Mechanisms of hamstring injury. Implications for return to sport

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Epidemiology of Hamstring Injury – Which hamstring muscle

Most papers show predominant hamstring injury is in the biceps muscle

- Askling 2008 Sprinters 18 – Biceps 100%
- Connell 2004 ARF 42 – Biceps 85%, primary 72%
- Verrall 2003 ARF 68 – Biceps 81%, primary 72%
- Slavotinek 2002 ARF 37 – Biceps 87%, primary 70%
Epidemiology of Hamstring Injury – Which hamstring muscle

Biceps femoris is most common muscle injured in sports requiring interval sprinting

Why?
Theories of hamstring injury – why biceps

• Cross 2 joints
• More type 2 fibres in muscle structure
• More recently pennation and angle of insertion of fibres
Epidemiology of Hamstring Injury – When does injury occur

Studies vary but are consistent. They demonstrate fatigue is probably a factor in the injury

- Sprinters – late in race
- Verrall 2003 ARF predominately in 3rd quarter. Few in first quarter
- Brooks 2006 Rugby – Late in both halves
- Woods 2004 Soccer – late in both halves
Fatigue

A fatigued muscle can absorb less energy than a non-fatigued muscle. Able to do less work.

Mair et al 1996

Energy absorption is a very important role of hamstrings especially in their eccentric contraction (slowing the femur) mode.
Hamspring

- Muscle contraction is much like the oscillation of a simple spring
- We therefore built our model of the hamstrings using a spring mass system
**Hamstring Muscles: Architecture and Innervation (Woodley & Mercer, 2005)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal attachment (cm)</th>
<th>Length (cm)</th>
<th>Distal attachment (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>11.1</td>
<td>25.9</td>
<td>6.8</td>
</tr>
<tr>
<td>ST</td>
<td>1.2</td>
<td>31.5</td>
<td>11.1</td>
</tr>
<tr>
<td>BF</td>
<td>6.5</td>
<td>28.1</td>
<td>9.2</td>
</tr>
</tbody>
</table>
Hamstring Muscle Kinematics During Treadmill Sprinting (Thelen et. al. 2005)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Stretch Percentage</th>
<th>Change in Length (calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>7.4 %</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>ST</td>
<td>8.1 %</td>
<td>3.2 cm</td>
</tr>
<tr>
<td>BF</td>
<td>9.5 %</td>
<td>4.2 cm</td>
</tr>
</tbody>
</table>
Spring Constants = Stiffness of muscles

- Use force ratio, and calculate spring constants

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Spring Constant (Nm$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>423.3</td>
</tr>
<tr>
<td>ST</td>
<td>422.5</td>
</tr>
<tr>
<td>BF</td>
<td>422.1</td>
</tr>
</tbody>
</table>

SemiM is the stiffest spring (muscle)
The three muscles

SemiM: Concrete
SemiT: Fibreglass
Biceps: Soft rubber
Semimembranosus
Semitendinosus
Biceps Femoris

Answer to Question Why biceps

- Biceps more movement (displacement) during sprinting
- Hooke’s law states that Force is proportional to displacement from natural length
Conclusion

• In eccentric exercise the Biceps Femoris is most likely to injure as it is constantly exerting more force to contract in phase with the other hamstring muscles.

• Hence it performs more work than the other 2 hamstring muscles AND is therefore more prone to muscle fatigue.

• Maybe short head evolved to assist in force production.
Basic Concepts of the Mechanism of Hamstring Muscle Injuries
BASIC THEORY

Increase in biomechanical load that exceeds the tolerance of hamstring muscle.

- Increase load
- Decrease tolerance
INCREASE LOAD

• Forcible stretch (waterskiing)
• Forced flexion (rugby)
• Overhead kicking (dancing, soccer)
• Acceleration
• Change of position of pelvis
DECREASE TOLERANCE

- Fatigue
- Risk factors
- How do these factors reduce load tolerance of the muscle is not entirely clear (Some of those theories in training adaptation lecture)
Forced/stretch-fatigue/shear model of hamstring muscle injury
Epidemiology of Hamstring Injury – Waterskiing

• Adelaide is near the Murray river – waterskiing popular
• Some of the earliest radiological papers are from areas associated with river systems – the hamstring injuries they described were severe and involved in many cases the semiM muscle
• Waterskiing is a very forced stretch (fast stretch injuries) INCREASE IN LOAD
Semimembranosus injuries

Dancers demonstrate a predilection to semimembranosus hamstring injuries (Askling AMJSPM ED 2008). Slow-stretch injuries increase in load.
Stiffness

Calculating spring constants

Dolman and Verrall:

STIFFNESS SemiM > SemiT > Biceps

FORCED STRETCH/FLEXION – Waterski, Ballet, World football (overhead kick)

FORCED FLEXION Australian football, American football rugby

INCREASE IN LOAD
Resting Length

Forced stretch
Resting Length

Forced stretch
Forced stretch

May involve one two or three muscles.

Muscle injures at the point of least resistance – In this case the muscle is unprotected (will discuss in a moment) so not necessarily will the injury be entirely contained to the musculotenditous junction.

