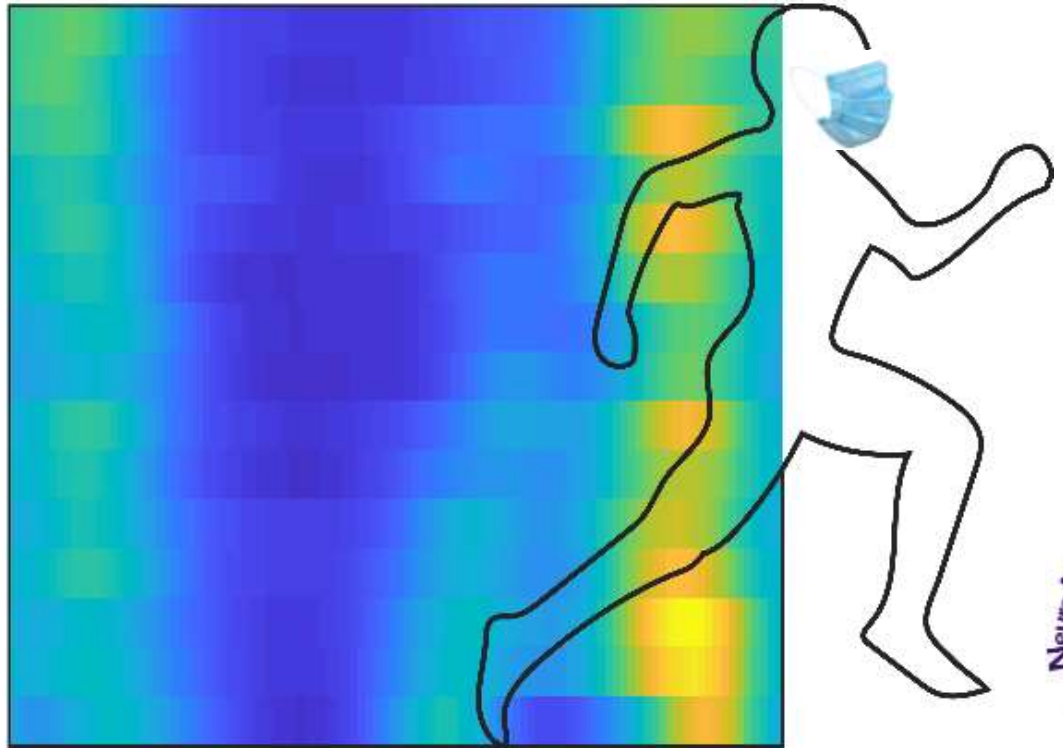
Hamstring muscle function in high-speed running and in hamstring exercises

PhD thesis and all publications are free to download using the following link:

http://urn.fi/URN:ISBN:978-951-39-8035-1



András Hegyi

Postdoctoral Researcher

University of Nantes, France

FULGUR project

Twitter: @And_Hegyi

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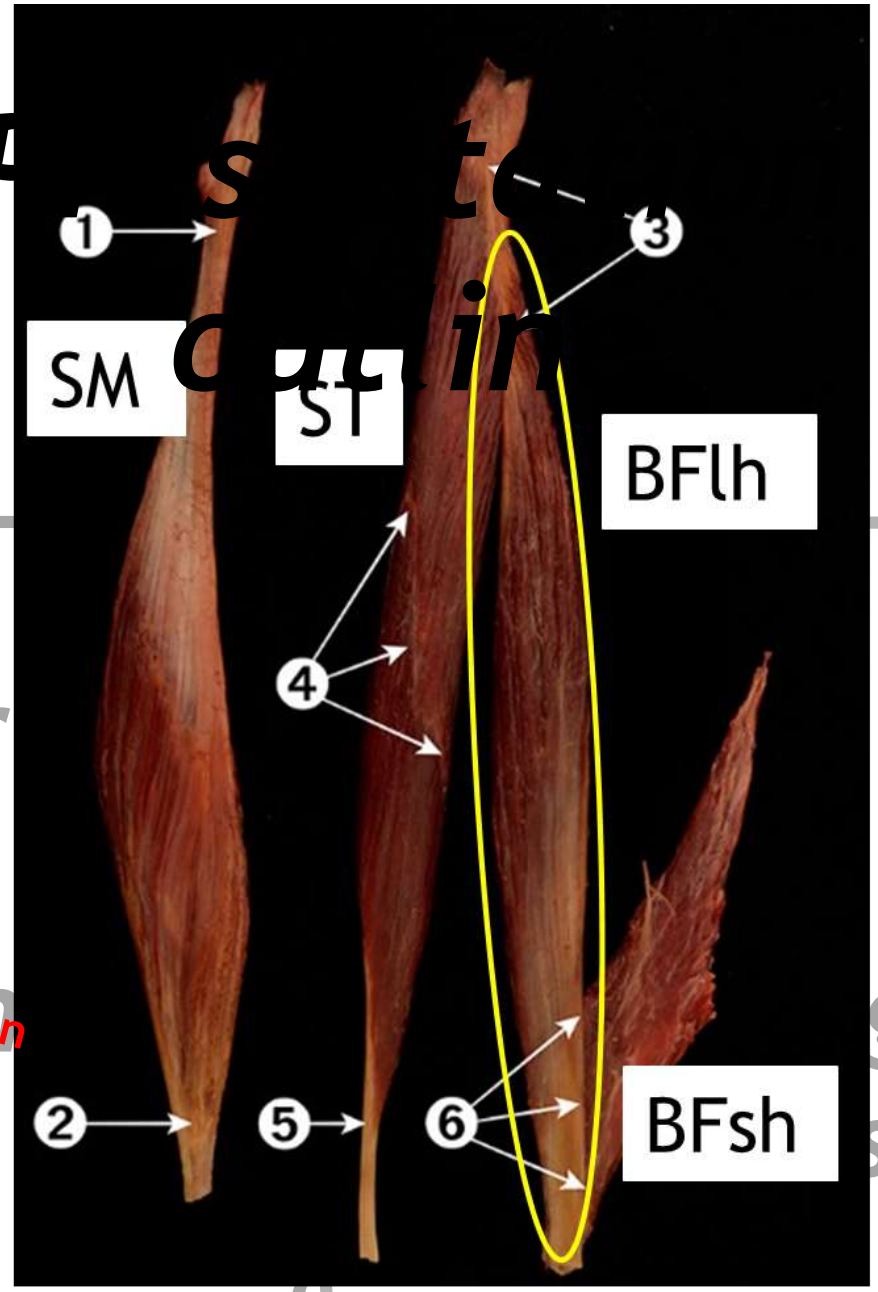
NeuroMuscular Research Center JYVÄSKYLÄ FINLAND

UNIVERSITY OF JYVÄSKYLÄ

UNIVERSITÉ DE NANTES

FULGUR

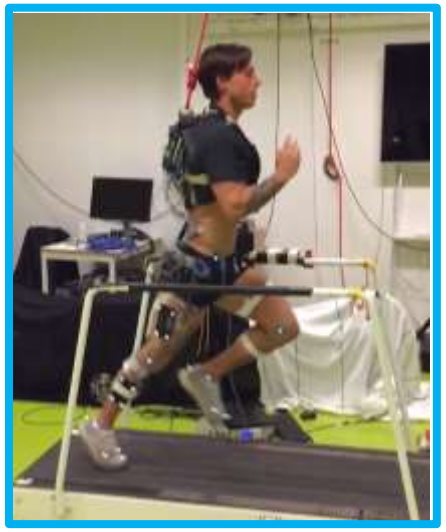


Long length

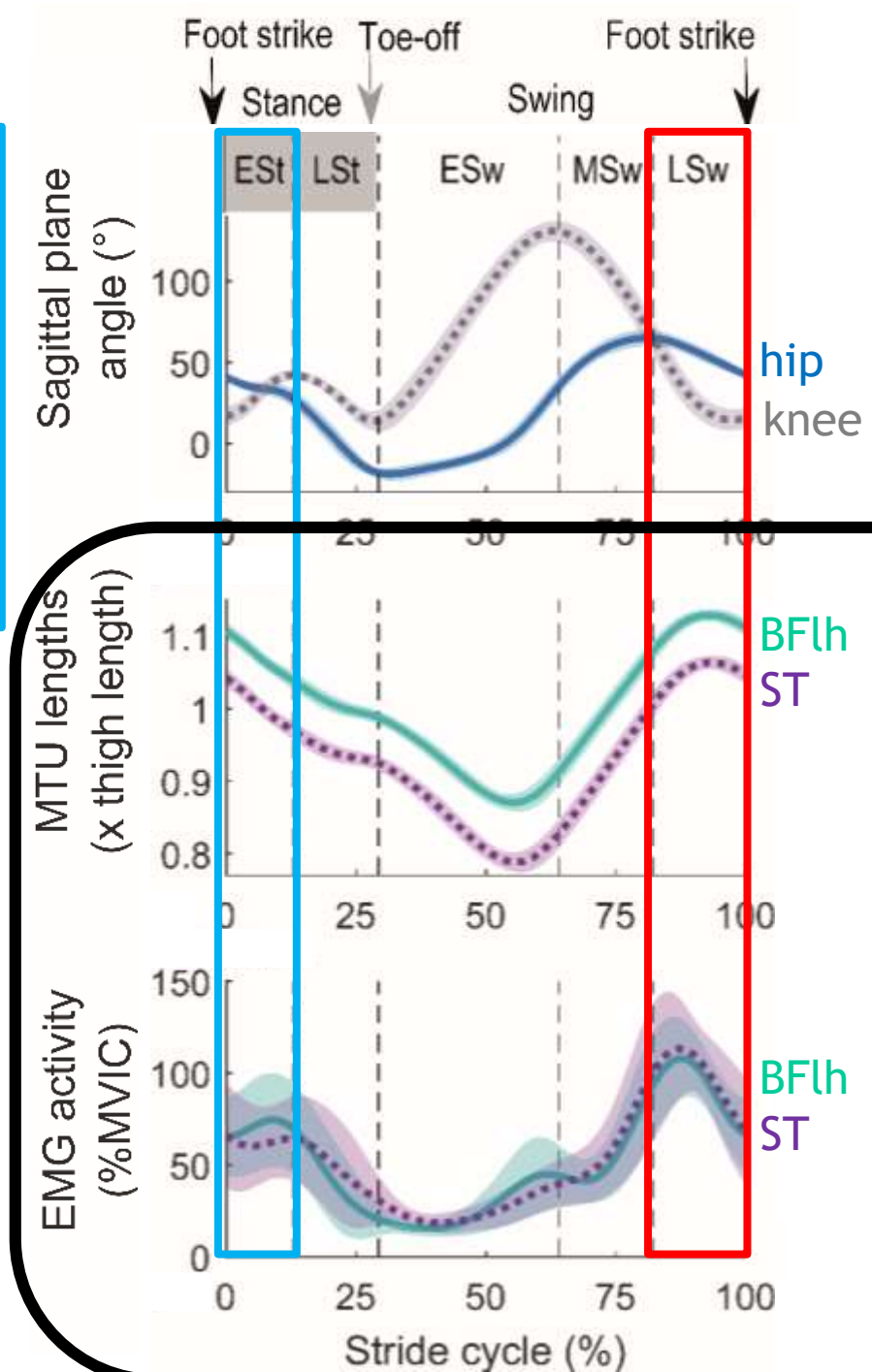
High activation

Stępień et al. 2019

Early stance



Late swing



Presentation outline

Part 1

Running

Part 2

Hamstring Exercises

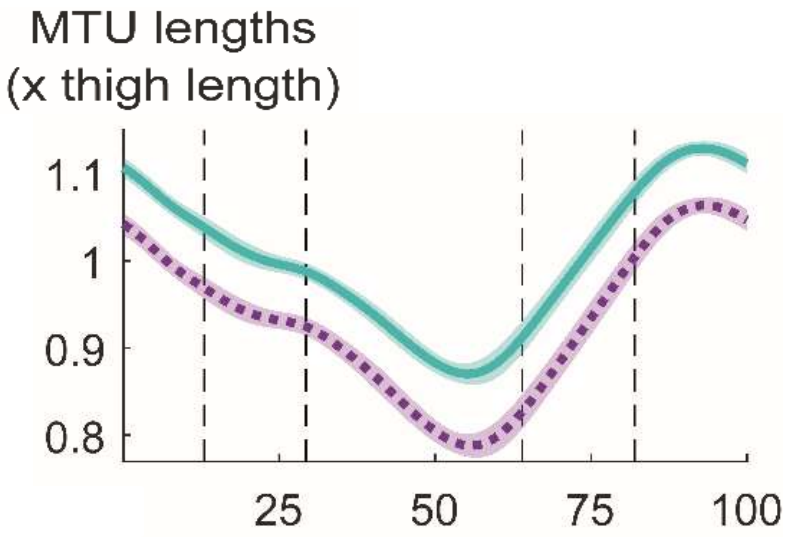
Back in 1993…

Muscle damage is not a function of muscle force but active muscle strain

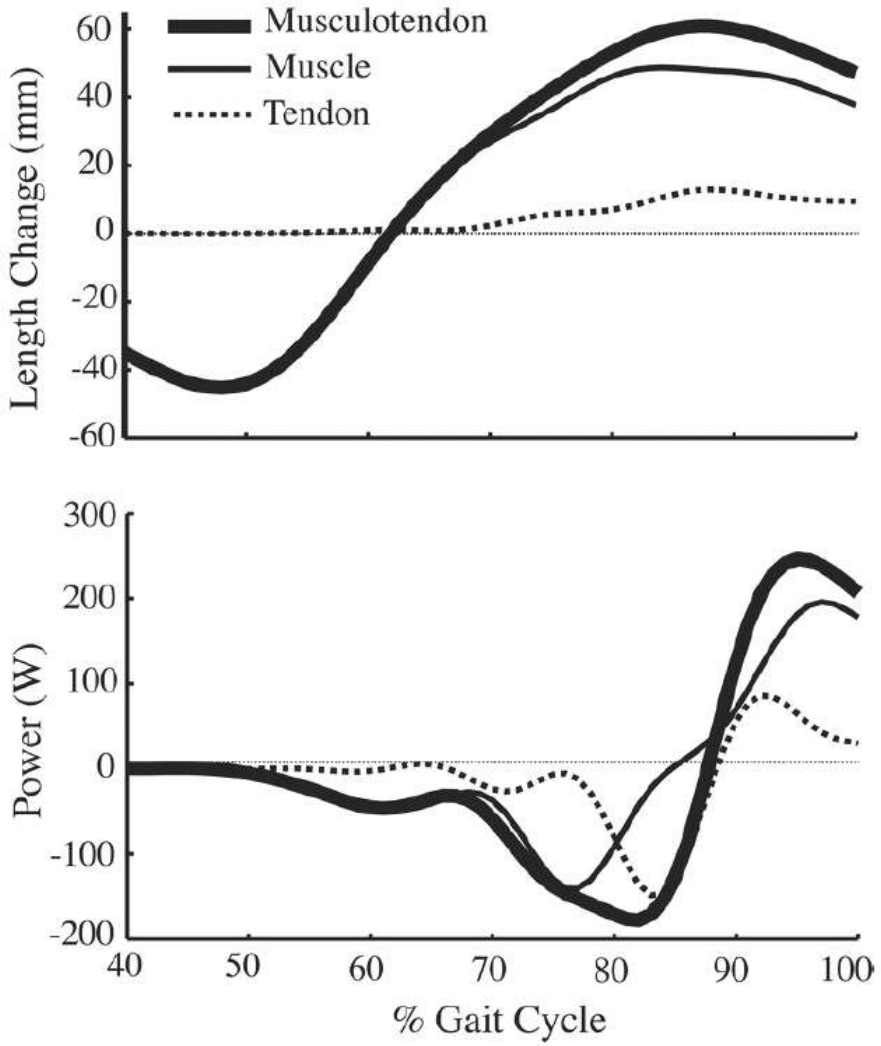
RICHARD L. LIEBER AND JAN FRIDÉN
Department of Orthopedics and Biomedical Sciences Graduate Group, University of California and Veterans Affairs Medical Centers, San Diego, California 92161; and Departments of Anatomy and Hand Surgery, University of Umeå, S901 87 Umeå, Sweden

