"Optimizing muscle coordination and pedaling technique" what does it mean and is it really beneficial for performance?

Sylvain Dorel

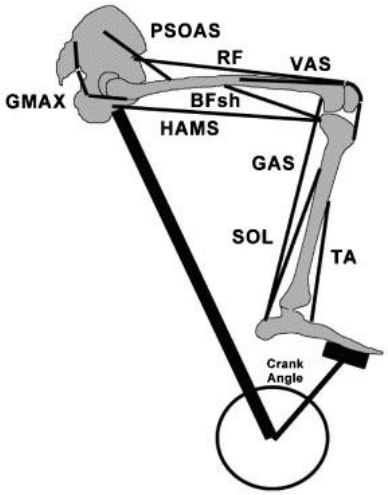
Laboratory « Motricité-Interaction-Performance », EA 4334, Nantes

Laboratoire
Motricité - Interactions - Performance
EA 4334 Nantes - Le Mans

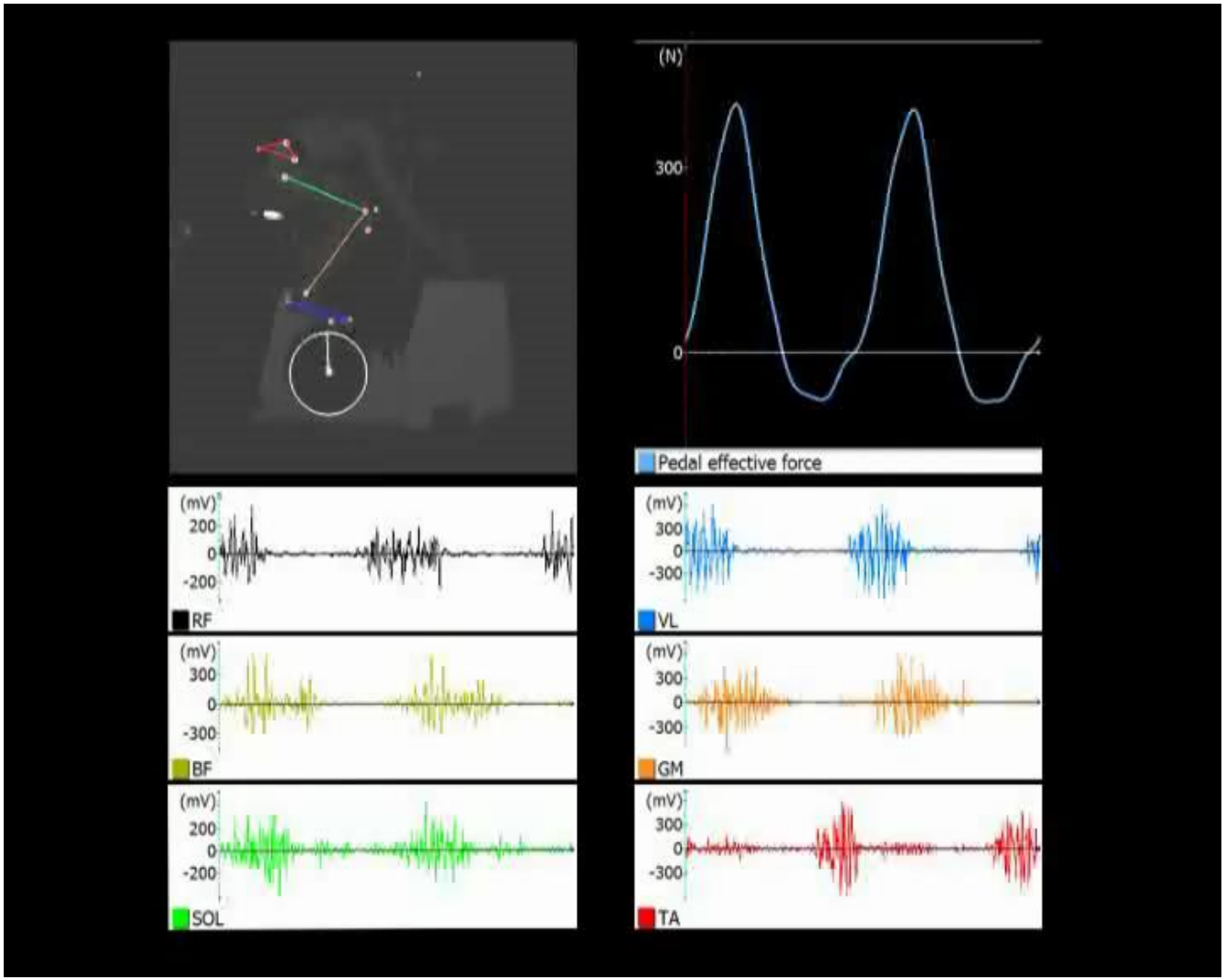
INSEP
Laboratory SEP

FÉDÉRATION FRANÇAISE DE CYCLISME
French Team (Sprint-BMX)

Muscle Coordination



EMG


(N)
300
0
Pedal effective force
(mV)
200
0
-200
RF
(mV)
300
0
-300
VL
(mV)
300
0
-300
BF
(mV)
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GM
(mV)
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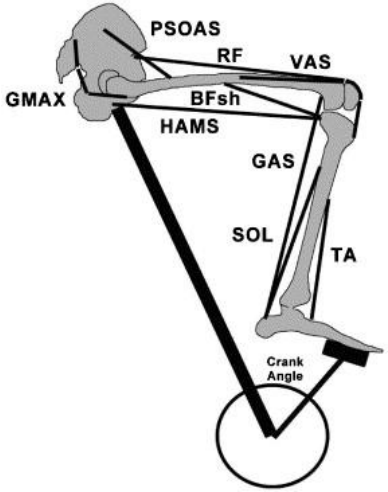
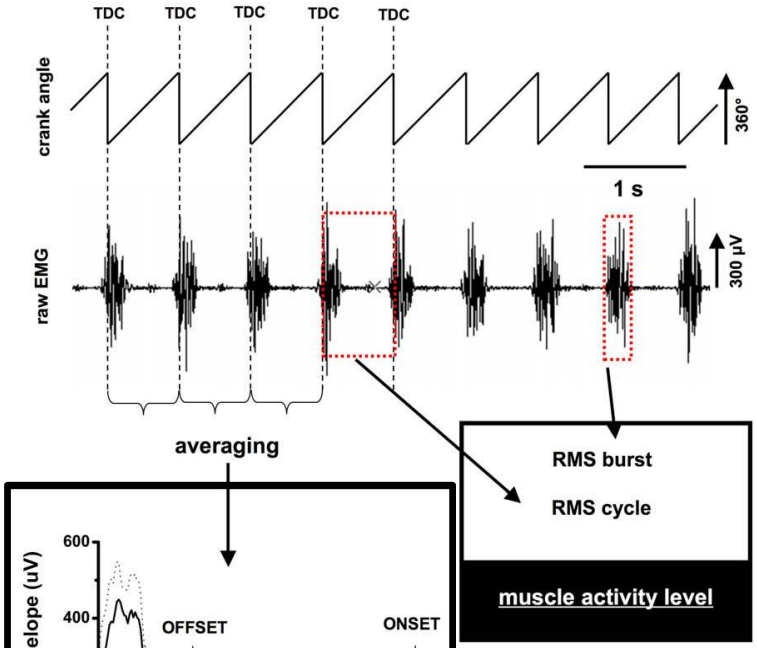
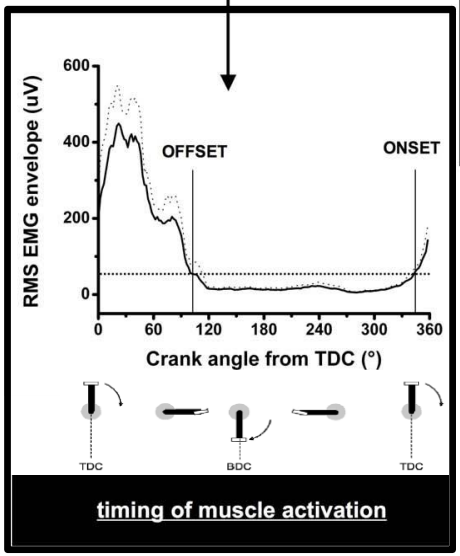
0
-200
SOL
(mV)
300
0
-300
TA

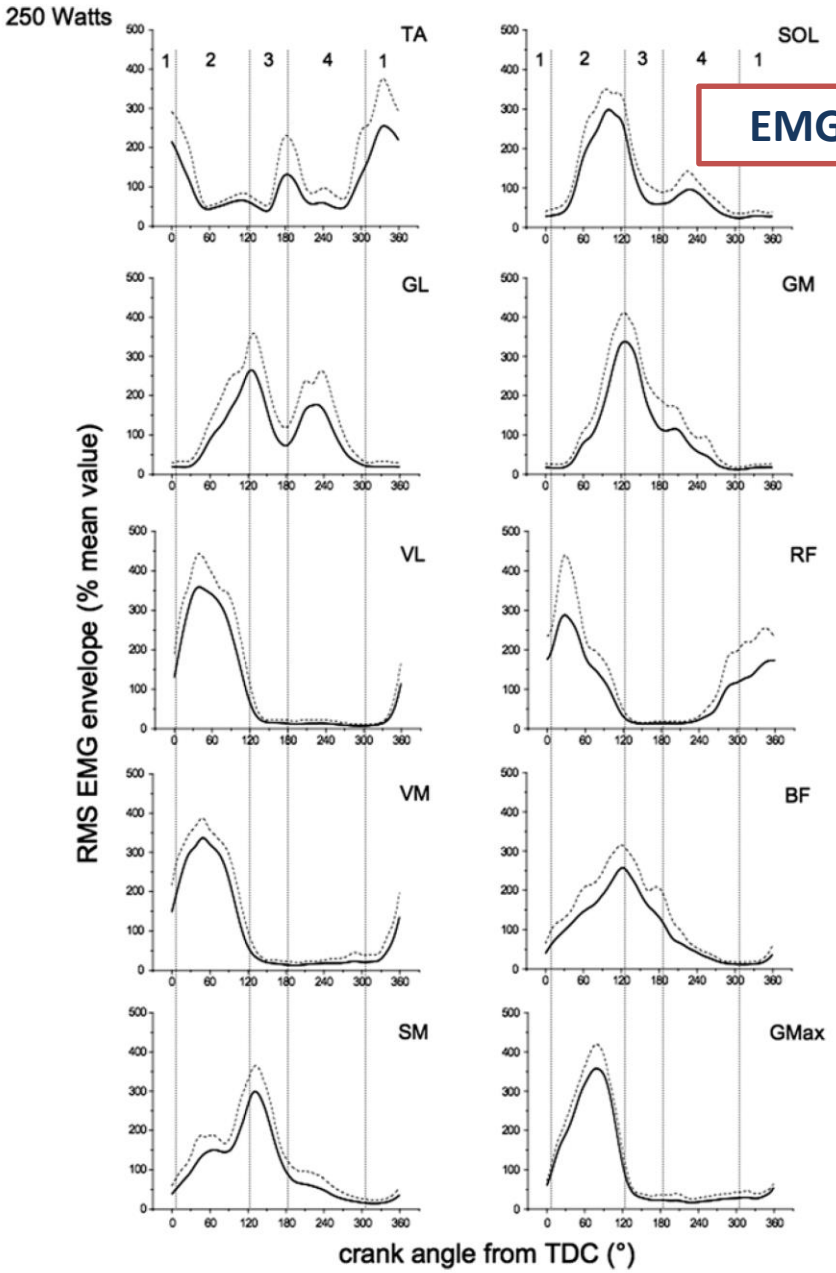
EMG

Muscle Coordination



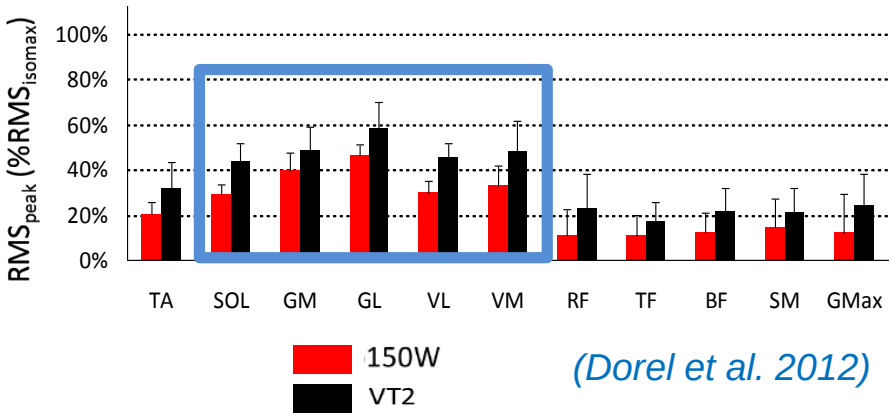






EMG Patterns

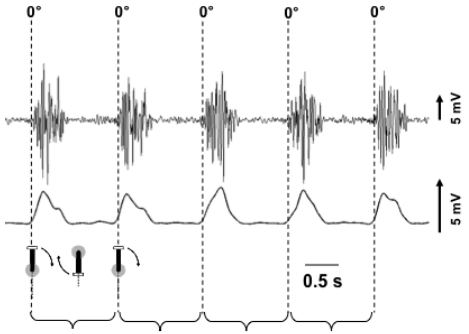
Level of activity

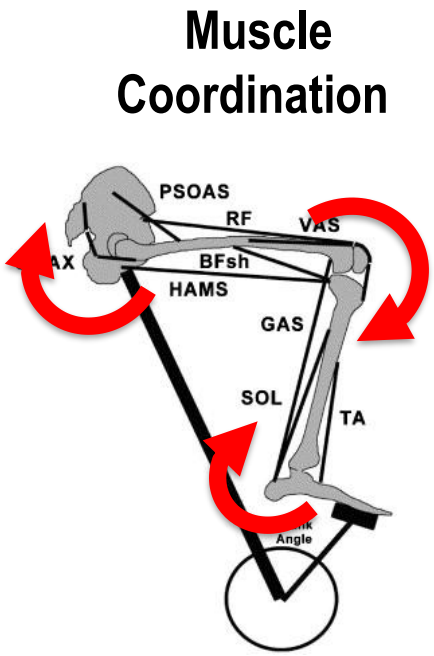


(Dorel et al. 2012)

Triceps surae and quadriceps
40-60% of EMG_{max}

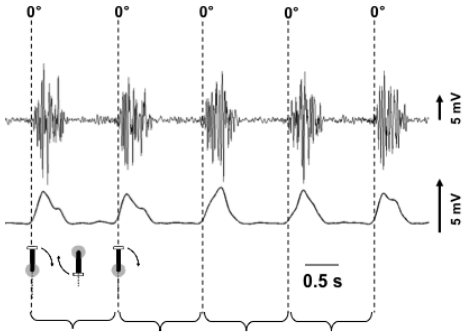
« Neuromuscular aspect »



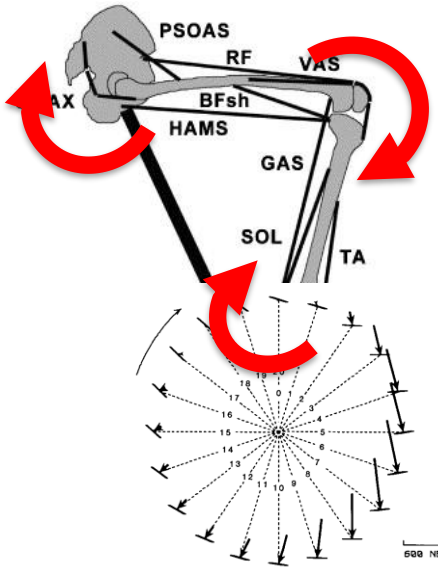


Distribution of activation or force among individual muscles to produce given combination of joint torques *(Prilutsky 2000)* or more generally to perform a given task *(Kautz et al. 2000)*

