
  - Greater than 50% tendon thickness
  - No complete defect, but loss of normal straight margins of tendon

Grade 3c injury to long head of biceps femoris
Muscle injury grading


• Grade 4 = complete tear
  – Sudden onset pain, athlete will fall to ground
  – Palpable gap felt on exam
  – Often less pain on contraction than with grade 3
Muscle injury grading

- **Grade 4** = complete tear
  - Grade 4 = complete muscle tear
  - Grade 4c = complete tendon tear

Grade 4 injury to proximal biceps femoris.
Muscle injury grading

  - Currently in use with elite track and field in UK
  - Still needs validation of utility
Return to Play

• **Orchard and Best Clinical J Sports Medicine 2002**
  – Injuries over 7 year period in Australian Football League
    • 858 hamstring
    • 251 quad
    • 217 calf
    • 123 thigh contusion

Return to Play

• Cumulative risk highest in hamstring, at over 30% for the season

• Strain in one muscle increases risk in other muscles (altered biomechanics?)


<table>
<thead>
<tr>
<th>Weeks after return from initial injury</th>
<th>Hamstring strain (n = 858)</th>
<th>Quadriceps strain (n = 251)</th>
<th>Calf strain (n = 217)</th>
<th>Thigh contusion (n = 123)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>8.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>6.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.3</td>
</tr>
<tr>
<td>4–5</td>
<td>4.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6–8</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.8</td>
<td>1.3</td>
</tr>
<tr>
<td>9–14</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.5</td>
<td>1.1</td>
<td>1.6</td>
</tr>
<tr>
<td>15–22</td>
<td>1.4</td>
<td>2.2</td>
<td>2.1</td>
<td>0.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Cumulative risk of recurrence for remainder of season (%): 30.6 22.9 23.8 12.2

<sup>a</sup> Significantly greater than weekly risk of reinjury during following season (p < 0.05).
<sup>b</sup> No recurrence reported during this time period.
Return to Play

- Risk levels off after 1 week with contusion
- Risk decreases, but persists for many weeks with strain

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<table>
<thead>
<tr>
<th>Weeks after return from initial injury</th>
<th>Weekly percentage risk of injury recurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hamstring strain (n = 858)</td>
</tr>
<tr>
<td>1</td>
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<td>6.8&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>15–22</td>
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</tr>
<tr>
<td>Cumulative risk of recurrence for remainder of season (%)</td>
<td>30.6</td>
</tr>
</tbody>
</table>

<sup>a</sup> Significantly greater than weekly risk of reinjury during following season (p < 0.05).

<sup>b</sup> No recurrence reported during this time period.
Return to Play

- Connell et al AJR 2004

Longitudinal Study Comparing Sonographic and MRI Assessments of Acute and Healing Hamstring Injuries

- Australian rules football players
- 60 athletes
- US and MRI at initial injury, 2 weeks, 6 weeks
- 2 MSK radiologists interpreted images, blinded to findings of other modality
- **Biceps femoris > semitendinososis > semimembranosis**
Return to Play

• Connell et al AJR 2004

• Parameters evaluated
  – Injured muscle
  – Site within muscle unit
  – Injured cross sectional area
  – Length of injury
  – Presence of intermuscular hematoma
  – Presence of intramuscular hematoma

Connell et al AJR 2004

Initial (0-3 days)
- MRI abnormal in 70%, US abnormal in 75%

2 weeks
- MRI abnormal in 59%, US abnormal in 51%

6 weeks
- MRI abnormal in 35%, US abnormal in 22%

Return to Play

- **Connell et al AJR 2004**
- Larger area of abnormality on MRI in all groups
- MRI findings persist longer than US
- All but 1 player had returned to play at 6 weeks

Return to Play

- Connell et al AJR 2004
  - Moderate Grade injury time course
Return to Play

- Connell et al AJR 2004
  - Best predictor = length
    - $P<0.001$
  - Others with predictive value ($p<0.05$)
    - Biceps injury
    - Cross sectional area