Magnitude of muscle fibre strain is a good predictor of strain injury

Hamstrings in sprinting: only entire muscle-tendon unit funtion is known

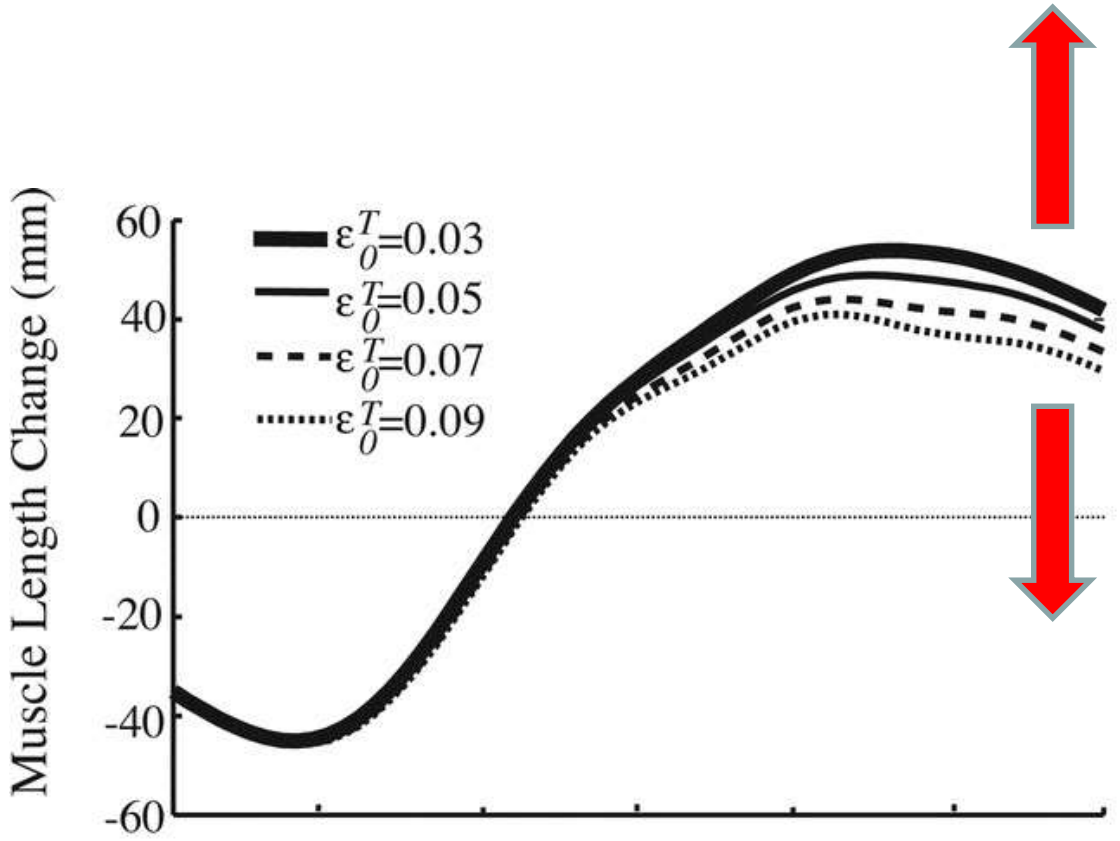


BFlh muscle-tendon decoupling in the swing



Thelen et al., 2005

Tendon stiffness affects muscle behavior

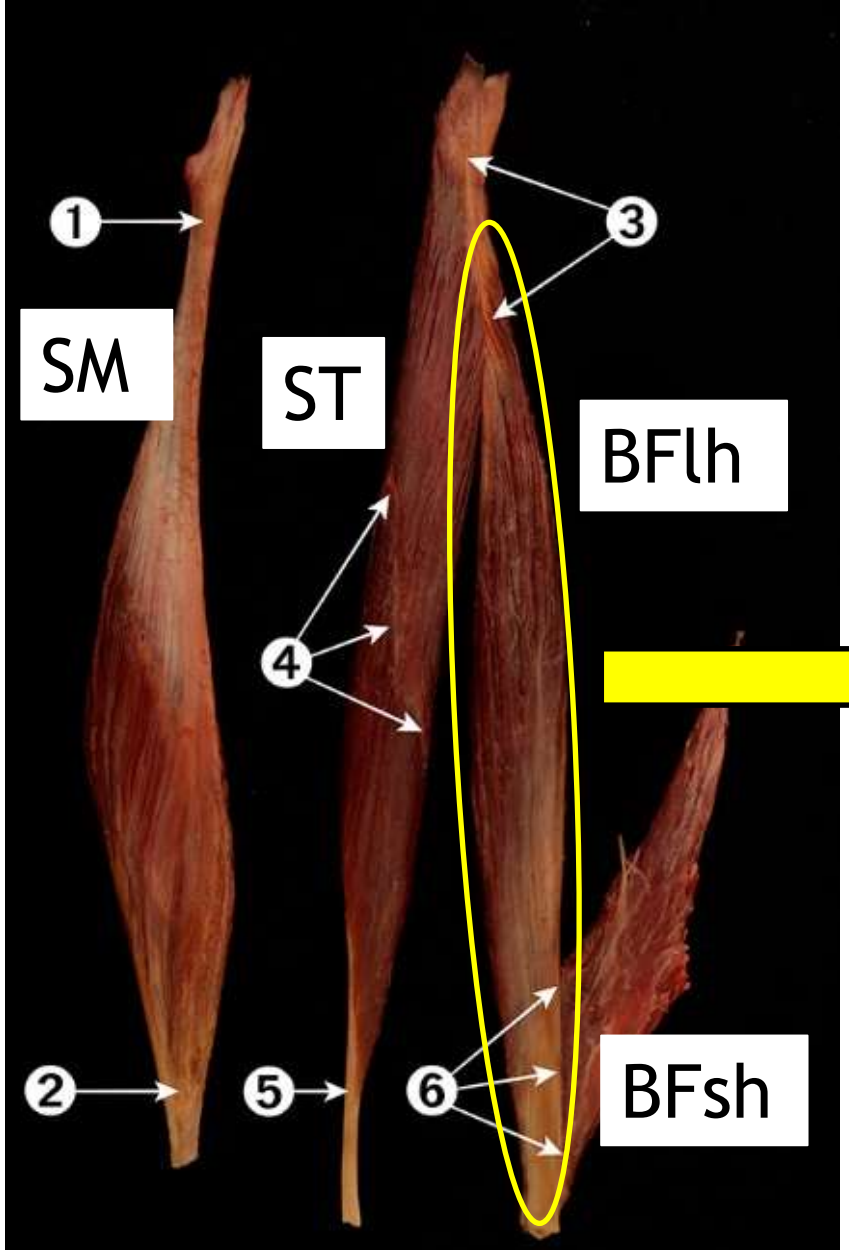


Stiff tendon

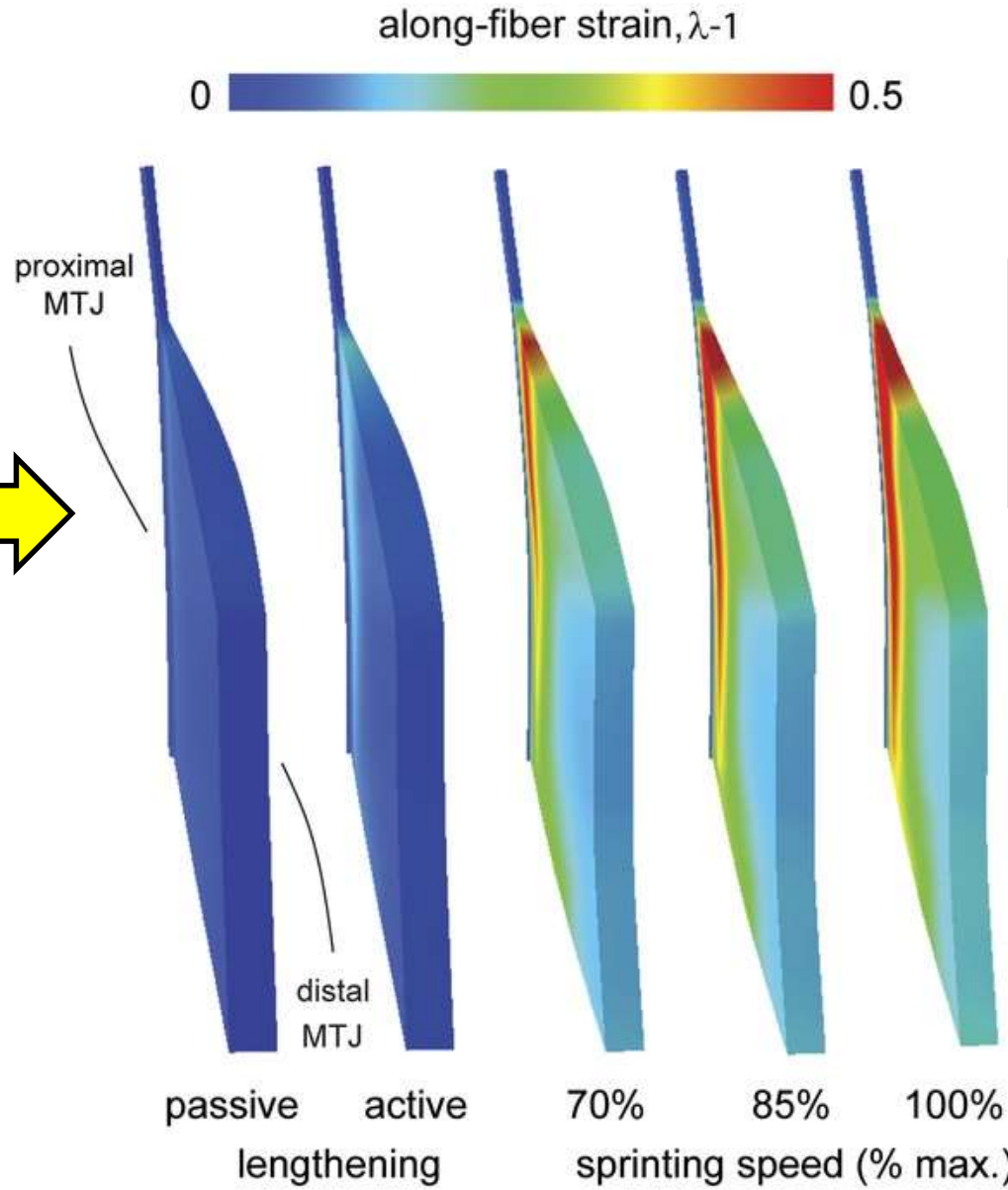
Compliant tendon

Stiff tendon → Higher strain injury risk

Heterogeneous strain distribution along BFlh



Stępień et al. 2019



Fiorentino et al. 2014

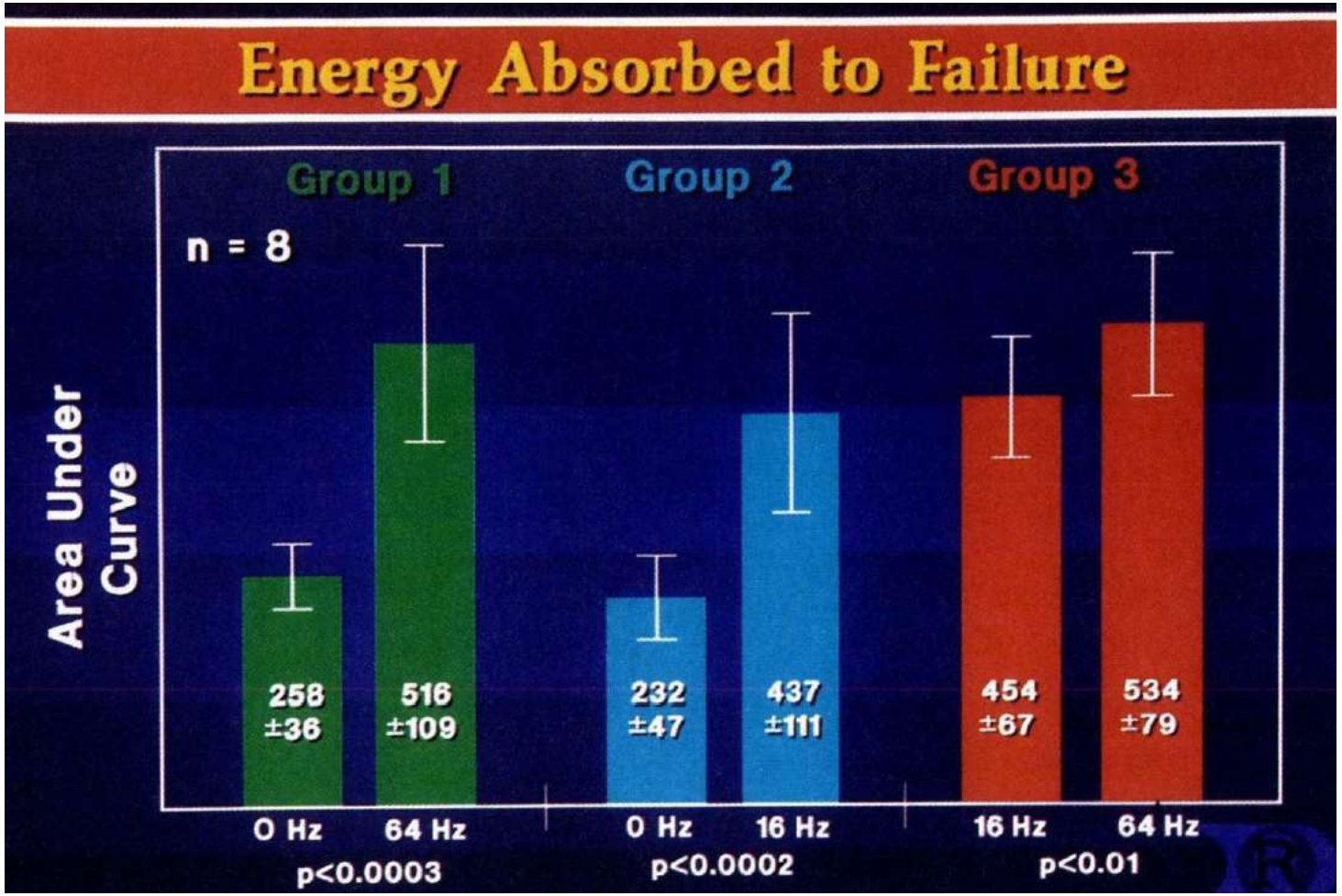
This study assumed that muscle activation is homogeneous within BFlh, which may not be valid.

