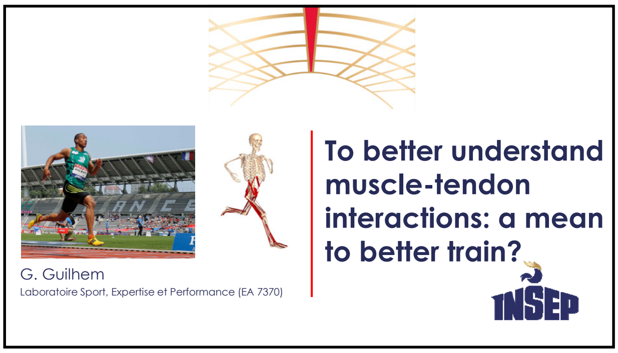
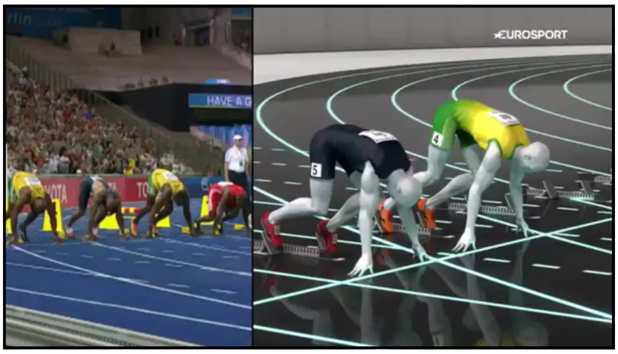
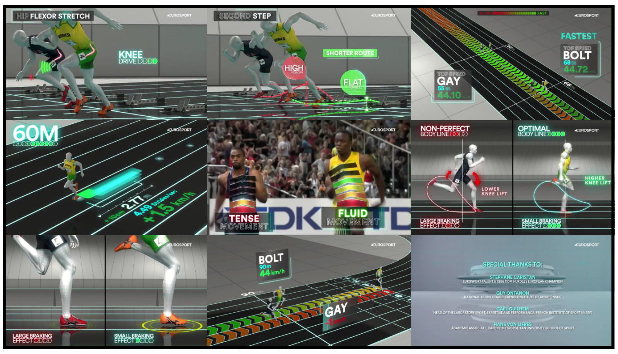
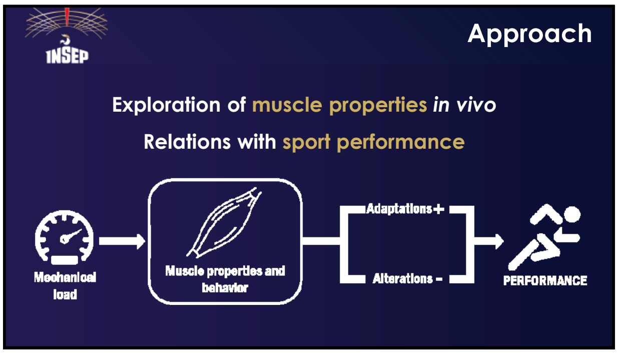

To better understand muscle-tendon interactions: a mean to better train?
G. Guilhem
Laboratoire Sport, Expertise et Performance (EA 7370)
INSEP


INSEP
Memories in 'Chambé'
7 € EUROS
START 20H00
S.O.C HOCKEY SUR GLACE
SAMEDI 4 OCTOBRE
Chambéry encore en rodage


INSEP
PhD project started in Chambéry
Sports Biomechanics
Reliability of the force-velocity-power variables during ice hockey sprint acceleration
Jerome Perez, Gaël Guilhem & Franck Brocherie


EUROSPORT


FLEXOR STRETCH
KNEE DRIVE
SECOND STEP
HIGH
FLAT
FASTEST
BOLT
GAY
60M
TENSE MOVEMENT
FLUID MOVEMENT
NON-PERFECT BODY LINE
OPTIMAL BODY LINE
LOWER KNEE LIFT
HIGHER KNEE LIFT
LARGE BRAKING EFFECT
SMALL BRAKING EFFECT
BOLT
GAY