- US and MRI with similar results

Return to Play

• Connell et al AJR 2004
  – Intramuscular myotendinous junction
    • 62% on MRI, 52% on US
  – Epimysial
    • 37% MR, 31% US
  – No significant difference in return to play between myotendinous or epimysial injury (25.9 days vs. 27.1 days)

Disruption central tendon of biceps femoris
Return to Play

• Connell et al AJR 2004
  – Average return to play for entire group = 21 days (range 4-56 days)
    • 38% return to play before 2 weeks
    • 58% between 2 and 6 weeks
    • 4% longer than 6 weeks
  – Normal MRI average return to play = 7 days
Return to Play

• Connell et al AJR 2004

  – Potential problems

  • player's ability to return to full competition depends on many factors not assessed in this study
    – Player management within the club (importance to team, timing during season)
    – Player characteristics (pain threshold)
    – Medical history
    – Concurrent injuries

Return to Play

• Connell et al AJR 2004
  – **Potential problems**
    • some players showed larger injuries 2 weeks after their acute assessment.
      – These injuries were evident on both MRI and US, possibly due to insufficient rehabilitation and premature return to training
    • Grade 3 tears requiring surgical intervention not included

Return to Play


MRI observations at return to play of clinically recovered hamstring injuries

Gustaaf Reurink,1,2 Gert Jan Goudswaard,2 Johannes L Tol,2 Emad Almusa,3 Maarten H Moen,4 Adam Weir,2 Jan A N Verhaar,1 Bruce Hamilton,5 Mario Maas6

- Evaluated 53 athletes with hamstring injuries
- MRI #1 within 5 days of injury
- MRI #2 within 3 days of return to play (RTP)
  - RTP based on clinical assessment (asymptomatic full ROM, strength, etc)
Return to Play

  - Return to play based on MRI findings

<table>
<thead>
<tr>
<th>Dutch cohort</th>
<th>Qatar cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclusion criteria</td>
<td>Inclusion criteria</td>
</tr>
<tr>
<td>Age 18–50 years</td>
<td>Age 18–50 years</td>
</tr>
<tr>
<td>Clinical diagnosis of acute</td>
<td>Acute onset of posterior thigh pain</td>
</tr>
<tr>
<td>hamstring injury</td>
<td>Presenting and MRI within 5 days from injury</td>
</tr>
<tr>
<td>Presenting and MRI within 5</td>
<td>MRI confirmed grades I or II hamstring lesion</td>
</tr>
<tr>
<td>days from injury</td>
<td>Second MRI available within 3 days of RTP</td>
</tr>
<tr>
<td>MRI confirmed grades I or II</td>
<td>Gender: male</td>
</tr>
<tr>
<td>hamstring lesion</td>
<td>Available to perform five sessions physiotherapy a week at the clinic</td>
</tr>
<tr>
<td>Second MRI available within</td>
<td>Available for follow-up</td>
</tr>
<tr>
<td>3 days of RTP</td>
<td></td>
</tr>
</tbody>
</table>

| Exclusion criteria            | Exclusion criteria                                                          |
| Contraindication to MRI       | Contraindication to MRI                                                     |
| Chronic hamstring injury      | Reinjury or chronic hamstring injury                                         |
| Chronic low back pain         | Concurrent other injuries inhibiting rehabilitation                         |
| Cause of injury is an         | Unwilling to comply with follow-up                                          |
| extrinsic trauma              |                                                                             |
| Not capable of performing     | Needle phobia                                                               |
| rehabilitation                 | Overlying skin infection                                                    |
| No intention to return to     | Diabetes, immunocompromised state                                           |
| full sports activity          | Medication increasing bleeding risk (eg, Plavix)                            |
| Unwilling to receive the      |                                                                              |
| intramuscular injections       |                                                                              |
| Injection therapy received    |                                                                              |
| for this injury before        |                                                                              |
| RTP, return to play.          |                                                                              |
Return to Play