« Neuromuscular aspect »



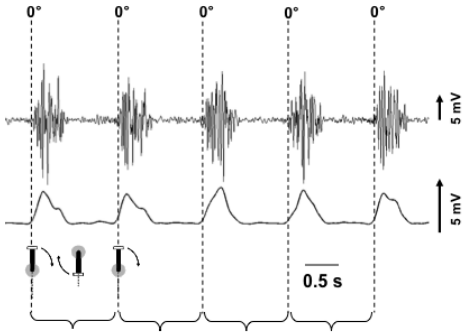
Muscle Coordination



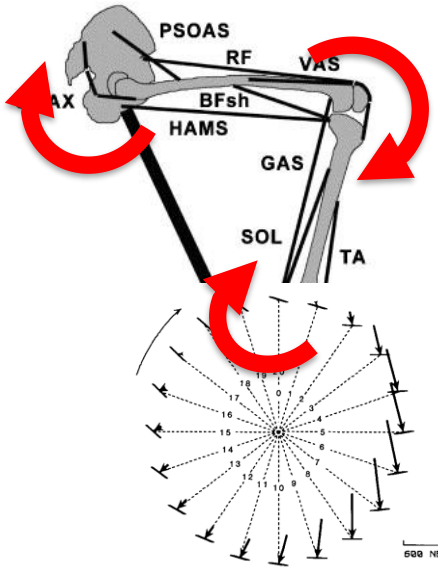
Joint torques/powers

Pedal force
amplitude and orientation

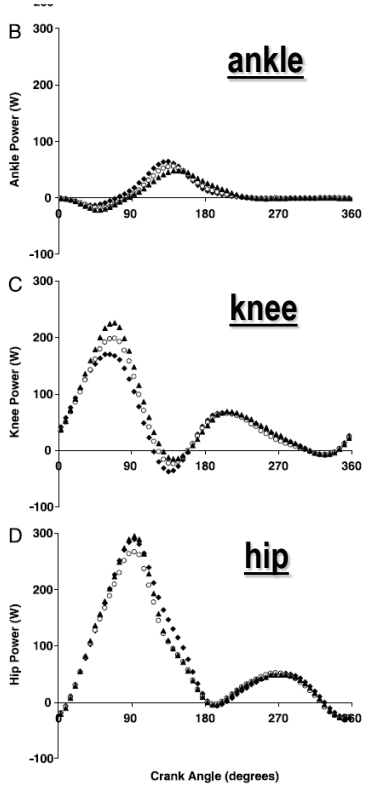
« Neuromuscular aspect »



Muscle Coordination

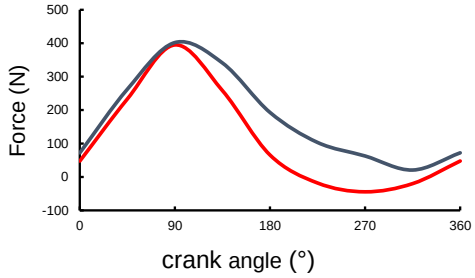


Joint torques/powers



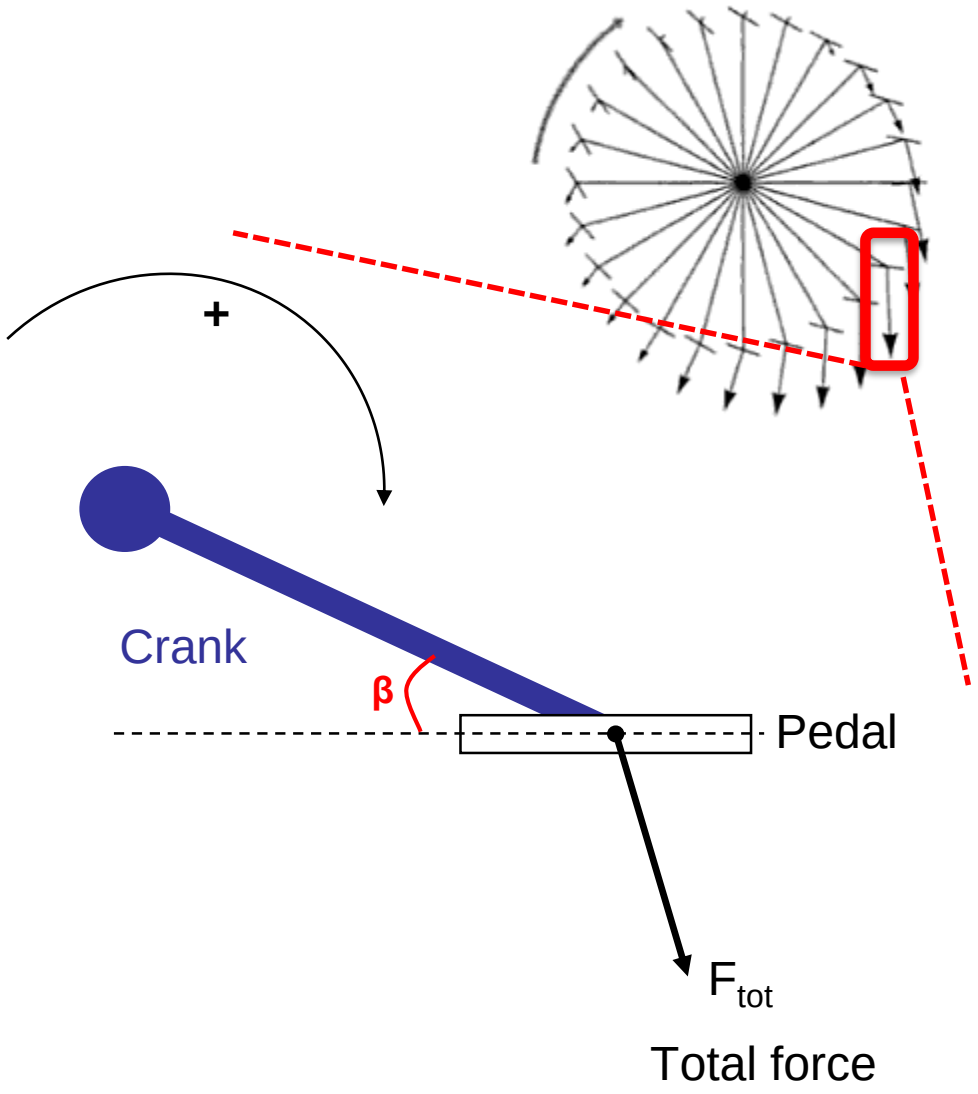
« Inverse dynamic / joint contribution»

« Pedaling technique »

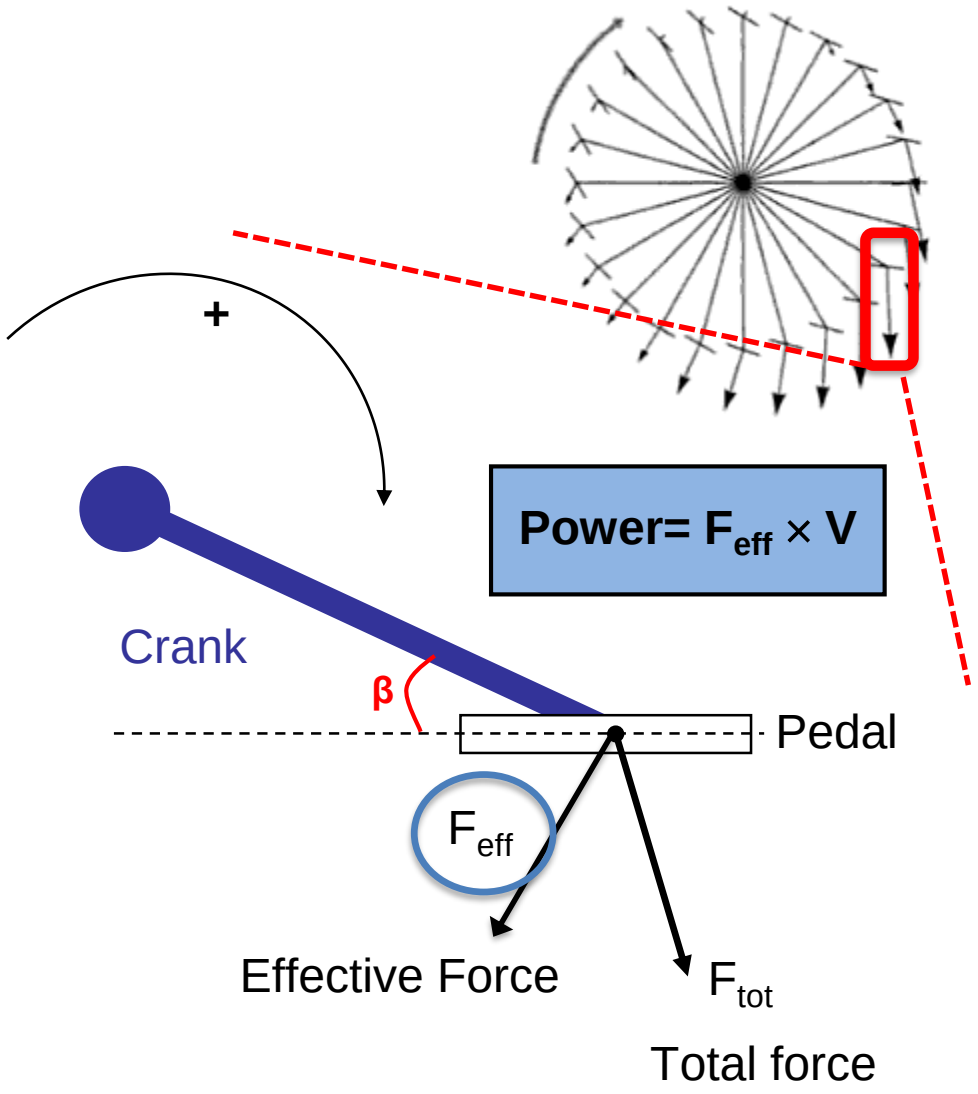


Pedal force
amplitude and orientation

Torque or “effective force” profile

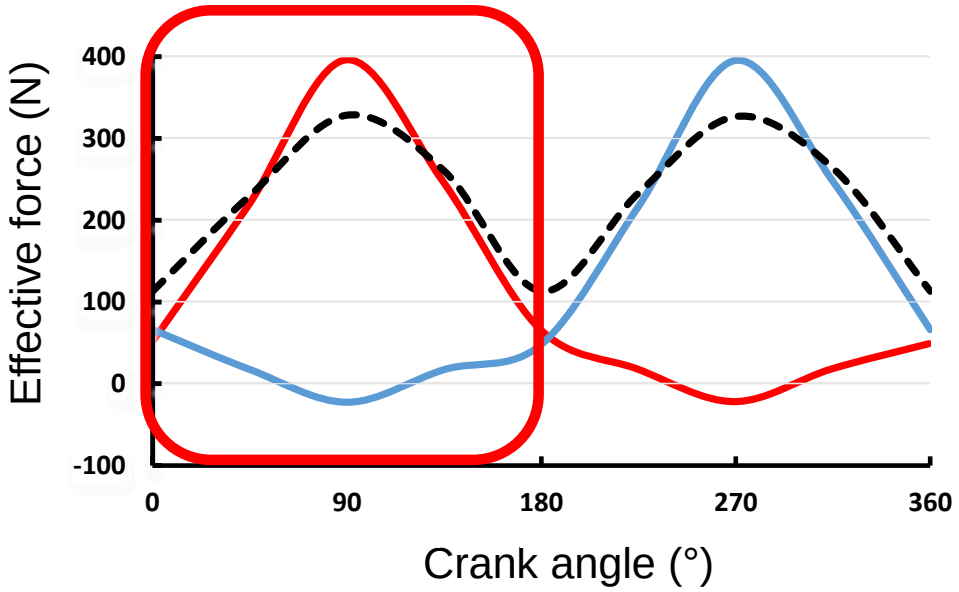


Torque or “effective force” profile

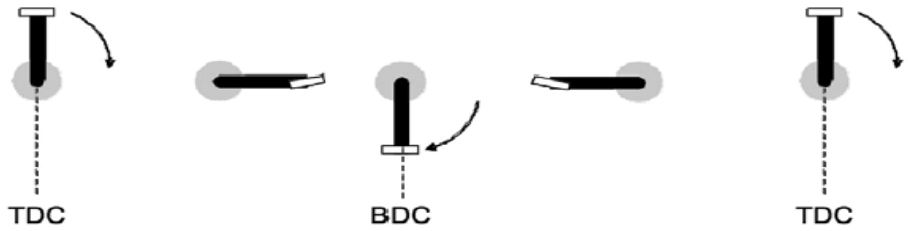


Torque or “effective force” profile

1. Ttorque / effective force on one pedal: downstroke/upstroke phase



2. Antiphase action of both lower limbs : pushing (downstroke), pulling or not (upstroke)

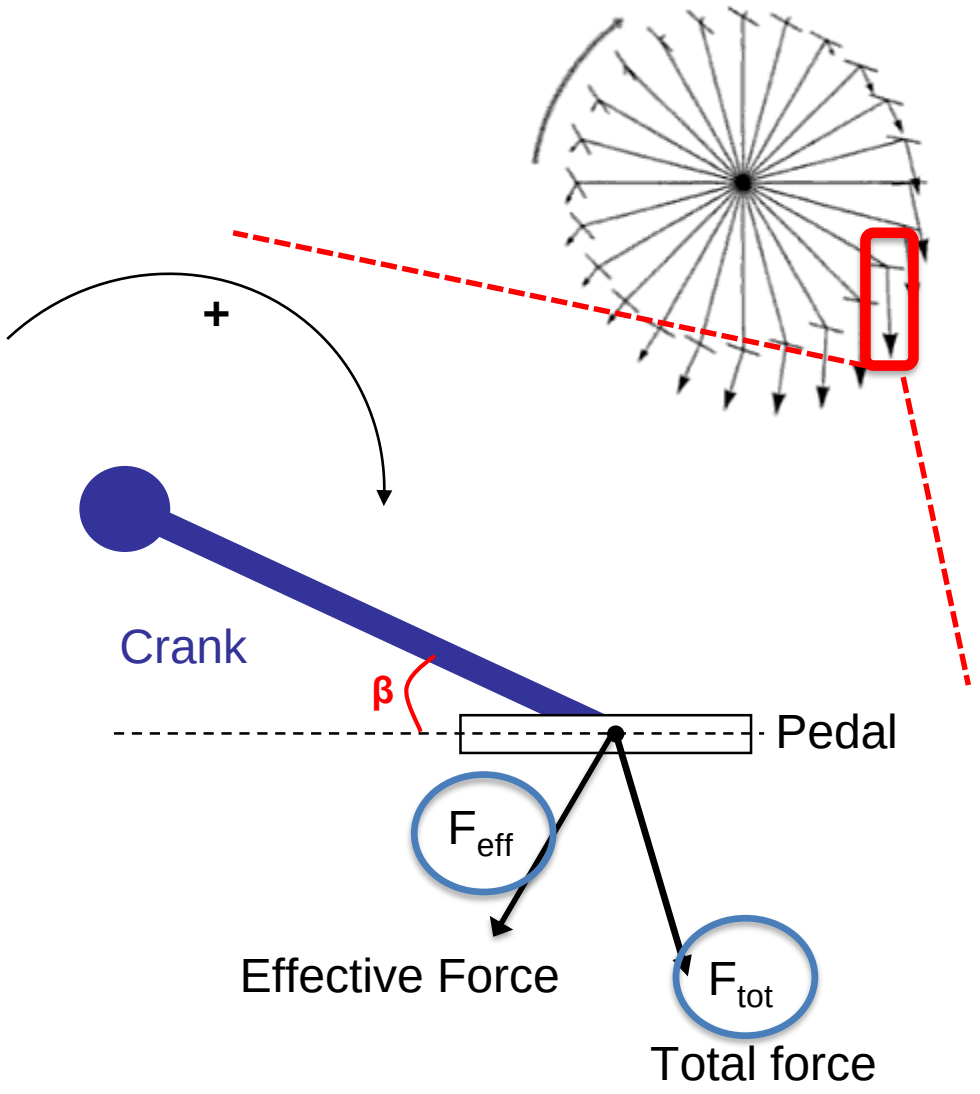


Force orientation? concept of effectiveness (IE)

