Inserm U1093

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

Changes in corticospinal excitability after whole body exercise

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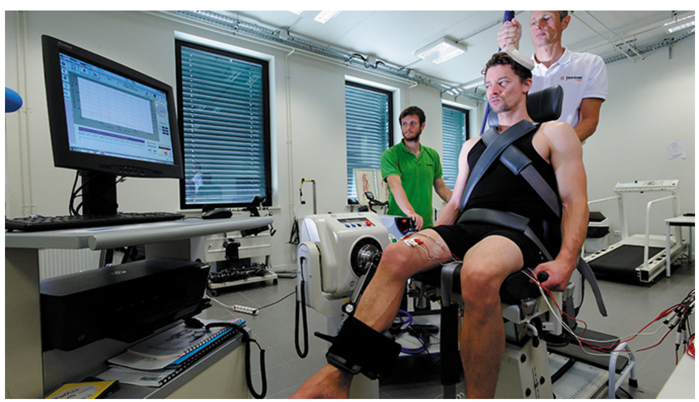
ActiFS Activité Physique Fatigue Santé

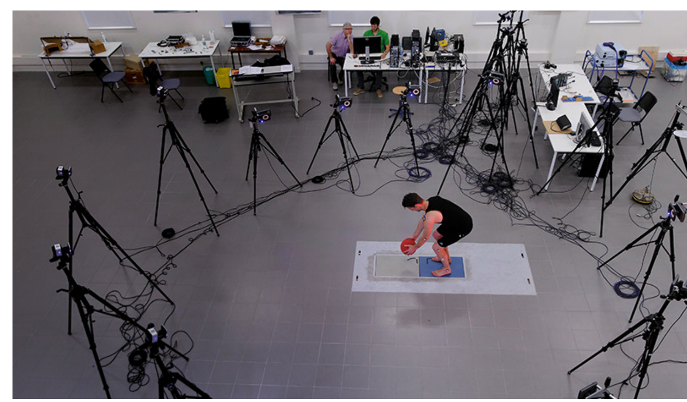
04 Avril 2019

Presentation

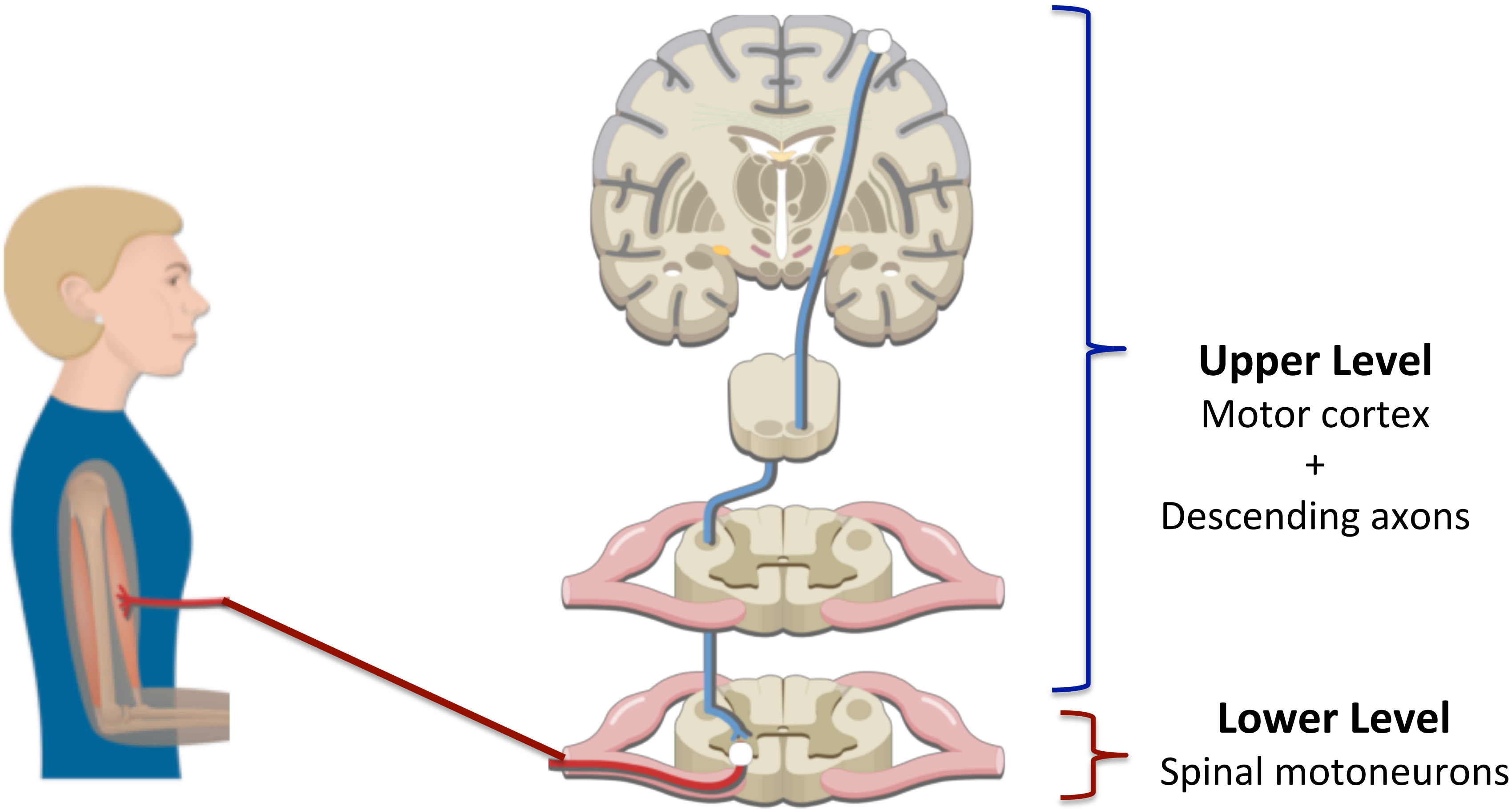
Dijon-Le Creusot
2100 students
(1500 Licence, L1 : 694)

Laboratory : **INSERM U 1093 – CAPS**
Cognition Action & Plasticité Sensorimotrice
(6 PU, 13 MCU, 8 PU-PH, 4 INSERM/CNRS, 4 IE, 18 PhD students)



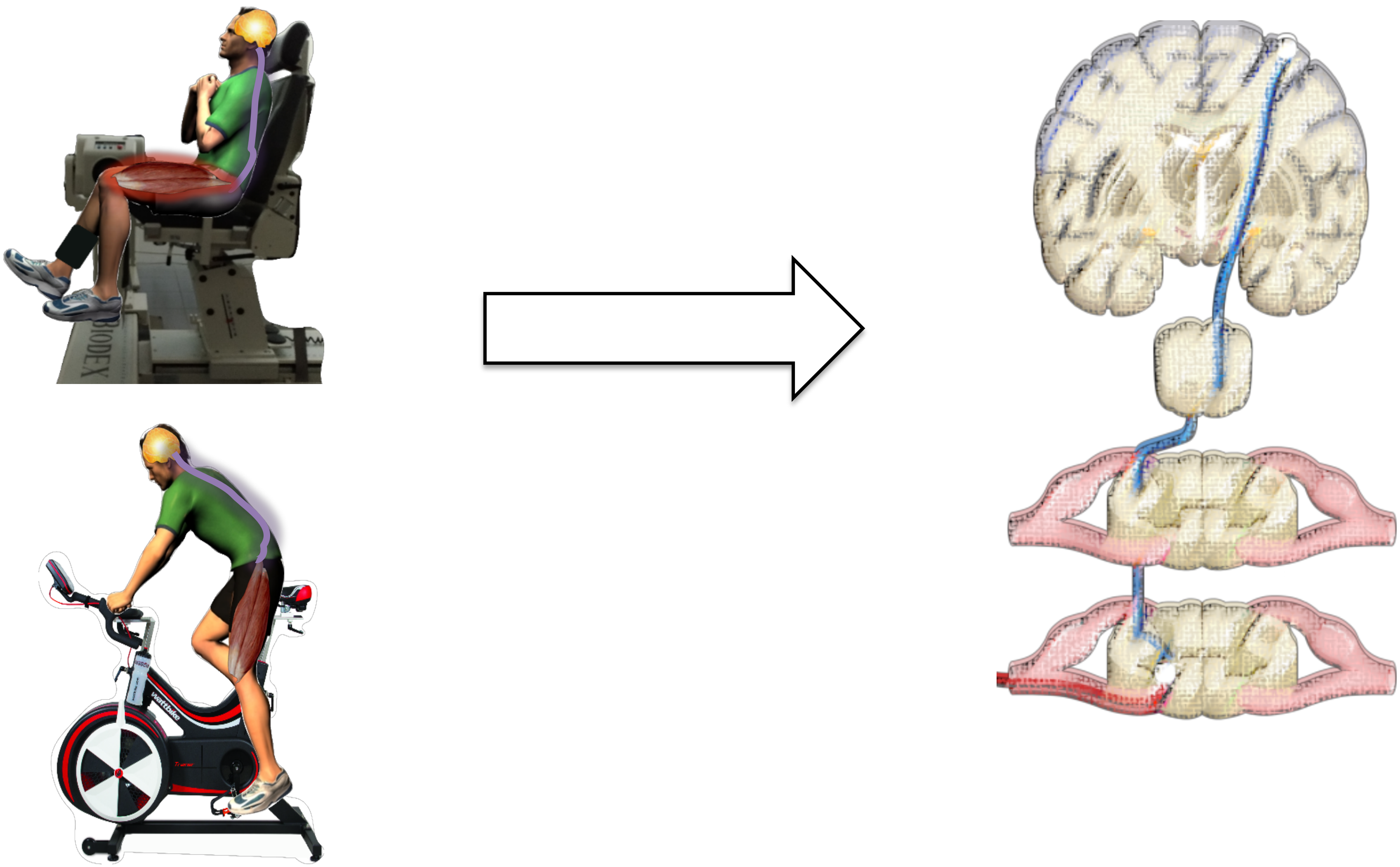


Corticospinal (CS) motor pathway

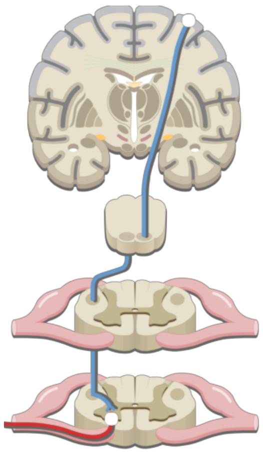


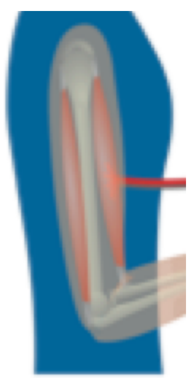
Exercise

Alterations of
CS efficacity (excitability)



Alterations of Corticospinal excitability





↓ CS excitability

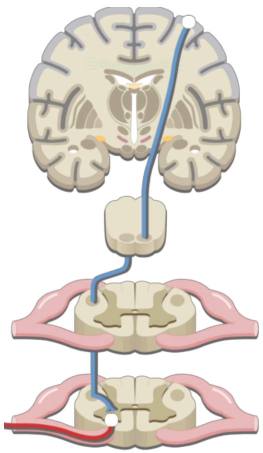
+

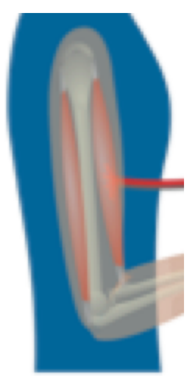
↑ Input into the motor cortex and/or spinal motoneuron (greater central motor drive)

⇩

Muscle activation = Cste

Alterations of Corticospinal excitability





↓ CS excitability

+

~~↑ Input into the motor cortex and/or spinal motoneuron (greater central motor drive)~~