0363-5465/87/1505-0448$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 15, No. 5

Biomechanical comparison of stimulated and nonstimulated skeletal muscle pulled to failure*

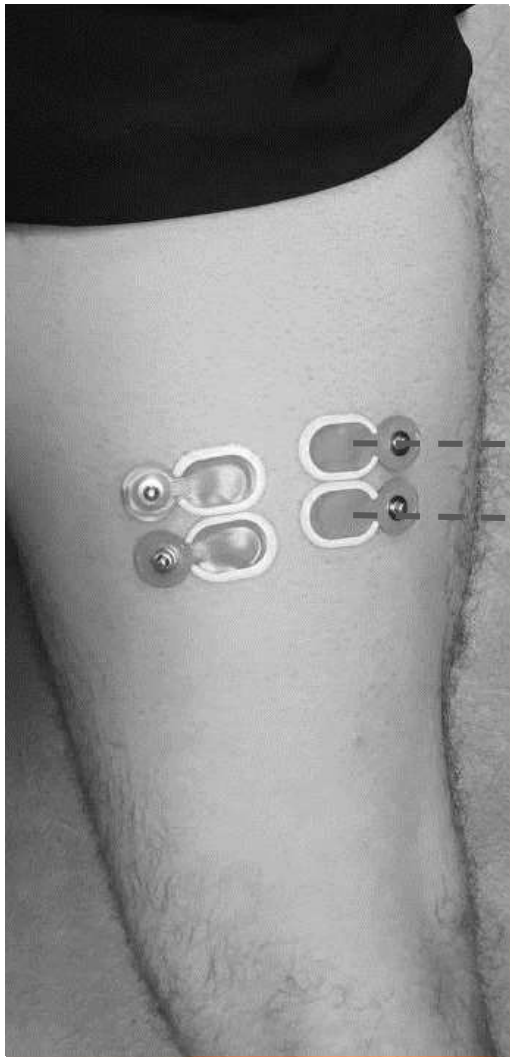
WILLIAM E. GARRETT, JR, MD, PhD, MARC R. SAFRAN, ANTHONY V. SEABER,†
RICHARD R. GLISSON, AND BETH M. RIBBECK, MS

Increased muscle activation → decreased strain injury risk



Electromyography (EMG)

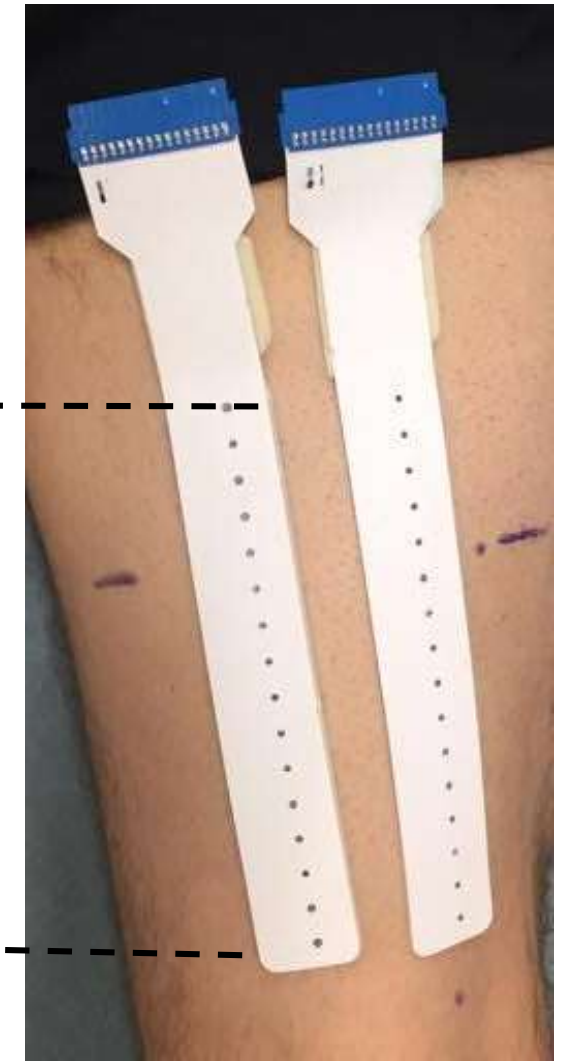
Bipolar EMG



Semitendinosus

Biceps femoris long head

High-density EMG



Semitendinosus

Biceps femoris long head

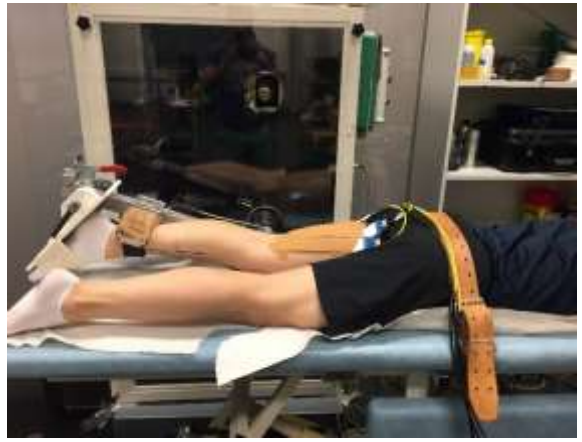
Participants:

13 male football/Gaelic football players
No previous hamstring injury

High-density EMG

Warm-up

MVIC (normalisation)

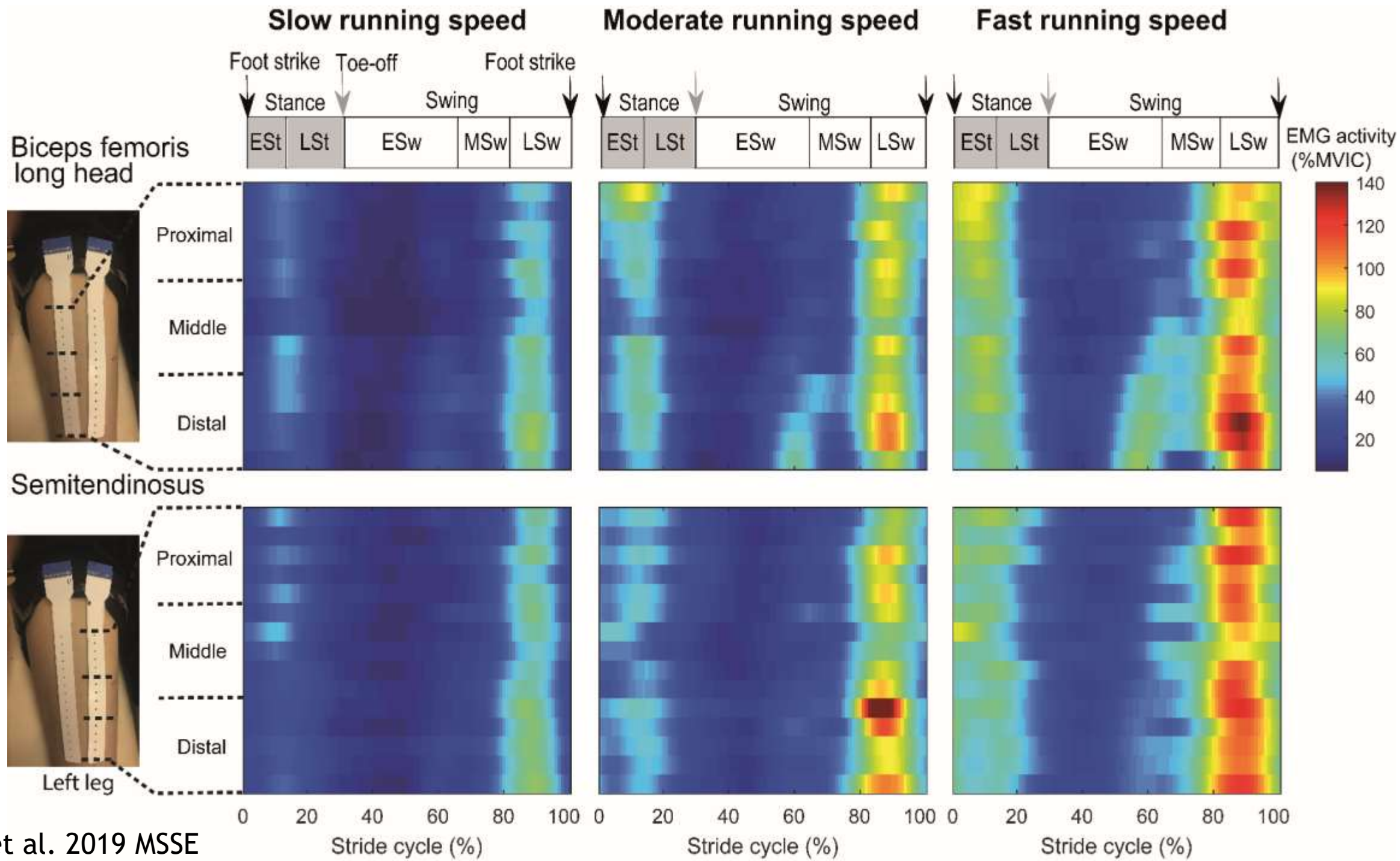


Running

3-D motion analysis &
force-sensitive resistors

Speeds:

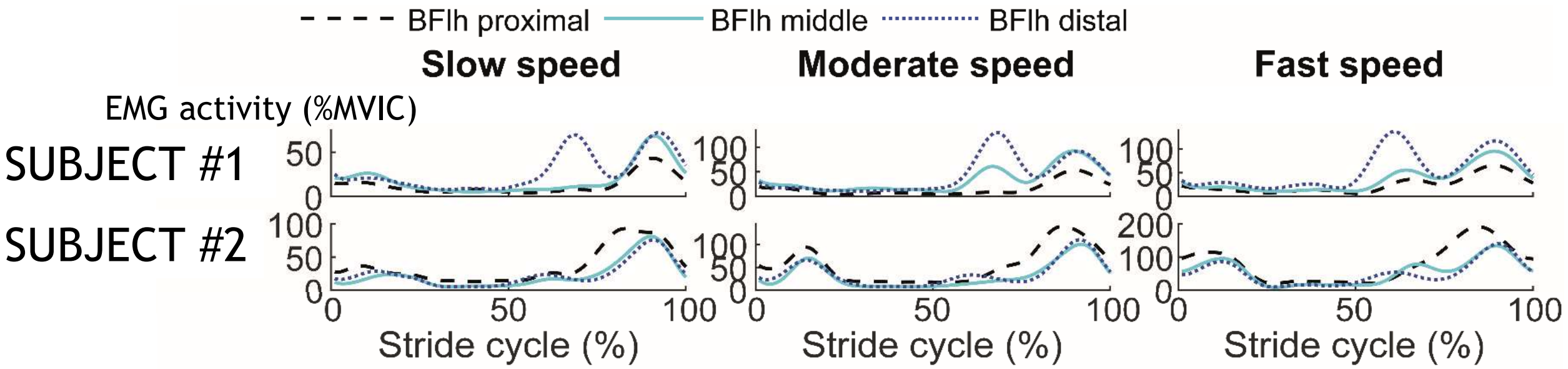
I. 4.1 $m \cdot s^{-1}$ (14.8 $km \cdot h^{-1}$) SLOW
II. 5.4 $m \cdot s^{-1}$ (19.4 $km \cdot h^{-1}$) MODERATE
III. 6.8 $m \cdot s^{-1}$ (24.5 $km \cdot h^{-1}$) FAST



Hegyi et al. 2019 MSSE

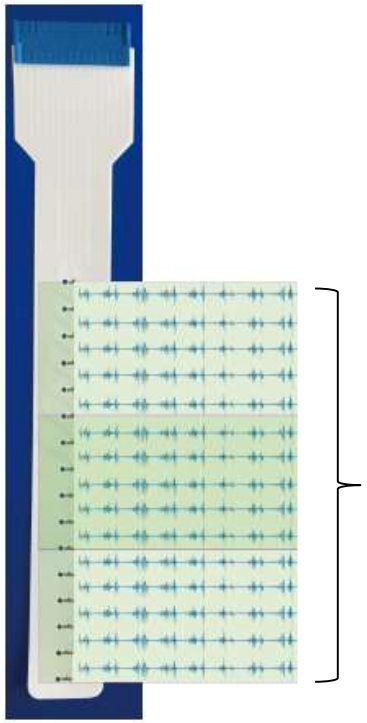
Running, individual region-specific patterns

Large inter-individual variability in regional EMG activity

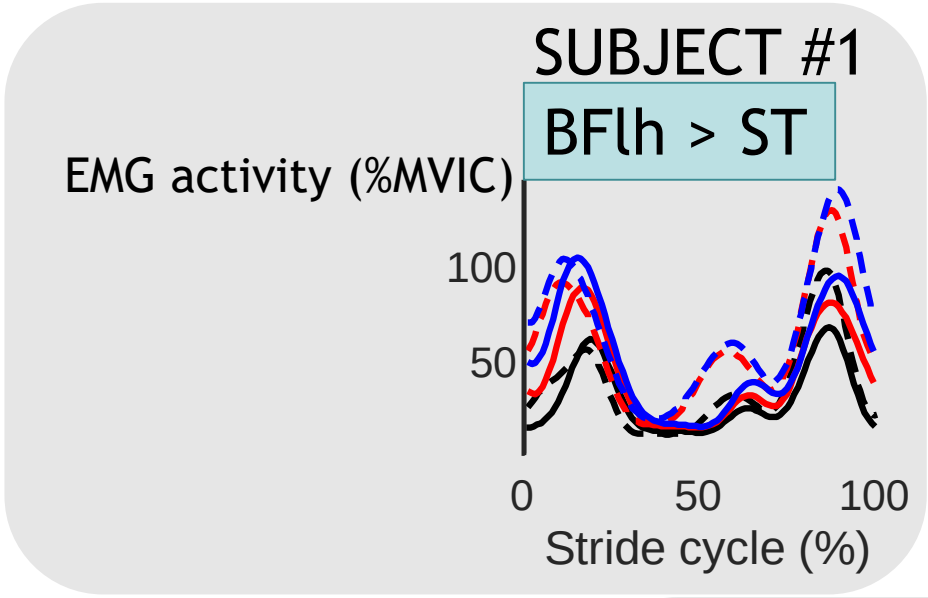


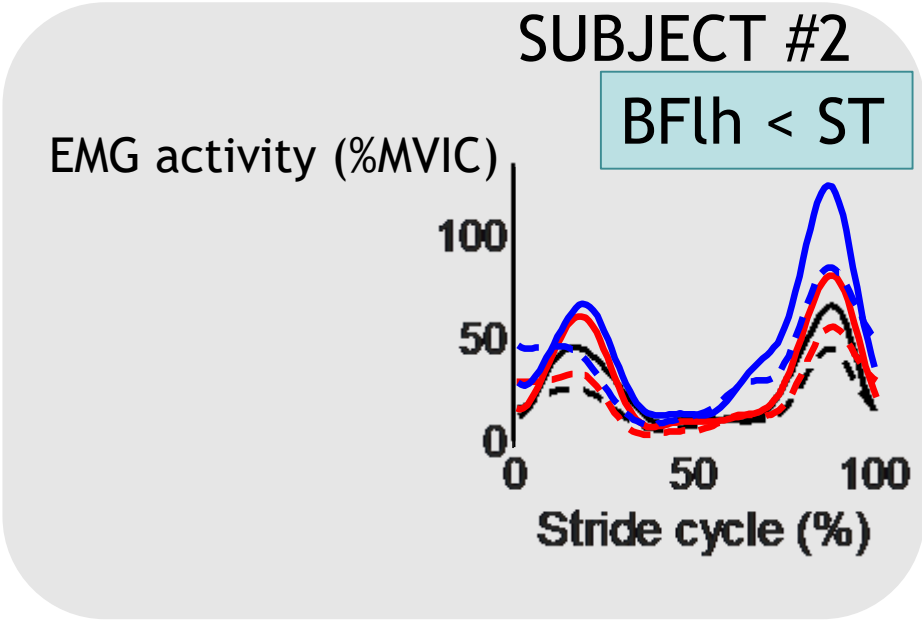
Running, muscle-specific EMG activity

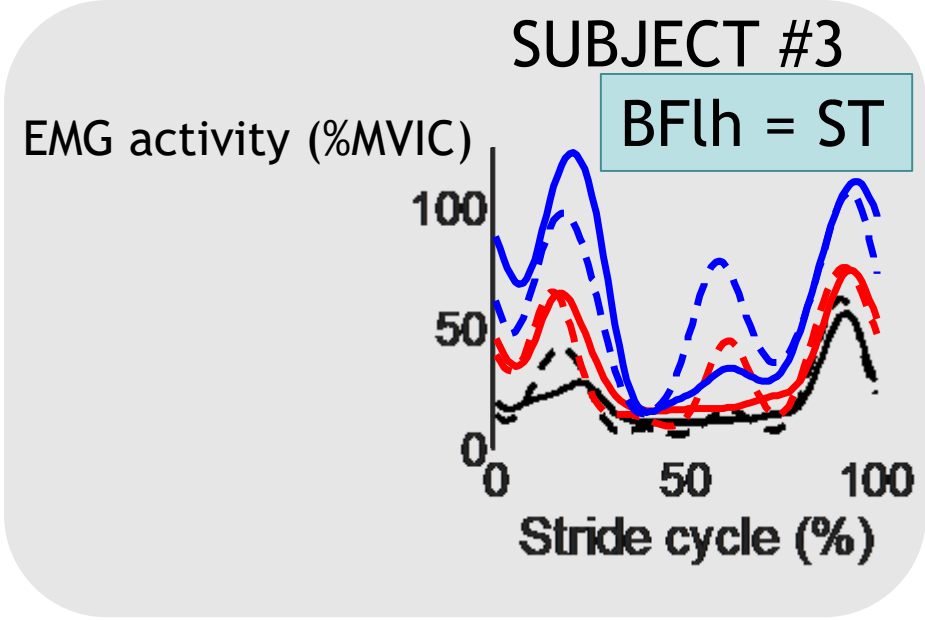
Large inter-individual variability in muscle-specific EMG activity