Index of mechanical effectiveness

$$IE = 100 \times \frac{F_{eff}}{F_{tot}}$$

(Ericson et al 1988)



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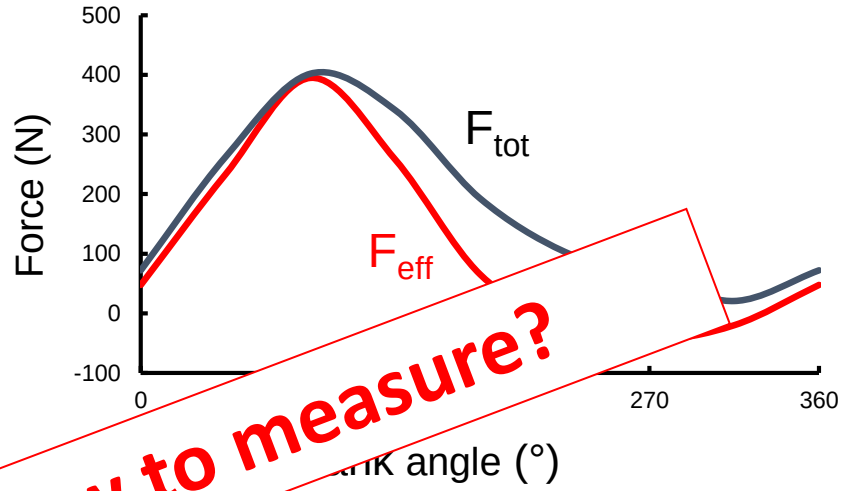
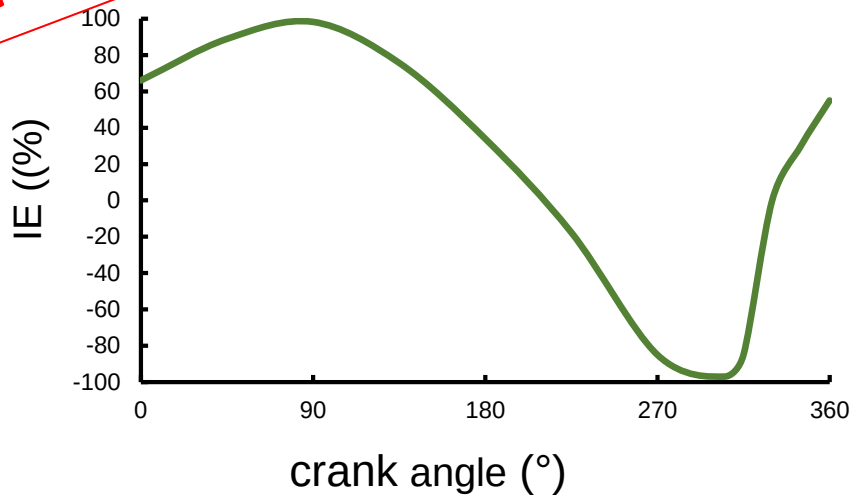


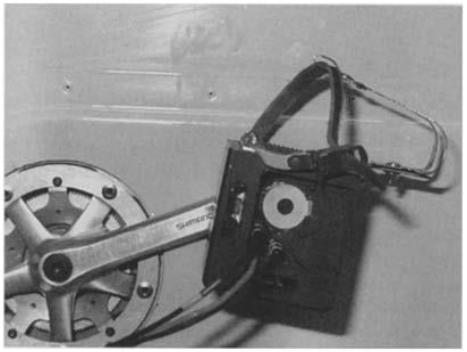
Practically: how to measure?

Instantaneous IE
cycle

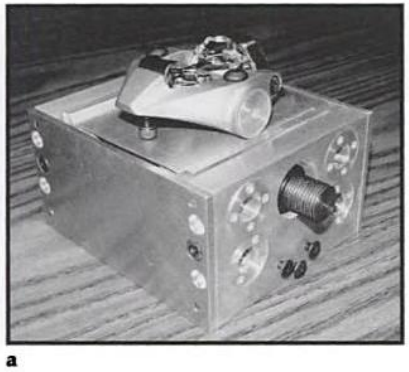


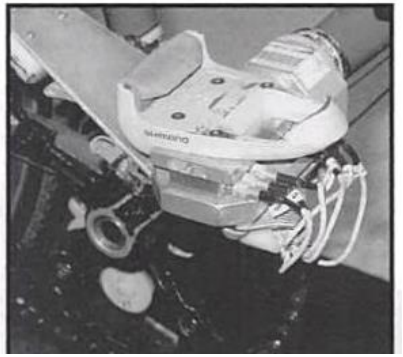
Practically: how to measure?

Instrumented pedals



1990





2000

2005

2020 ?

2015

2010

Lot of factors influence biomechanics and coordination during pedaling :

level of power output, pedaling rate,
body position (+ bike fitting), shoe-pedal interface, fatigue…

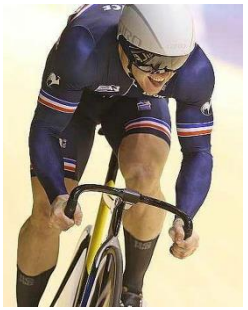
Link with PERFORMANCE ?

Endurance cycling

ROLE OF EXPERTISE ?

EFFECT OF TRAINING ?

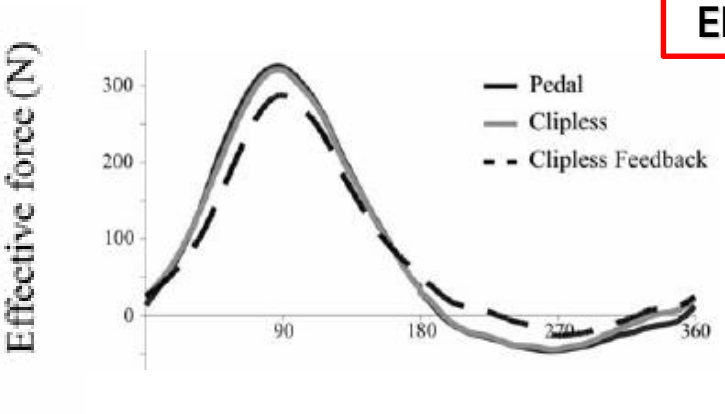
Sprint cycling



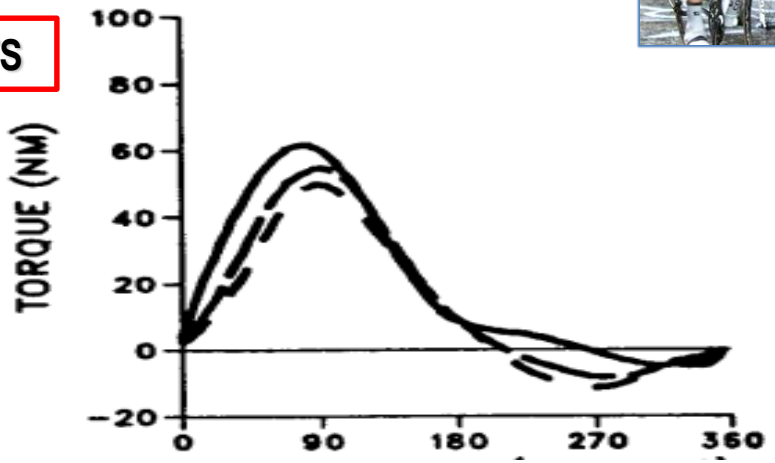
A. Cross sectional observations on biomechanics and muscle coordination

Torque profile: Expert / Novice

ELITE CYCLISTS

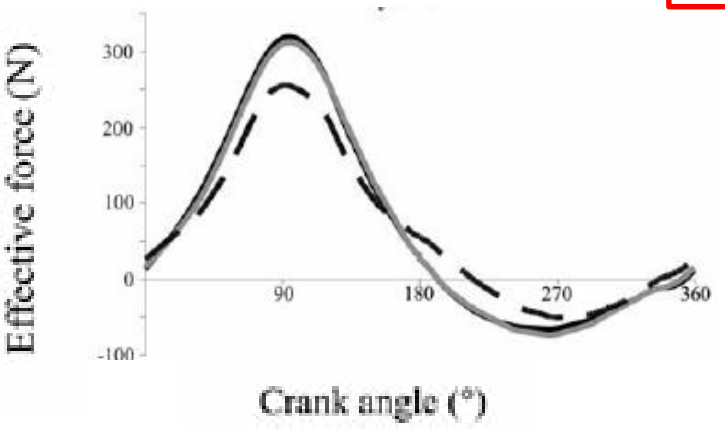


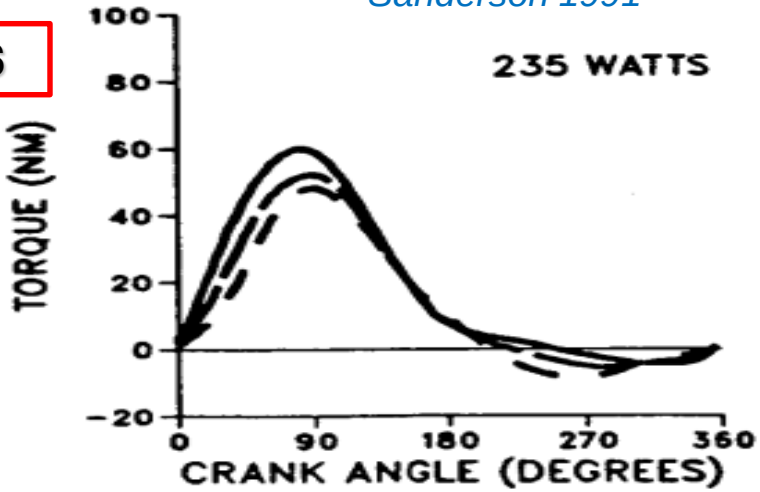
Mornieux et al 2008



Sanderson 1991

NON CYCLISTS





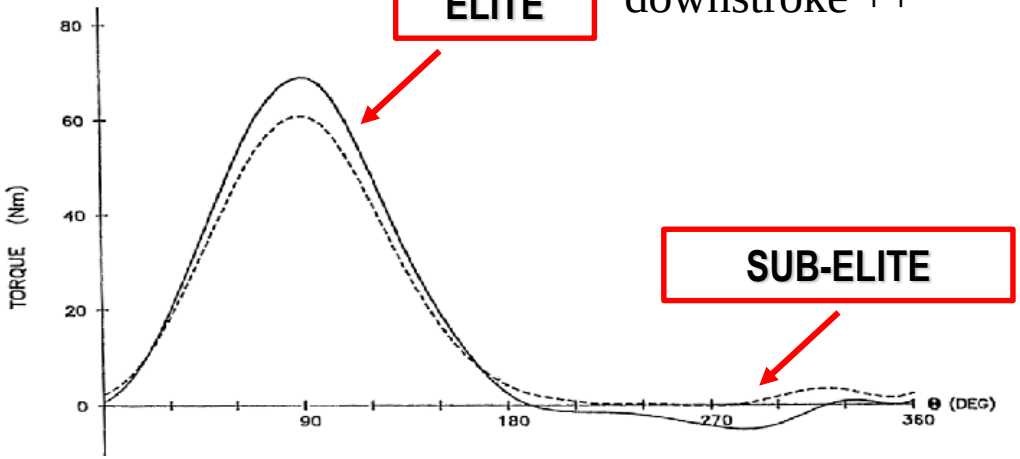
A. Cross sectional observations on biomechanics and muscle coor

Torque profile: Expert / Novice

And lot of others studies with contrasted results…

(Coyle, 1991)

ELITE downstroke ++

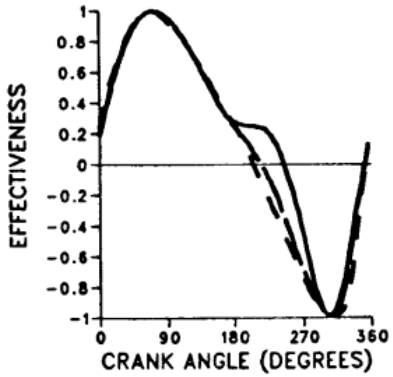


SUB-ELITE

But… ➡ Peak torque in downstroke ++ for non cyclists for a condition *(Takaishi et al., 1998; Burke, in Hig tech cycling)*

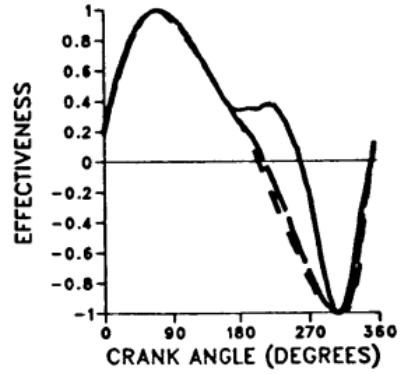
No real difference Expert / Novice

ELITE CYCLISTS



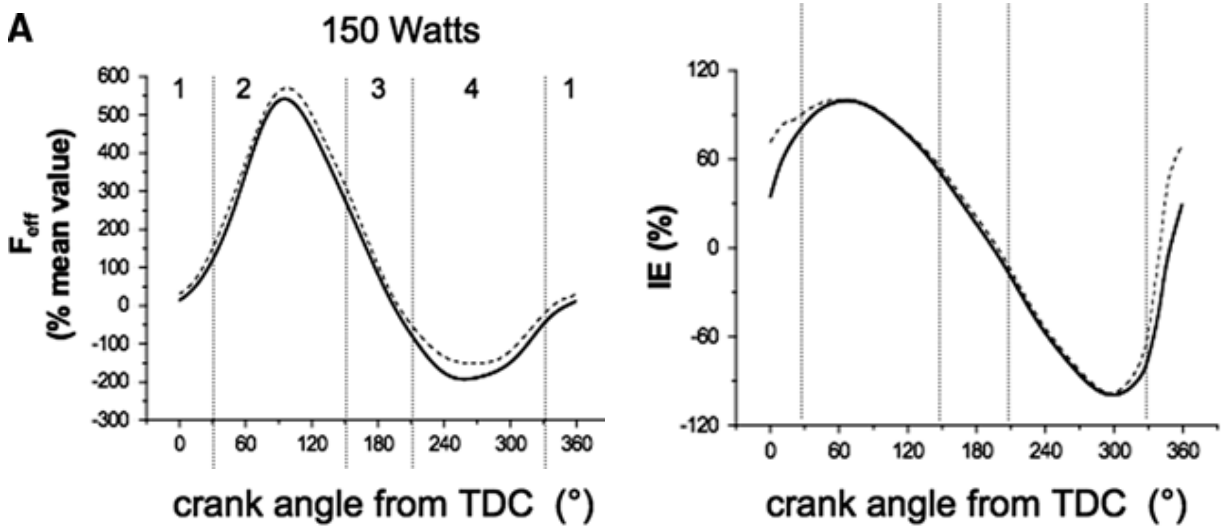
Sanderson 1991

NON CYCLISTS



Torque profile: Interindividual variability

low variability even in homogenous elite population



(Hug et al 2008)