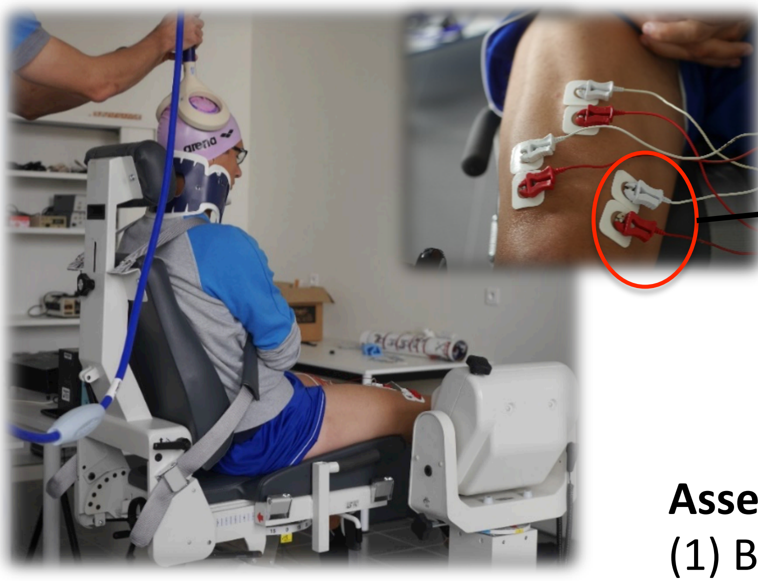
⇩

↓ Muscle activation

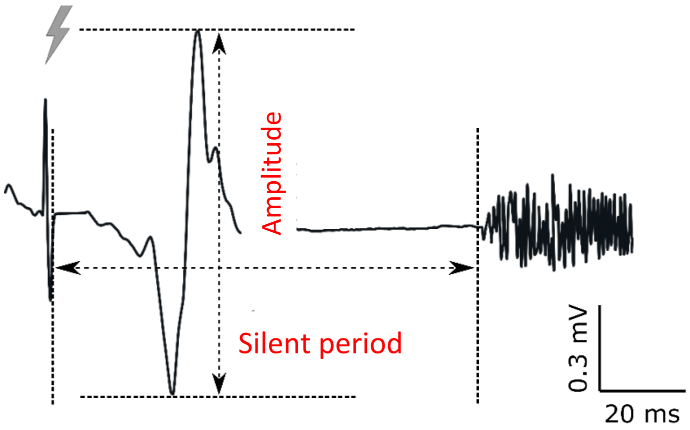
Central Fatigue

How to evalutate the corticospinal excitability ?

Transcranial magnetic stimulation (TMS)



Motor-evoked potential (MEP)



Assessment - 3 different types of contraction :

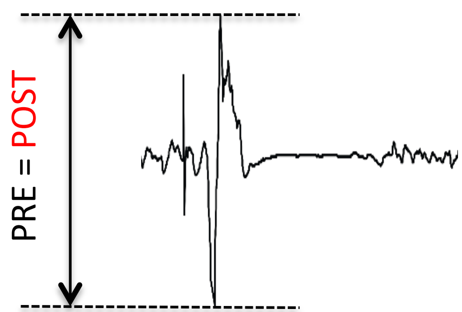
(1) Brief submaximal constant force contractions

(2) Brief constant EMG contractions

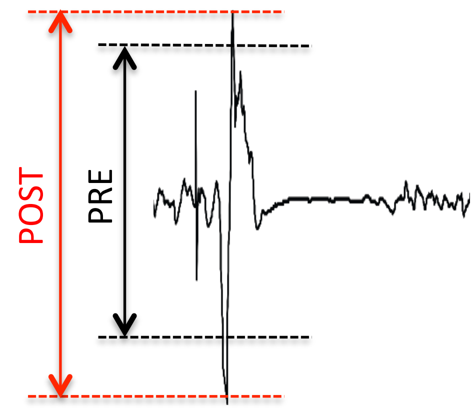
(3) Brief contractions of a given relative intensity (% MVC)

Corticospinal excitability changes after prolonged whole body exercise

MEP =



MEP ↗



Girard et al. (2013)
(MVC: -11%)

O'Leary et al. (2016)
(MVC: -9%)

Fernandez del Olmo et al. (2013)
(MVC: -17%)

Jubeau et al. (2014)
(MVC: -25%)

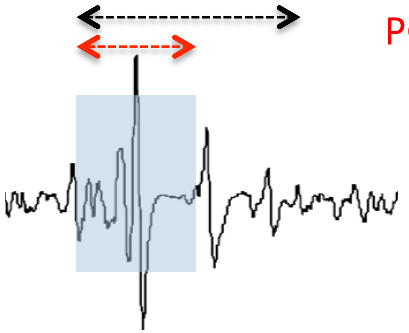
Temesi et al. (2014)
(MVC: -34%)

?

Magnitude of neuromuscular fatigue ↔ Corticospinal excitability

Corticospinal silent period changes after prolonged whole body exercise

CSP ↘



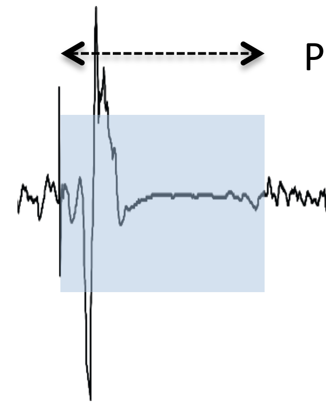
POST < PRE

MEP =

O'Leary et al. (2016)

(MVC: -9%)

CSP =



PRE = POST

MEP ↗

Fernandez del Olmo et al. (2013)

(MVC: -17%)

Jubeau et al. (2014)

(MVC: -25%)

Temesi et al. (2014)

(MVC: -34%)

NO CONSENSUS

Characteristics of an (whole body) exercise training ?

Duration

Type

Intermittent, Continuous

Intensity

Mode of contractions

Isometric, Dynamic
Concentric /Eccentric

Characteristics of an (whole body) exercise training ?

Duration

Type

Intermittent, Continuous

Intensity

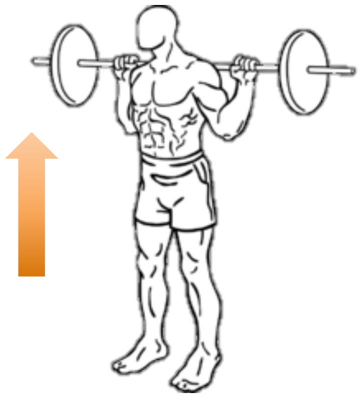
Mode of contractions

Isometric, Dynamic
Concentric /Eccentric

Mode of contractions

Concentric versus eccentric

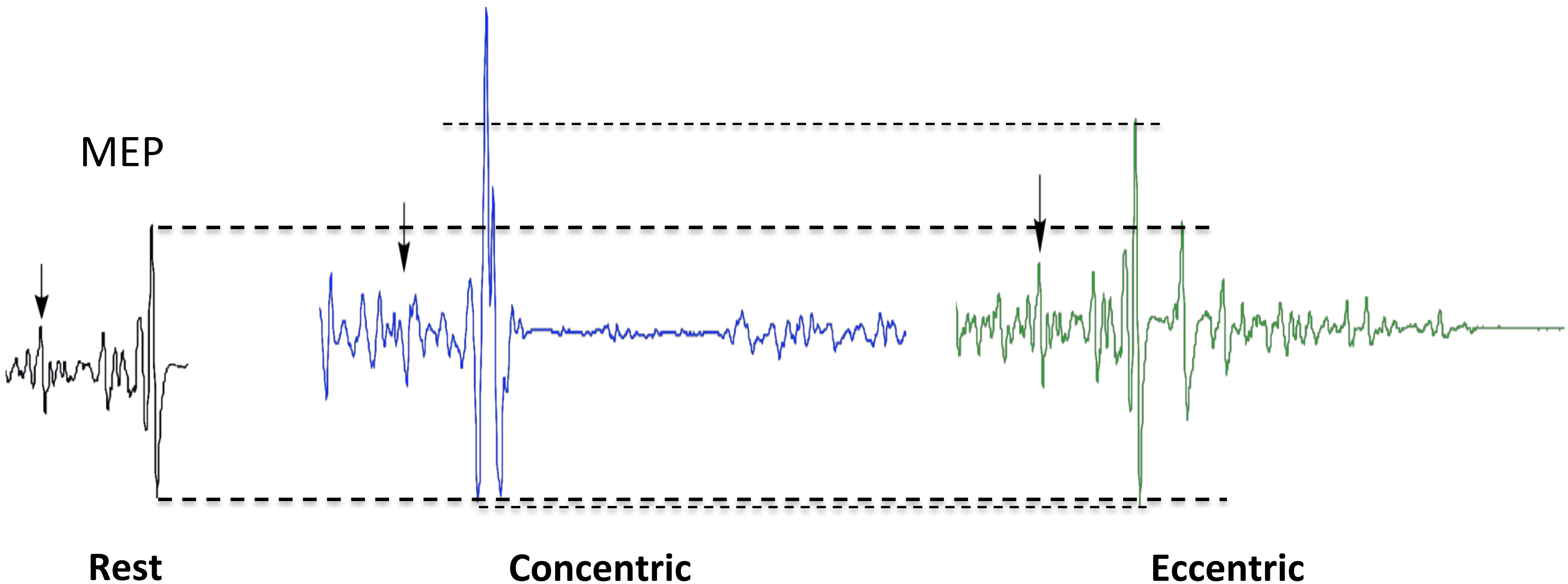
Knee extensor muscles



Concentric

Eccentric

Mode of muscle contraction and corticospinal excitability



↑++ MEP amplitude

↑++ Cortical silent period (CSP)

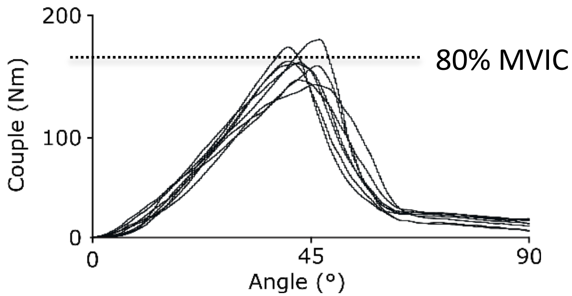
↑+ MEP amplitude

↓CSP

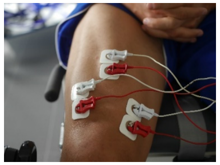
(Duclay et al. 2014)

Mode of muscle contraction and fatigue interactions in corticospinal excitability : <u>Single-joint exercise</u>

- ✓ 12 subjects (age: 28 ± 8 yrs)
- ✓ 10 × 10 contractions
- ✓ 30 s rest between set
- ✓ Velocity : + 60°.s^{-1} (concentric) or -60°.s^{-1} (eccentric)
- ✓ Intensity : 80% MVIC ; <u>same total work</u>

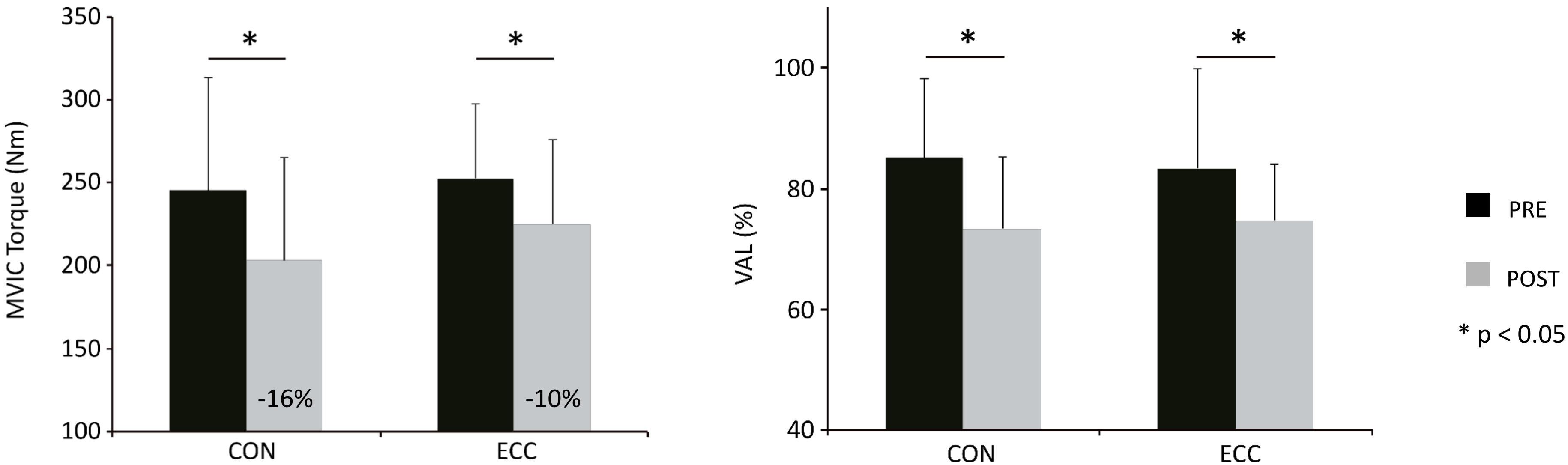


Measurements PRE/POST : MVC, VAL, Dt, MEP, CSP



Garnier et al. (2019)