Muscle-specific EMG activity

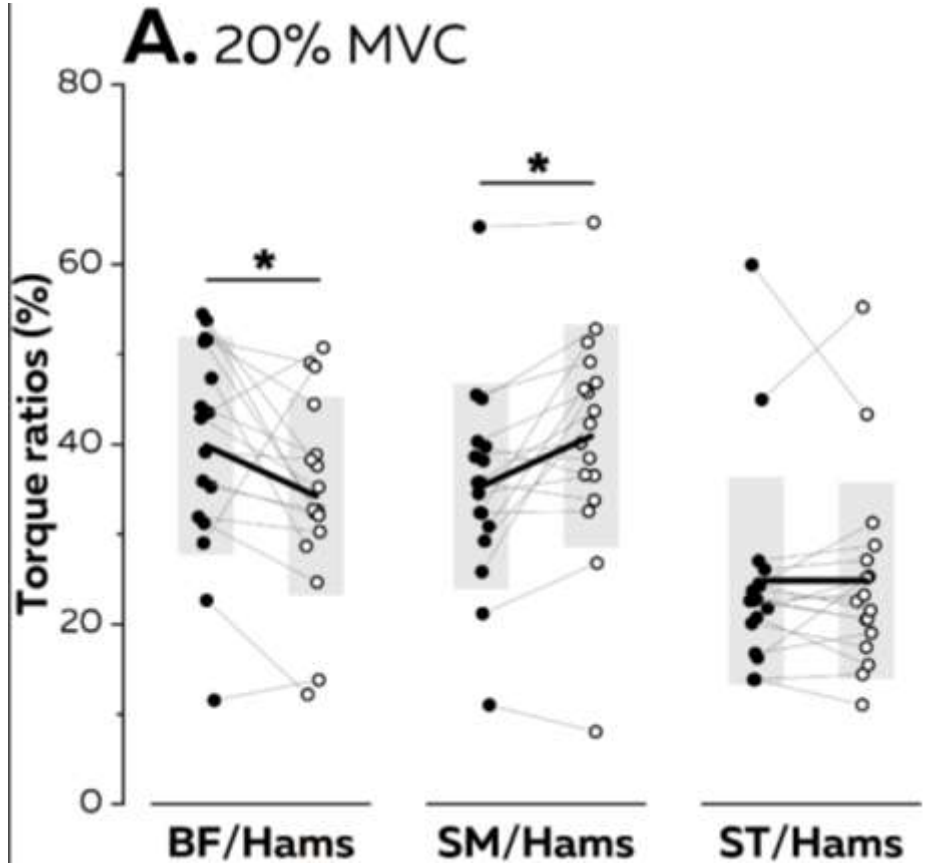






Importance of intermuscular EMG distribution

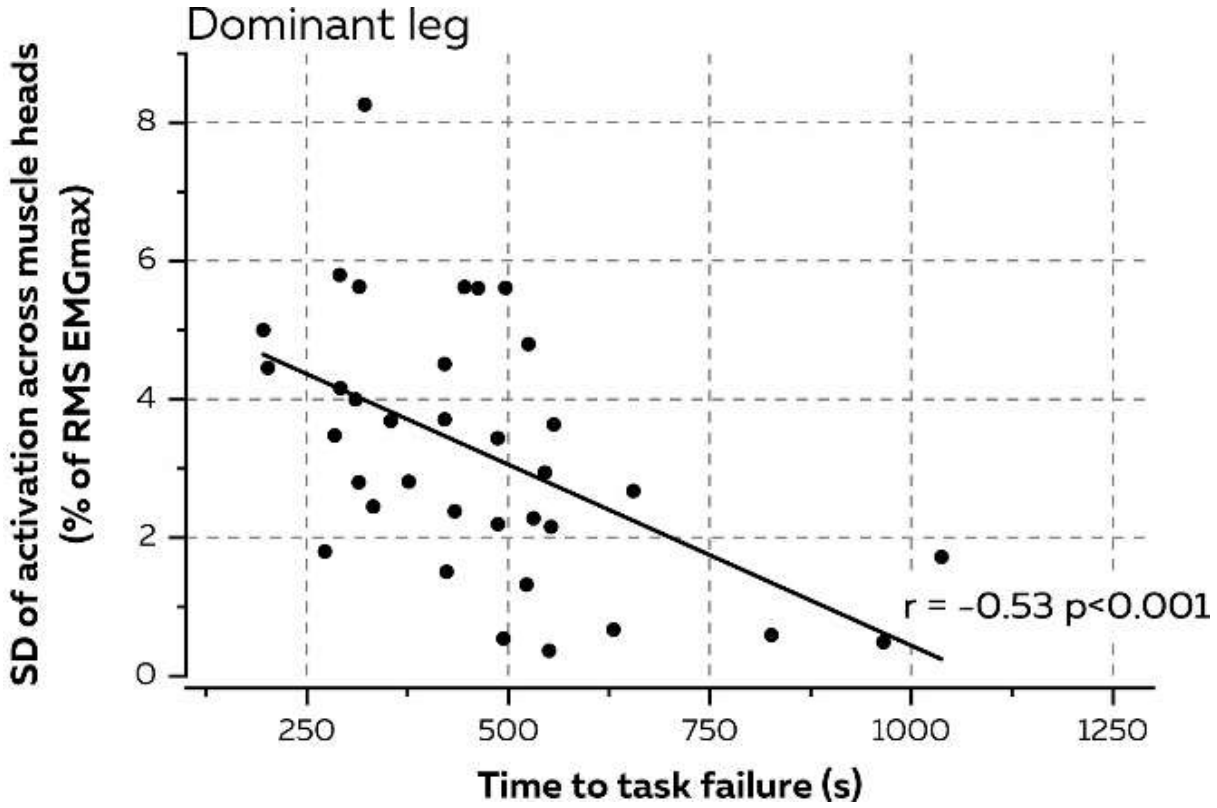
Lower torque of BFlh after a hamstring injury, which is compensated by higher SM torque



Avrillon et al. 2020

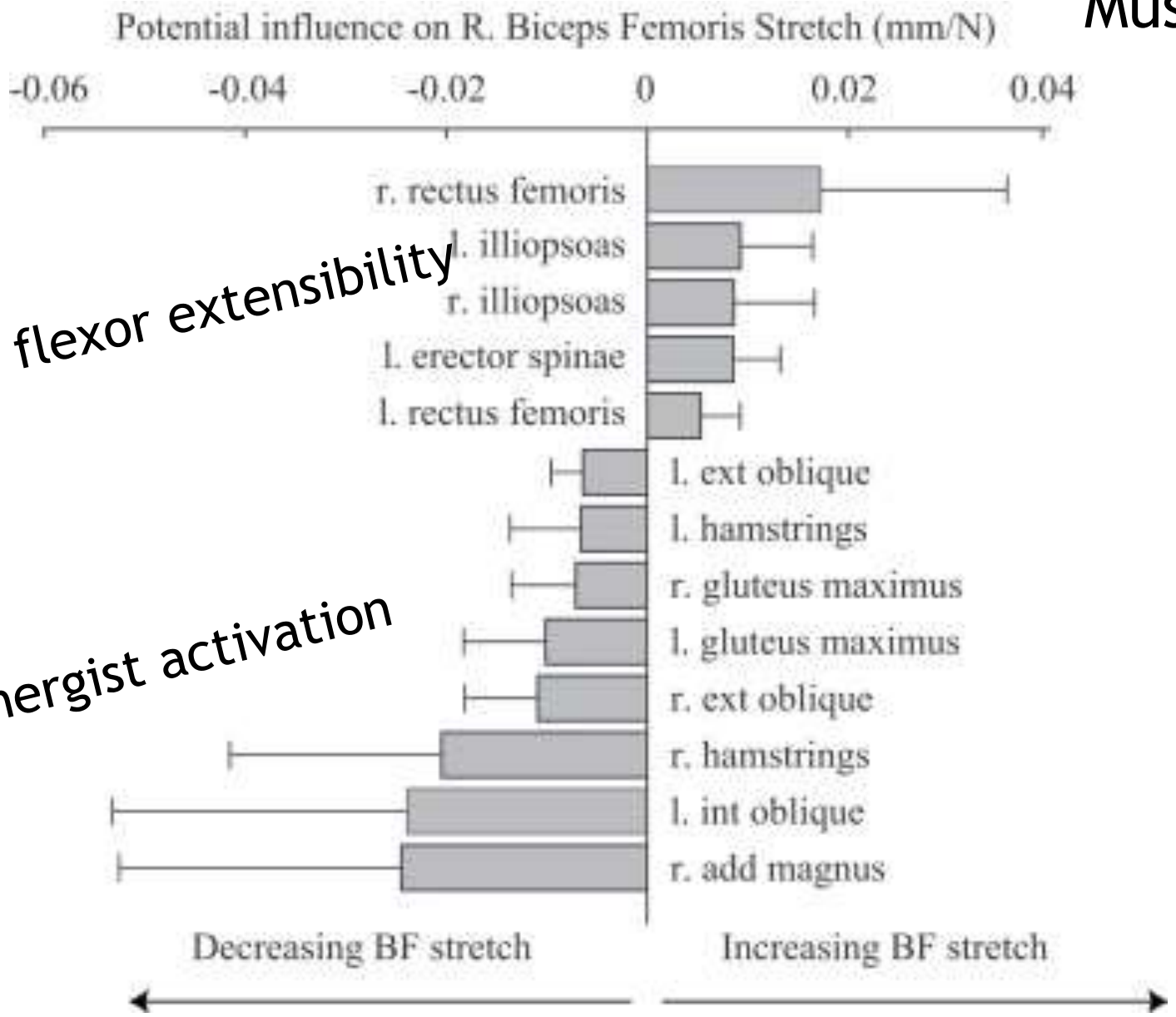
Higher EMG imbalance between hamstring muscles

Increased fatiguability



Avrillon et al. 2018

Muscles work in complex system



Hip flexor extensibility

Synergist activation

”Muscles in the lumbo-pelvic region have the largest potential to influence biceps femoris stretch during double float phase.”

Chumanov et al. 2007

Proximal Neuromuscular Control Protects Against Hamstring Injuries in Male Soccer Players

A Prospective Study With Electromyography Time-Series Analysis During Maximal Sprinting

Joke Schuermans,*† PT, PhD, Lieven Danneels,† PT, PhD, Damien Van Tiggelen,† PT, PhD, Tanneke Palmans,† Dipl-Ing, and Erik Witvrouw,† PT, PhD
Investigation performed at the Department of Rehabilitation Sciences and Physiotherapy, Ghent University, Ghent, Belgium

ELSEVIER

Journal of Biomechanics
Volume 92, 19 July 2019, Pages 112-119

Late swing running mechanics influence hamstring injury susceptibility in elite rugby athletes: A prospective exploratory analysis

Claire Kenneally-Dabrowski [a, b], Nicholas A.T. Brown [b, d], John Warmenhoven [b, i], Benjamin G. Serpell [c, d], Diana Perriman [a, g, h], Adrian K.M. Lai [f], Wayne Spratford [d, e]

Gait & Posture 57 (2017) 270–277

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Deviating running kinematics and hamstring injury susceptibility in male soccer players: Cause or consequence?

Joke Schuermans*, Damien Van Tiggelen, Tanneke Palmans, Lieven Danneels, Erik Witvrouw
Department of Rehabilitation Sciences and Physiotherapy Ghent, Ghent University, Ghent, Belgium

You may want to avoid:

- Anterior pelvic tilt
- Lateral trunk flexion to the ipsilateral side
- Forward leaning posture
- Kick-back

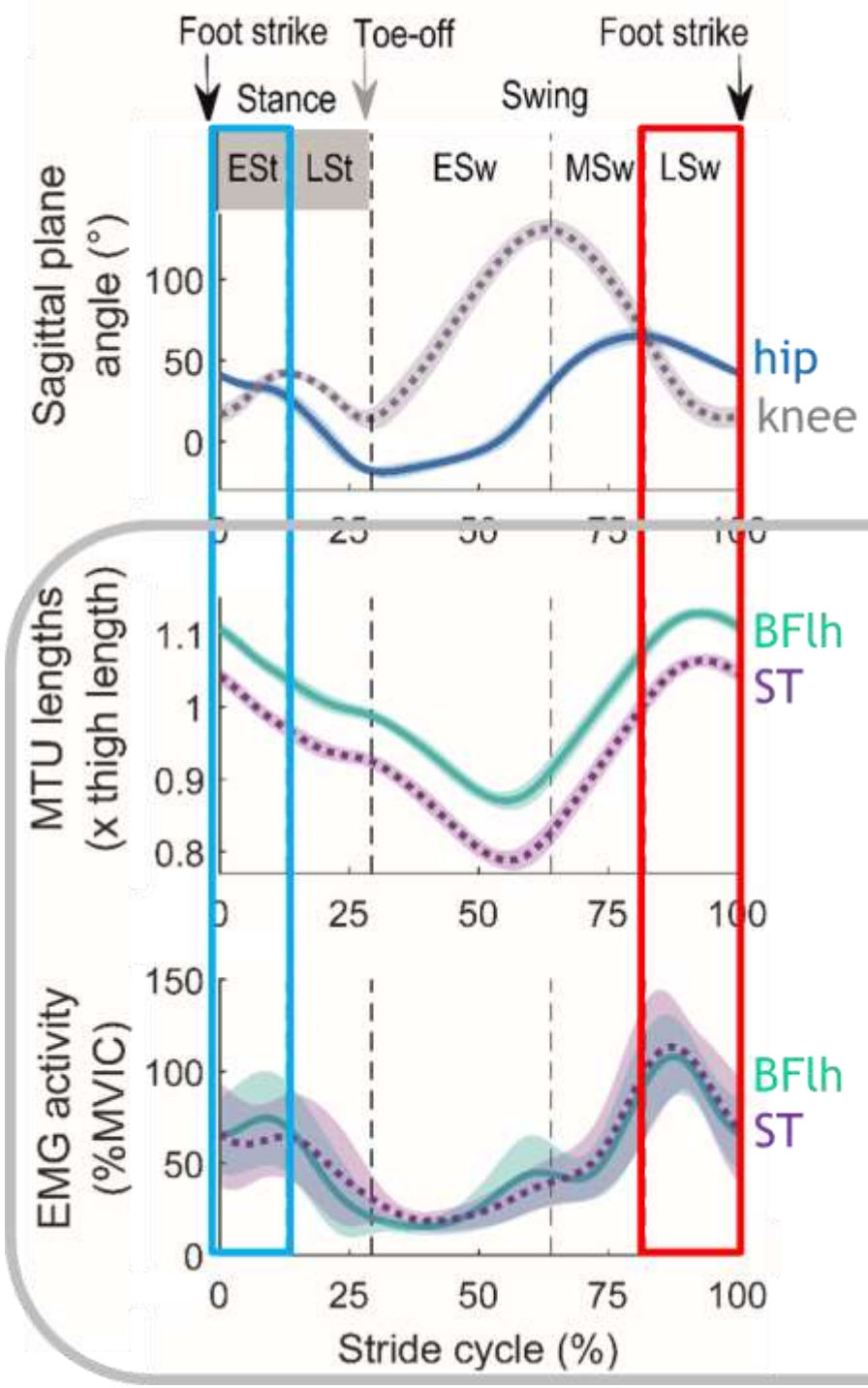
Intermuscular coordination

Sprint kinematics (technique)

Part 1 – key points

I. EMG activity in running
   a) > 100% MVIC at long hamstring muscle lengths
   b) highly individual patterns
   c) qualitatively consistent across a range of running speeds
      → running early after hamstring injury to restore normal neuromuscular function

II. The sources and consequences of heterogeneous and highly individual activation patterns should be related to injury and sprint performance



Presentation outline

Part 1

Running

Part 2

Hamstring Exercises

Study I.