IE = 30-40%

Power output effect: ↗

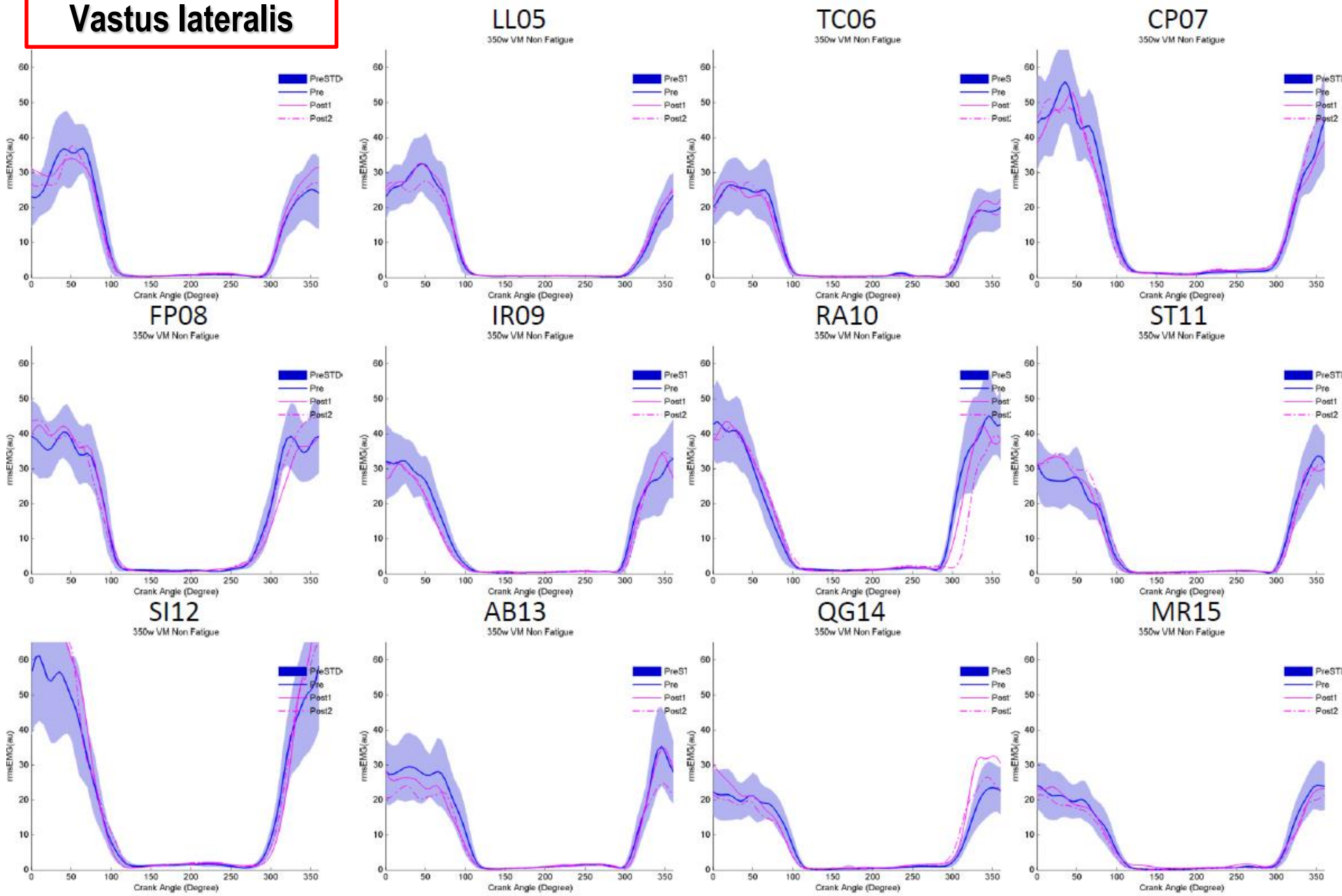
Cadence effect: ↘

Some differences but not very important

Muscle coordination

(Brochner Nielsen et al 2017)

Vastus lateralis



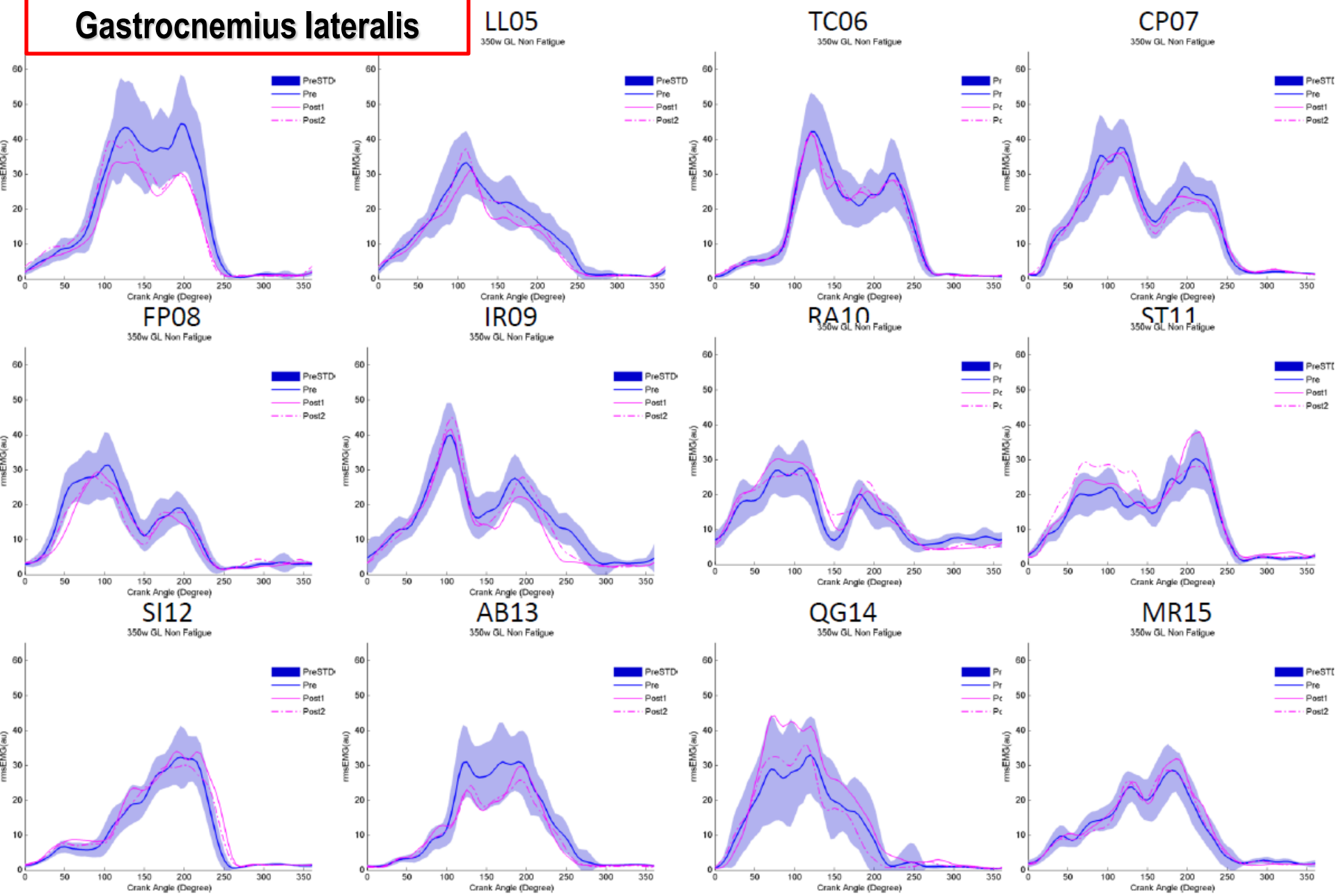
Muscle coordination

Stereotypical coordination but…

➡ **Important variability**

(Brochner Nielsen et al 2017)

Gastrocnemius lateralis

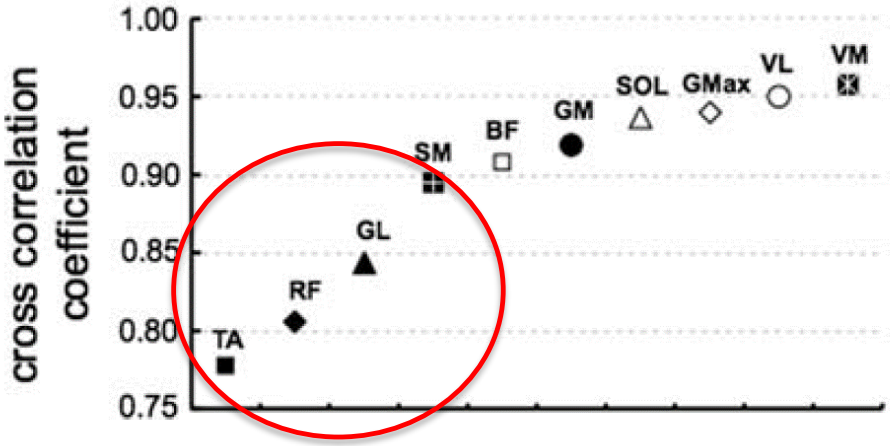


Muscle coordination

Stereotypical coordination but…

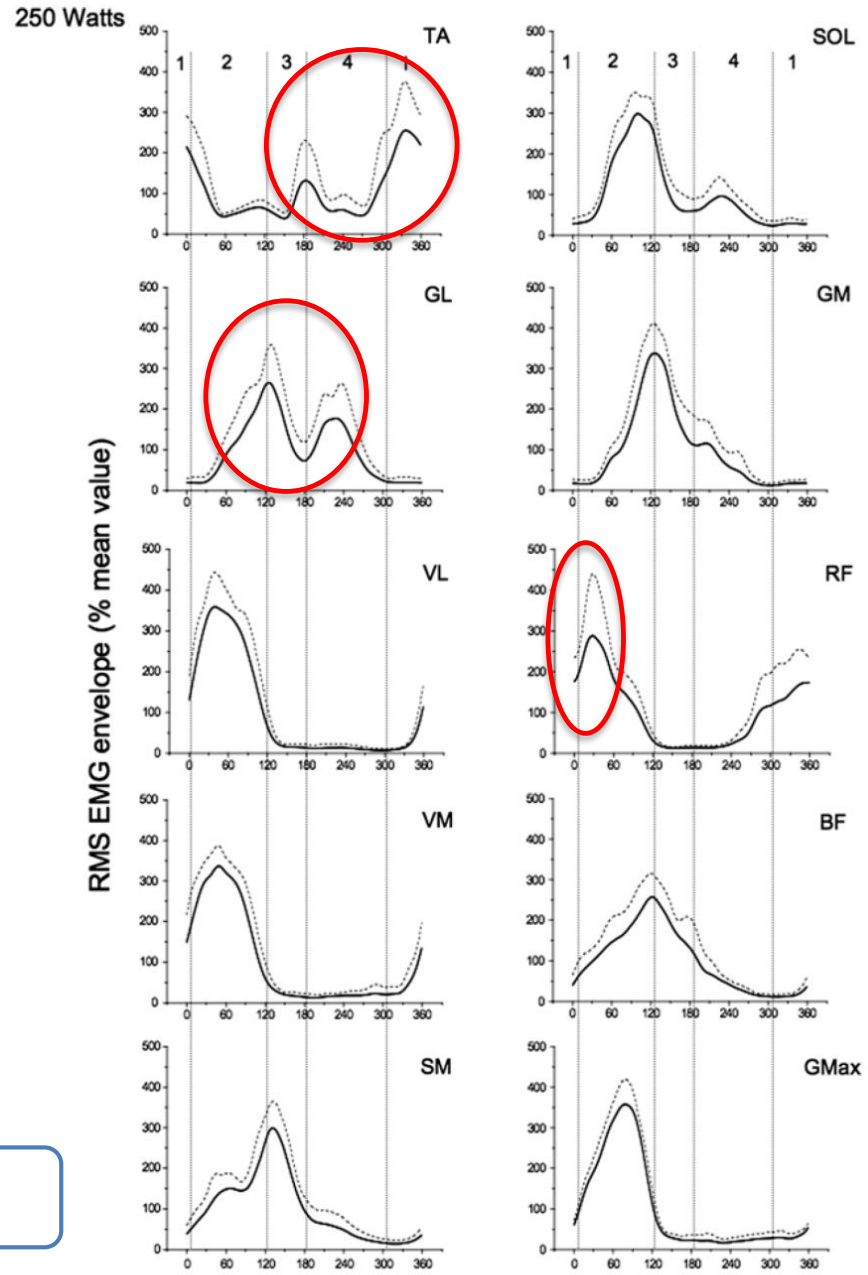
➡ **Important variability** (redondancy)

Variability also in homogenous elite population



Individual coordination strategy

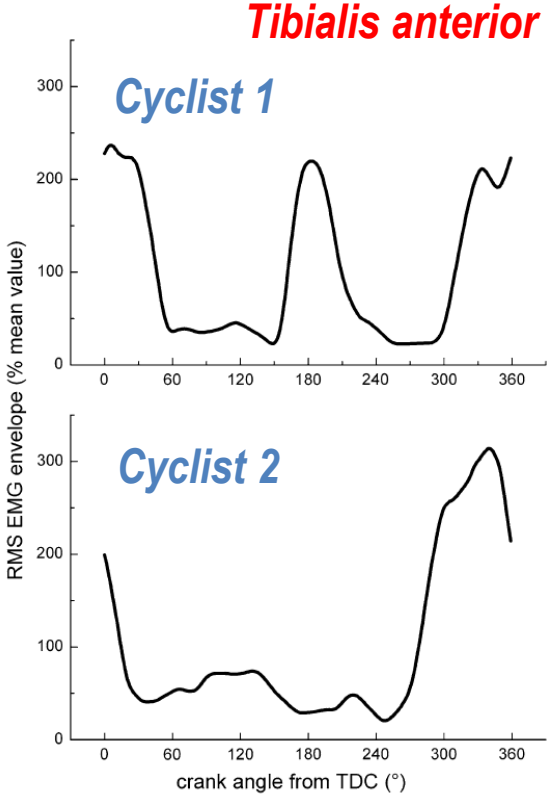
Variability ++ for two-joint muscles and TA

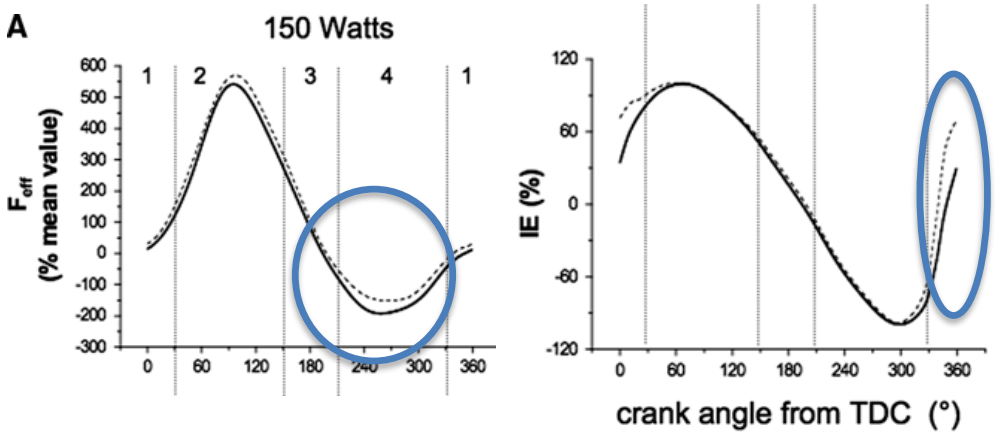


Hug et al. 2008

Again: **individual** ankle strategy

Is one better than the other ?