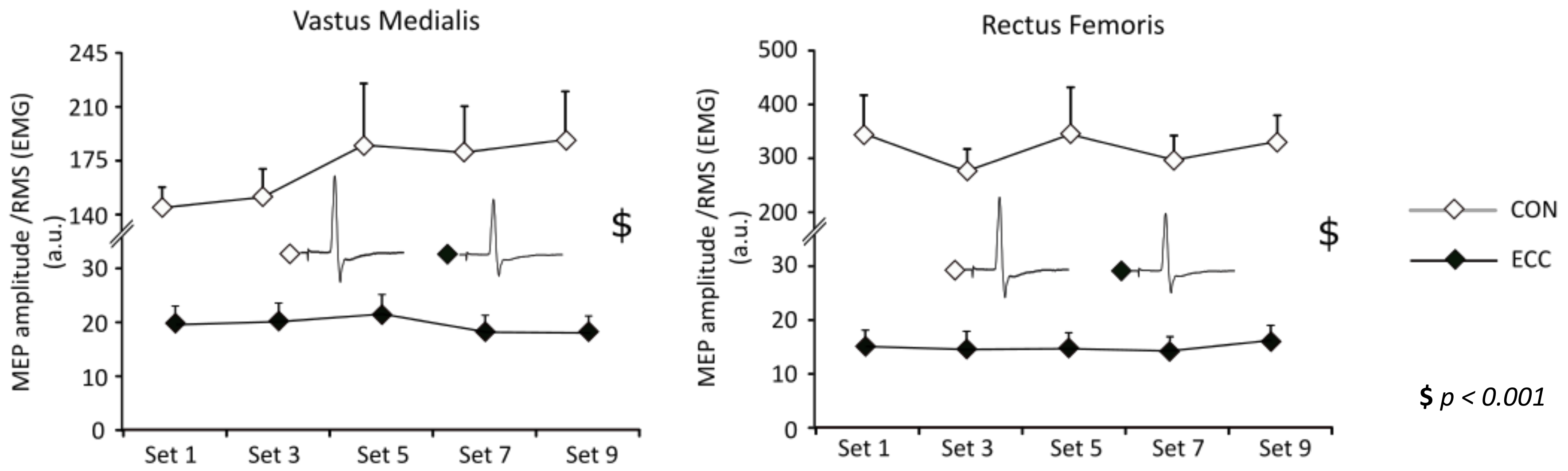
Level of neuromuscular fatigue



•Similar peripheral fatigue after both exercises

Matched total muscular work ➔ Similar level of muscle fatigue

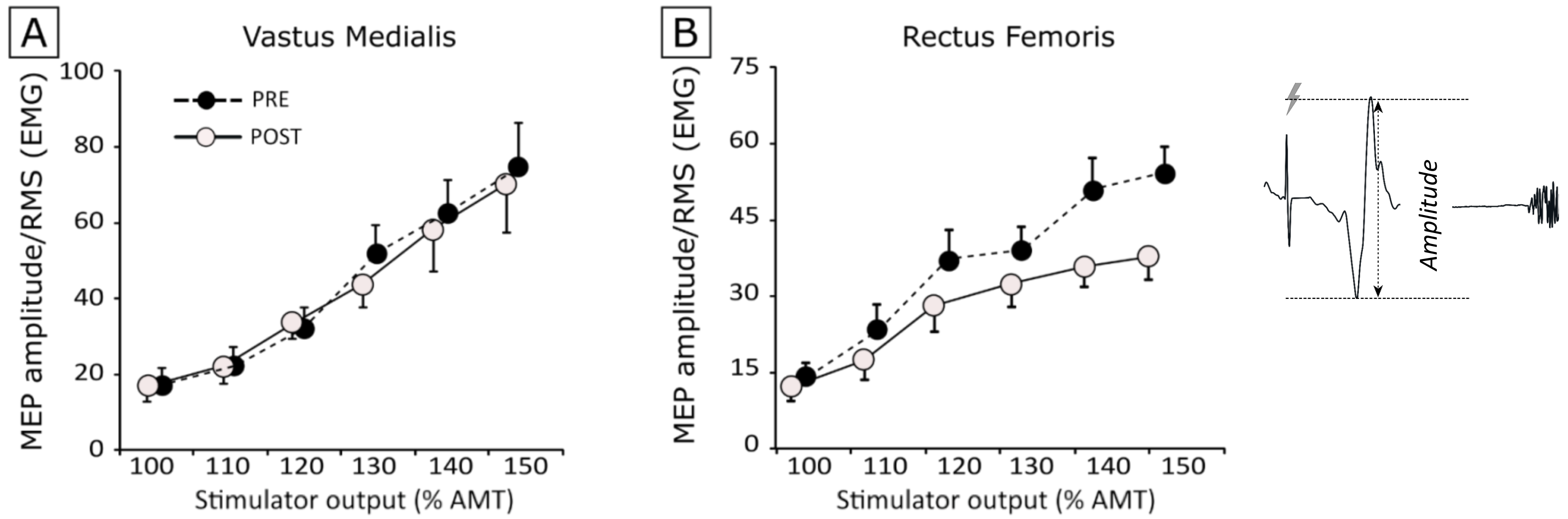
Corticospinal excitability during the fatiguing exercise



No change of CS excitability during exercise

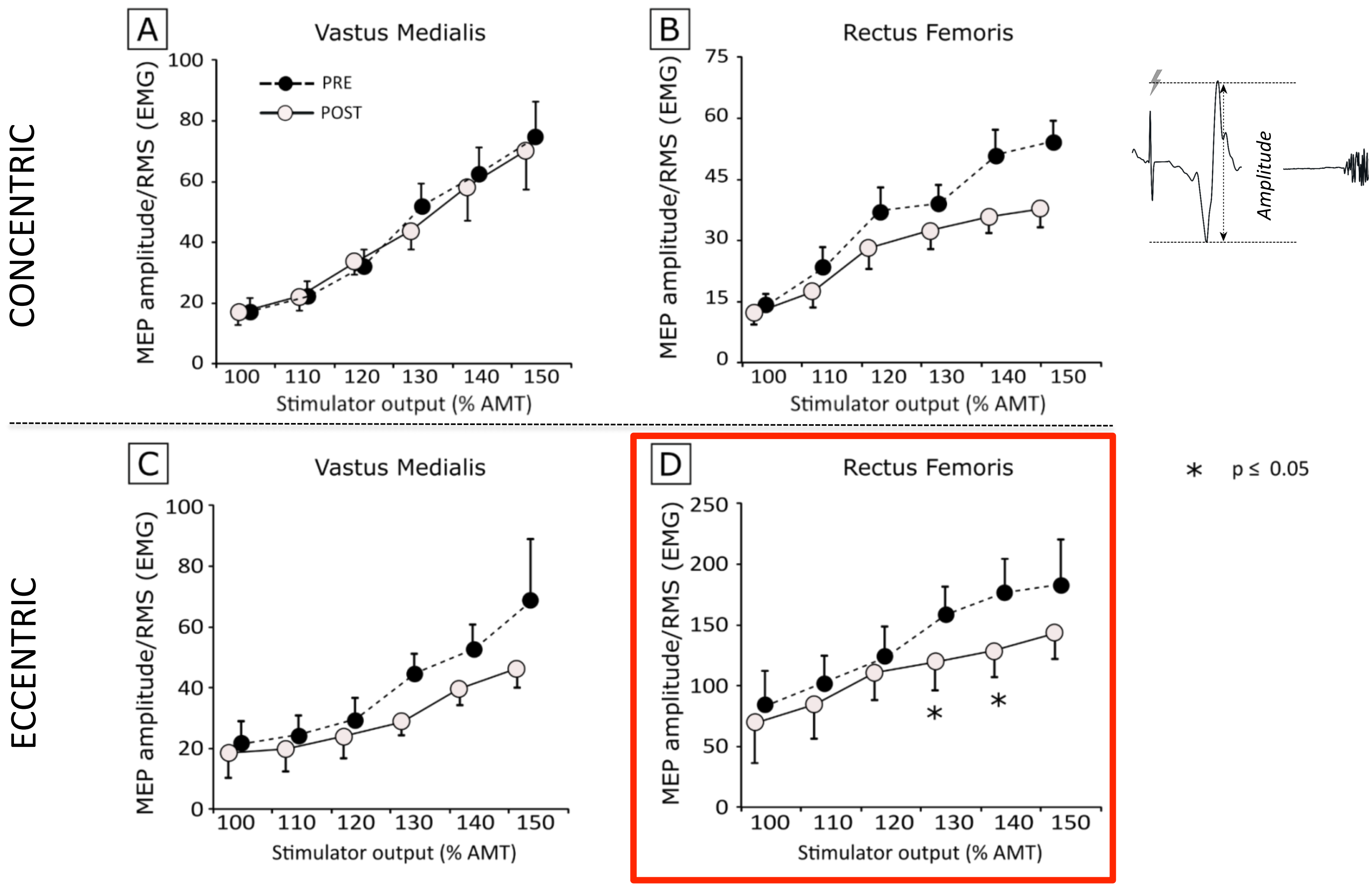
Corticospinal excitability <u>after</u> exercise