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE IN SPORTS

ORIGINAL ARTICLE

Region-dependent hamstrings activity in Nordic hamstring exercise and stiff-leg deadlift defined with high-density electromyography

A. Hegyi, A. Péter, T. Finni, N. J. Cronin,

Study II.

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE IN SPORTS

ORIGINAL ARTICLE

High-density electromyography activity in various hamstring exercises

András Hegyi, Dániel Csala, Annamária Péter, Taija Finni, Neil J Cronin,

Study III.

Research Report

Impact of Hip Flexion Angle on Unilateral and Bilateral Nordic Hamstring Exercise Torque and High-Density Electromyography Activity

AUTHORS

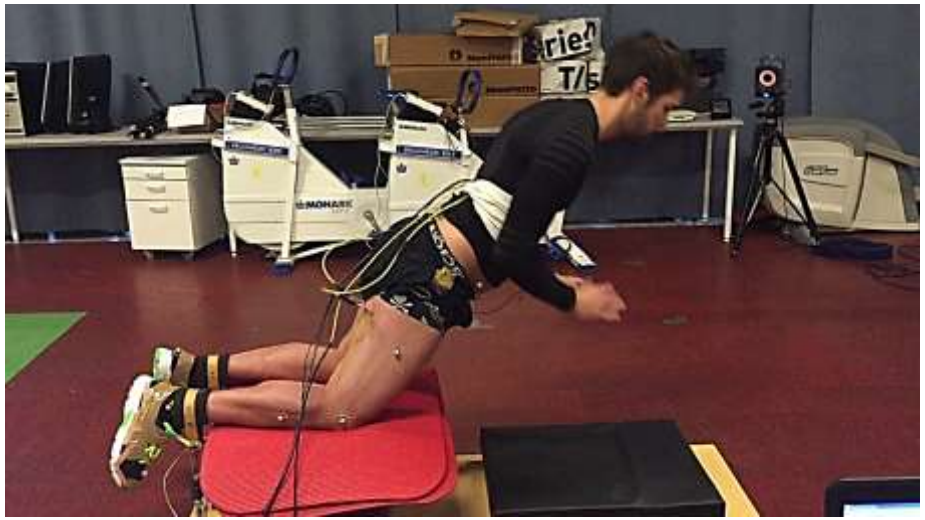
AFFILIATIONS

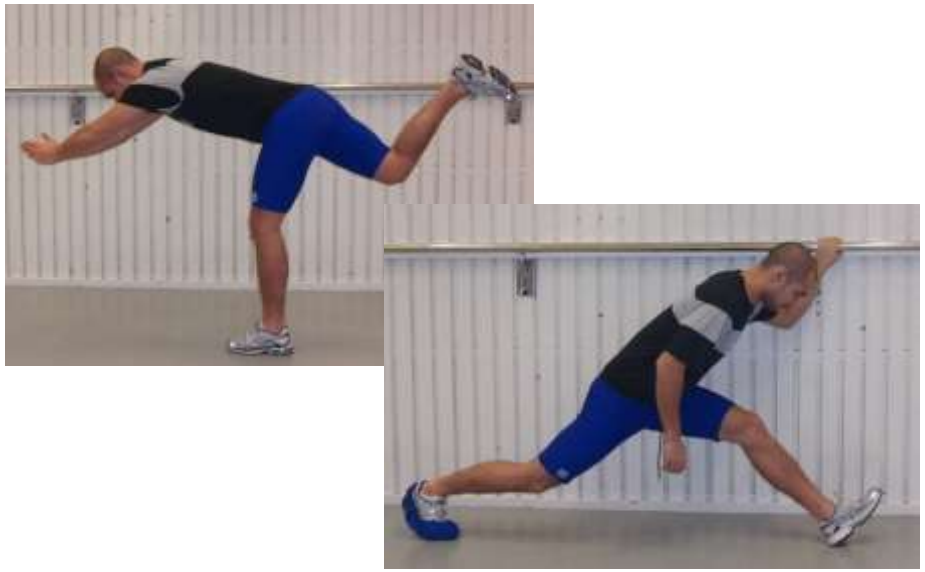
Journal of Orthopaedic & Sports Physical Therapy
Published Online: July 31, 2019 | Volume 49 Issue 8 | Pages 584-592
https://www.jospt.org/doi/10.2519/jospt.2019.8801

Part 2

Hamstring Exercises

Hamstring exercises for injury risk reduction





Review

Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta-analysis of 8459 athletes FREE

Nicol van Dyk[1], Fearghal P Behan[2], Rod Whiteley[3]

Original article

Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols FREE

Carl M Askling[1, 2], Magnus Tengvar[3], Alf Thorstensson[1]

Original article

Acute hamstring injuries in Swedish elite sprinters and jumpers: a prospective randomised controlled clinical trial comparing two rehabilitation protocols

Carl M Askling[1, 2], Magnus Tengvar[3], Olga Tarassova[1], Alf Thorstensson[1]

Regional differences in muscle activation

Muscle functional MRI

Non-uniform changes in magnetic resonance measurements of the semitendinosus muscle following intensive eccentric exercise

Jun Kubota, Takashi Ono, Megumi Araki, Suguru Torii, Toru Okuwaki & Toru Fukubayashi

European Journal of Applied Physiology **101**, 713–720 (2007) | Cite this article

Nonuniform Changes in MRI Measurements of the Thigh Muscles After Two Hamstring Strengthening Exercises

Mendiguchia, Jurdan[1]; Garrues, Mirian A.[2]; Cronin, John B.[3,4]; Contreras, Bret[3]; Los Arcos, Asier[5]; Malliaropoulos, Nikos[6]; Maffulli, Nicola[7]; Idoate, Fernando[8]

Author Information

Journal of Strength and Conditioning Research: March 2013 - Volume 27 - Issue 3 - p 574-581
doi: 10.1519/JSC.0b013e31825c2f38

PLoS One. 2016; 11(9): e0161356. PMCID: PMC5008723
Published online 2016 Sep 1. doi: 10.1371/journal.pone.0161356 PMID: 27583444

MRI-Based Regional Muscle Use during Hamstring Strengthening Exercises in Elite Soccer Players

Alberto Mendez-Villanueva,[1,*] Luis Suarez-Arrones,[1,2] Gil Rodas,[3] Rodrigo Fernandez-Gonzalo,[4] Per Tesch,[4] Richard Linnehan,[5] Richard Kreider,[6] and Valter Di Salvo[1,7]

Electromyography

ORIGINAL RESEARCH

Regional Differences in Muscle Activation During Hamstrings Exercise

Schoenfeld, Brad J.; Contreras, Bret; Tiryaki-Sonmez, Gul; Wilson, Jacob M.; Kolber, Morey J.; Peterson, Mark D.

Author Information

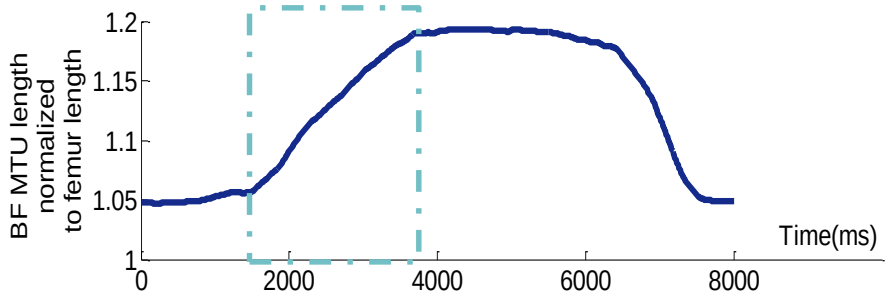
Journal of Strength and Conditioning Research: January 2015 - Volume 29 - Issue 1 - p 159-164
doi: 10.1519/JSC.0000000000000598

Study I.

Stiff-leg deadlift – 80% 1RM

Hip dominant

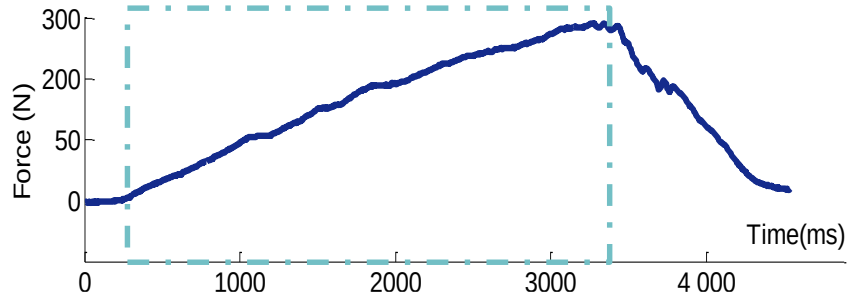
Long muscle length



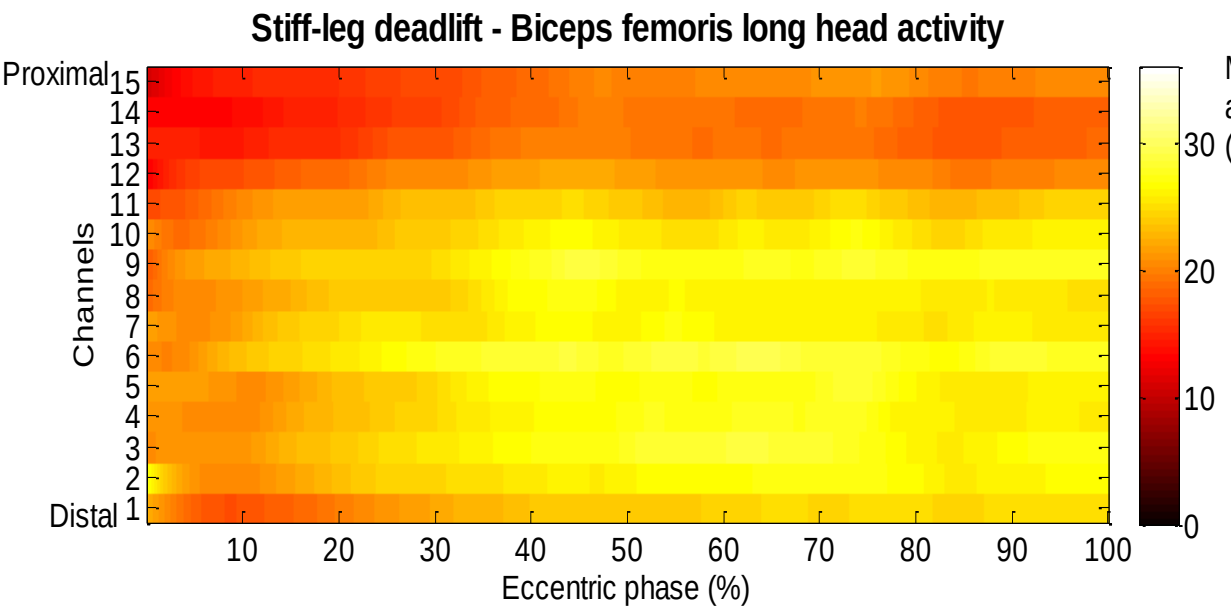
Nordic hamstring exercise

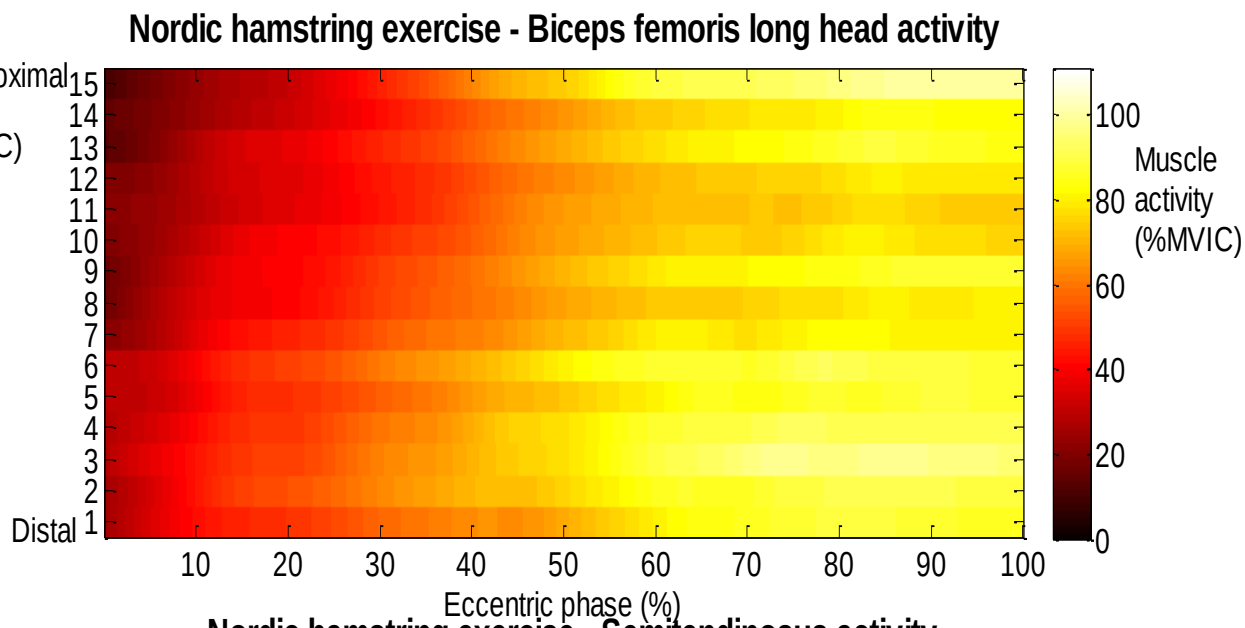
Knee dominant

Short muscle length



Study I.