In line with variability of biomecahnics in BDC and TDC

B. Intervention: Effect of training on biomechanics and muscle coordination

Intervention on pedaling technique is possible!

Training with feedback

Sanderson and Gavanagh 1990

Mornieux et al. 2010

Korff et al. 2007

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J Sci Cycling. Vol. 2(1), 11-24

REVIEW ARTICLE **Open Access**

Pedal force effectiveness in Cycling: a review of constraints and training effects

Rodrigo R Bini[1,2]✉, Patria Hume[1], James Croft[3], Andrew Kilding[1]

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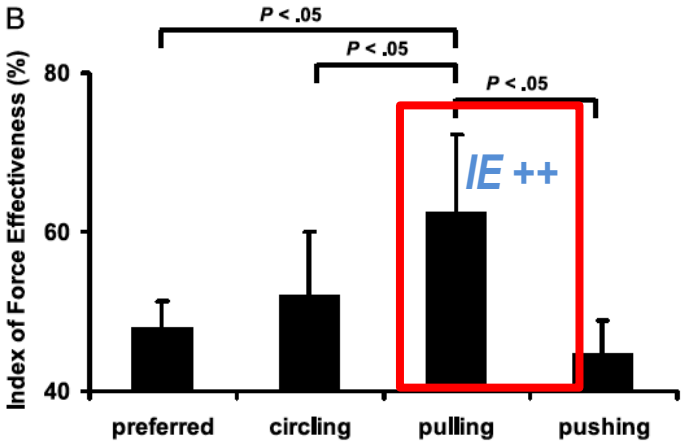
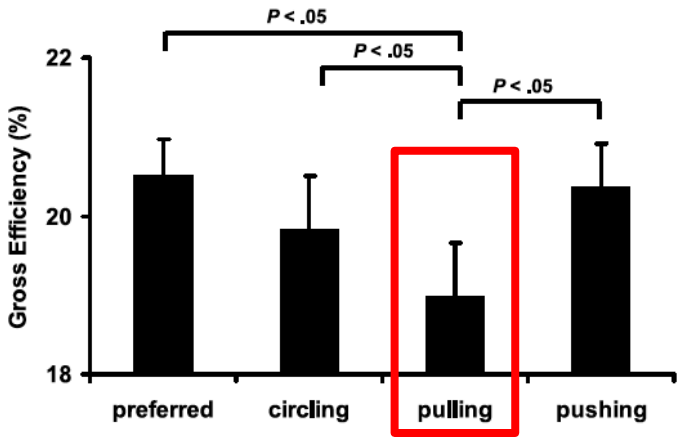
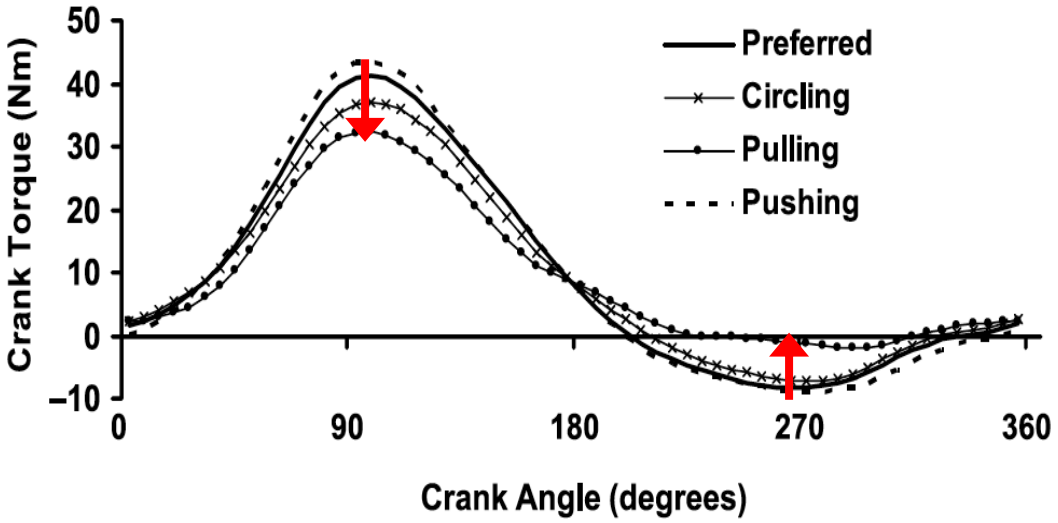
Intervention on pedaling technique is possible!





Korff et al. 2007

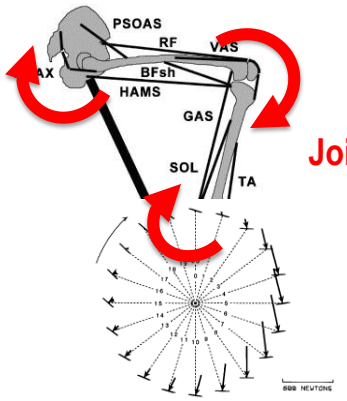


Short-term = decrease of gross efficiency

(Mornieux 2010)

Some explanations…. To explain absence of direct link between pedaling technique and performance

Muscle Coordination



Bi-function msucles
Co-activation
Energy transfer

Joint torque-power

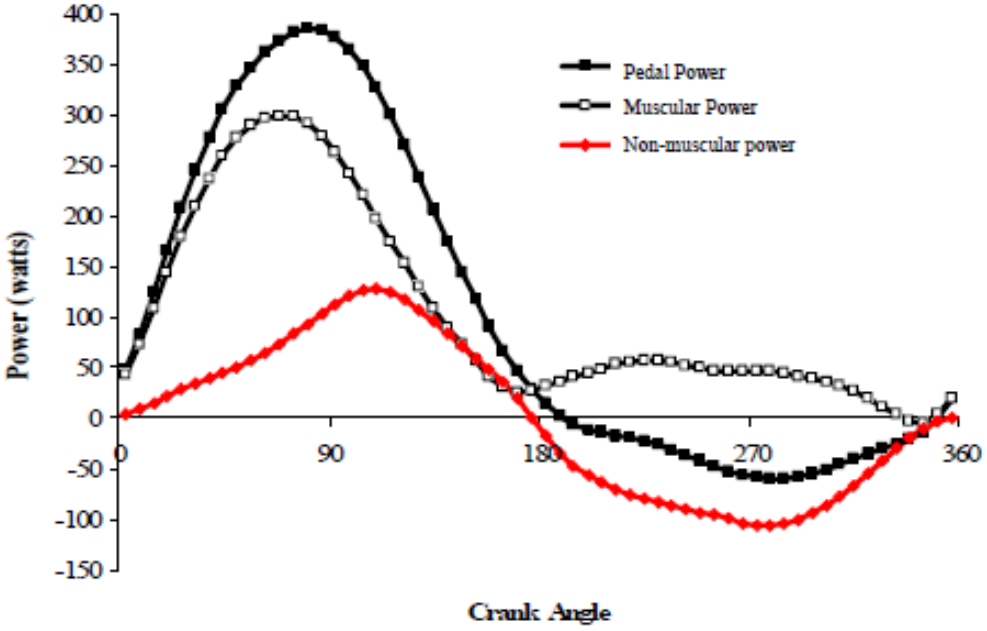
Joint force

Inertial properties of the segments

Pedal force
amplitude and orientation

- ***Coordination in multi-joint task is very complex***

Pedal power =
muscle power + non muscular power



- ***Pedal force and IE depend on other non-muscular elements***

Theory on the control of coordination….

Coordination = Minimization of cost functions

Optimal control theory : suggests the muscle coordination depends on different cost functions
(Prilutsky 2000).

Problem = a lot of functions

Minimization of :
. total force and stress
. metabolic demand,
. muscle fatigue
. between joint energy transfer
. perceived effort
. neural activity
. error-variability

1. **no single factor** as the governing mechanism in muscle coordination *(Kautz et al. 2000)*
2. **trade-off between these cost functions** exist and interactions with the biomechanical constraints of the task may occur *(Brochner Nielsen et al. 2016)*

Take home messages and perspectives….

No direct link between torque profile/effectiveness and performance

Individual coordination strategy

Some perspectives about long-term effect of training… but:

- ***Do not try to improve IE alone!***
- ***Training program should improve/optimize something linked to PERF***

2 mains goals to verify it participates to improve performance

Decrease FATIGUE/ RPE

Increase time to exhaustion

Save metabolic energy for better finishing

Increase efficiency - reduce energy cost

Increase time to exhaustion

Higher intensity on a given distance: increase power on time trial

+ others: comfort, prevention injury, aerodynamics etc…

First positive observations *(Theurel et al. 2012)*

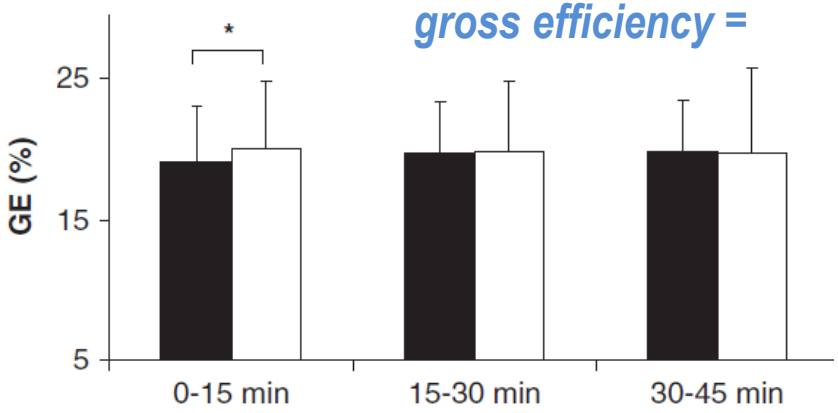
Training with feedback

45 min at 75% of MAP

■ Feedback: pulling
□ Normal

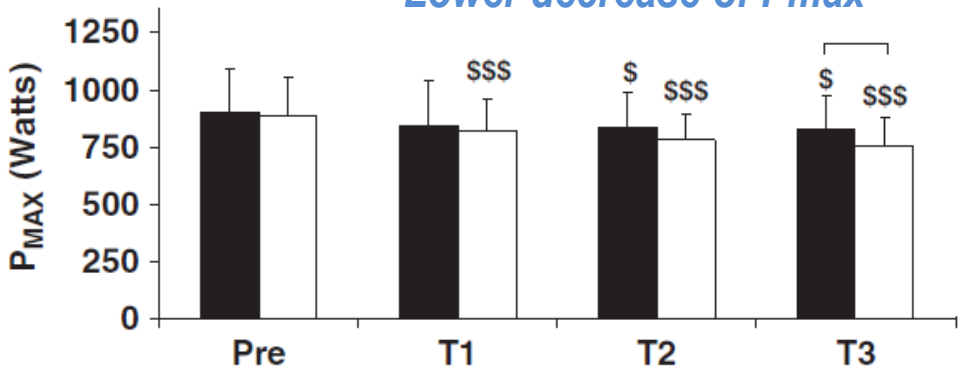
Theurel et al. 2012

gross efficiency =



EFFICIENCY

Lower decrease of Pmax



SPRINT : Maximal Power

No problem for efficiency with time

Better capacity to repeat sprint with fatigue

Recreational cyclists: low neuromuscular adaptations

Some ideas….

Strength training / specific strength training / feedback training

- **Classical strength training: knee and ankle extensors**

Mujika et al 2015
Rønnestad et al 2015 :

- **Enhance the capacity and involvement of other muscles (Flexors) : delay fatigue of knee extensors (most fatigable?)**

➡ But: capacity to really modify the coordination?

- **Effect of very long term training and early in the career with specific tools?**

Master Your Pedalling Technique To Improve Your Cycling

POSTED ON AUGUST 8TH, 2017 IN TECHNIQUE

How to improve your pedalling efficiency and technique

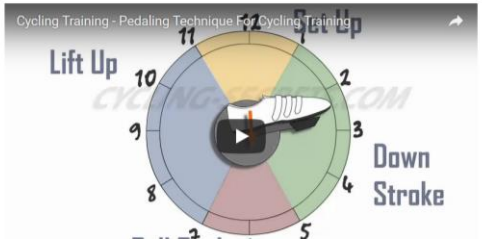
Want to pedal like a pro? Here's how...

BY ASHLEY QUINLAN

NOVEMBER 24, 2017 | BY BADASSERY | NO COMMENTS | FITNESS

Cycling: Using drills to improve my pedalling effectiveness

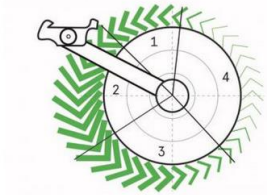
Pedaling Technique

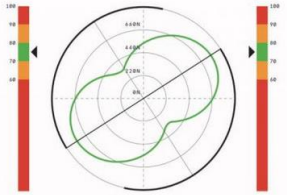


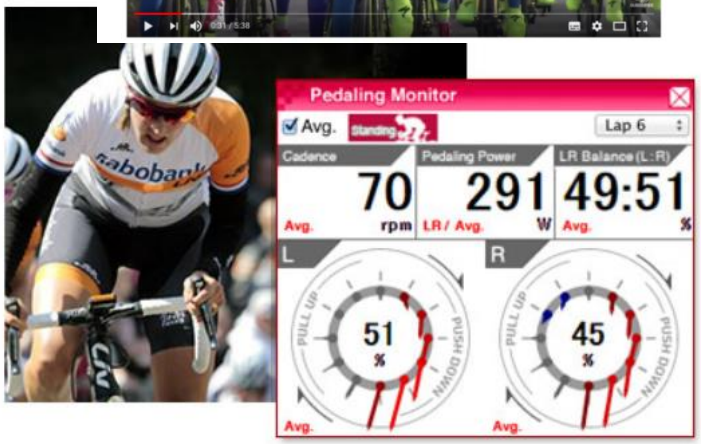
How to pedal perfectly, according to Wattbike

by Mat Brett August 14 2017

Indoor bike trainer now comes with Pedalling Effectiveness Score designed to help you optimise your pedal stroke

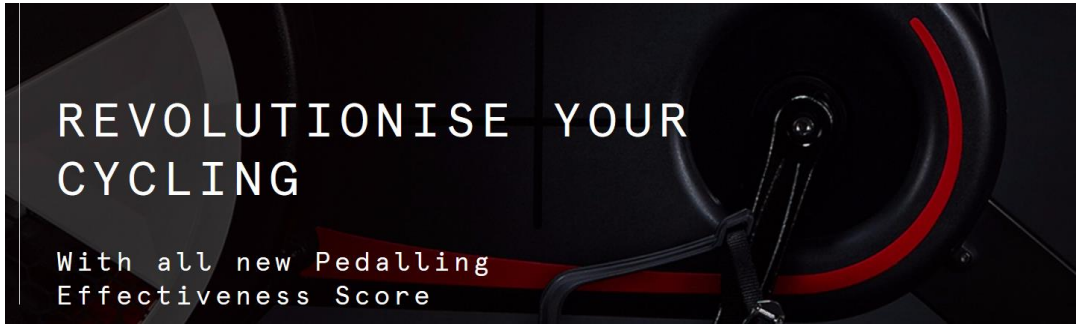






8 Ways to Smooth Out Your Pedal Stroke

PRACTICE THESE POINTERS REGULARLY, AND YOU'LL BE RIDING WITH SOUPLESSE IN NO TIME



Some ideas….