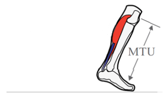

INSEP
Approach
Exploration of muscle properties in vivo
Relations with sport performance
Mechanical load
Muscle properties and behavior
Adaptations +
Alterations -
PERFORMANCE

Roadmap

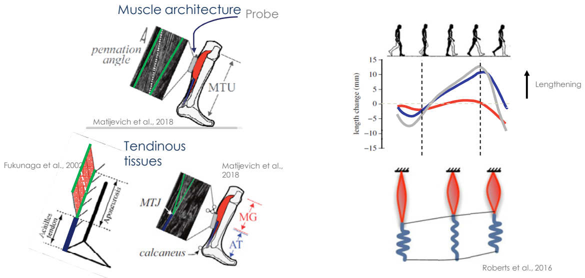
1. Muscle-tendon interactions and **explosive performance**
2. Muscle-tendon interactions and **power attenuation**
3. Muscle-tendon properties and **injury**
4. **Muscle coordinations**, performance and injury

Muscle-tendon interactions

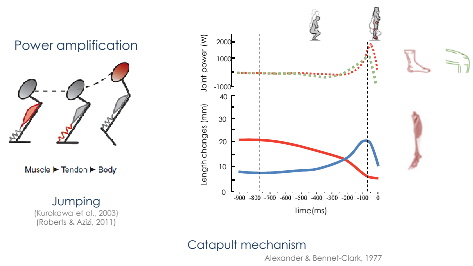
Muscle architecture



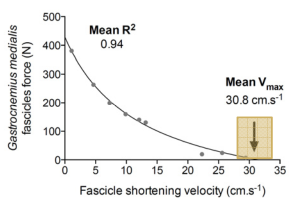
Muscle-tendon interactions



Muscle-tendon interactions during dynamic conditions



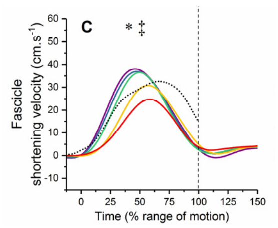
Evaluation of fascicle maximal velocity



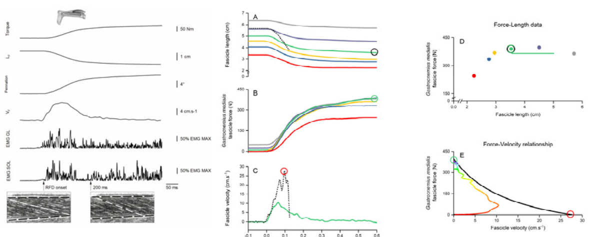
Edman's Slack Test applied in vivo

Edman 1979 J Physiol; Sasaki & Ishii 2005 J Physiol
Hager et al. 2018 J Exp Biol

Fascicle shortening during slack test

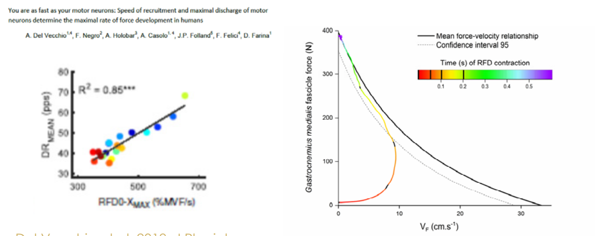


Fascicle shortening during RFD



Hager et al. In revision in J Appl Physiol

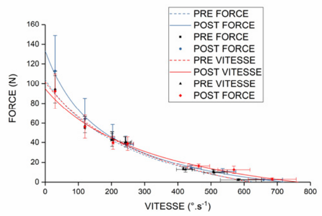
Fascicle shortening during RFD



Del Vecchio et al. 2019, J Physiol

Training-effect on FV relationship

Training protocol
12 weeks – 30 sessions
Plantarflexions
2 groups: FORCE vs VELOCITY
FORCE: 10 × 5s MVC
VELOCITY: 10 × 10 No load
ballistic contraction