Stiff-leg deadlift - Biceps femoris long head activity
Proximal
Distal
Channels
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100
Eccentric phase (%)
Muscle activity (%MVIC)
30
20
10
0


Nordic hamstring exercise - Biceps femoris long head activity
Proximal
Distal
15
14
13
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11
10
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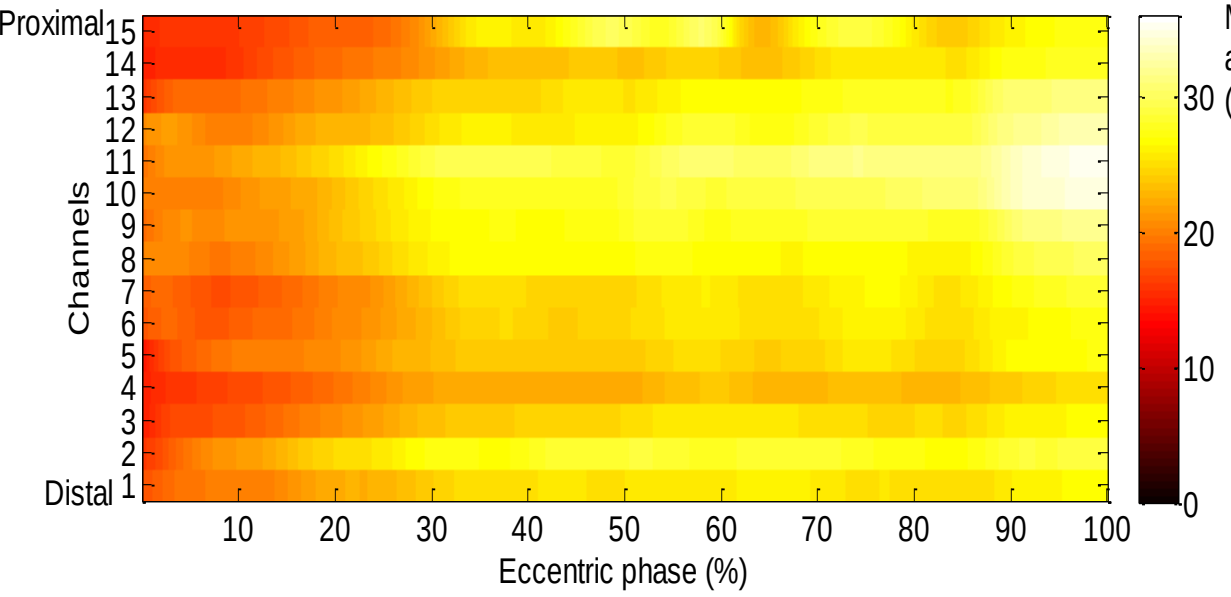
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100
Eccentric phase (%)
Muscle activity (%MVIC)
100
80
60
40
20
0


Stiff-leg deadlift - Semitendinosus activity
Proximal
Distal
Channels
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
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30
40
50
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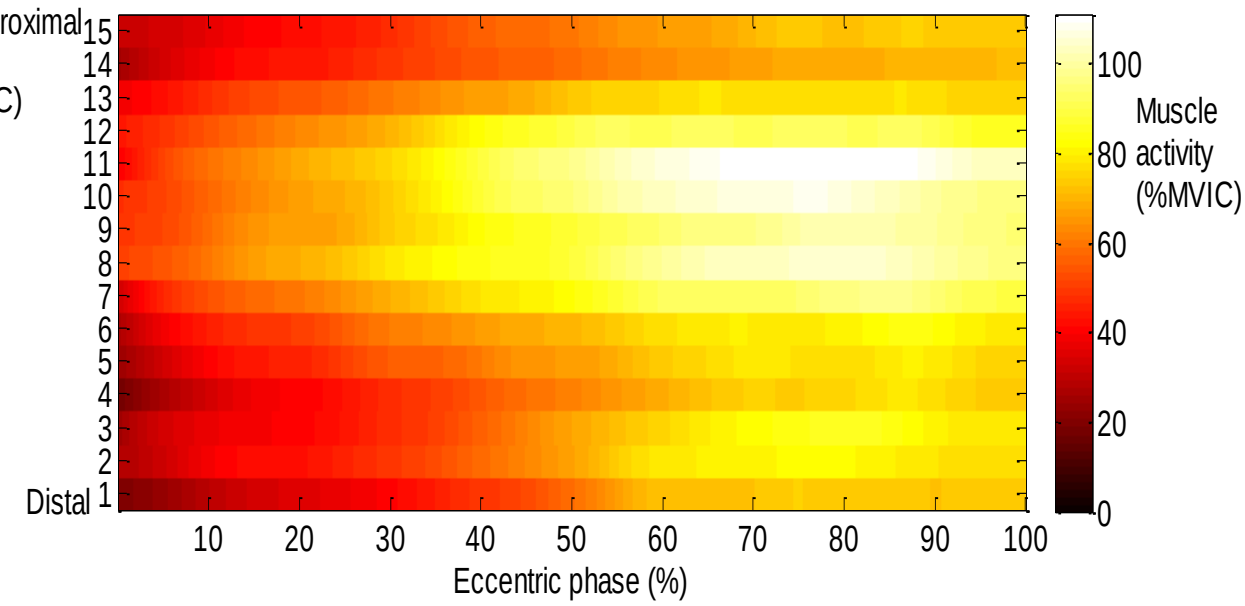
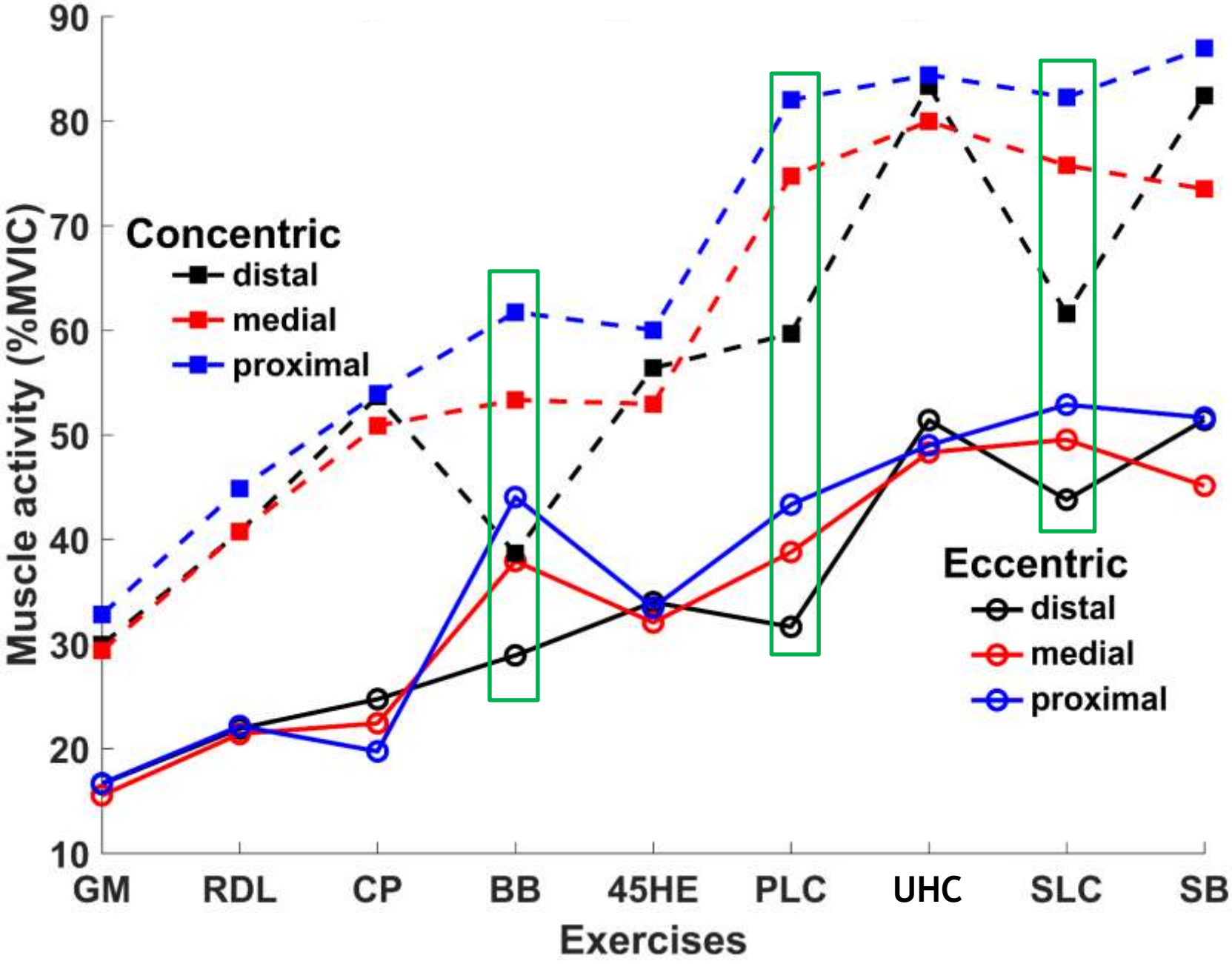
70
80
90
100
Eccentric phase (%)
Muscle activity (%MVIC)
30
20
10
0


Nordic hamstring exercise - Semitendinosus activity
Proximal
Distal
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100
Eccentric phase (%)
Muscle activity (%MVIC)
100
80
60
40
20
0

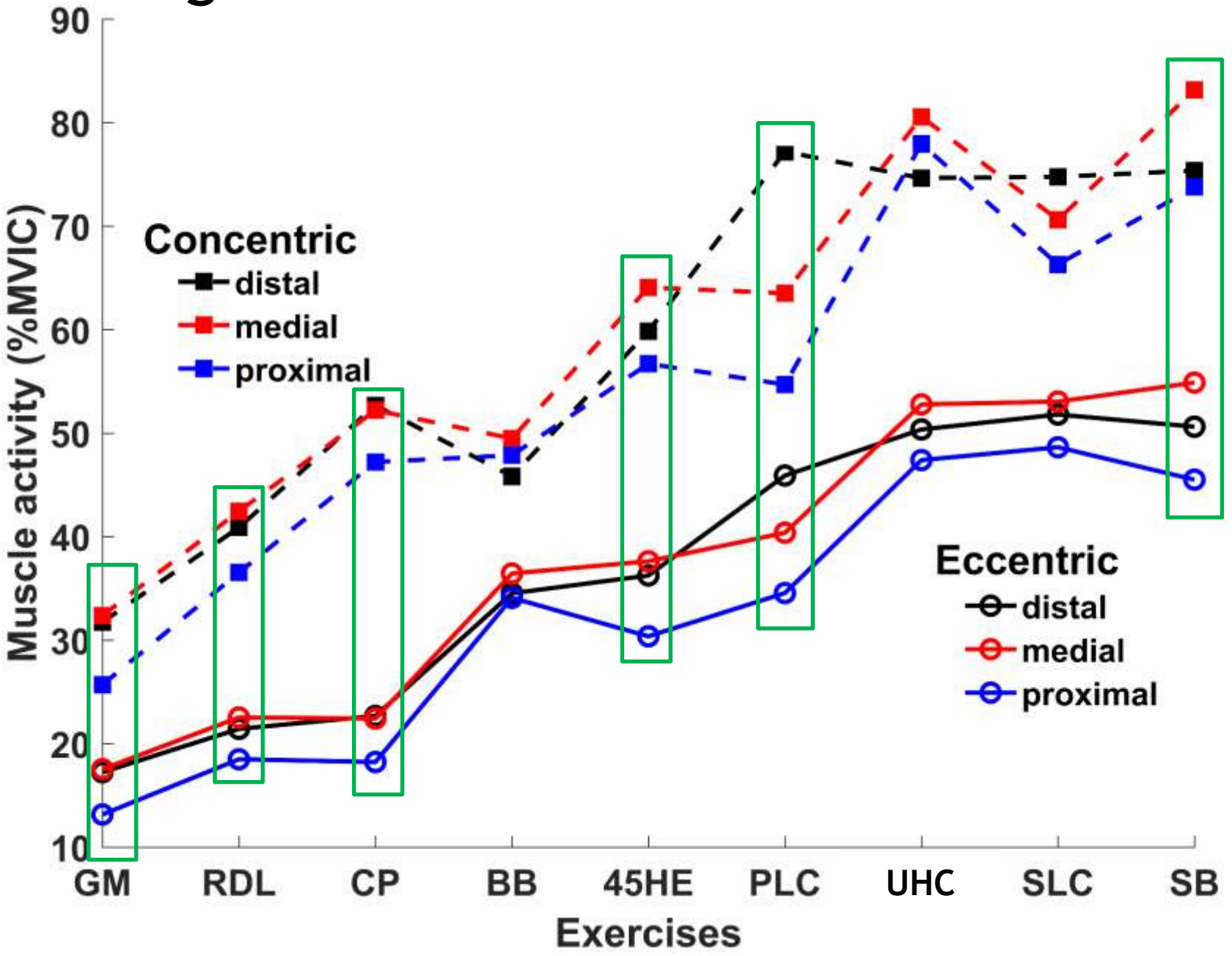
Study II.


Prone leg curl (PLC)
45° hip extension (HE)
Upright hip-extension conic-pulley (UHC)
Straight-knee bridge (SB)
Unilateral Romanian deadlift (RDL)
Bent-knee bridge (BB)
Good morning (GM)
Cable pendulum (CP)
Slide-leg curl (SLC)

Study II. Regional distribution of EMG within semitendinosus

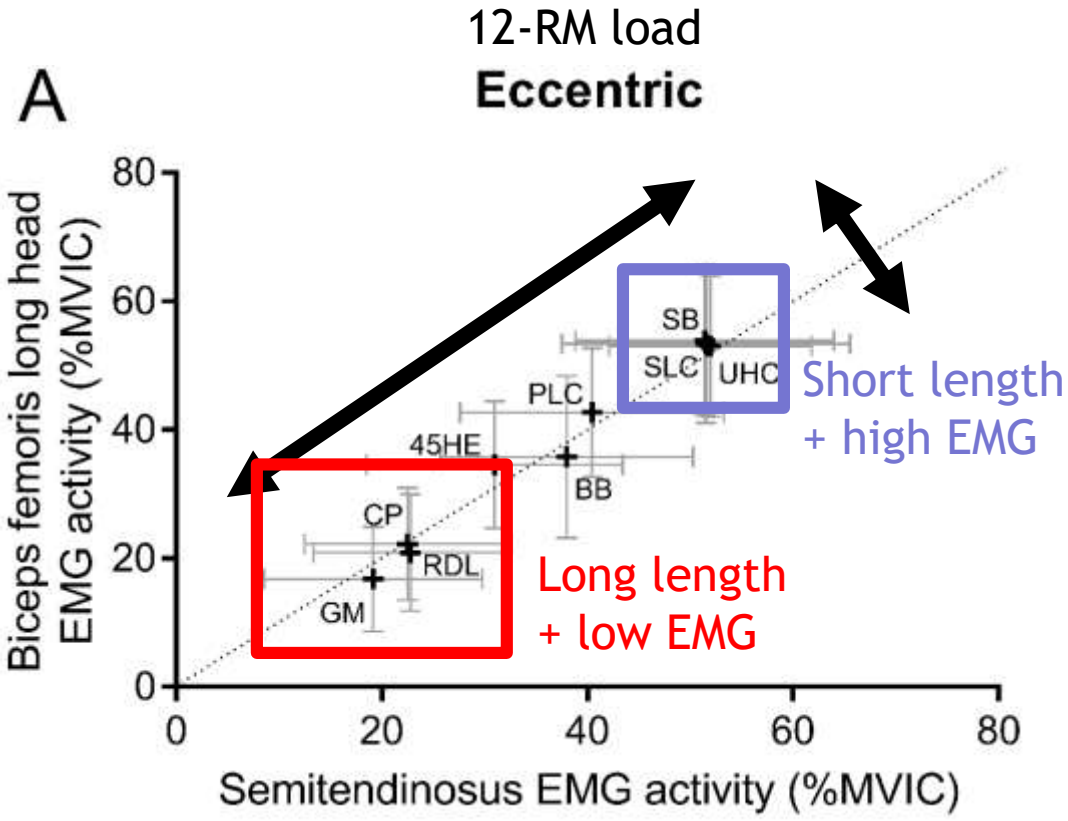


Study II. Regional distribution of EMG within BFlh



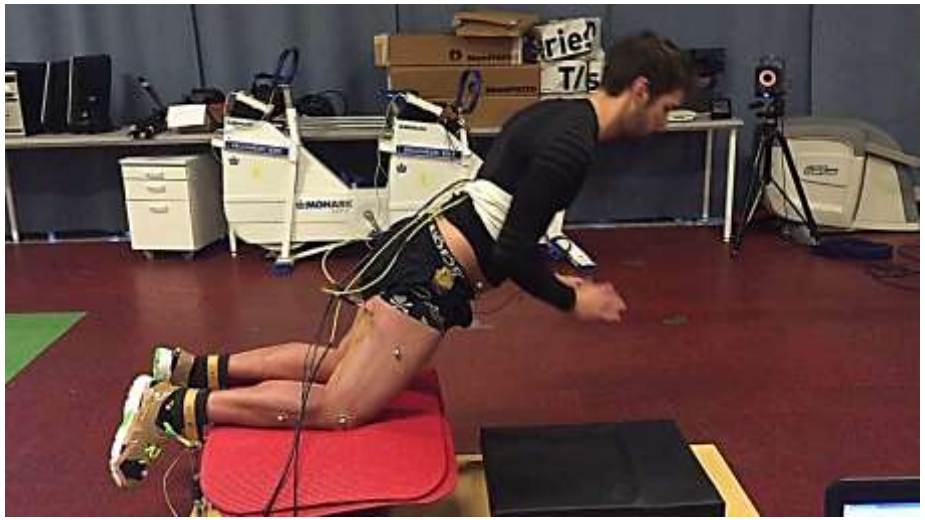
Study II.