CONCENTRIC



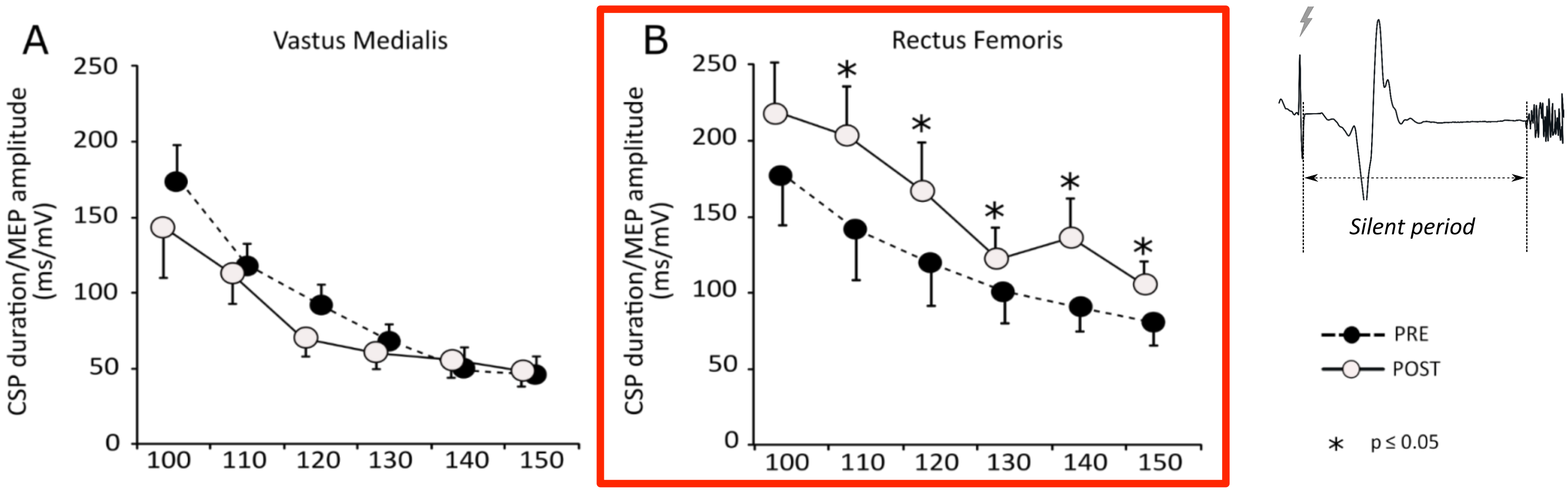
No significant changes

Corticospinal excitability after exercise

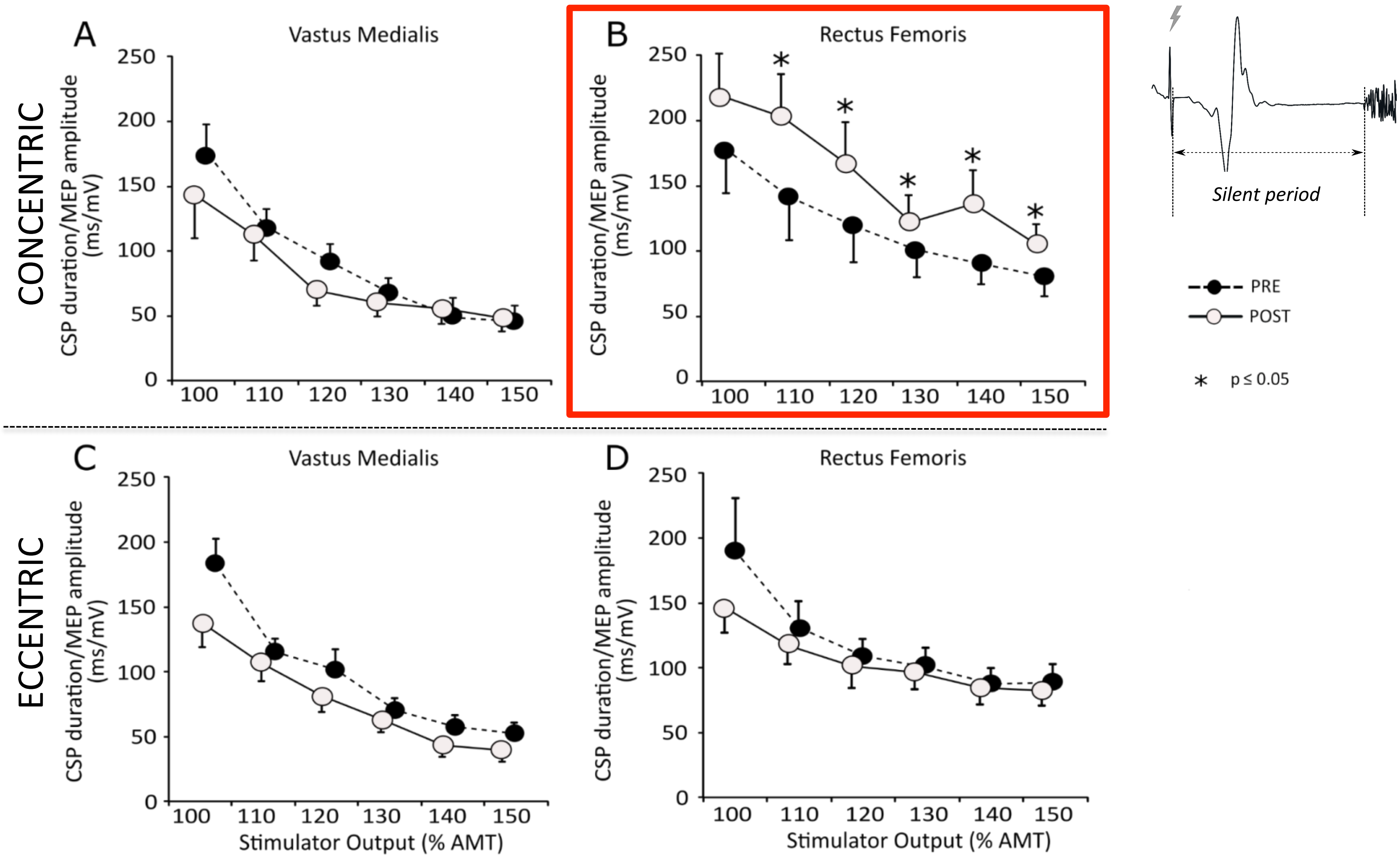


Cortical Silent Period after exercise

CONCENTRIC



Cortical Silent Period after exercise



Mode of muscle contraction and fatigue interactions in corticospinal excitability : Single-joint exercise

Summary

☑ No difference in the amount and etiology of fatigue induced for a similar workload

☑ Lower CS excitability during eccentric exercise

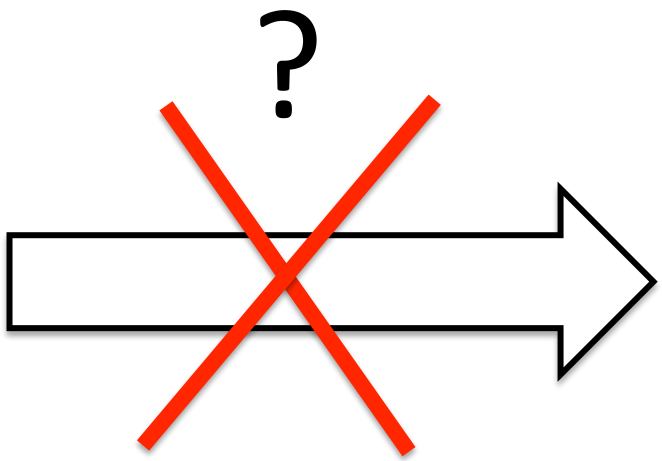
☑ Specific modulations for RF muscle after exercise (MEP amplitude and CSP)

➔ RF bi-articular muscle → Control of joint torque ?

From single-joint exercise to whole body exercise

Single-joint exercise

Isometric & dynamic



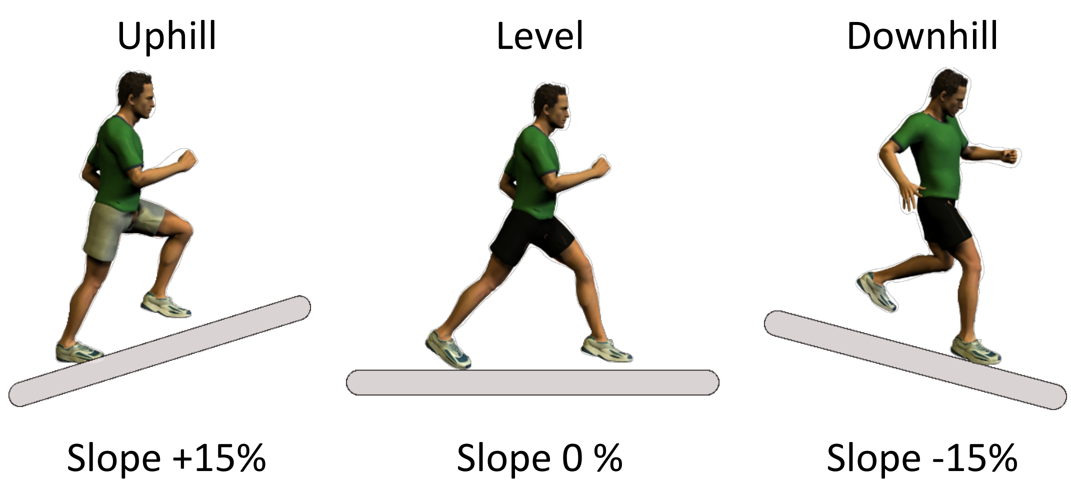
Whole body exercise

≠

mucle mass, muscular work,
arterial pressure, heart rate,
hydratatus status, …

Mode of muscle contraction and fatigue interactions in corticospinal excitability : <u>Running</u> exercise

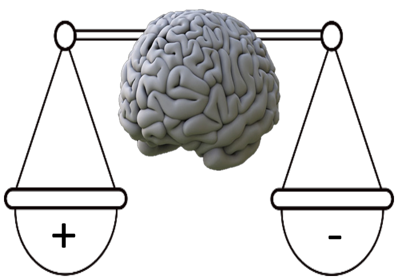
- 11 healthy volunteers (age = 26 ± 7 years; VO_{2max} = 58 ± 6 $ml.min^{-1}.kg^{-1}$)
- 3 conditions : 45-min treadmill exercise / 75% HRr



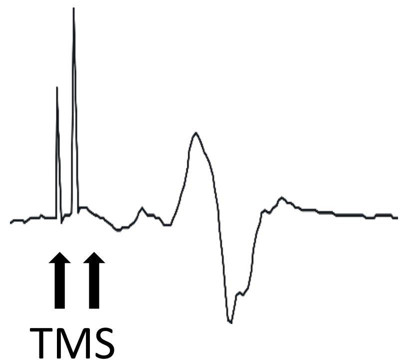
Measurements PRE/POST : MVC, VAL, Dt, MEP, CSP, SICI

Garnier et al. (under revision)

Short-Interval Cortical Inhibition (SICI)



Ridding et al. (1999)



(Kujirai et al. 1993)

$$\text{SICI} = \frac{\text{Conditionned MEP Size}}{\text{Unconditionned MEP Size}}$$

Ratio ↓	=	Inhibition ↑
Ratio ↑	=	Inhibition ↓

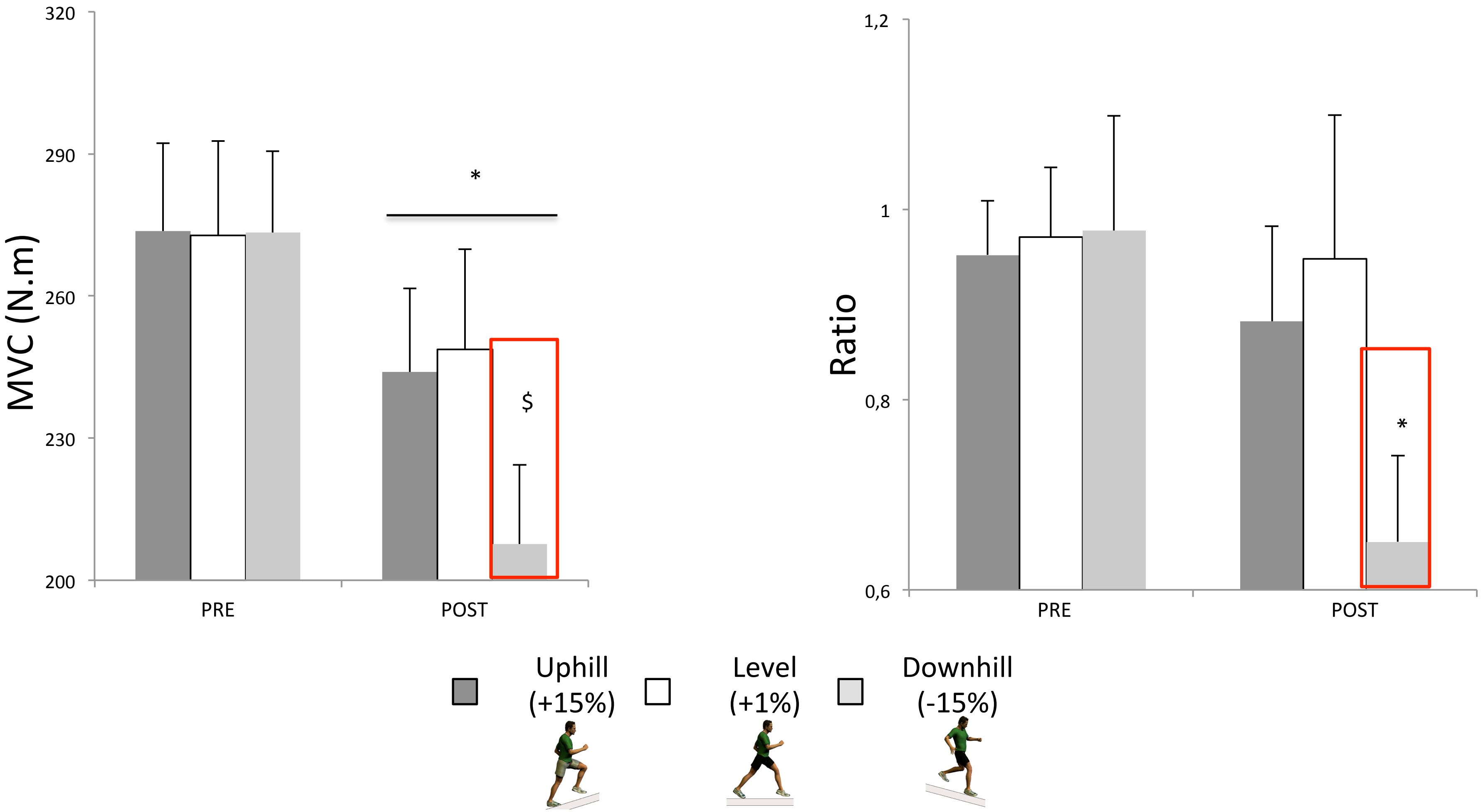
<u>*Examples :*</u>

↘ SICI with muscle damages *(Pitman et al., 2012)*

↗ SICI after severe intensity exercise (92% VO_{2max}) *(O'Leary et al., 2015)*

= SICI after moderate intensity exercise (52% VO_{2max}) *(O'Leary et al., 2015)*