Training-effect on fascicle FV relationship

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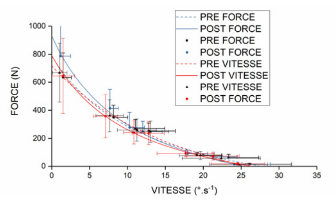
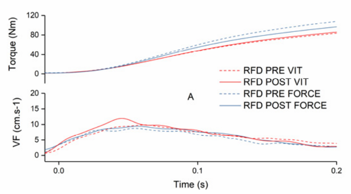
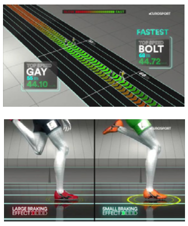


Training-effect on fascicle dynamics

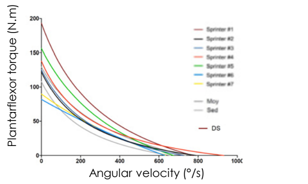
Training protocol
12 weeks
Plantarflexions
2 groups: FORCE vs VELOCITY
FORCE: 10 × 5s MVC
VELOCITY: 10 × 10 No load
ballistic contraction



Training-effect on fascicle dynamics



Relations between contractile and elastic properties, and maximal velocity in sprint running



SPRINTCH project, contract n°14i09
MsC of C. Lecomte, F. Moneger
Main investigators: Dr G. Rabita, Dr G. Guilhem

Arampatzis et al 2007 J Biomech
Weyand 2010 J Appl Physiol
Kubo et al 2000 Acta Physiol Scand

Key takeaway

- There is **no direct method to assess fascicle Vmax** in vivo
- **Tendinous tissues play a major role** in preactivated maximal dynamic contractions
- **FV properties present a limiting factor** for the rapid force-generating capacity 100 ms after RFD onset
- **Fascicle FV relationship is sensitive to training stimulus**, with consistent repercussions on RFD time-course

Roadmap

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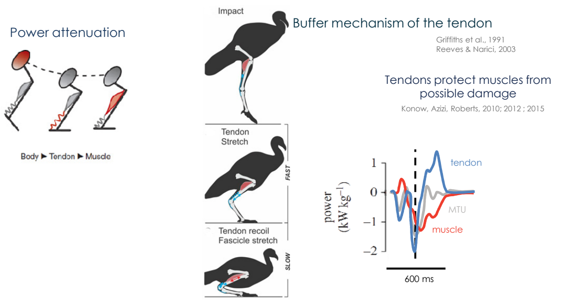
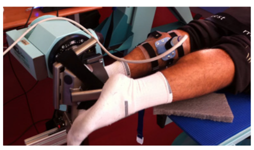
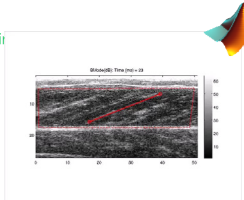
Energy dissipation: the key role of tendons



Muscle mechanics in eccentric contractions

High-frame ultrasound
Automatic muscle fascicle tracking

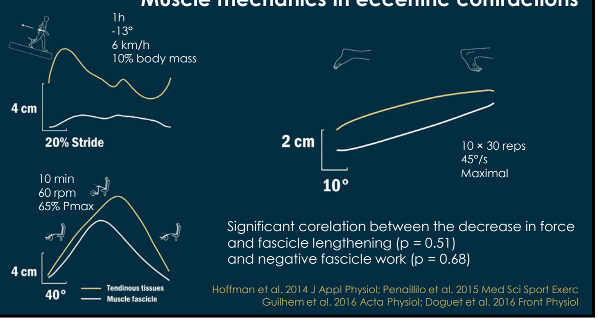




Cronin et al 2011 J Appl Physiol

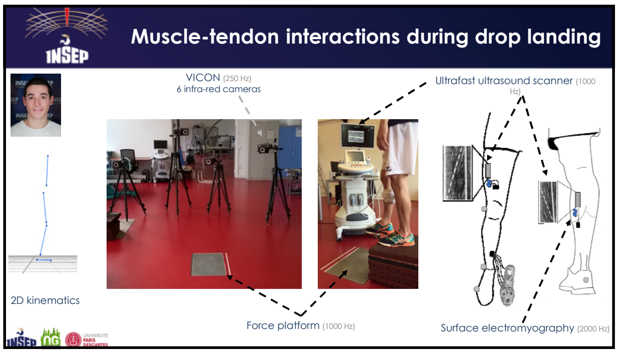
Cronin & Lichtwark 2013, Gait & Posture; Farris et al. 2016; Grieve, 1972