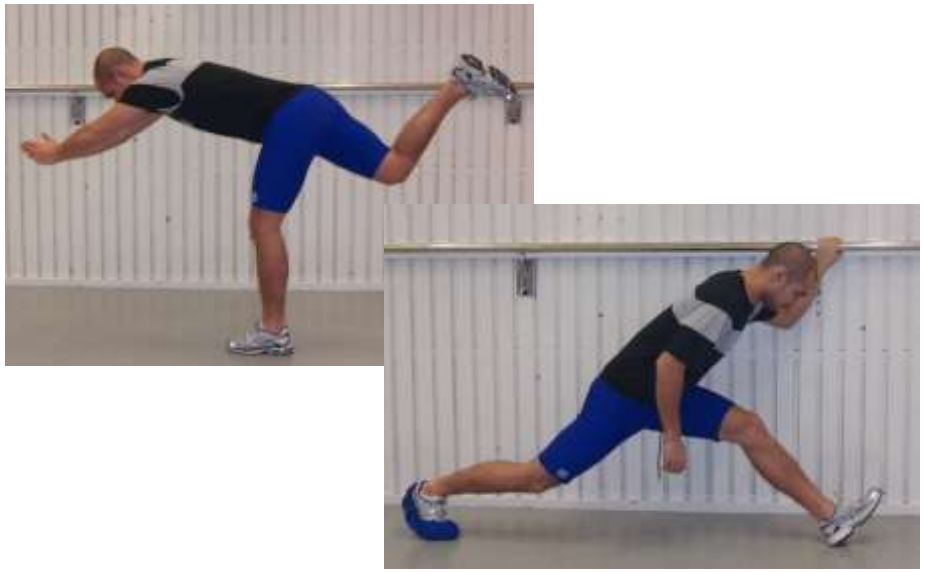
Hamstring exercises – EMG vs length



Overall EMG activity – large effect
Muscle-specific activity – small effect

Hamstring exercises for injury risk reduction





High muscle activation
+
Short muscle length

Review

Including the Nordi
programmes halve
and meta-analysis of 8459 a

Nicol van Dyk[1], Fearghal P Behan[2], Rod Whiteley[3]

Low muscle activation
+
Long muscle length

Original article

Acute hamstring ir
randomised contr
protocols FREE

Carl M Askling[1, 2], Magnus T

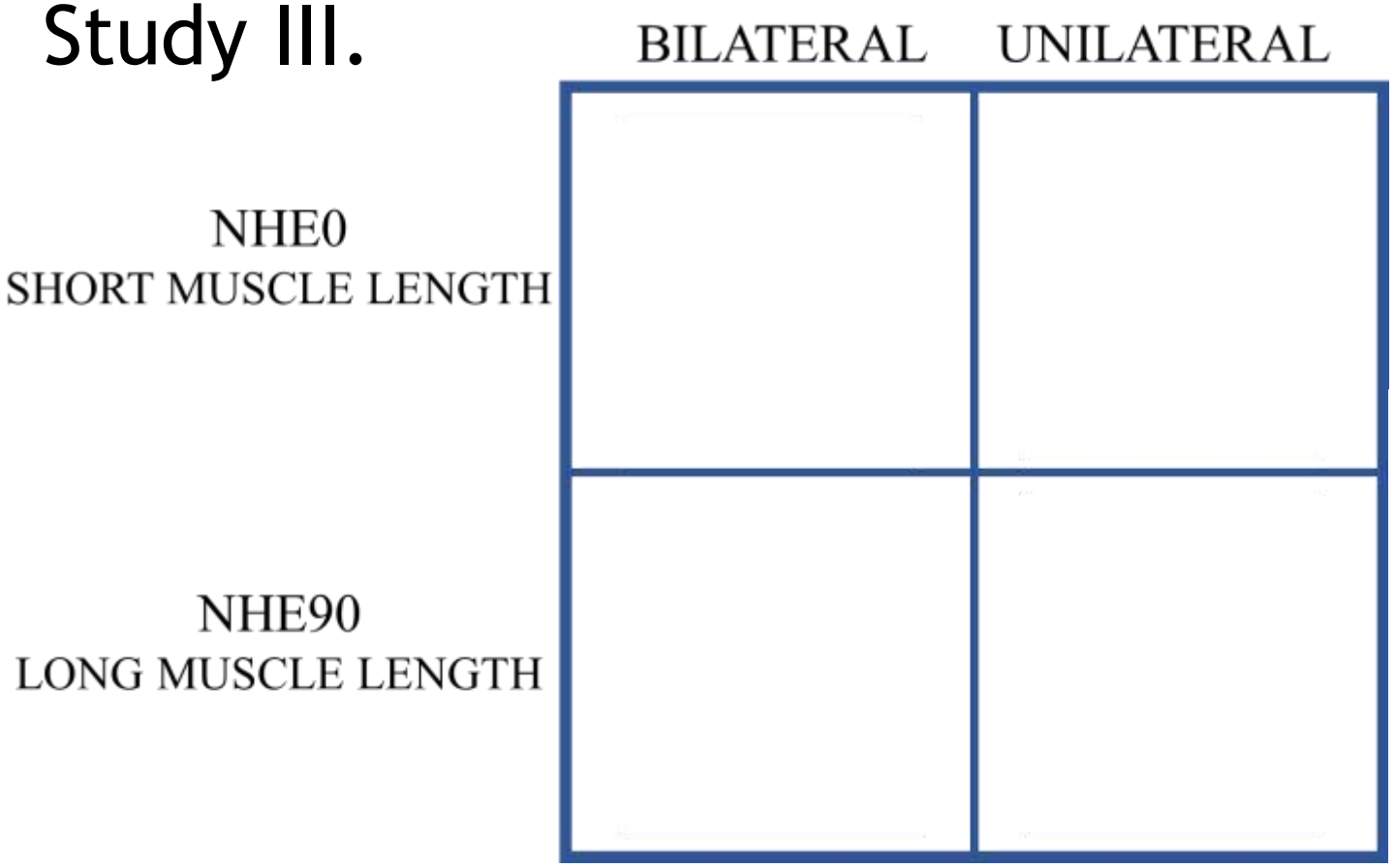
Original article

Acute hamstring injuries in Swedish
prospective randomised controlled clinical tria
rehabilitation protocols

Carl M Askling[1, 2], Magnus Tengvar[3], Olga Tarassova[1], Alf Thorstensson[1]

Study III.

NHE0 vs NHE90
(Hegyi et al. 2019)



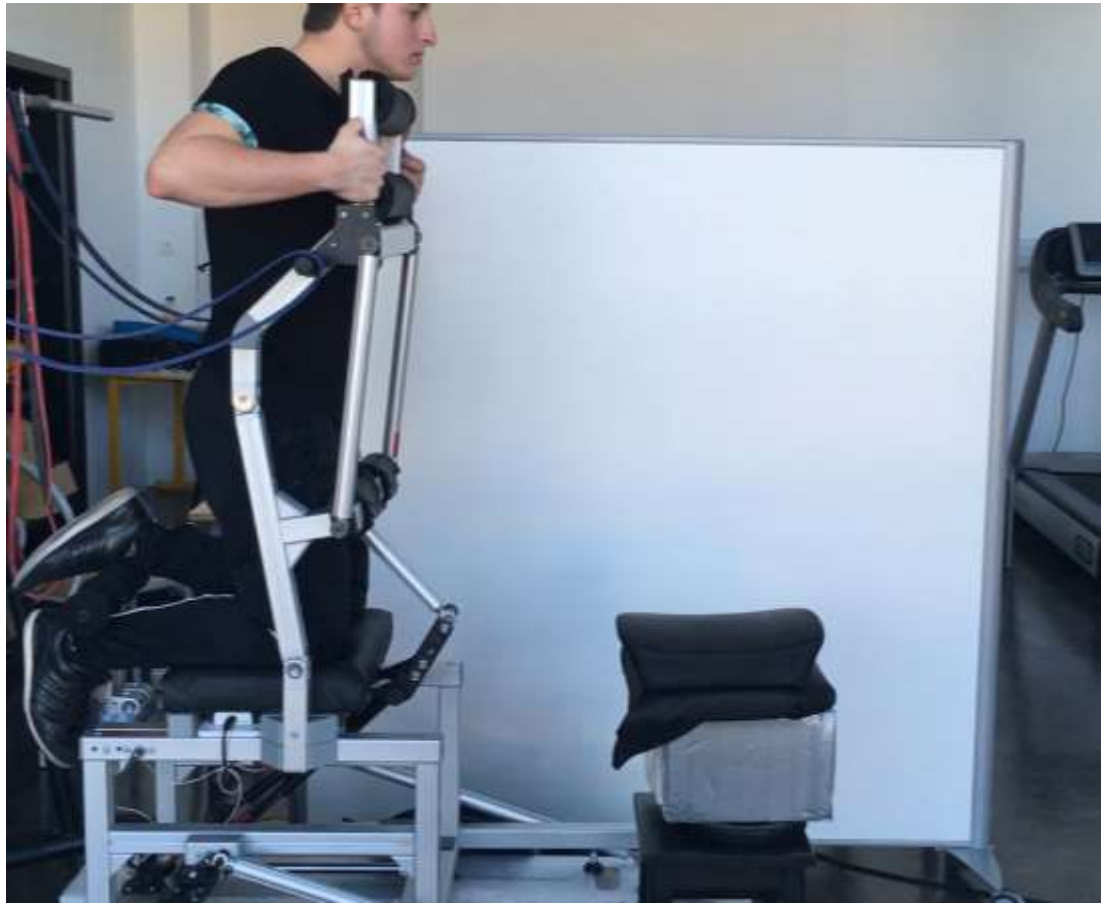
- 13 football/rugby players without prior hamstring injury
- 5-sec pace
- Eccentric 1-RM load

Study III.

NHE0 vs NHE90
(Hegyi et al. 2019)

	BILATERAL	UNILATERAL
NHE0 SHORT MUSCLE LENGTH		✓
NHE90 LONG MUSCLE LENGTH		

- 13 football/rugby players without prior hamstring injury
- 5-sec pace
- Eccentric 1-RM load



Study III.

NHE0 vs NHE90
(Hegyi et al. 2019)