  - Assessed
    - Muscle injured
    - Muscle grade
      - 27 Grade 1 (51%)
      - 26 Grade 2 (49%)
    - Extent muscle signal abnormality
    - Re-injury within 2 months RTP
Return to Play

  - Average time to 1\textsuperscript{st} MRI 2 days after injury (1-5 range)
  - Average time to 2\textsuperscript{nd} MRI 2 days after RTP (range 3 days before to 3 days after)
  - Average return to play 28 days (14-76 range)
Return to Play

  - Intramuscular high T2 signal present in 89% of athletes at RTP MRI

![Initial MRI](image1.png)
![RTP MRI](image2.png)
Return to Play

  - Intramuscular low signal (scar) present in 42% of athletes at RTP MRI (present on initial MRI in 4)
Return to Play

  - What does decreased T1 signal represent?
    - Likely scar
    - No path correlation
  - What does increased T2 signal represent?
    - Unclear
    - Does not seem to fit with temporal course of inflammation and edema
Return to Play

• Reurink et al Br J Sports Med 2014
  – 5 re-injuries within 2 months (9%)
  – 4 had increased T2 signal on RTP MRI (80%)
  – 4 had decreased T1 signal on RTP MRI (80%)
  – Insufficient power to make any conclusions
Return to Play

• Reurink et al Br J Sports Med 2014
  – Problems
    • Part of study evaluating PRP vs control (saline)
    • Unlikely to affect MRI in authors opinion
    • 2 cohorts without the same RTP criteria
    • 2 cohorts slightly different MR protocols
  – Conclusions
    • Normalization T2 signal not required for RTP, and of unlikely prognostic value
    • Low signal on T1 might be relevant for assessing future injury risk, but uncertain clinical relevance
Return to Play

– Other Studies:

  • **Pomeranz et al**: 14 athletes with hamstring injuries
    – Prolonged return to play with >50% cross sectional area involvement, intramuscular hemorrhage, distal MTJ tears, ganglion fluid collections in muscle

  • **Slavotinek et al**: 37 athletes with hamstring injuries
    – Linear relationship with cross sectional area and return to play
    – No correlation with location in muscle

  • **Verral et al**: 83 athletes with hamstring injuries
    – Normal MRI good predictor of early return
    – Normal MRI = 16 day average
    – Abnormal MRI = 27 day average
Return to Play

  - Comprehensive lit search 1950-2011
  - 140 European Society of Sports Traumatology, Knee Surgery (ESSKA) members survey response

Diagnosis and prognosis of acute hamstring injuries in athletes

Gino M. M. J. Kerkhoffs · Nick van Es · Thijs Wieltraaijer · Inger N. Sierevelt · Jan Ekstrand · C. Niek van Dijk
Return to Play

  -- Clinical

<table>
<thead>
<tr>
<th>Test</th>
<th>Important (%)</th>
<th>Not important (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpation to identify the site of injury</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Palpation to identify the injured muscle(s)</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Knee flexion against resistance</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td>Inspection of the posterior thigh</td>
<td>93</td>
<td>7</td>
</tr>
<tr>
<td>Posture and gait inspection</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>Hip extension against resistance</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>Assessing referred pain</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>Active straight leg raise</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>Sit-and-reach test</td>
<td>83</td>
<td>17</td>
</tr>
<tr>
<td>Passive knee extension</td>
<td>81</td>
<td>19</td>
</tr>
<tr>
<td>Active knee extension</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Passive straight leg raise</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>Take-off-the-shoe test/hamstring-drag test</td>
<td>79</td>
<td>21</td>
</tr>
<tr>
<td>Prognostic laboratory tests</td>
<td>13</td>
<td>87</td>
</tr>
<tr>
<td>Diagnostic laboratory tests</td>
<td>4</td>
<td>96</td>
</tr>
</tbody>
</table>
Return to Play