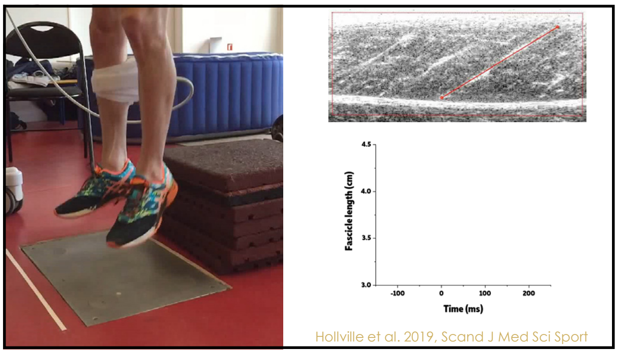
Muscle mechanics in eccentric contractions

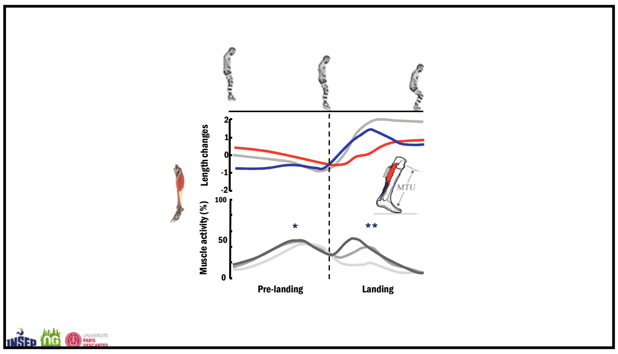


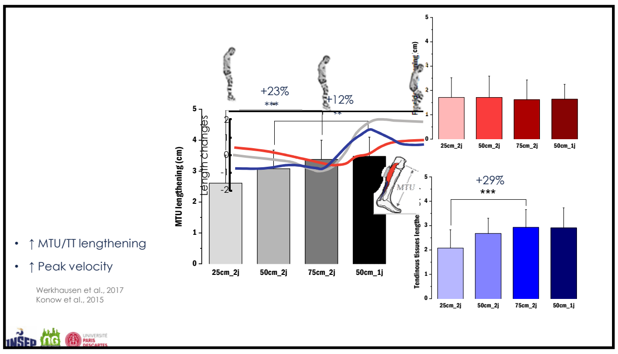
Significant corelation between the decrease in force and fascicle lengthening (p = 0.51) and negative fascicle work (p = 0.68)

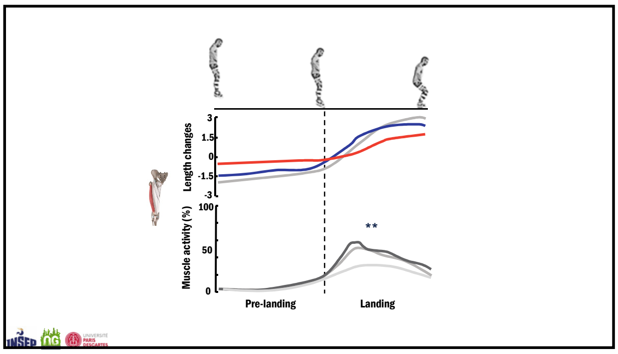
Hoffman et al. 2014 J Appl Physiol; Penailillo et al. 2015 Med Sci Sport Exerc
Guilhem et al. 2016 Acta Physiol; Doguet et al. 2016 Front Physiol

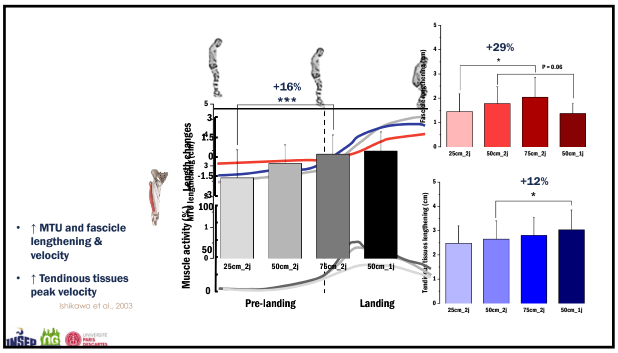

Muscle-tendon interactions during drop landing
VICON (250 Hz)
6 infra-red cameras
Ultrafast ultrasound scanner (1000 Hz)
2D kinematics
Force platform (1000 Hz)
Surface electromyography (2000 Hz)