Maximal Voluntary Isometric Contraction **Dt10 Hz / Dt100 Hz torque**

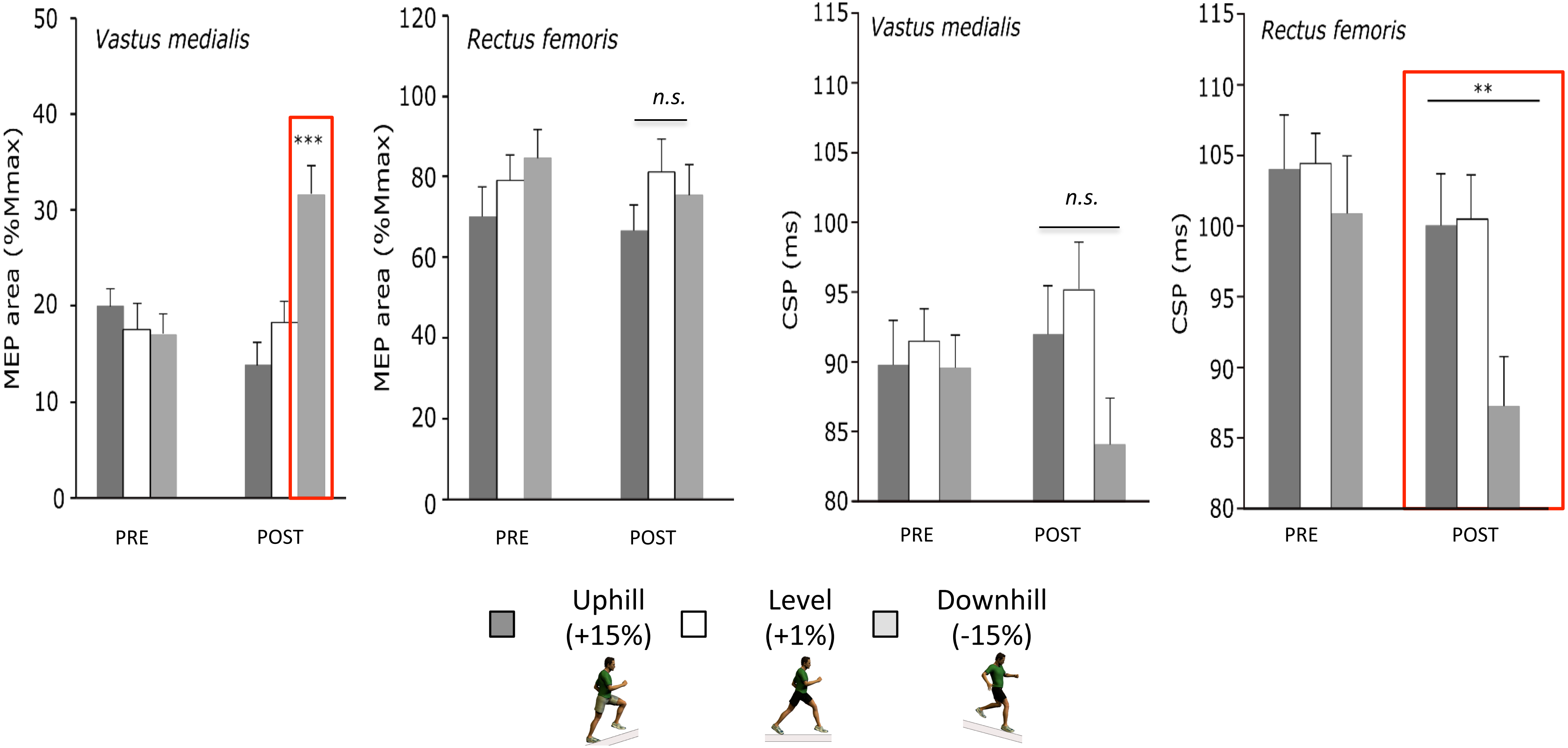


Downhill ➔ Greater muscle fatigue (peripheral)

* Significantly different from PRE , $ significantly different from all other conditions (*p < 0.001*)

MEP Area

Cortical Silent Period

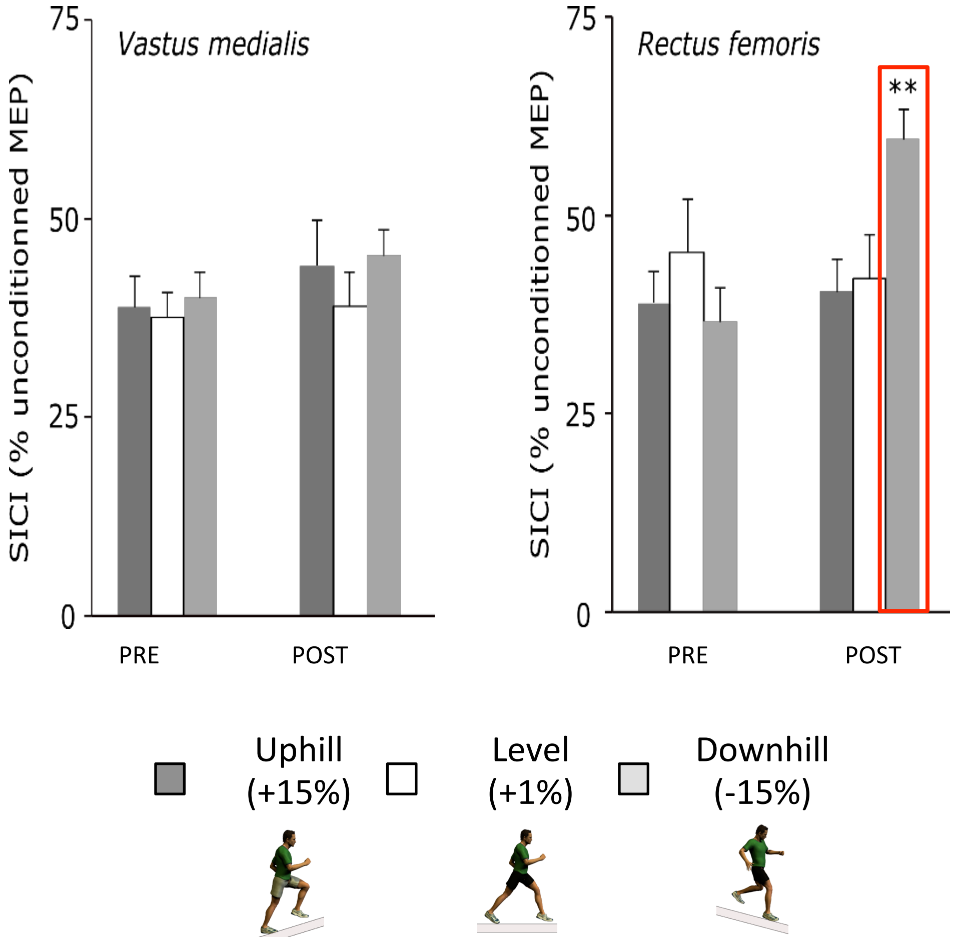


Downhill exercise :

VM muscle : MEP ↗ and CSP = Cste

RF muscle : MEP = Cste and CSP ↘

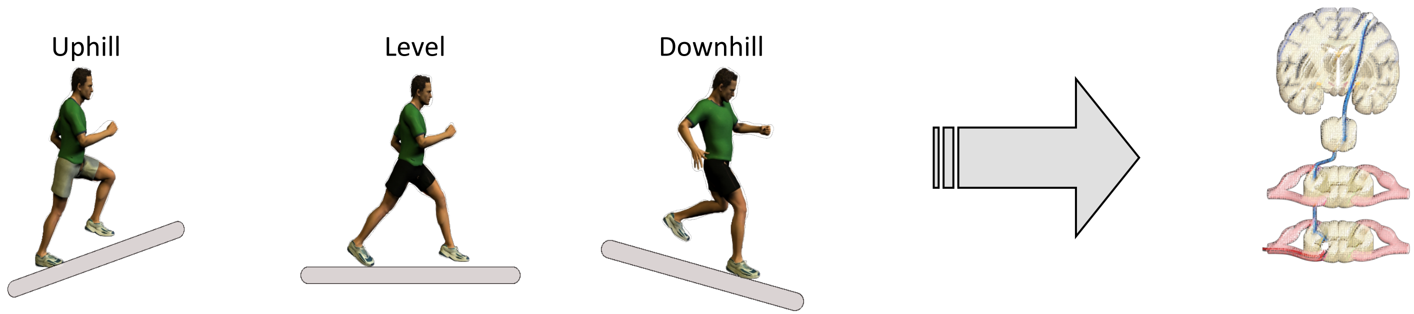
Short-Interval Cortical Inhibition



Ratio ↑ = Inhibition ↓

VM muscle : Inhibition does not change
RF muscle : Inhibition ↘

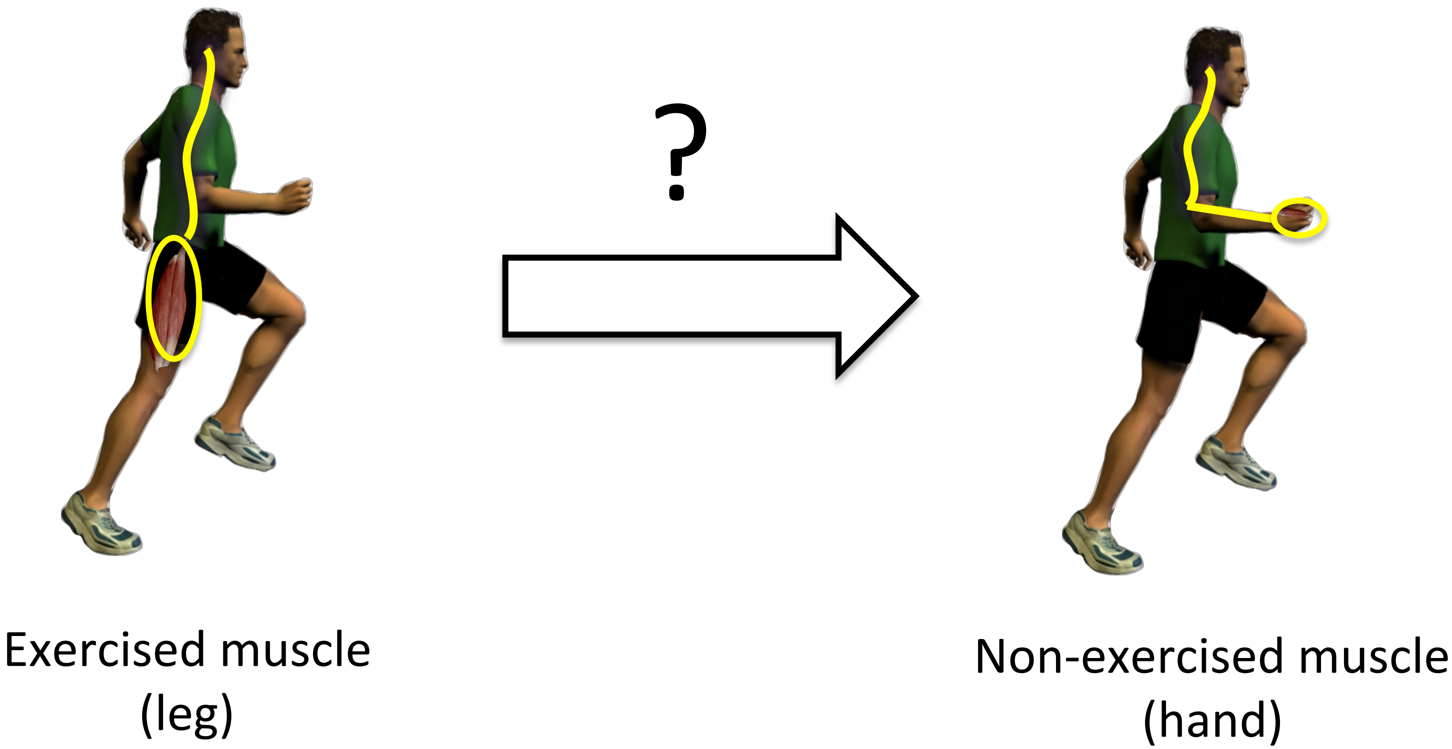
Mode of muscle contraction and fatigue interactions in corticospinal excitability : Running exercise