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NHE0 SHORT MUSCLE LENGTH		
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- 5-sec pace
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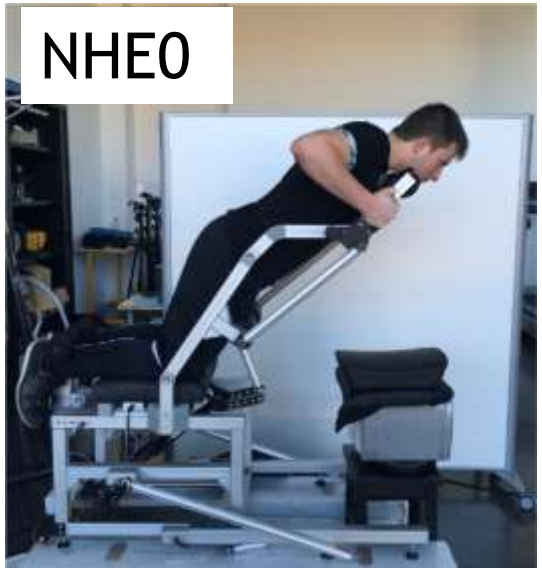
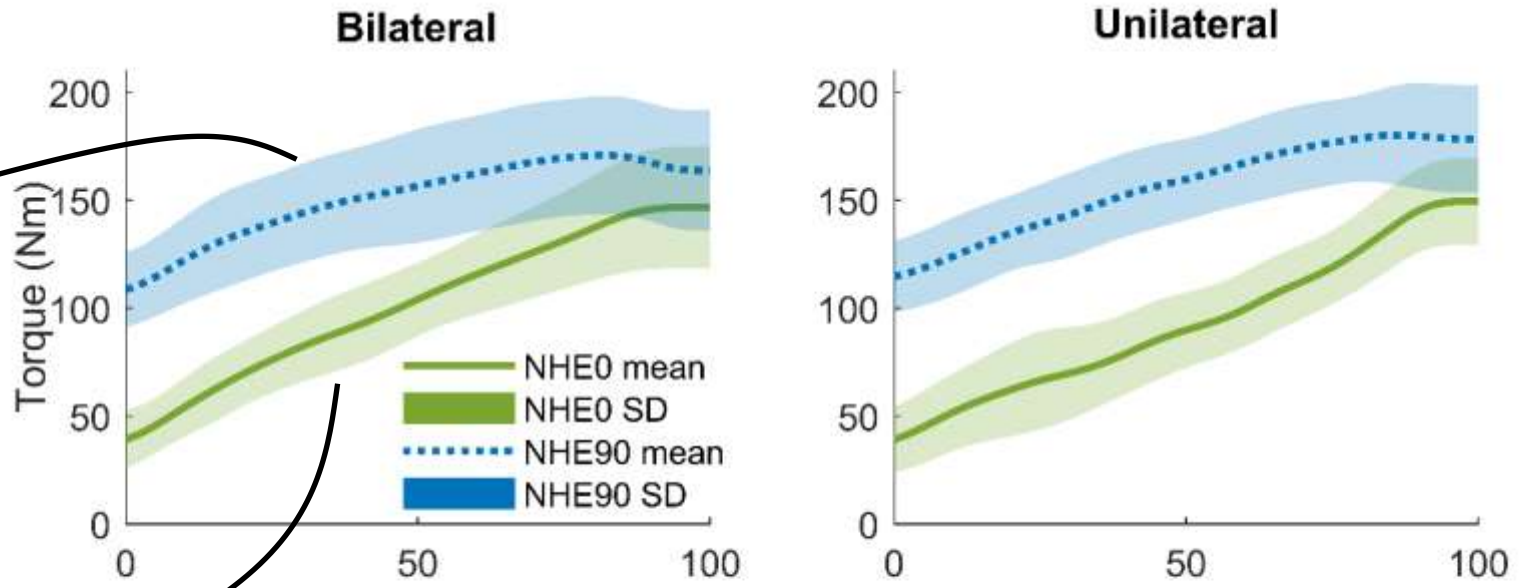
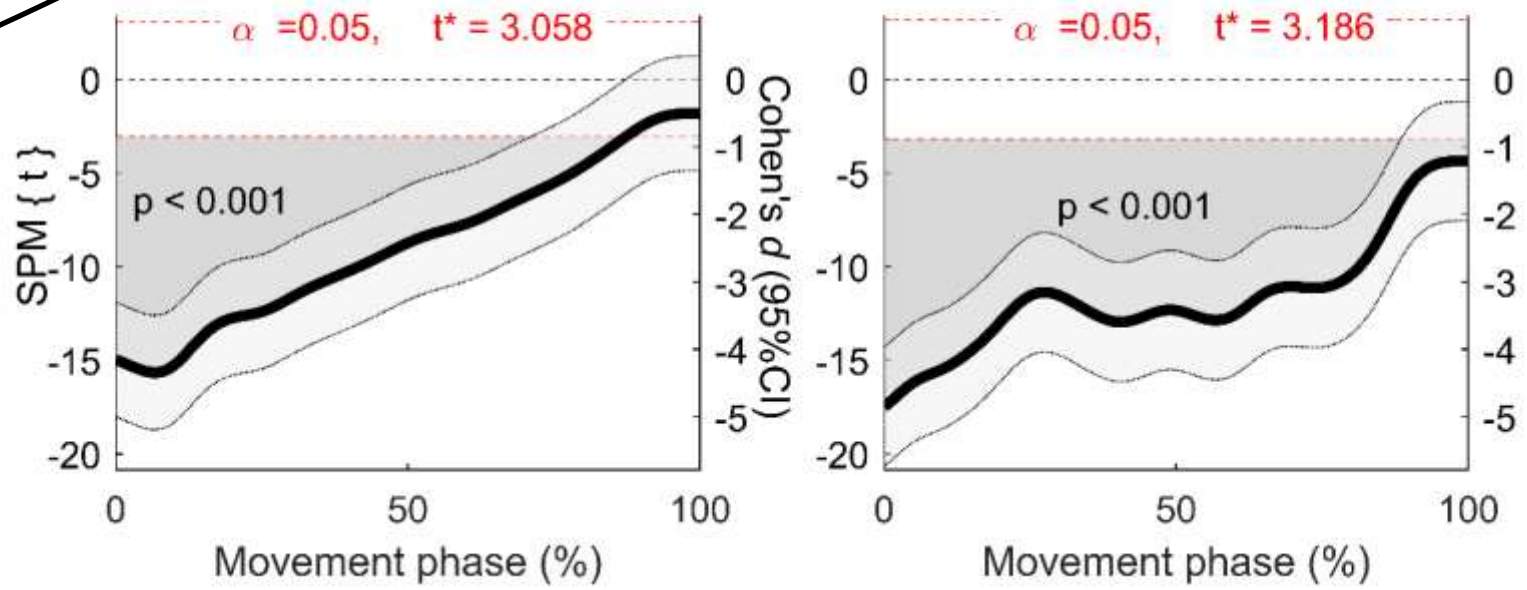
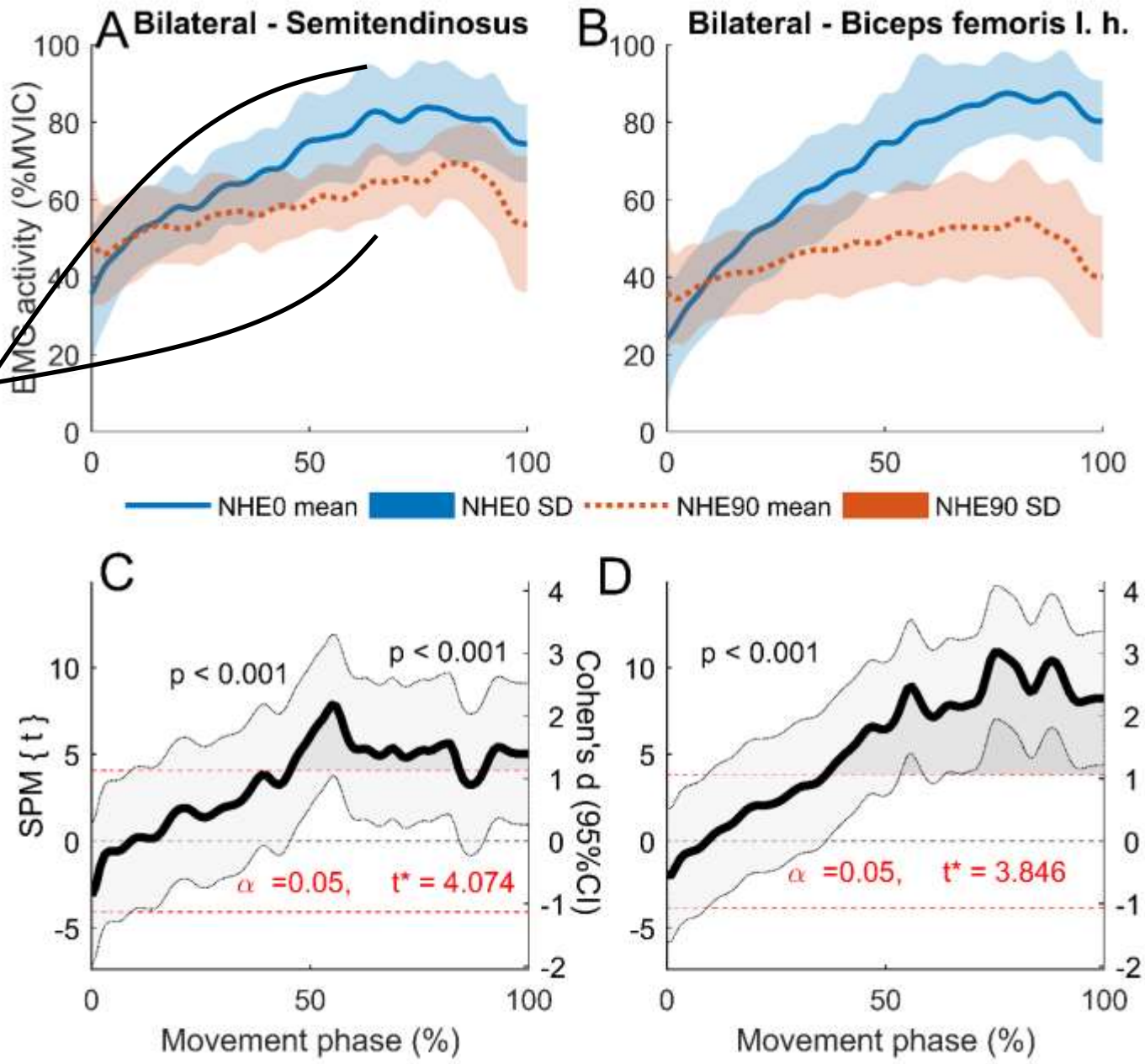
Study III - Torque





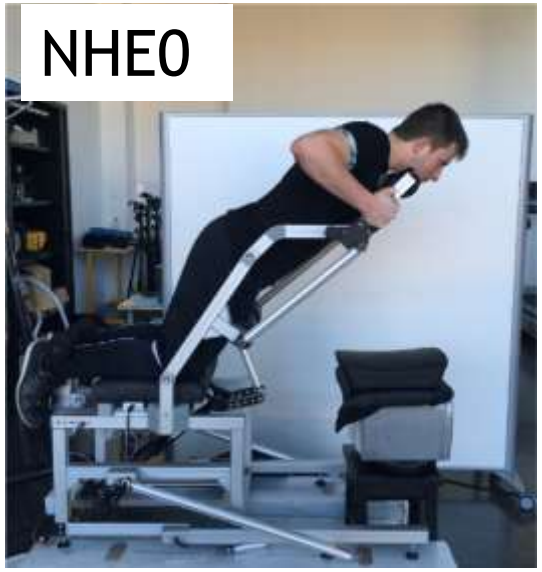


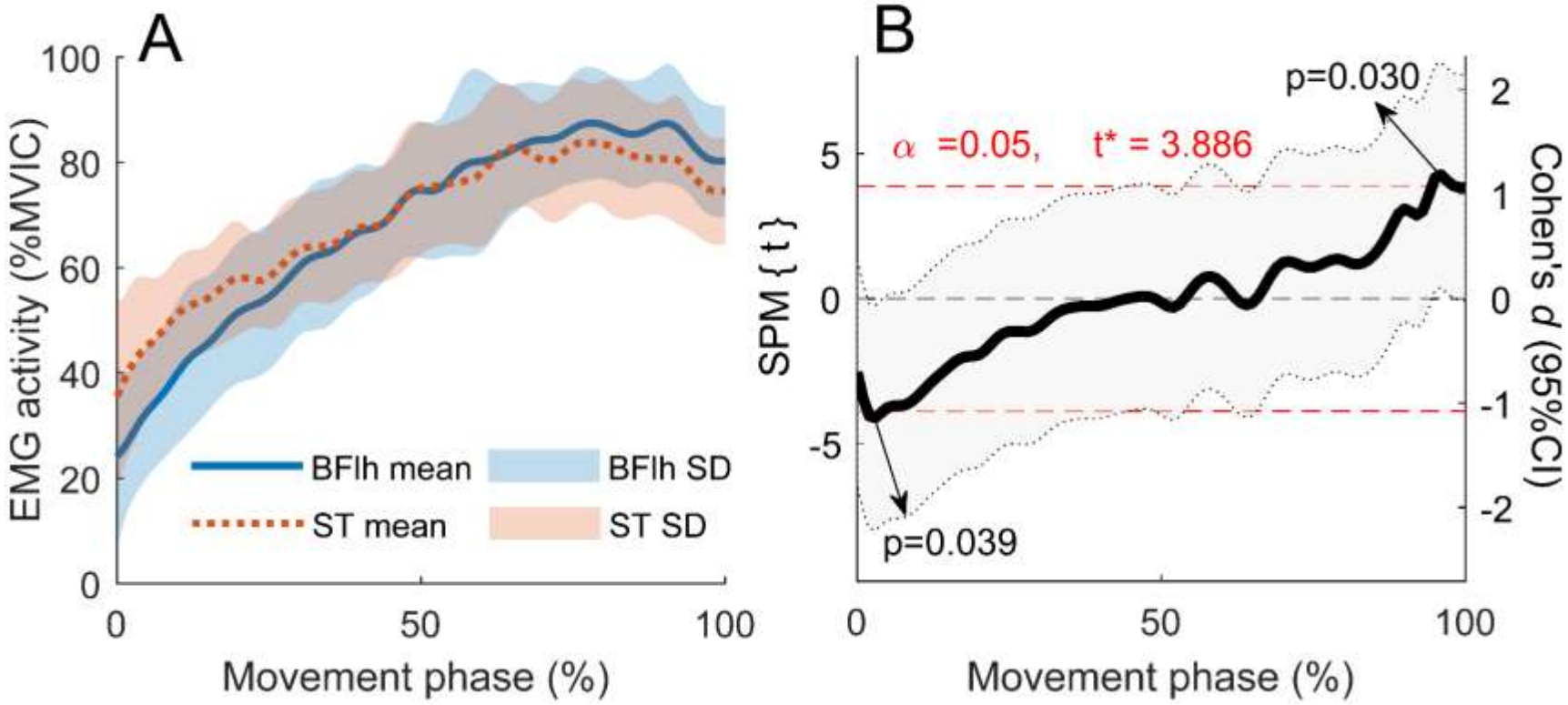
Study III - EMG



Study III – EMG

Bilateral NHE0 – effect of knee ROM on intermuscular coordination





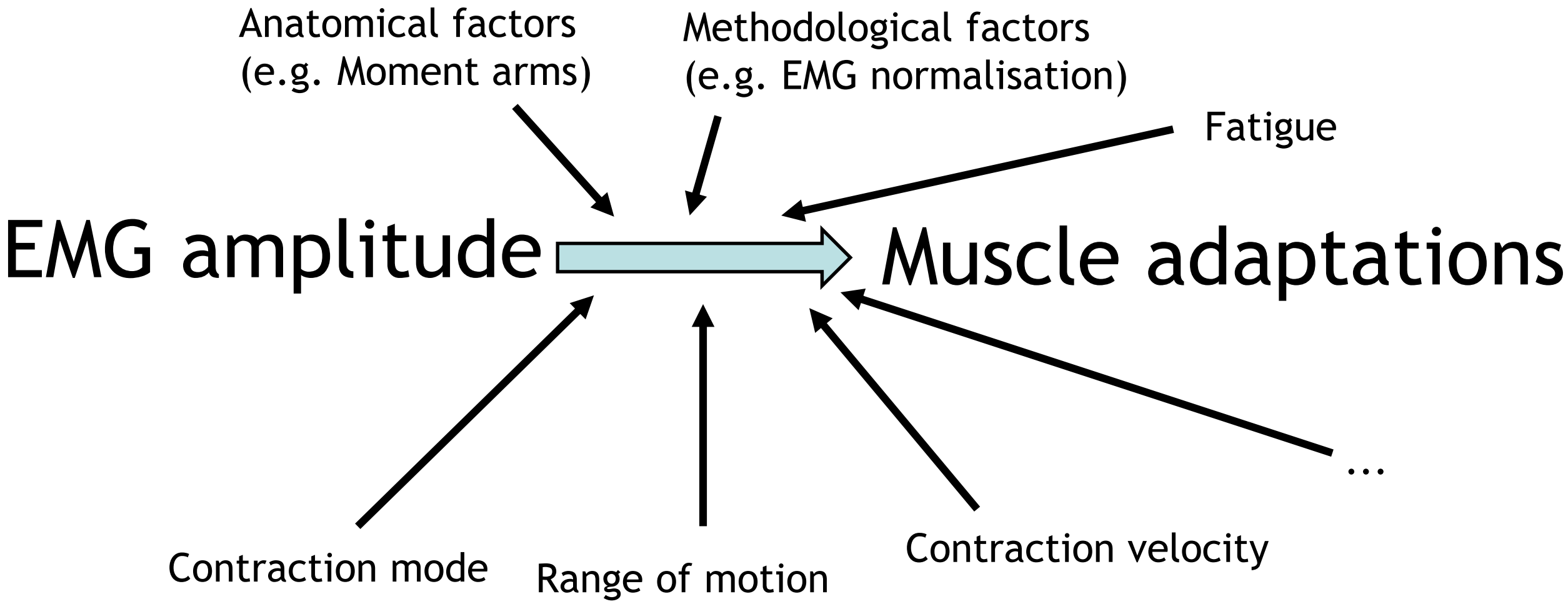
Part 2 – key points

I. At long muscle length, it is challenging to achieve high muscle activation during typical hamstring exercises

II. NHE0: Mainly ST activation at flexed knee, and mainly BFlh activation at near-extended knee

III. NHE90:
- long muscle length
- Higher passive force than in NHE0
- Higher ST/BFlh ratio than in NHE0
- Lower overall EMG activity

IV. Regional differences are substantial (typically lowest EMG in the proximal region of BFlh)


Anatomical factors
(e.g. Moment arms)
Methodological factors
(e.g. EMG normalisation)
Fatigue
EMG amplitude
Muscle adaptations
...
Contraction mode
Range of motion
Contraction velocity

Thank you for your attention!

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