Bleeding present

Calf injuries similar
Injury Association

Observational
Video analysis of 12 running/sprinting hamstring injuries

Trunk Flexion (video)

• Increase Load/Tension

• Increasing Speed/Acceleration

• (INCREASE IN BIOMECHANICAL LOAD)
Fatigue/Shear model

The following conditions are necessary:

• Muscle fatigue (more common in biceps).

DECREASE IN MUSCLE LOAD TOLERANCE

• Increased force (more energy to be absorbed) e.g. acceleration, bending forward, maintaining speed

INCREASE IN BIOMECHANICAL LOAD
MRI: Where is injury

Location of Injury

- M/T junction only
- M/T junction and belly
- M/T junction and belly and extending outside muscle
MRI: Where is injury

Number of muscles Injured

One
Greater than one
Injury model for biceps

FACTORS THAT NEED TO BE ACCOUNTED FOR

• Fatigue and its actions on a muscle

• Musculotendinous junction (Injury should occur at the point of least resistance. It does not seem logical that this area through evolution would be the weakest point. Specialized cells. Increased sarcolemma)

• No bleeding (except in big “office” injuries). (Overlap)

• More than one muscle injured in many injuries.

• Athletes often describe a cramp – especially the minor injuries
Fatigue/Shear model

Eccentric action of muscles

Develop force as the fibres are lengthened

More force (work done is the area under curve of a force/length model) when compared to concentric contractions

Complex biochemical and mechanical changes at the contracting myofilaments
Fatigue/Shear model

Failure of muscle cross bridging

Influx of Ca2+

Relative tetanus of the part of the muscle affected (athlete “cramps”)

Rest of muscle continues to stretch

Shearing injury at point of subsequent least resistance
Fatigue/Shear Model

Shear injury

Muscle belly protection from tetanus (no blood vessels damaged)

Affects the musculotendinous junction

INJURY
Muscle contracts 3 times, injury invokes, blue box appears

- Click mouse/press down to zoom in on injury
- Click mouse/press down for slightly slower version
Biceps femoris injuries

Most prone to fatigue as it does more work (work is proportional to displacement and the biceps stretches (displaces) more to sustain unitary action) in the eccentric action of slowing the femur.
Displacement

Time

In phase

Not in phase

SM

ST

BF
Eccentric phase

The predominant work is done (energy absorption) in the swing phase of the gait cycle.

Most work is done in early phase of swing

I think failure can occur anywhere along the swing (eccentric pathway)

The earlier the failure occurs in the swing the less contribution the biceps has made – still got to slow down femur –
What is going to stop the runaway train now

Semi T
Semi M

A secondary muscle is injured as it cannot stop the freight train easily. The most likely muscle injured would be the one that has a similar function to the biceps. i.e. SemiT.

Not got protection as not cramped – occasional small bleeding even in fatigue/shear injuries.
Footstrike

However at foot strike Newtons 3rd law states that for each reaction there is an equal and opposite reaction.

Upon footstrike the biceps is tetanused/cramped and it should be shortening concentric contraction.

More mass therefore more force therefore more shear therefore more injury.

If you could avoid footstrike I expect many of these injuries would be significantly less in size.
Confused

Quote
“A stitch in time would have confused Einstein”
Unknown
Does any of this matter?

Injury prevention
Understanding mechanism should help
Useful for treatment and return to sport and prevention of recurrent injury.
Guiding athlete to return to sport:

Is the mechanism of hamstring injury relevant?
He concluded that forced slow stretch injuries were (compared to sprinter fatigue/shear biceps injuries):

- Smaller (as measured by the MRI)
- Had a longer convalescent interval
- Had a worse long term prognosis
Prognosis and Mechanism

My data suggests with respect to mechanism that the worse prognosis for interval sprinter athletes is from

- Fatigue/shear injuries. (Longer convalescent interval, Higher recurrence rate).
- Force/Stretch injuries are better for sprinting athletes as they generally do not need to repeat the circumstances that gave them the injury in the first place.
Semimembranosus Injuries

In running athletes – much better prognosis
Often appear larger on MRI imaging techniques – stretch – blood products, fibre damage
For all size injuries they had a 9 day better outcome.
Mean days lost biceps 30, semimembranosus 21
For size >50% of affected area they had a 12 day better outcome
Semimembranous Injuries

Recurrence rate was less. We do have images where an athlete has had a semiM injury and then in the same season recurrence have a Biceps injury.

HOWEVER
Semimembranosus Injuries

Early return to functional activity maybe warranted in the right circumstances.

My current practice is that once there soreness abates they should do some functional eccentric exercises and if they are not painful should return to some running immediately with an accelerated functionally graded rehabilitation program.
Guiding athlete to return to sport:

Is the mechanism of hamstring injury relevant?

ACL injuries: Contact and Non contact

Ankle injuries: Non rotation mechanisms give unusual ankle findings and unpredictable RTS
Soccer Mens

Olympics 1996 Atlanta

Australia 2 – Spain 3
Womens Basketball

World Championships 2006 Brazil

Australia 72 – Spain 68
Mens Hockey

World Cup 2010

Australia 2 – Spain 0
Webber 202
Alonso 191
Mens Basketball

Summer Olympics Sydney 2000

Australia 91 – Spain 80
Womens Hockey
Summer Olympics 2008
Australia 6 – Spain 1
Tennis

Davis Cup final 2003

Australia 3 – Spain 1
Thank you!

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