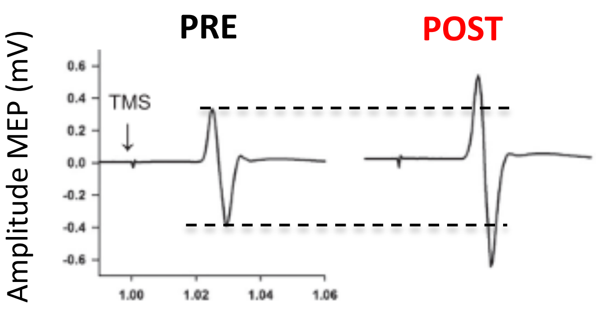
Summary

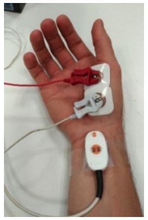
- ☑ Greater peripheral alterations after downhill treadmill exercise
- ☑ Corticospinal excitability and inhibition changes after downhill
- ☑ Cortical inhibition changes after downhill (RF muscle)

Changes in corticospinal excitability after whole body exercise

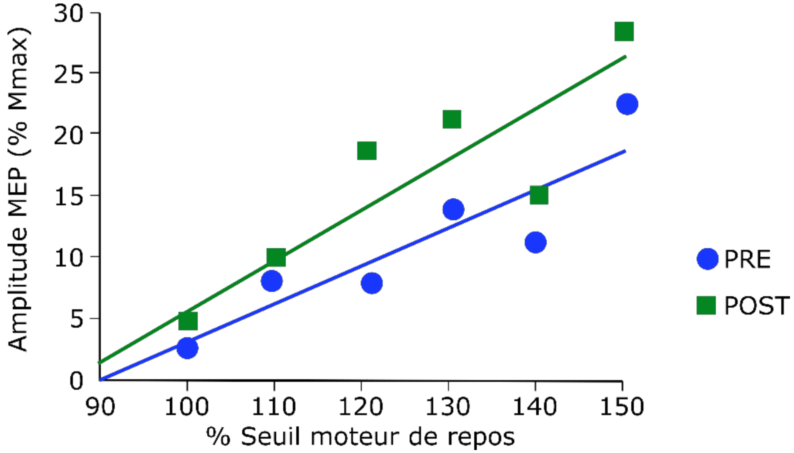


Changes in corticospinal excitability after whole body exercise (non-exercised muscle)





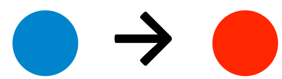
Paired associative stimulation (PAS)

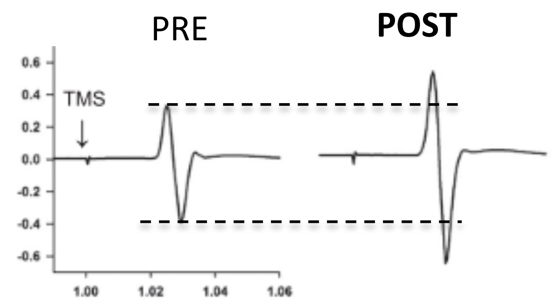


(McDonnell et al., 2013, Singh et al., 2014)

Paired associative stimulation (PAS)

PAS : Increases CS excitability





Example **PAS 25**
200 paired stimuli (0.25 Hz, 15 min) of median nerve electrical stimulation followed by transcranial magnetic stimulation of the hand M1 area (ISI 25 ms)

(Stefan et al., 2000)

Changes in cortico-spinal excitability following uphill versus downhill treadmill exercise (**non-exercised muscle**)

N = 12 (24 ± 4 yrs)

<u>4 sessions</u>

slope : +10%

slope : -10%

Exercise alone

Exercise
+
PAS

30 min

60% H

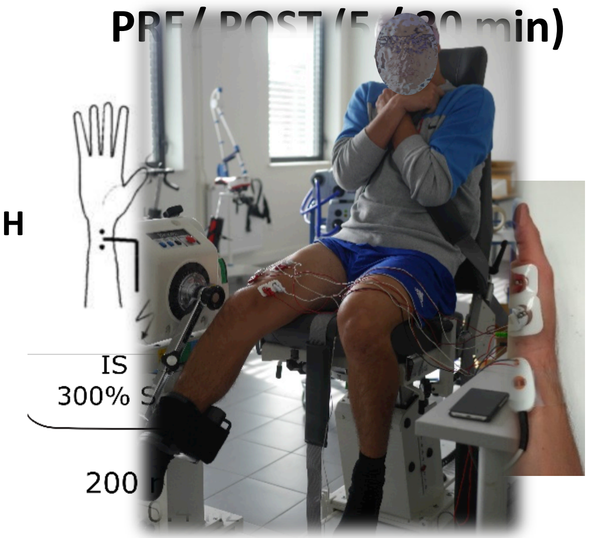
Exercise alone

Exercise
+
PAS

<u>Corticospinal excitability</u>

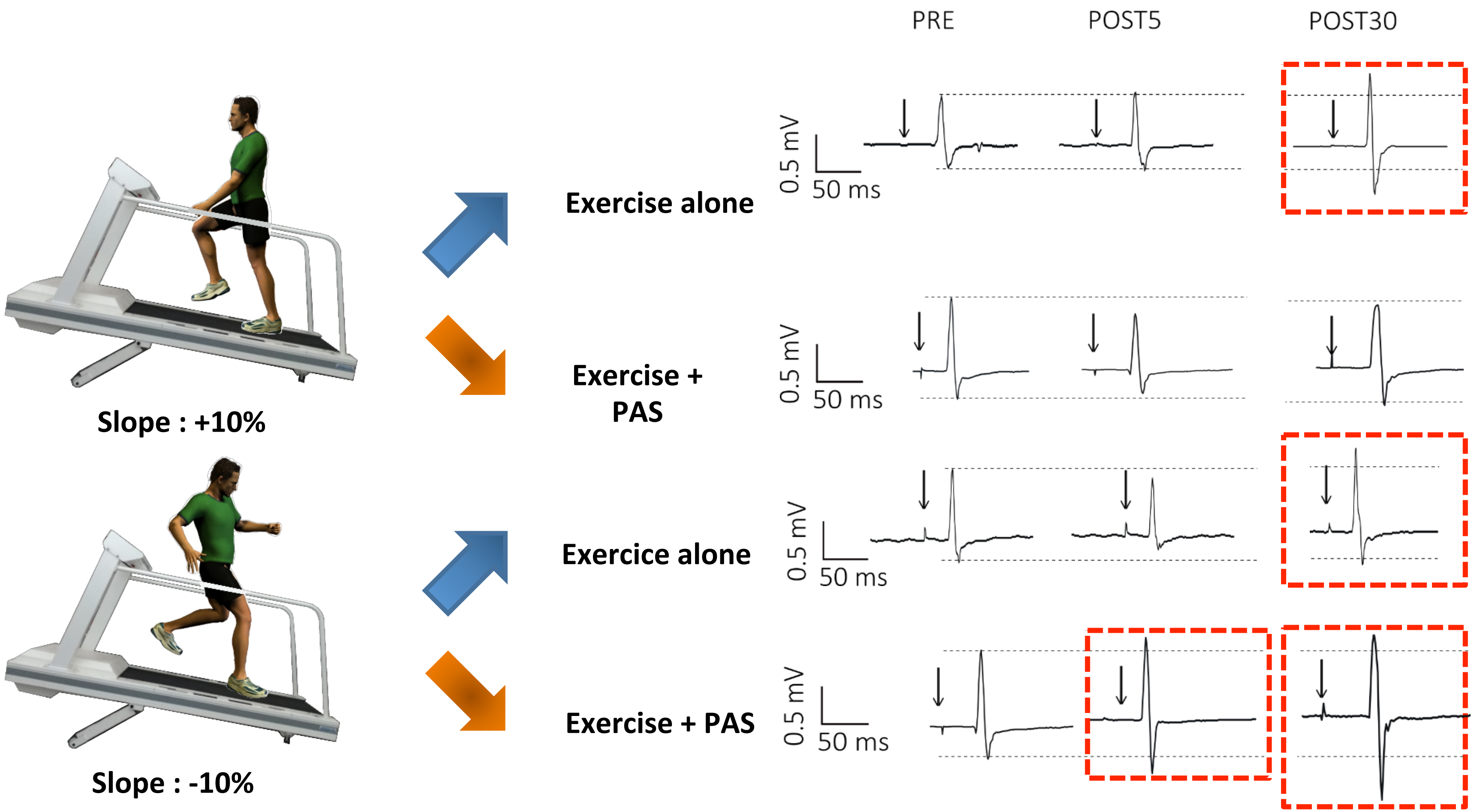
abductor pollicis brevis

PRE / POST (5 / 30 min)

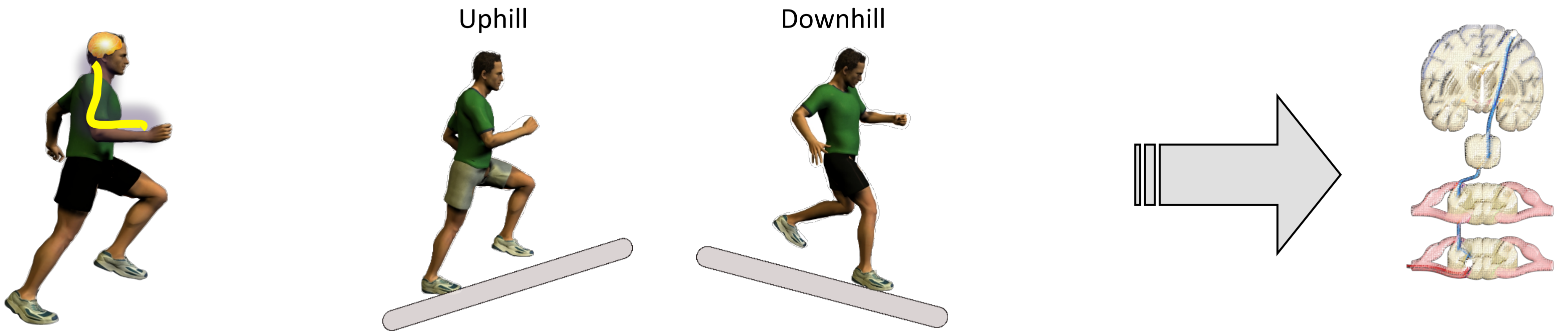


Garnier et al. (2017)

Changes in cortico-spinal excitability following uphill versus downhill treadmill exercise (**non-exercised muscle**)



Changes in cortico-spinal excitability following uphill versus downhill treadmill exercise (**non-exercised muscle**)



Summary

- ☑ Sub-maximal non-fatiguing locomotor exercise on a treadmill affects CS excitability within a delayed period of 30-min
- ☑ The predominant mode of muscle contraction does not influence the CS excitability changes
- ☑ Specific neural changes exist in uphill compared to downhill exercises as highlighted by different responses when exercises were followed by a facilitating PAS25 protocol

