Long-term Morphological and Functional Changes Following an Acute Hamstring Injury

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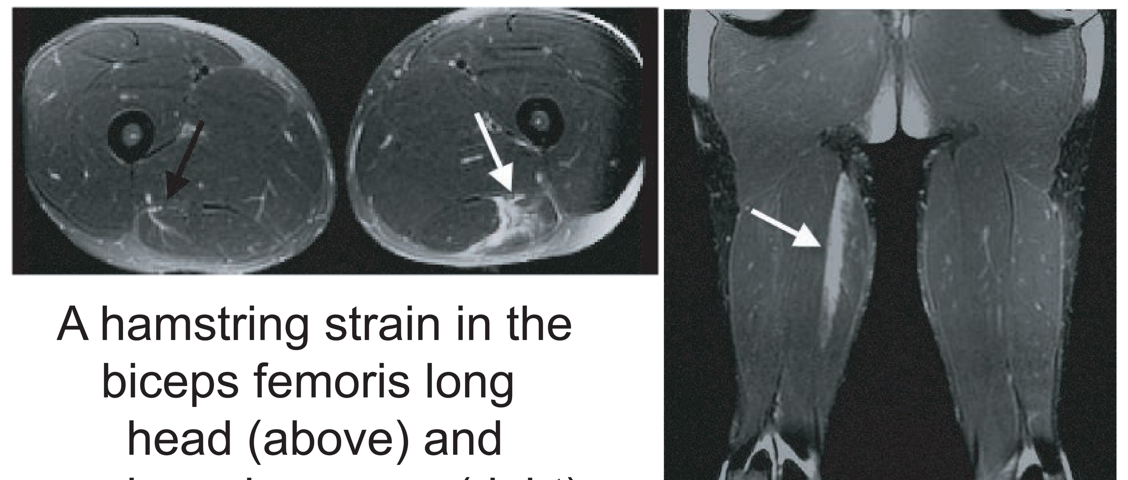
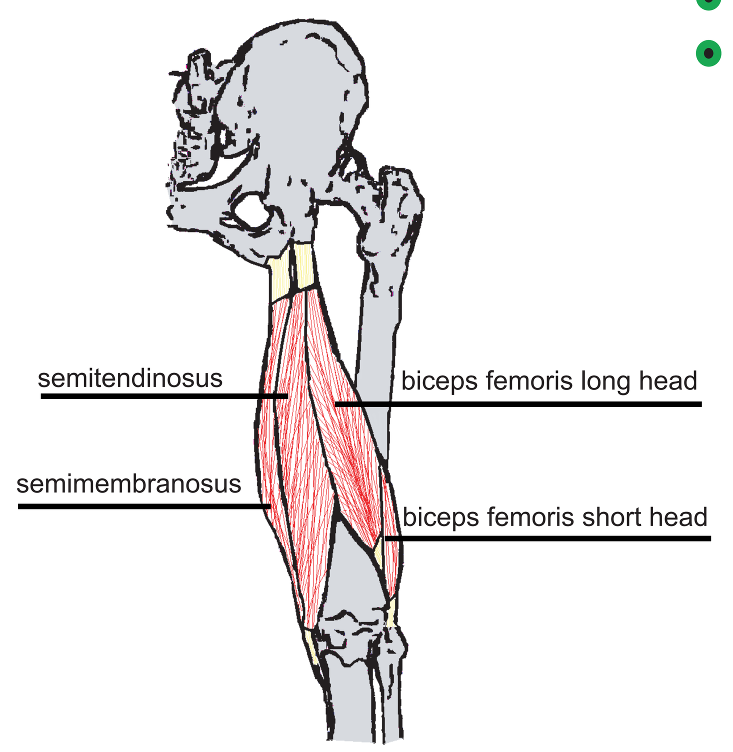
Hamstring strains are common during high speed running (e.g. track, baseball, softball, soccer).

MRI has can be used to assess the severity of initial injury[1].



A hamstring strain in the biceps femoris long head (above) and semimembranosus (right).



most commonly injured[1,2,3].

~30% of all individuals will incur a re-injury[2].
Subsequent injuries are often more severe than the initial injury[2].