Strength training / specific strength training / feedback training

- **Classical strength training: knee and ankle extensors**

Mujika et al 2015
Rønnestad et al 2015 :

- **Enhance the capacity and involvement of other muscles (Flexors) : delay fatigue of knee extensors (most fatigable?)**

➡ But: capacity to really modify the coordination?

- **Effect of very long term training and early in the career with specific tools?**

1. Specific strength training

Force and high level of activity (sprint)

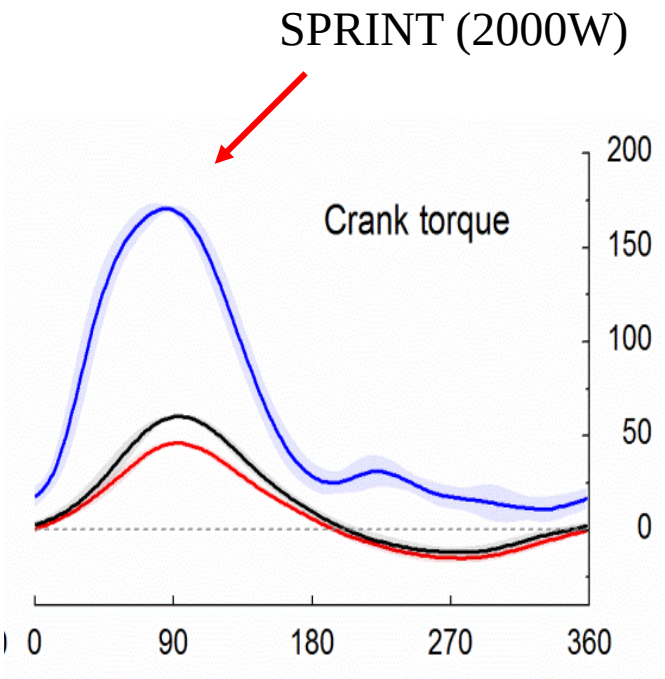
2. Increase voluntary activation

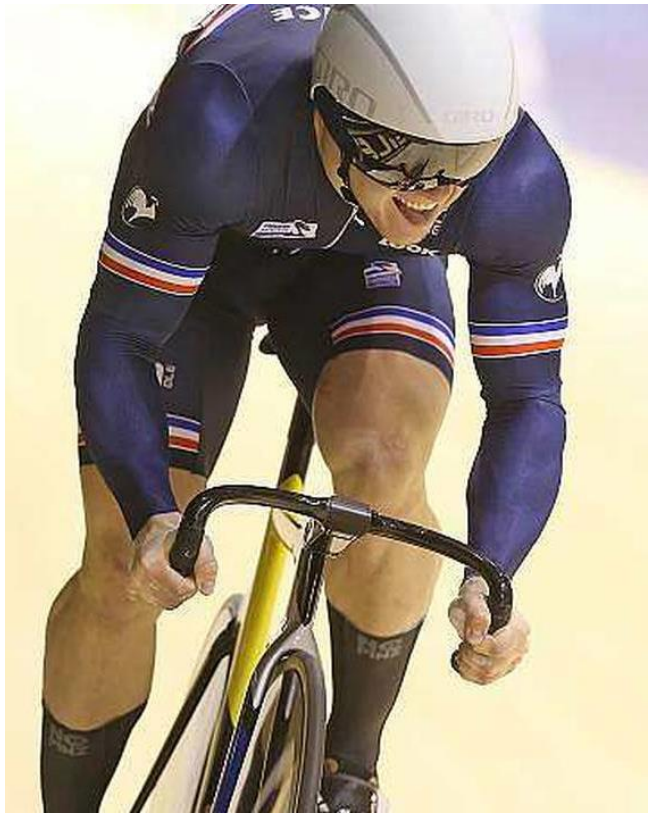
real-time feedback

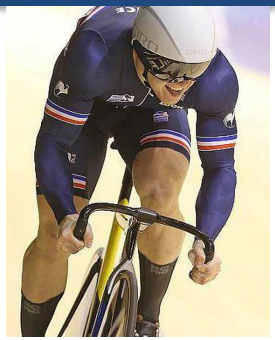
3. Impose an increase of activation using another pedaling coordination

one leg cycling, powercranks

A. Pedal force: effect of expertise and inter-individual variability

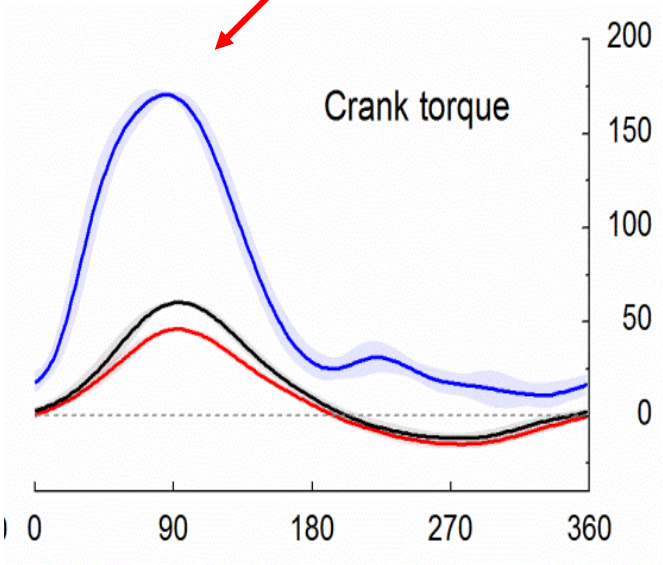






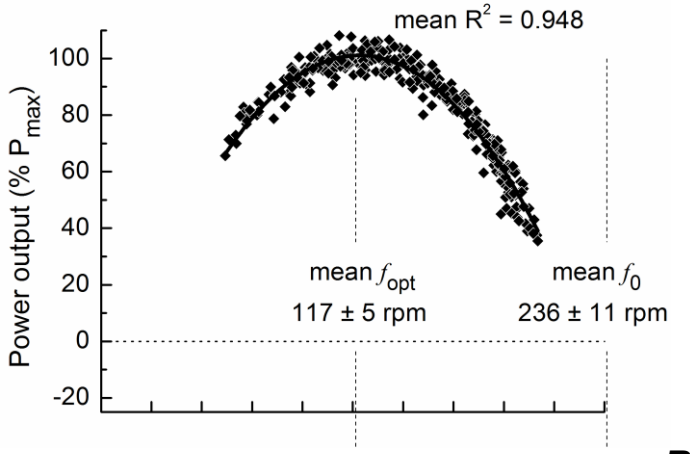
A. Pedal force: effect of expertise and inter-individual variability

SPRINT (2000W)



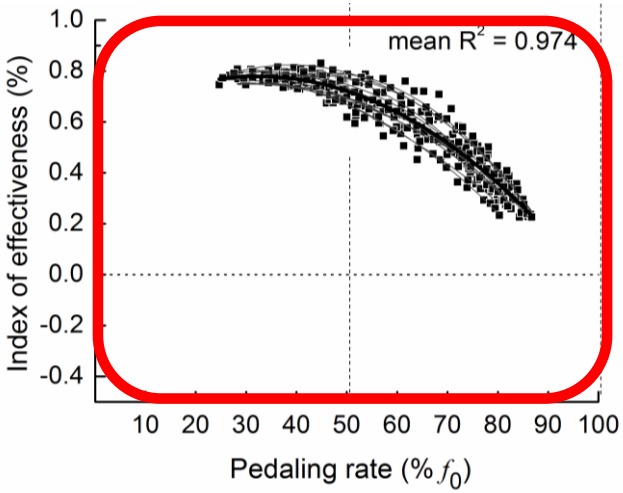
Muscle function of extensor + flexor muscles involved in upstroke phase

(Martin and Brown 2009)



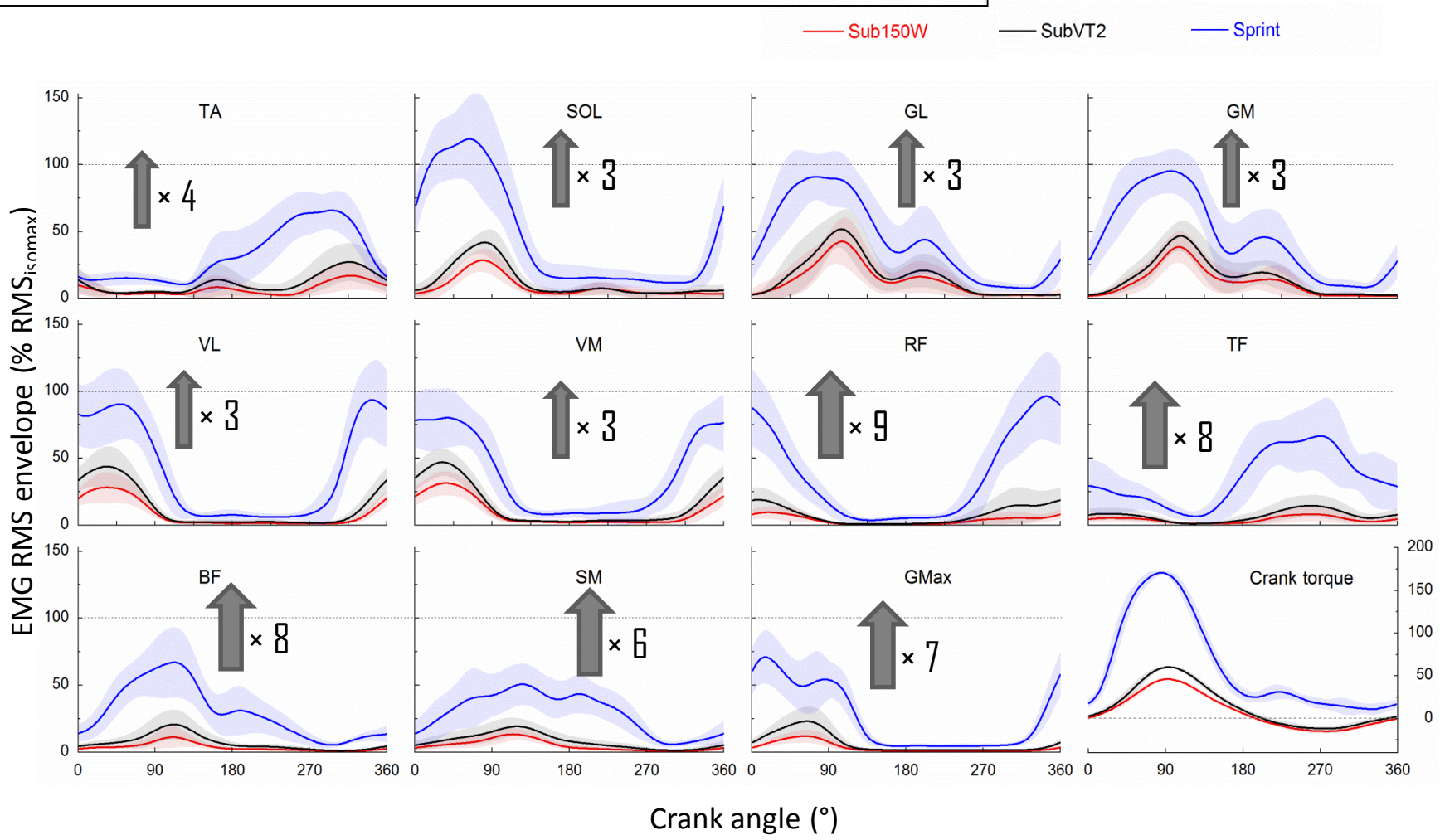
Very high values of IE inter-subject variability

Role of technical aspects? Expertise?



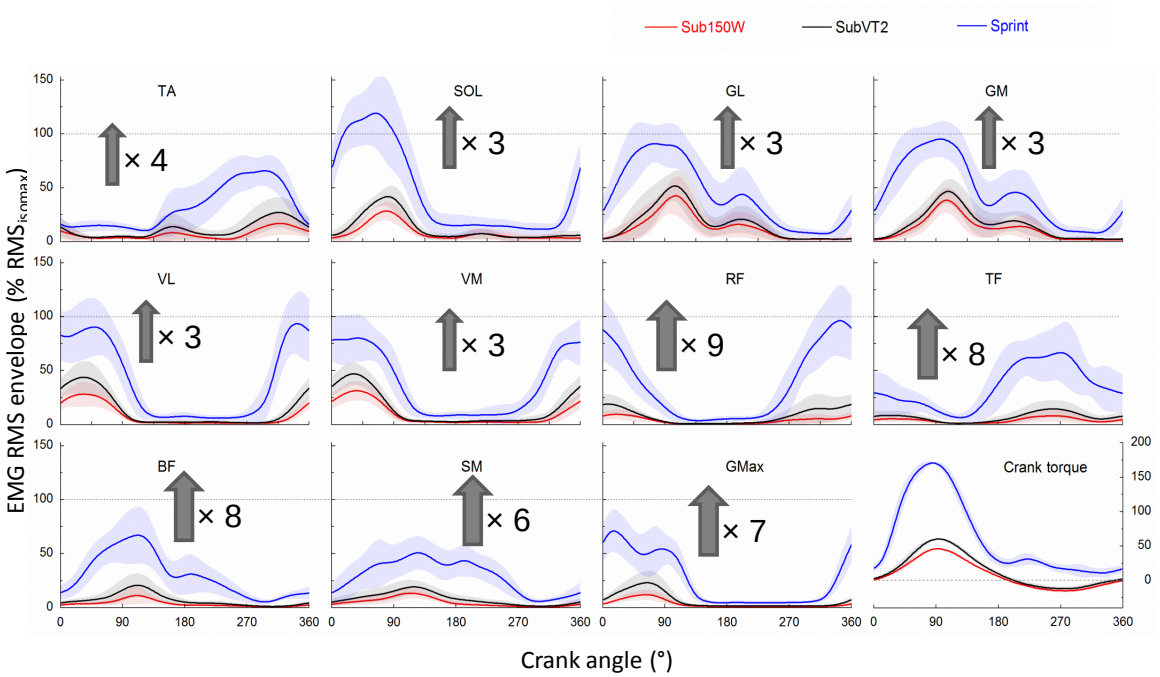
(Dorel et al. 2010)

B. Specific coordination in sprint / Submaximal exercise



(Dorel et al. 2012)

B. A specific coordination in sprint / Submaximal exercice



► Very large increase in the hip and knee flexors and hip extensors

➡ **Additional evidence of role of flexor muscles**

► Non “maximal” EMG activity and important variability for hamstrings and gluteus

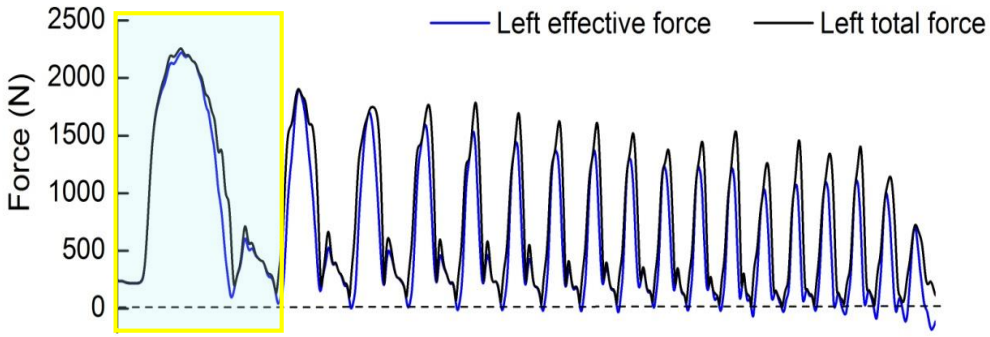
► Important increase in the duration of activity: enhance the work

➡ **Strategy to improve IE by muscle coordination optimization?**

C. Some preliminary positive results in sprint performance in top-level track cyclists

- ► Population: 15 top level sprinters
- ► Protocol: 125m sprint starting machine
- ► Maximal Force and Index of effectiveness IE

Performance measurement: 50m time

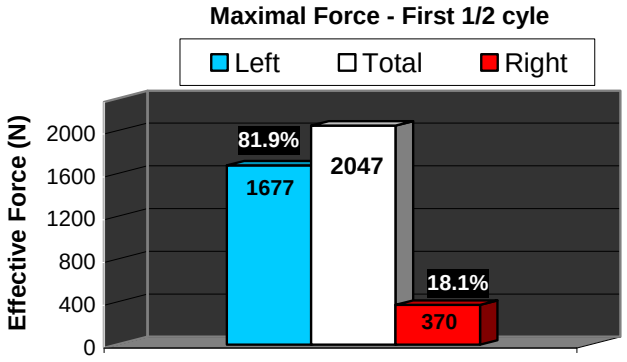


VélUS

FONDATION D'ENTREPRISE FRANÇAISE DES JEUX

Even greater upstroke contribution than on ergometer

Very higher IE : 85-95%



Force MAX totale (N/kg)
25.1

Downstroke IE
94%

Upstroke IE
95%

Theory on the control of coordination….