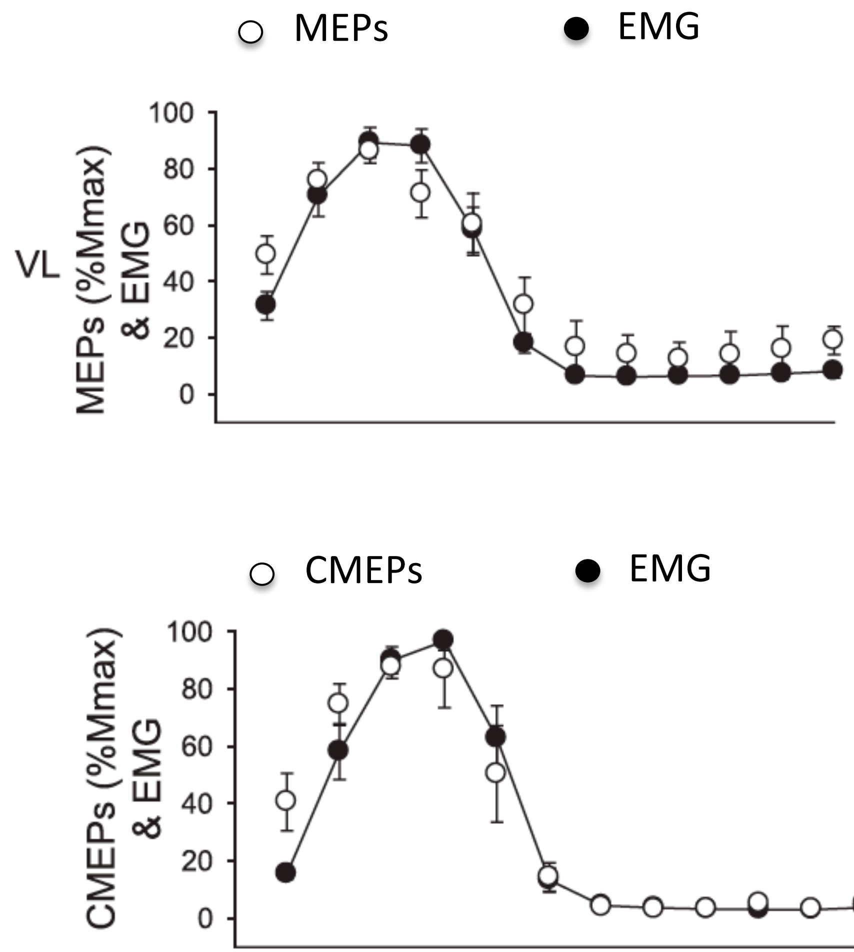
Main limit of these works

Changes in corticospinal excitability are examined **after** exercise and for **different** movements (i.e. isometric contraction)

➔ Corticospinal changes **during** the whole body exercise ?

Evaluation of corticospinal excitability during exercise

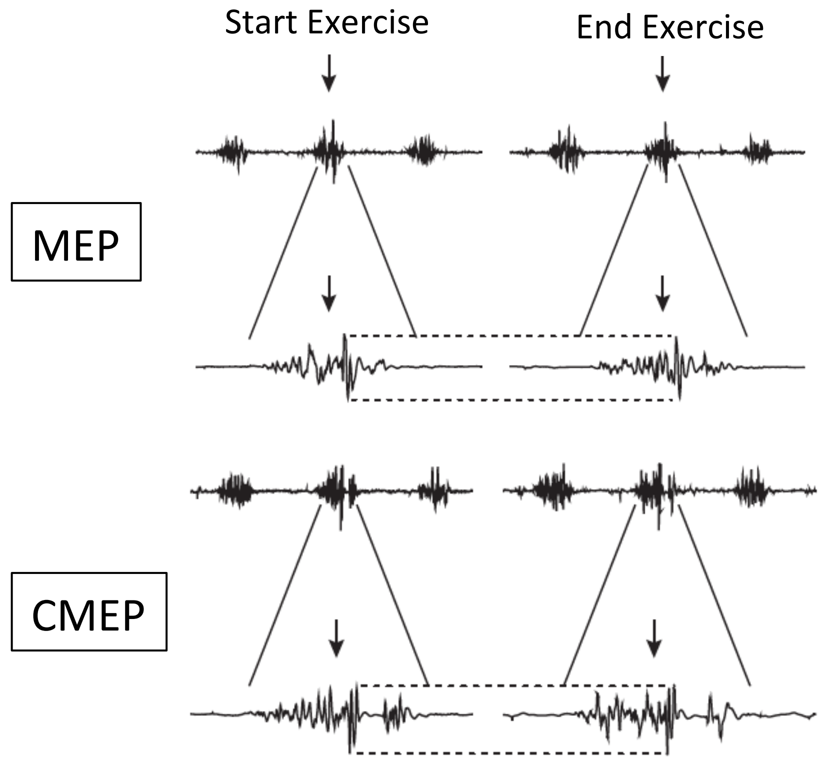
Non-fatiguing exercise



Sidhu et al. (2011)

Evaluation of corticospinal excitability during <u>fatiguing</u> exercise

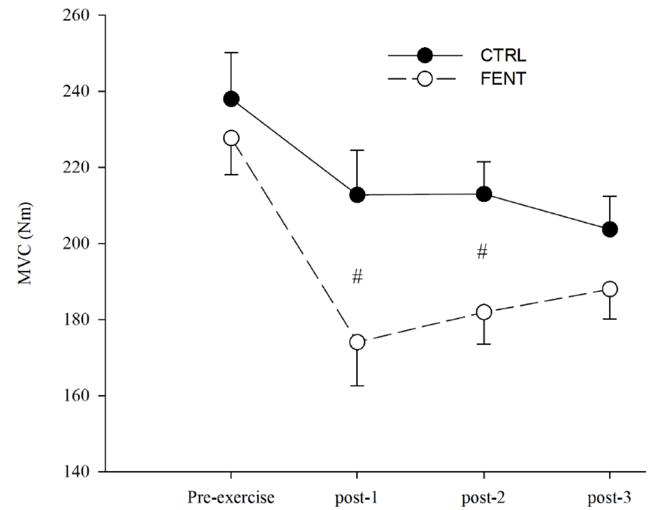
Fatiguing exercise
80% W_{peak} to exhaustion



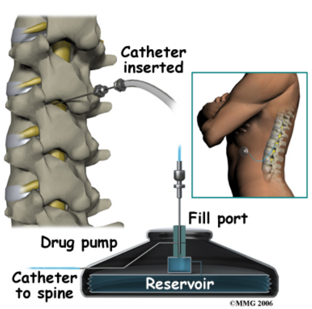
MEPs and CMEPs remained unchanged during the fatiguing trial

Weavil et al. (2016)

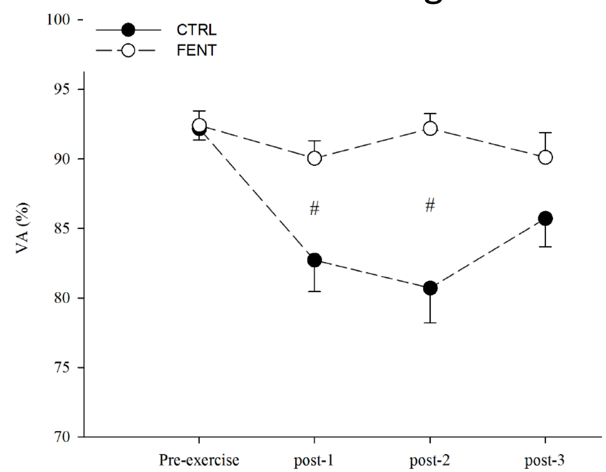
Evaluation of corticospinal excitability during <u>fatiguing</u> exercise



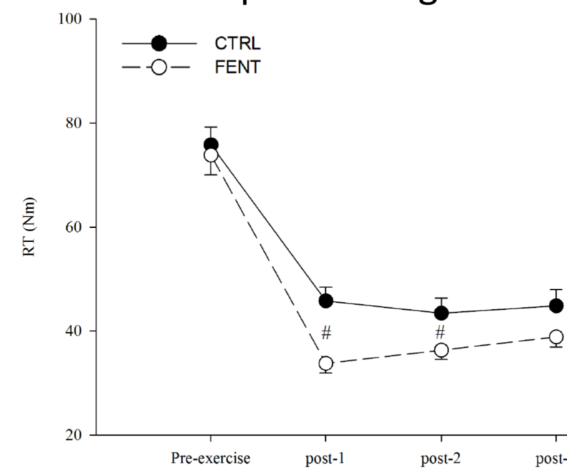
Fatiguing exercise
with lumbar intrathecal fentanyl (FENT) impairing feedback from leg muscle afferents



Central fatigue



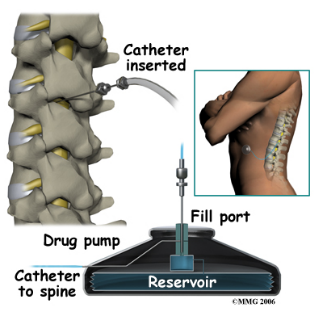
Peripheral fatigue

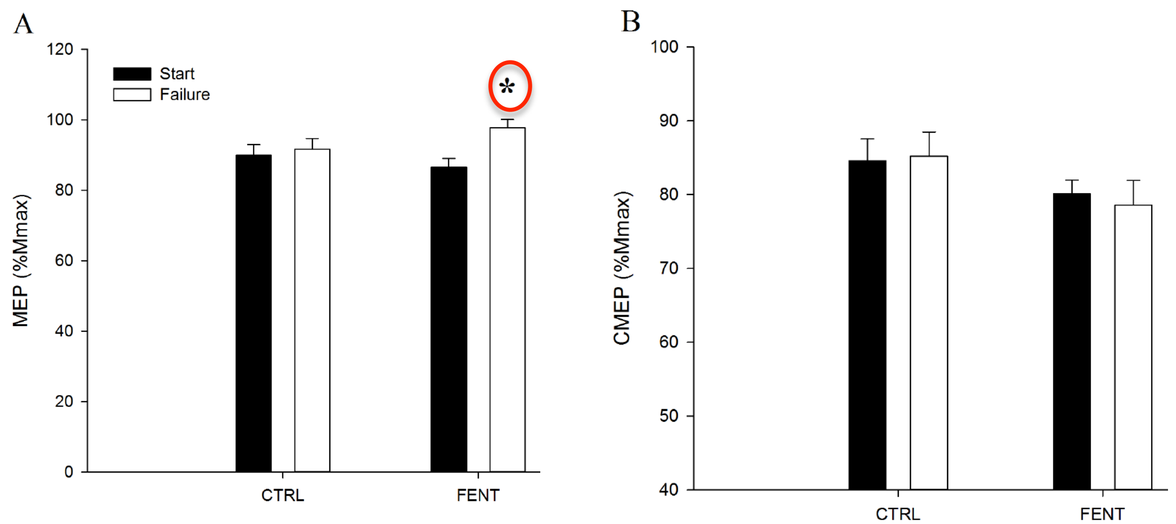


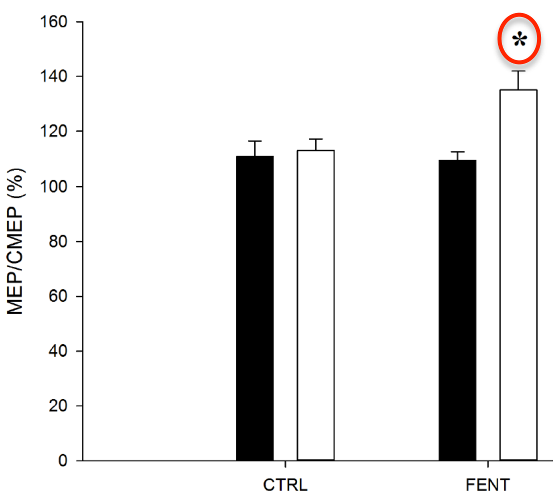
Sidhu et al. (2017)

Evaluation of corticospinal excitability during fatiguing exercise

Fatiguing exercise
with (FENT) /without (CTRL)