Objective

Characterize long-term changes in hamstring morphology and biomechanical function following a hamstring strain injury

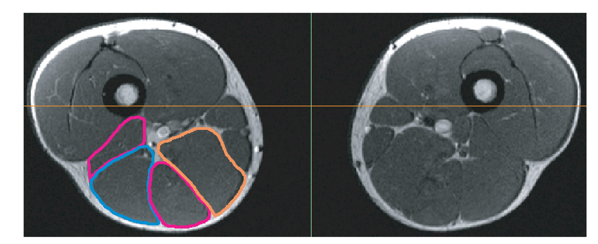
All subjects experienced a grade I or II hamstring strain injury between 5-13 months prior

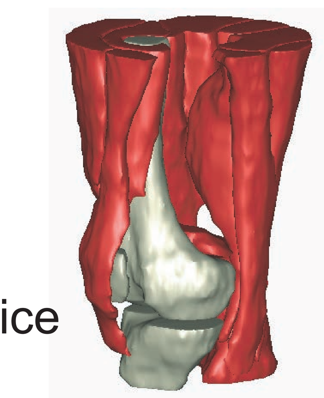
Abbreviations: biceps femoris (BF), semitendinosus (ST)

Subject	Gender	Age	Months from Injury	Side of Injury	Location of Injury	Number of Injuries	Activity at Time of Injury
1	Male	18	5	Right	Proximal BF	1	Soccer
2	Female	43	9	Right	Proximal BF	2	Softball
3	Male	31	5	Left	Proximal BF	2	Running
4	Male	19	13	Left (both)	Proximal BF (both)	2	Running
5	Female	19	7	Left (both)	Proximal BF (both)	2	Running
6	Male	18	8	Right (all)	Proximal BF (all)	3	Running
7	Female	45	6	Right	Distal BF	1	Running
8	Male	20	7	Right	Distal BF	1	Running
9	Female	17	5	Right (both)	Distal BF (both)	2	Running
10	Male	38	5	Left (recent) Right (prior)	Distal ST (recent) Proximal BF (prior)	2	Soccer
11	Male	23	5	Right (recent) Right (prior)	Distal BF (recent) Proximal BF (prior)	2	Running

Magnetic Resonance Imaging

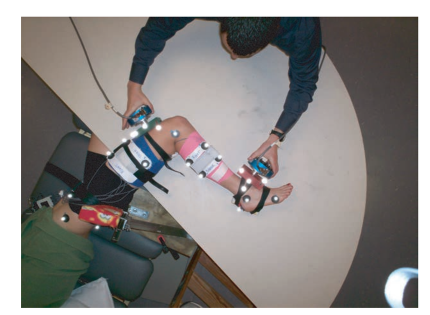
- T2-weighted coronal images were used to assess residual edema.
- T1-weighted or IDEAL reconstructed images were used to:
  1. assess the presence of fatty infiltration
  2. quantify hamstring tendon/scar and muscle volumes:
     - biceps femoris long head (BFLH), biceps femoris short head (BFSH)
     - proximal conjoint biceps femoris and semitendinosus tendon (PBFT), proximal semimembranosus tendon (PSMT)

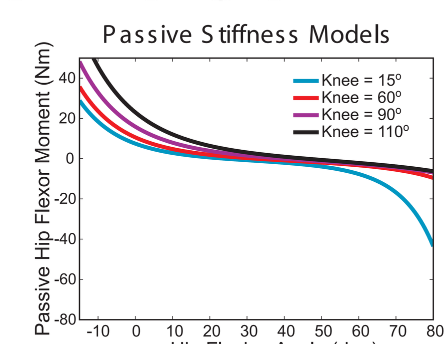




Muscles and tendons were manually outlined on each slice and used to calculate volumes.
volume = inter-slice distance x summed cross-sectional areas

Passive Joint Stiffness Testing





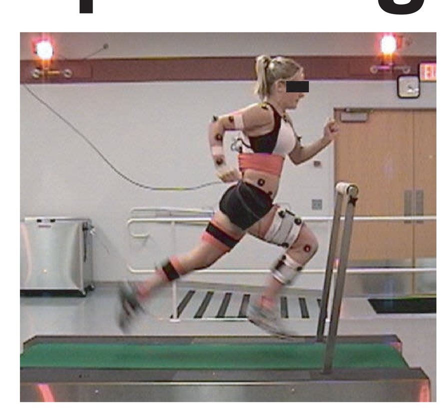
- Joint stiffness was measured and modeled for each subject[3].
- Hip and knee angles at peak BF musculotendon stretch were input into the passive stiffness models.

This resulted in the estimated peak passive hip extensor torque during running.

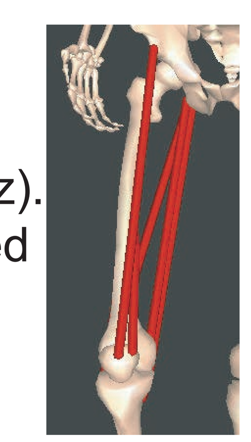
Results

We observed no consistent differences in passive stiffness between limbs.