Fascicle length (cm)
Time (ms)
Hollville et al. 2019, Scand J Med Sci Sport


Length changes
Muscle activity (%)
MTU
Pre-landing
Landing


• ↑ MTU/TT lengthening
• ↑ Peak velocity
Werkhausen et al., 2017
Konow et al., 2015
+23%
+12%
+29%
MTU lengthening (cm)
Tendinous tissues lengthening
25cm_2j
50cm_2j
75cm_2j
50cm_1j


Length changes
Muscle activity (%)
Pre-landing
Landing


• ↑ MTU and fascicle lengthening & velocity
• ↑ Tendinous tissues peak velocity
Ishikawa et al., 2003
+16%
+29%
+12%
P = 0.06
25cm_2j
50cm_2j
75cm_2j
50cm_1j
Pre-landing
Landing

Key takeaway

- **Fascicle negative work is related to the amount of decrease in force** subsequent to eccentric contractions
- Power attenuation is achieved through **adjustment in fascicle-tendon interactions to withstand mechanical demand**
- **Tendinous tissues act as shock absorbers** by rapidly stretching and storing elastic energy, which is then released to the fascicles and dissipated through active muscle lengthening

Roadmap

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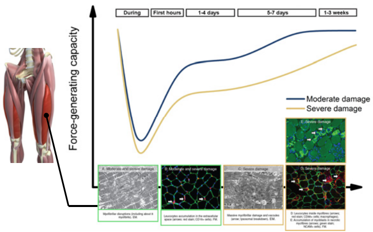
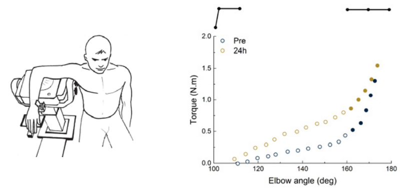
Exercise-induced muscle damage



Paulsen et al 2012 Exerc Immunol Rev

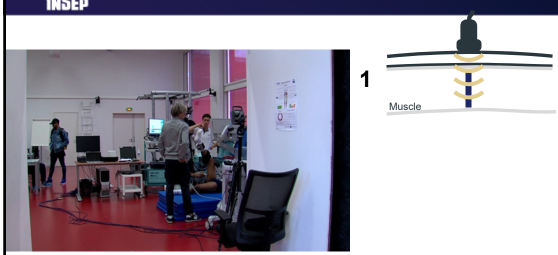
Passive torque as an index of stiffness



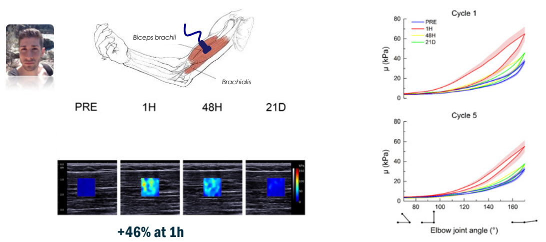
Composite contributions (tendons, ligaments, capsule, skin, synergist muscles) - Does not dissociate individual muscles

Howell et al 1993 J Physiol; Proske & Morgan 2001 J Physiol; Herbert et al. 2007 J Exp Biol

Shear Wave Elastography

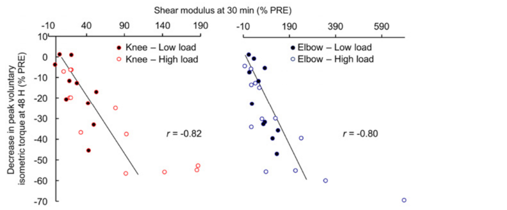


Impact of damage on muscle stiffness



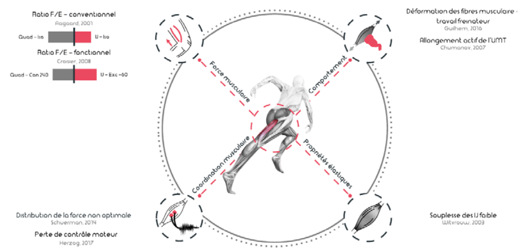
Green et al 2012 NMR Biomed; Yanagaswa et al. 2015 Springerplus
Andonian et al 2016 PLoS One; Lacourpaille et al 2014 Acta Physiol