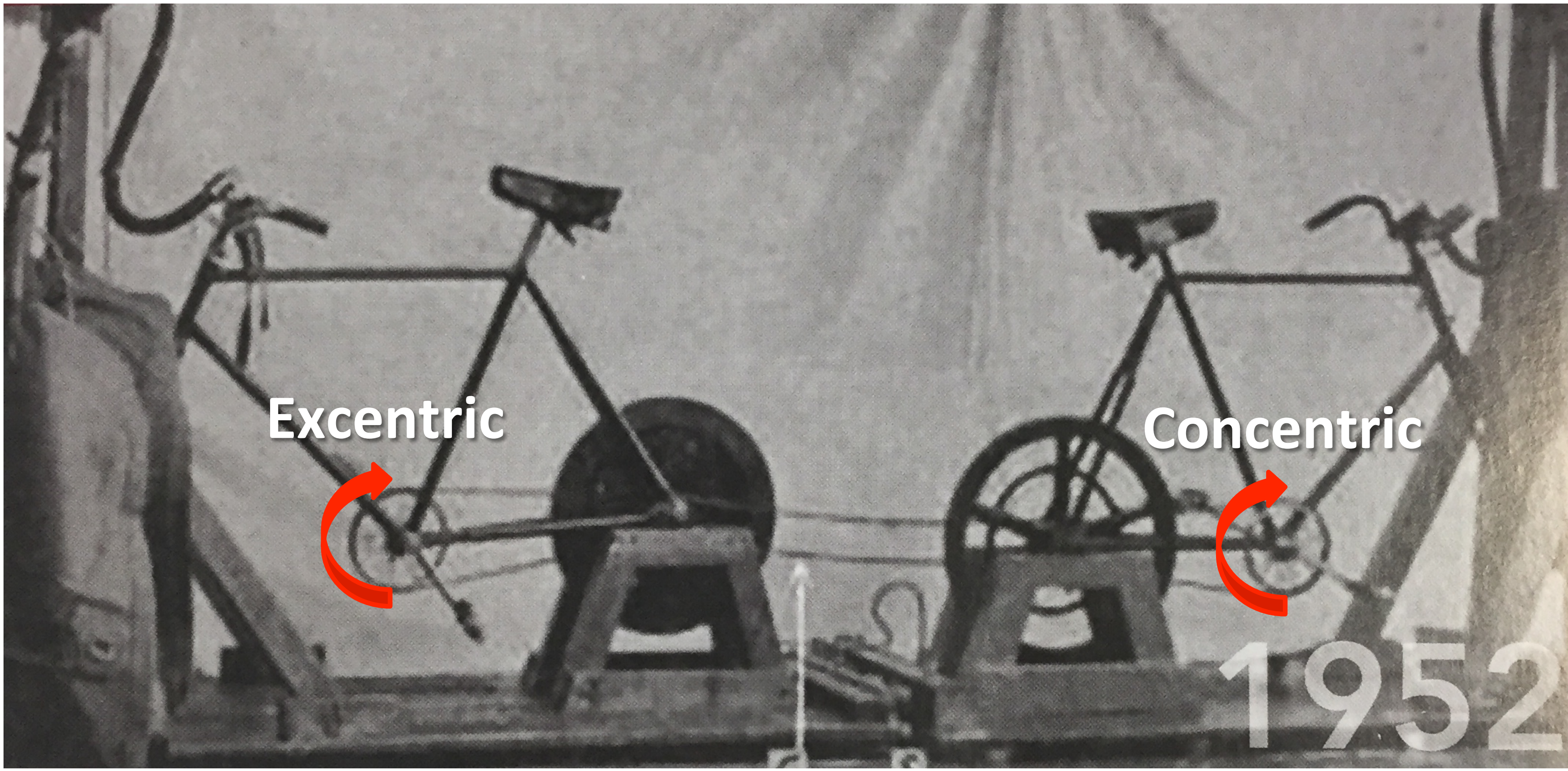




Group III/IV muscle afferents disfacilitate/inhibit the motor cortex and promote central fatigue

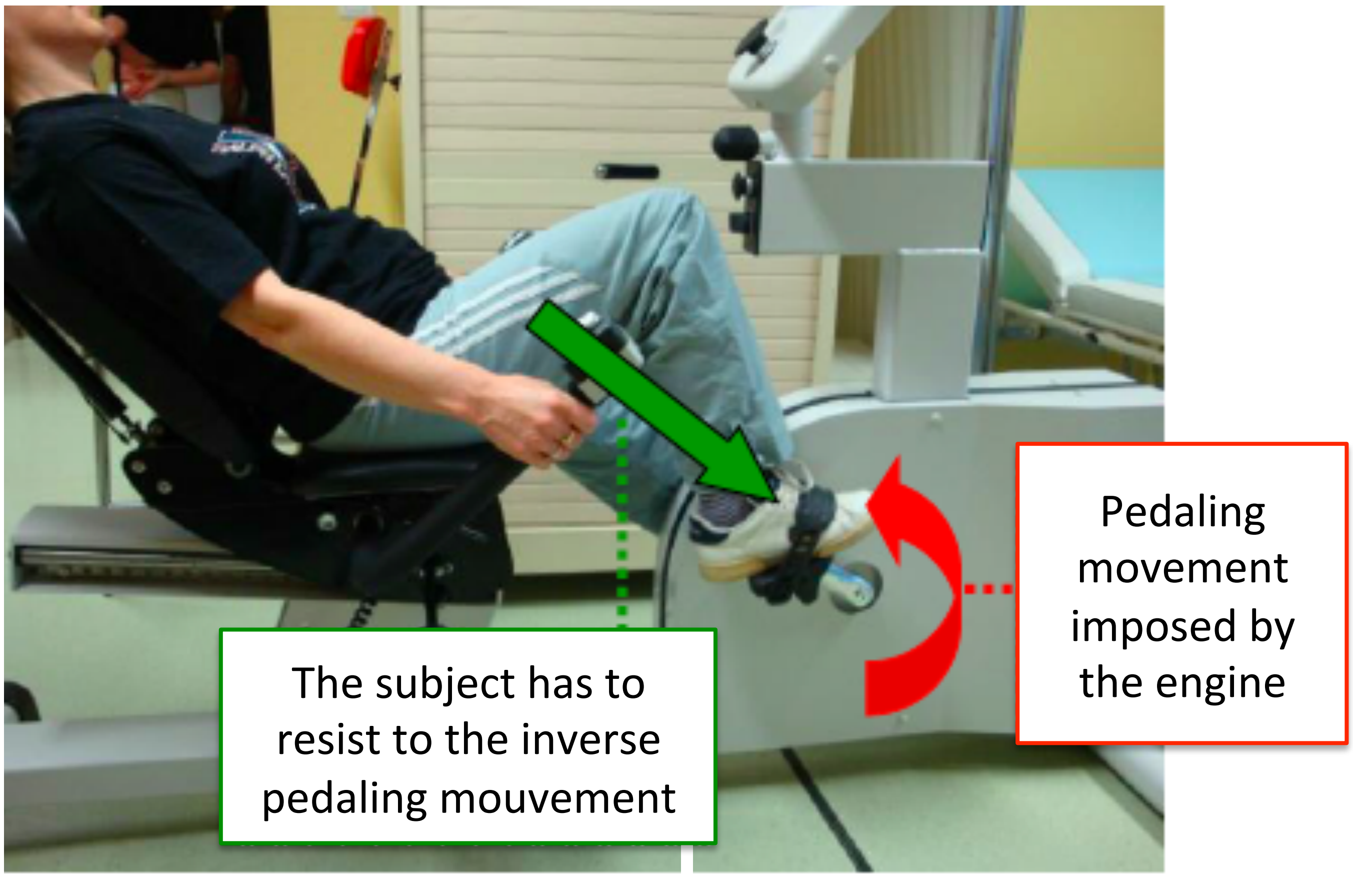
Sidhu et al. (2017)

Evaluation of corticospinal excitability during <u>eccentric *vs* concentric</u> cycling exercise



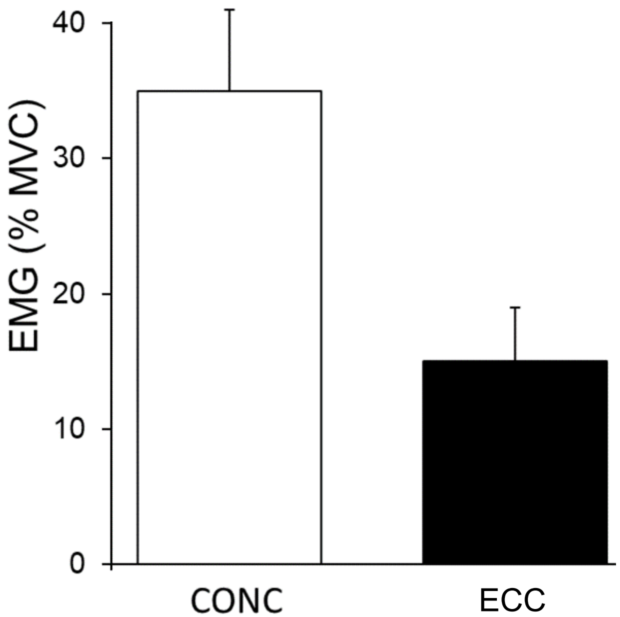
Abbott (1952)

Evaluation of corticospinal excitability during eccentric *vs* concentric cycling exercise

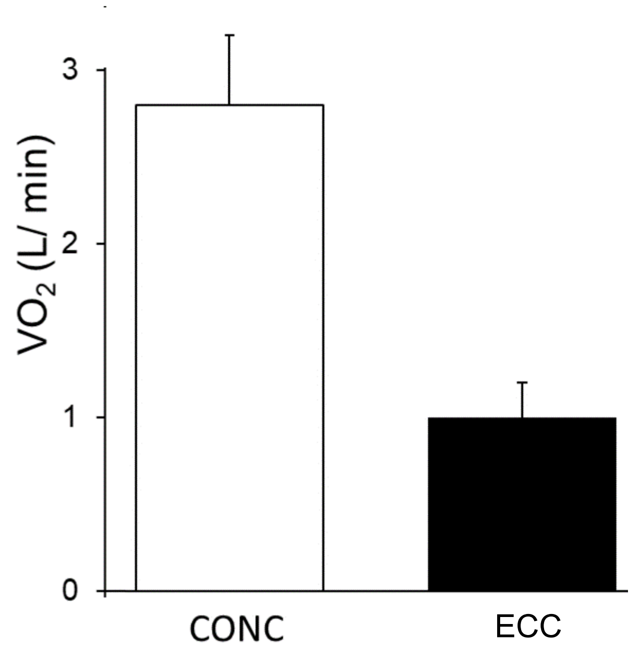


Physiological characteristics of eccentric pedaling

Muscle activation



Cardiorespiratory response

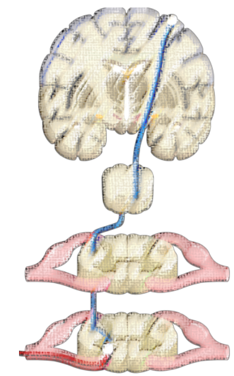


For the same level of torque

Peñailillo et al. (2017)

Changes in corticospinal excitability **after and during** eccentric *vs* concentric cycling exercise

?



PhD thesis of Pierre Clos (in progress)

Changes in CS excitability after whole body exercise

Take home message

☑ Fatiguing whole body exercise is characterized by changing processes simultaneously facilitating and inhibiting the CS pathway.

☑ Unchanged net CS excitability ≠ Absence of change
Counterbalance of excitatory and inhibitory processes
(e.g. ↓Motor cortical excitability and ↑central motor drive)

☑ Locomotor exercise enhance CS excitability in a non-exercised muscle.

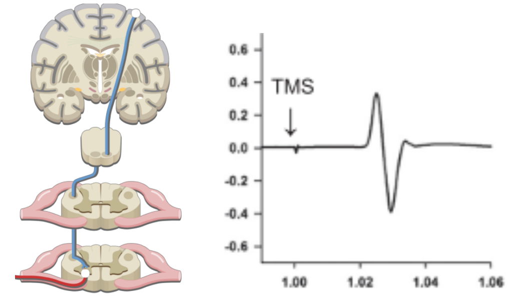
☑ The mode of muscle contraction influences the CS excitability changes.

THANK YOU

FOR YOUR ATTENTION

Romuald LEPERS

Remaining question



Corticospinal excitability

?

Cognitive functions

Others hypothesis :

- Hemodynamic (e.g. cerebral blood flow)
- Hormones