Sprinting Kinematics



- Subjects ran at 60, 80, 90 and 100% of maximum.
- We captured 3D full body kinematics (200Hz).
- Scaled musculoskeletal models were created for each subject.
- We estimated joint angles and hamstring musculotendon lengths during sprinting.



Muscle Activities During Sprinting

- EMG signals (2000Hz) from the rectus femoris (RF), vastus lateralis (VL), medial hamstrings (MH), and biceps femoris (BF)
- Signals were band-pass filtered (50-500Hz) and full wave rectified.
- Onset, offset, duration, and magnitude of muscle activity were estimated[4].

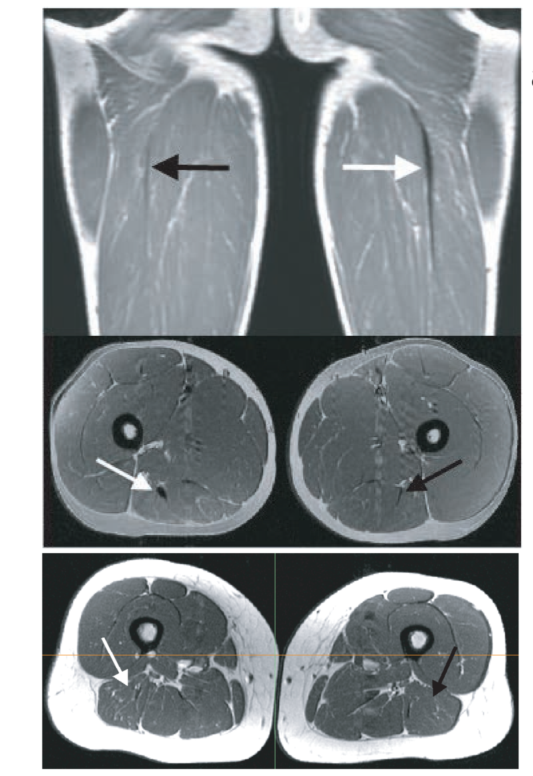
Isokinetic Strength Testing

- Bilateral knee flexion-extension at 60 deg/sec

Results

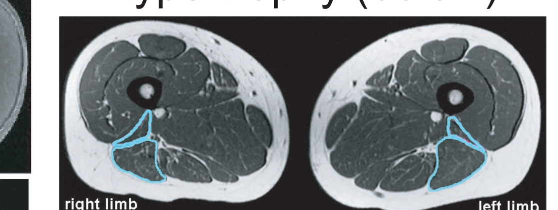
No consistent trends or significant differences:
- peak torque, angle of peak torque, hamstring/quadricep strength ratio

Magnetic Resonance Imaging Results



Scarring was present adjacent to the site of prior injury (left).

The previously injured limb had significant BFLH atrophy and BFSH hypertrophy (below).

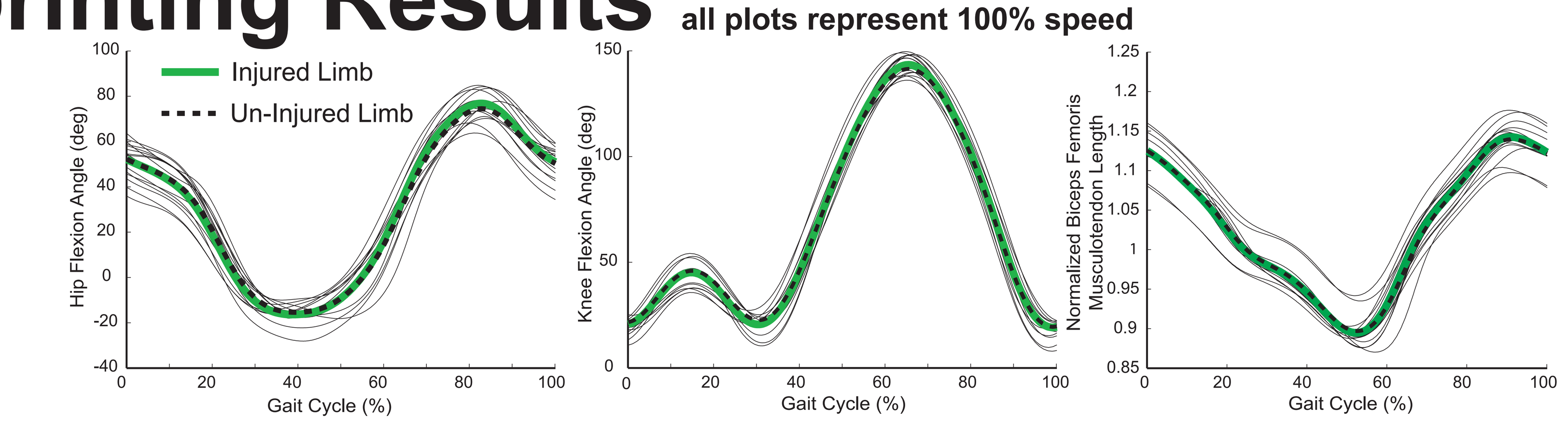


Fatty infiltration was present in two subjects with proximal biceps femoris injuries (left).