Non-invasive evaluation of EIMD

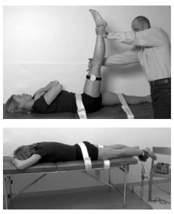


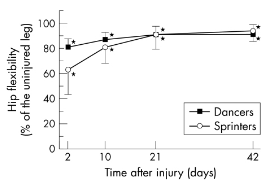
Lacourpaille et al 2017 Eur J Appl Physiol

Risk of injury



Flexibility and injury





Askling et al. 2007, Brit J Sport Med

Poor predictive value

The American Journal of Sports

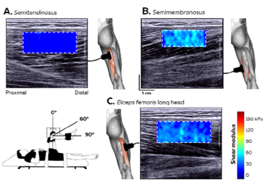
The American Journal of Sports Medicine

A comprehensive strength testing protocol offers no clinical value...

Isokinetic strength assessment offers limited predictive validity for detecting risk of future hamstring strain in sport: a systematic review and meta-analysis

Brady Green, Matthew N Bourne, Tania Pizzari

Hamstring elasticity



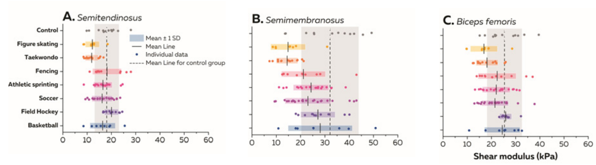
Elasticity and injury

- Study 1 : Impact elite sport
- Study 2 : Relation between muscle elasticity and injury
- Study 3 : Post-rehab restoration of muscle elasticity

7 Sports

113 Athletes

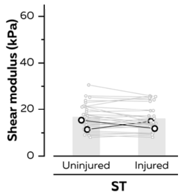
Shear modulus and sport



- Differences between muscles
- Shear modulus sensitive to sport

Avrillon et al. In revision in Scand J Med Sci Sport

Shear modulus and injury



- No impact of injury on muscle shear modulus (average post-injury measurements = 16 months)

Key takeaway

- Damaging exercise elicit an **immediate increase in shear modulus**
- The increase in shear modulus can be used as **a non-invasive index** of exercise-induced **decrease in muscle force**
- Shear modulus is **sport- and muscle head-dependent** within hamstrings
- Hamstring strain injury **does not induce long-lasting (> 1 year) changes in muscle elasticity**

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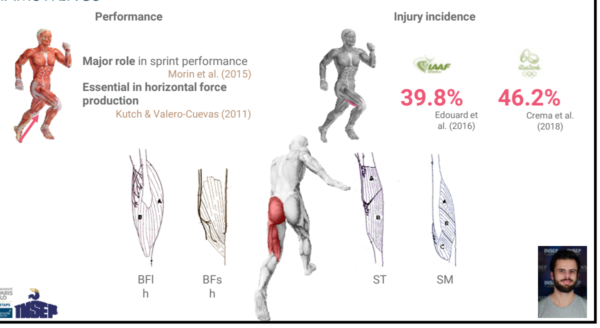
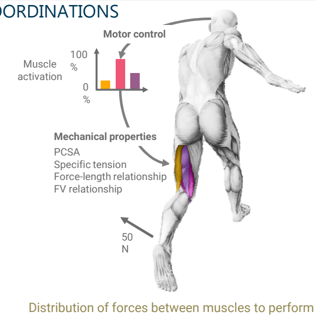
HAMSTRINGS