SPRINT is simpler!

<u>The motor control "challenge" can be reduced to a unique goal</u>

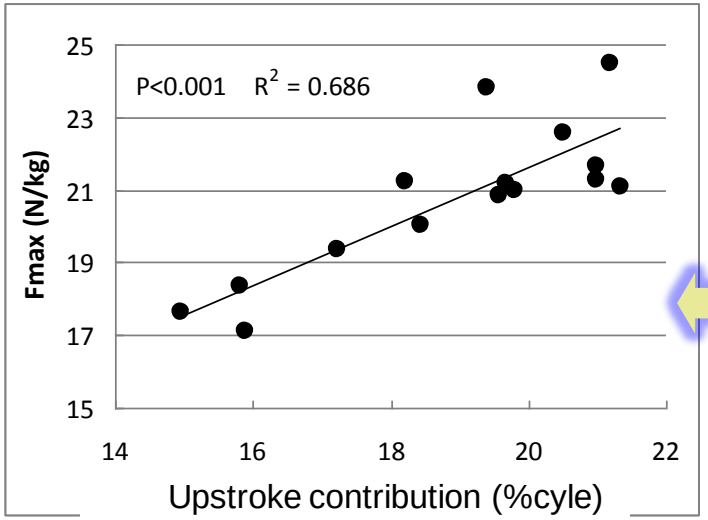
Coordination = Maximizing pedal power?

(+ minimizing FATIGUE for long sprint)

The question is to know if the coordination strategy and pedaling technique may be related to an improvement of the overall mechanical output (independently of the intrinsic mechanical properties of muscles)

C. Some preliminary positive results in sprint performance in top-level track cyclists

Fmax = performance factor



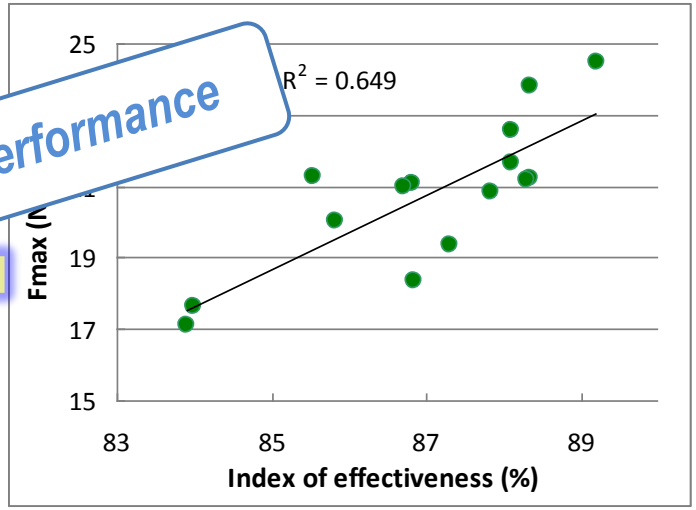
▶ UPSTROKE

18.9 ± 2.1 % with variability (14.9 to 21.3 %)
Role of flexor muscles
(Dorel et al 2010, Martin et al 2009)

▶ EFFECTIVENESS

Role of pedaling techn… and performance

First evidence of a link IE - Performance



Optimization of muscle coordination?

Role of intrinsic muscle capacity vs coordination ?

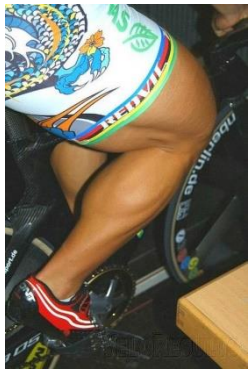
PhD of Iris Sachet….

- ► Importance of all muscle groups ?
- ► Optimization of muscle coordination: which aspects?

To confirm or find new practical implications….

Strength training / specific strength training

- **Maintain the goal to progress in the muscle capacity of the main single-joint power producers:** knee extensor + hip extensor
- Enhance the **muscle capacity of the knee and the hip flexors (when standing)** to enhance contribution of upstroke phase (performance factor)
- Very high level of activity of triceps surae:
  (higher than ISO and = explosive SJ)
  = **ankle extensor : limiting factor for performance ?**



Strength training / Coordination / Technique

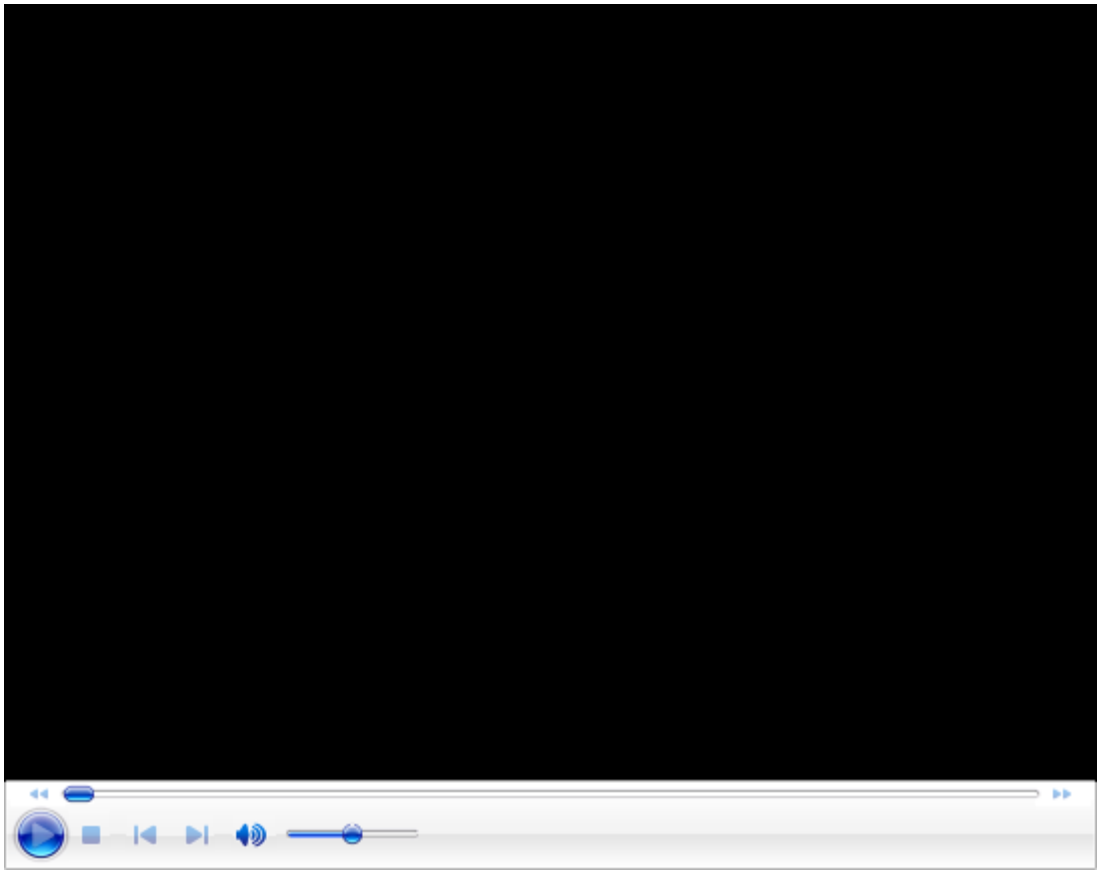
- Importance of maximizing activation duration throughout the cycle, especially for bi-articular: **improvement IE by optimization of muscle coordination** (level and duration of activity)

Strength training / Coordination / Technique

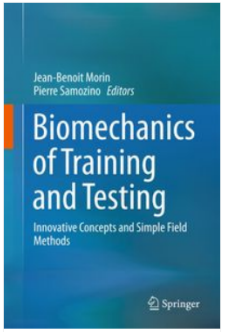
FÉDÉRATION FRANÇAISE DE CYCLISME

➡ Direct Feedback

during training session?



Thank you !



CHAPTER 3

Biomechanics of Training and Testing

Mechanical Effectiveness and Coordination: New Insights into Sprint Cycling Performance

Authors: Sylvain Dorel

The pedaling task remains a multijoint task with biomechanical constraints (e.g., circular trajectory of the pedal) requiring specific coordination of the lower-limb

<u>Scientists - Colleagues:</u>

• F Hug,

Laboratoire
Motricité - Interactions - Performance
EA 4334 Nantes - Le Mans

• A Couturier, G Guilhem

•Y Champoux, J-M Drouet

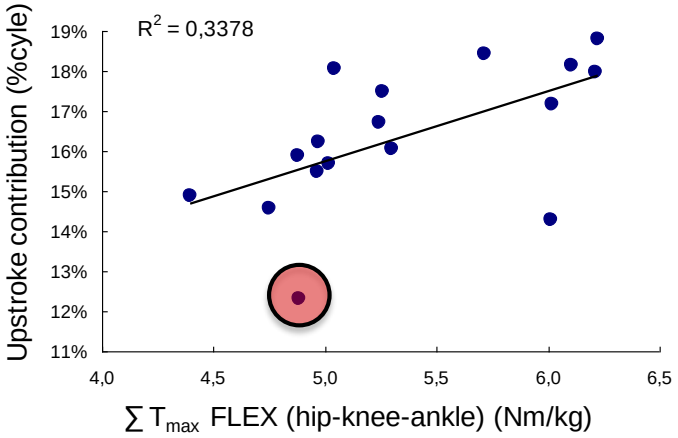
<u>French federation of cycling :</u>

F Rousseau, B Vétu, F Durivaux

All the athletes

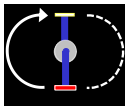
<u>Funding</u> : FdJeux.com, French Ministry of sport

pedaling (at 80%Vopt)



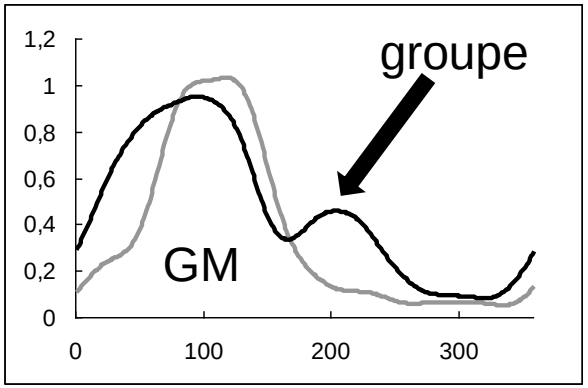
Role of upstroke phase

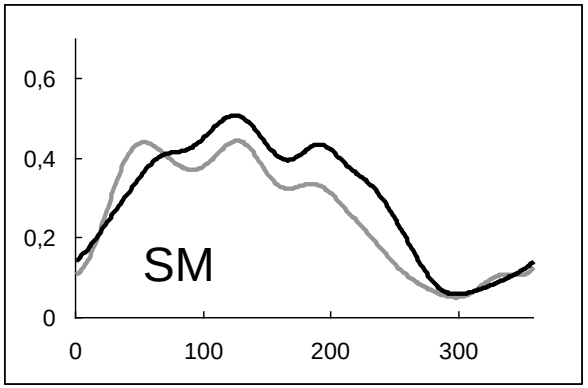
Upstroke contribution (%cyle)



▶ **Intrinsic flexor muscles capacities**

EMG Patterns (%RMSisomax): case study and feedback





Crank angle (°)

But: high variability

Expertise and role of muscle coordination

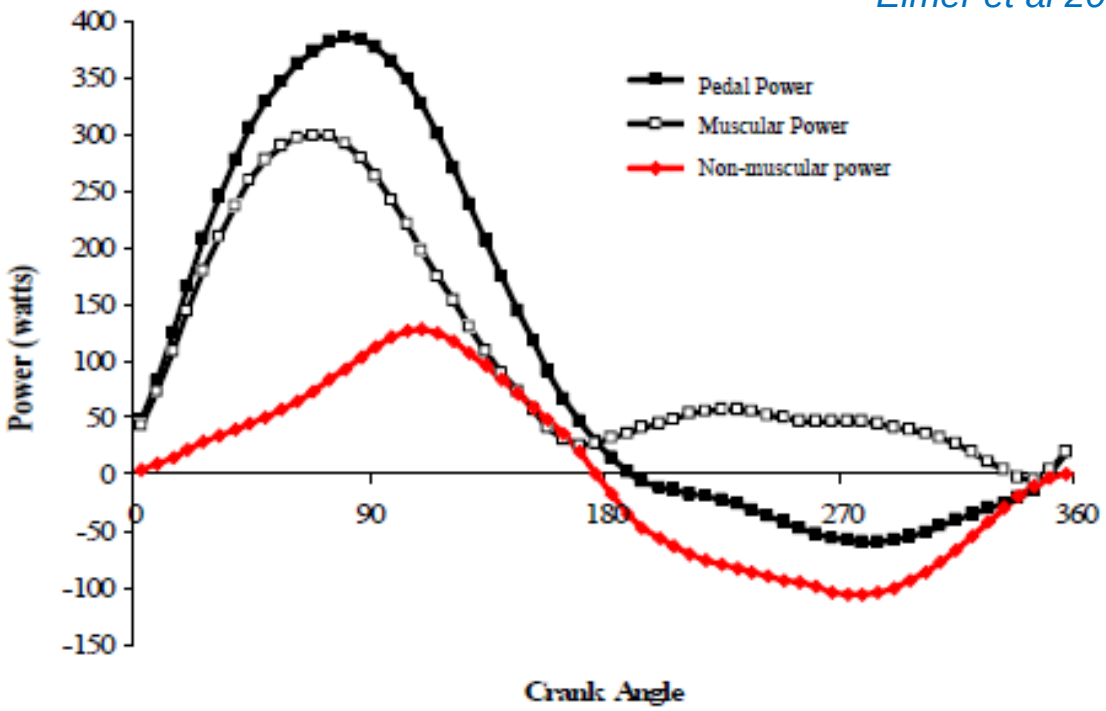
Bi-articular muscles?