• Kerkhoffs et al. Knee Surg Sports Traum Arthros 2013
  – Imaging
    • Consensus within 3 days for initial imaging
    • MRI more sensitive than US
    • No generalizable follow-up guidelines
      – 66% used if poor rehab
      – 61% used to assess rehab progression
      – 91% overall used some sort of imaging follow-up
## Return to Play


<table>
<thead>
<tr>
<th>Factors associated with a longer rehabilitation period</th>
<th>Literature</th>
<th>Expert opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete rupture or avulsion fracture [12, 31, 48, 62]</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Greater length of muscle tear on MR images or larger cross-sectional area of muscle tear on ultrasound images [13, 24, 50, 54]</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>MRI-positive hamstring injury [13, 24, 57]</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Recurrent hamstring injury [10, 17, 18, 35, 39]</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Persisting pain restriction at ROM tests, strength tests and sport exercises</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Injury resulting from excessive slow-speed stretching [4]</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Persisting signs of injury on follow-up imaging [5]</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Injury to the m. biceps femoris [13]</td>
<td>±</td>
<td>+</td>
</tr>
<tr>
<td>Sports type [5]</td>
<td>±</td>
<td>+</td>
</tr>
<tr>
<td>More cranially palpated injury [5]</td>
<td>±</td>
<td>+</td>
</tr>
<tr>
<td>Large and deep haematoma</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Hamstring injury involving the free proximal tendon [6]</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Higher subjective pain score at the time of injury on a Visual Analogue Scale (VAS) [57]</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Being unable to walk pain-free within 24 h of injury [61]</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Long period until initial treatment</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Low quality of the rehabilitation programme and minimal willingness of the patient to rehabilitate</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
Return to Play

Muscle Injury Complications

• **Myositis Ossificans**
  
  – Usually associated with blunt trauma and hematoma
  
  • 1: acute or pseudoinflammatory phase
  • 2: subacute or pseudotumoral phase
  • 3: chronic healing phase

Muscle Injury Complications

- **Myositis Ossificans**
  - Stage 1 and 2 with nonspecific inflammation on MR and US
  - Stage 3 with osteoid matrix
  - Peripheral calcification by 6 weeks on CT and plain film
  - Ossification by 6 months

Muscle Injury Complications

14 athletes with grade 1/2 injury 5-23 months previously

11 of 14 with increase in low signal at myotendinous junction (scar)
Muscle Injury Complications

– **Scar tissue**
  - Alters in vivo contraction mechanics
  - Less well organized and increased stiffness
  - Require functioning myotendinous fibers to lengthen more than previously
Muscle Injury Complications

- 13 of 14 with decrease in biceps femoris long head volume (often with increase in short head volume)

---

Fig. 3. Moderate to substantial atrophy of the previously injured biceps femoris long head (BFLH) was present with corresponding hypertrophy of the biceps femoris short head (BFSH) in seven of the 13 subjects with biceps femoris injuries. Four of the remaining six subjects presented with either BFLH hypertrophy (2 subjects) or BFSH atrophy (2 subjects). Shown here, atrophy of the right BFLH along with hypertrophy of the right BFSH.
Muscle Injury Complications

- 2 of 14 with fatty atrophy

Fig. 5. Fatty infiltration was observed within the long and short heads of the biceps femoris. The white arrow denotes the previously injured BFLH, while the black arrow designates the BFLH on the un-injured limb.
Conclusion

• Muscle injury common in elite athletes, particularly hamstring
• Two major mechanisms are direct trauma (contusion) and eccentric contraction
• Many variations of “1-2-3” grading schemes, still requiring validation of utility
• Return to play currently based mostly on clinical factors, as imaging resolution appears to lag behind clinical improvement
• Imaging has a role as adjunct to clinical assessment for prognosis and return to play
• Complications of muscle injury include scar formation, muscle atrophy, myositis ossificans, and increased risk of re-injury
References


• De Smet AA, Best TM. MR imaging of the distribution and location of acute hamstring injuries in athletes. AJR Am J Roentgenol 2000;174:393–9


References


References