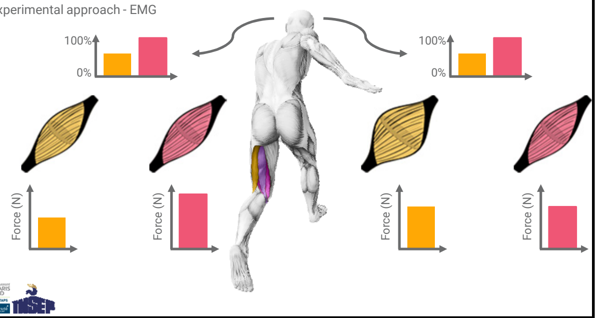
MUSCLE COORDINATIONS



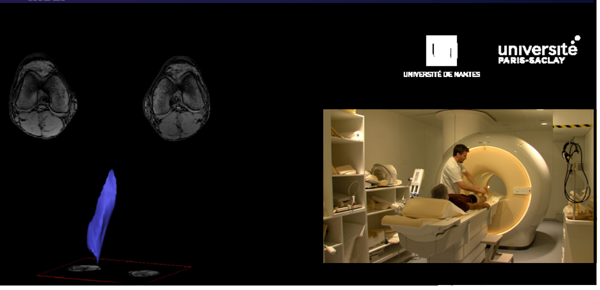
Distribution of forces between muscles to perform a given task

ESTIMATION OF MUSCLE COORDINATIONS

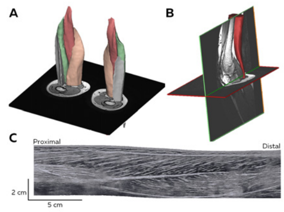
Experimental approach - EMG



Coordinations & performance



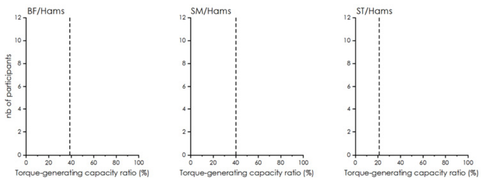
Coordinations & performance



Force index = EMG amplitude × PCSA × moment arm

Avrillon et al. 2018, J Appl Physiol

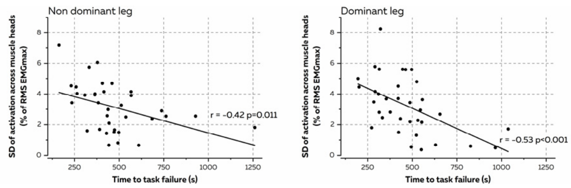
Coordinations & performance



High variability between individuals

Avrillon et al. 2018, J Appl Physiol

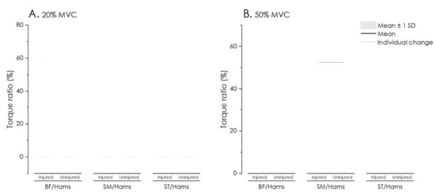
Coordinations et performance



Relationship between individual-specific activation strategies and performance

Avrillon et al. 2018, J Appl Physiol

Impact de la blessure



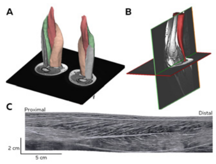
↓ Contribution of injured muscle (BF)

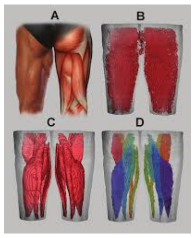
↑ Contribution of SM

Applications?

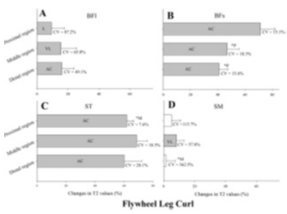
Applications?

Muscle ID





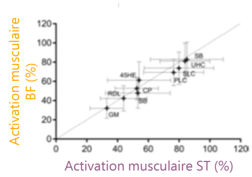
Muscles to target in training



- Training individualization

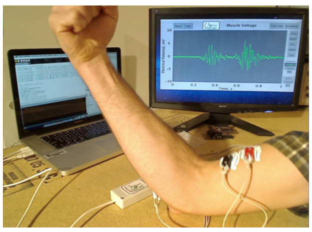
Mendez-Villanueva et al. 2016

Muscles to target in training



Hegyi et al. (2018)

Biofeedback?



- Effectiveness of instructions provided to the athlete

Release painful muscle?

- Exercises dedicated to enhance muscle control
- Psychological interventions
- Manual therapies
- ‘Tapping’

Hodges, 2011; Cowan et al. 2002