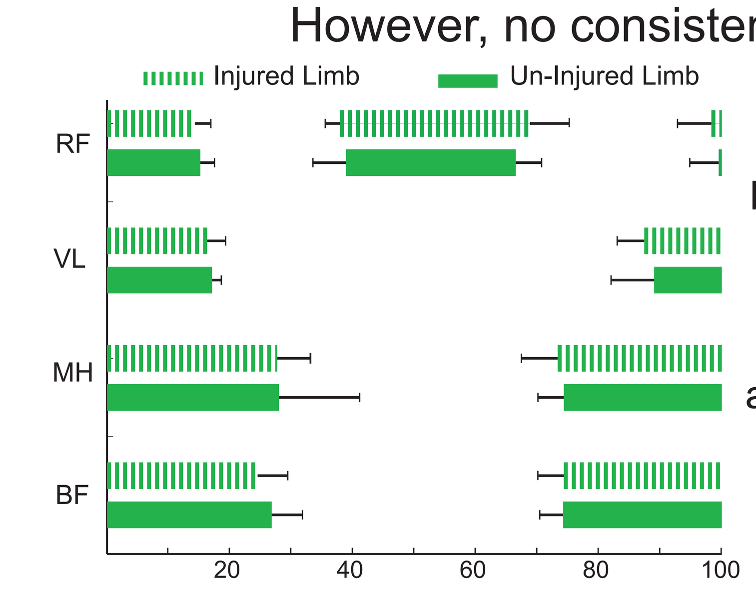
	Case	Muscle volume BFLH	Muscle volume BFSH	Tendon volume PBFT	Tendon volume PSMT
Proximal BF injury					
	1	-4	+23	+218	+8
	2	-20	+30	0	-4
	3	-23	+1	+114	-5
	4	-12	+17	+124	+12
	5	-16	+46	+105	+27
	6	+5	+16	-7	-1
	mean (SD)	-12 (11)	+22 (15)	+92 (85)	+6 (12)
	p-value	***0.02***	***0.01***	***0.02***	0.25
Distal BF injury					
	7	-26	+25	---	---
	8	-4	-3	---	---
	9	-6	+9	---	---
	mean (SD)	-12 (12)	+10 (14)	---	---
	p-value	0.16	0.27	---	---
Proximal & distal injury					
	10	+3	-21	-4	-46
	11	-1	-1	+132	+7

Sprinting Results

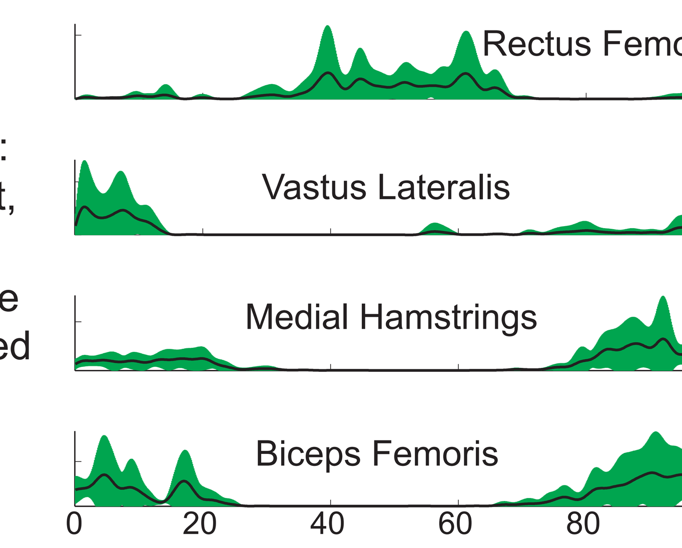
all plots represent 100% speed



Most subjects showed some degree of asymmetry between limbs during sprinting. However, no consistent or significant differences were observed.



Ensemble averaged: Muscle onset, offset, and duration (left)
Magnitude of muscle activities in the injured limb (right)



Conclusions

- Scarring along the musculotendon junction likely alters internal muscle mechanics and may contribute to re-injury risk.
- BFLH atrophy with corresponding BFSH hypertrophy may represent a compensatory process to maintain knee flexion strength following injury.
- Biomechanical measures (i.e. passive stiffness, strength, and sprinting kinematics) revealed no consistent asymmetries between limbs
  - local morphological changes may not be reflected in joint mechanics

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References

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