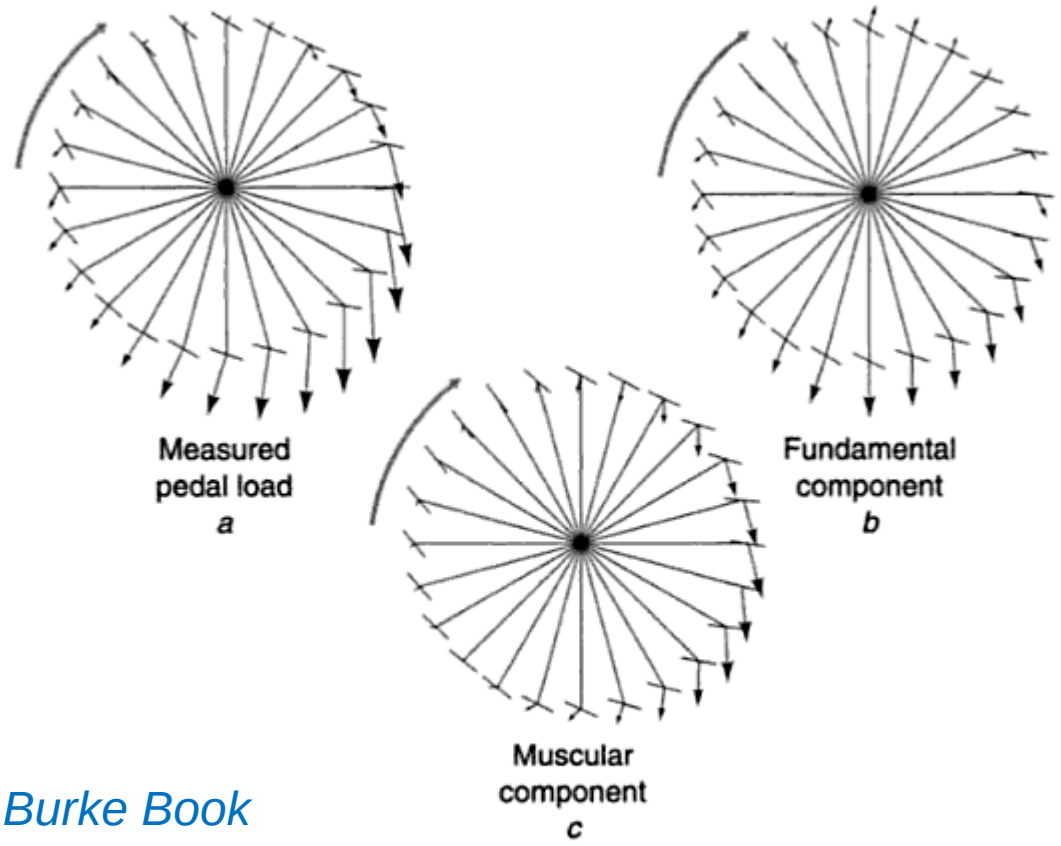
Pedal power = muscle power + non muscular power

Martin et al 2009
Elmer et al 2011

Muscle forces

Energy change of the segments: kinetic and potential



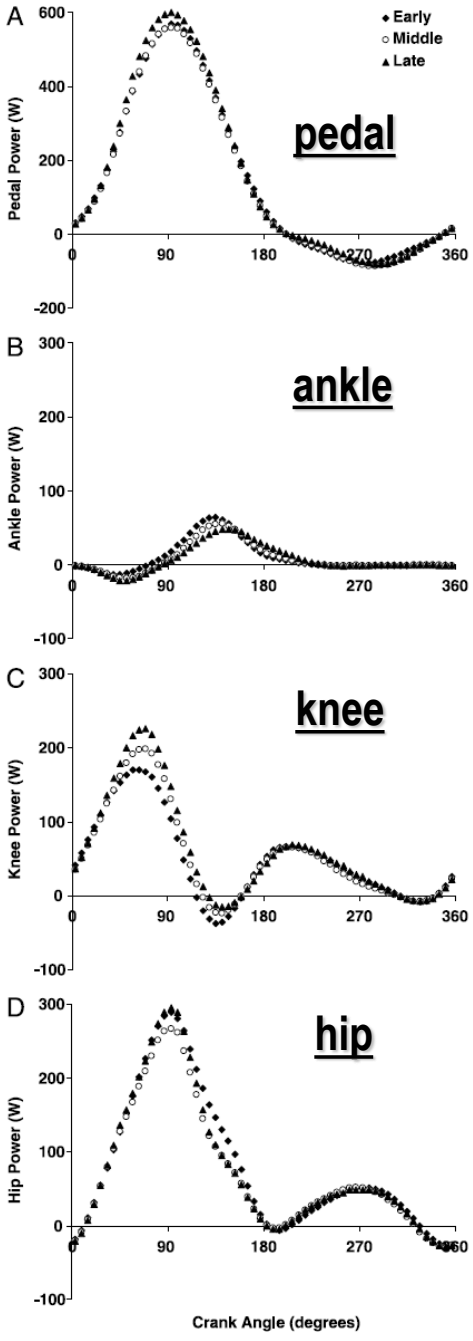


Burke Book

FIGURE 5.8 Clock diagrams illustrating the *(a)* measured, *(b)* natural (nonmuscular), and *(c)* muscular components of pedal loading for an elite U.S. National Team cyclist. The muscular and natural components sum to create the measured load. The natural component is derived from the inertial and gravitational effects present during pedaling, and thus arises at no cost to the rider.

A lot of studies:

Ericson,
Gregor,
Van Ingen Schenau
Martin JC, Elmer
Kautz
Neptune
Korff



► Possibility to estimate the contribution of each joint power (and indirectly the main muscles involved)

Submaximal exercice

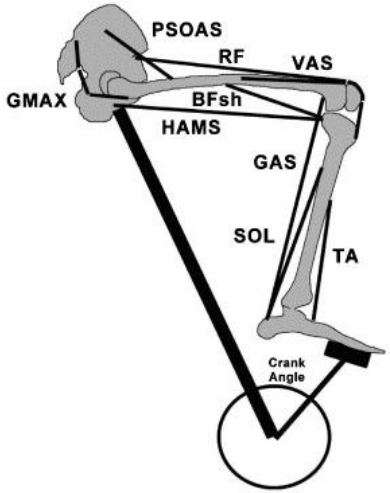
13 %

Flexion

Hip 4%

Knee 12%

Ankle -2%



87%

Extension

Hip 39%

Knee 30%

Ankle 17%

(Martin and Brown 2009)

Force and power-velocity relationhips
=
Muscle function of both extensors and to a lesser extent flexors

(Dorel et al 2010)

Sprint cycling

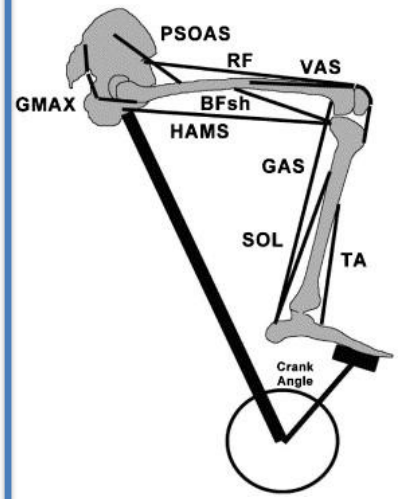
24 %

Flexion

Hip 6%

Knee 20%

Ankle -2%



76%

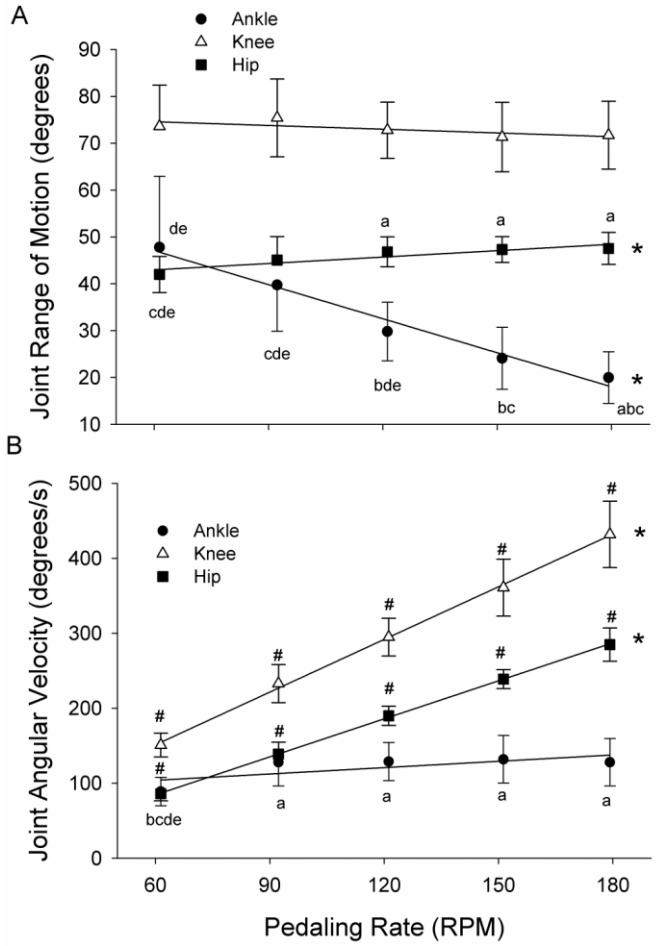
Extension

Hip 40%

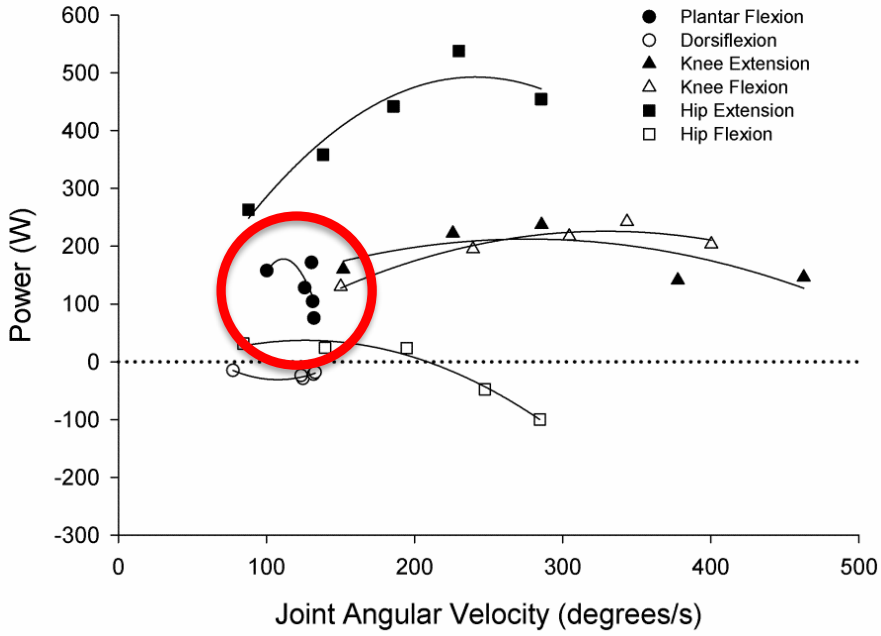
Knee 22%

Ankle 14%

(Martin and Brown 2009)



MC Daniel et al, 2014



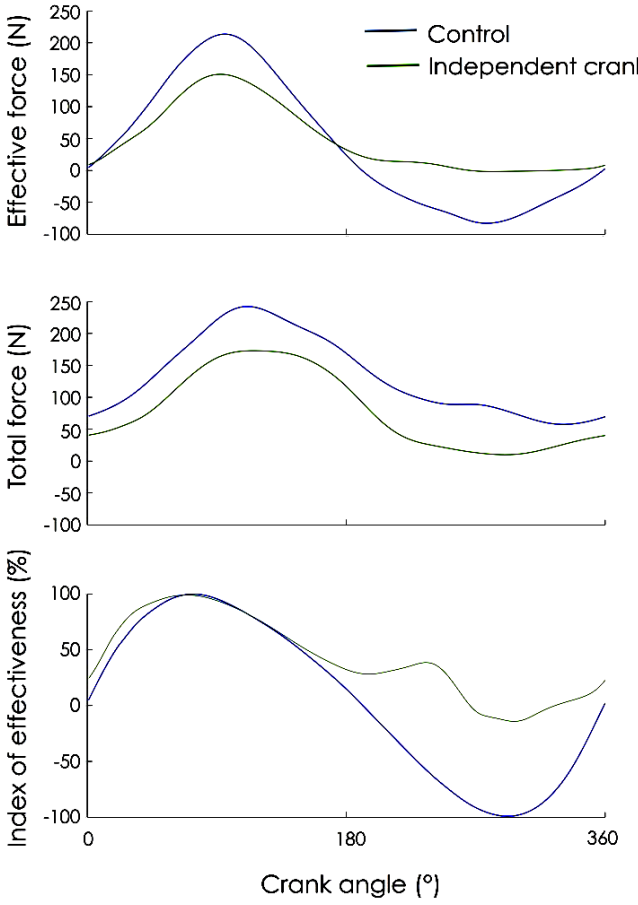
Ankle : decrease rage of motion
And constant velocity !!

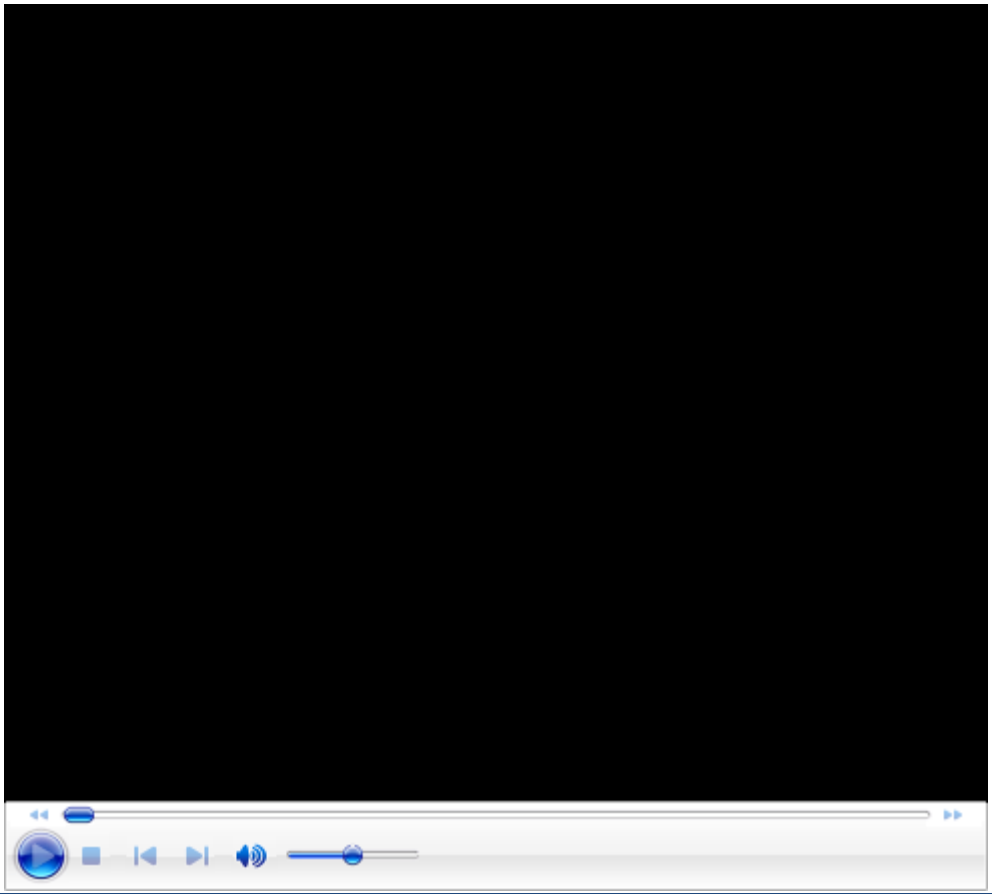
Low velocity value referring to Vmax
Fmax or Force-Power

Perspectives of optimization and training ?

Exemple: Powercranks system

Hug et Dorel 2013

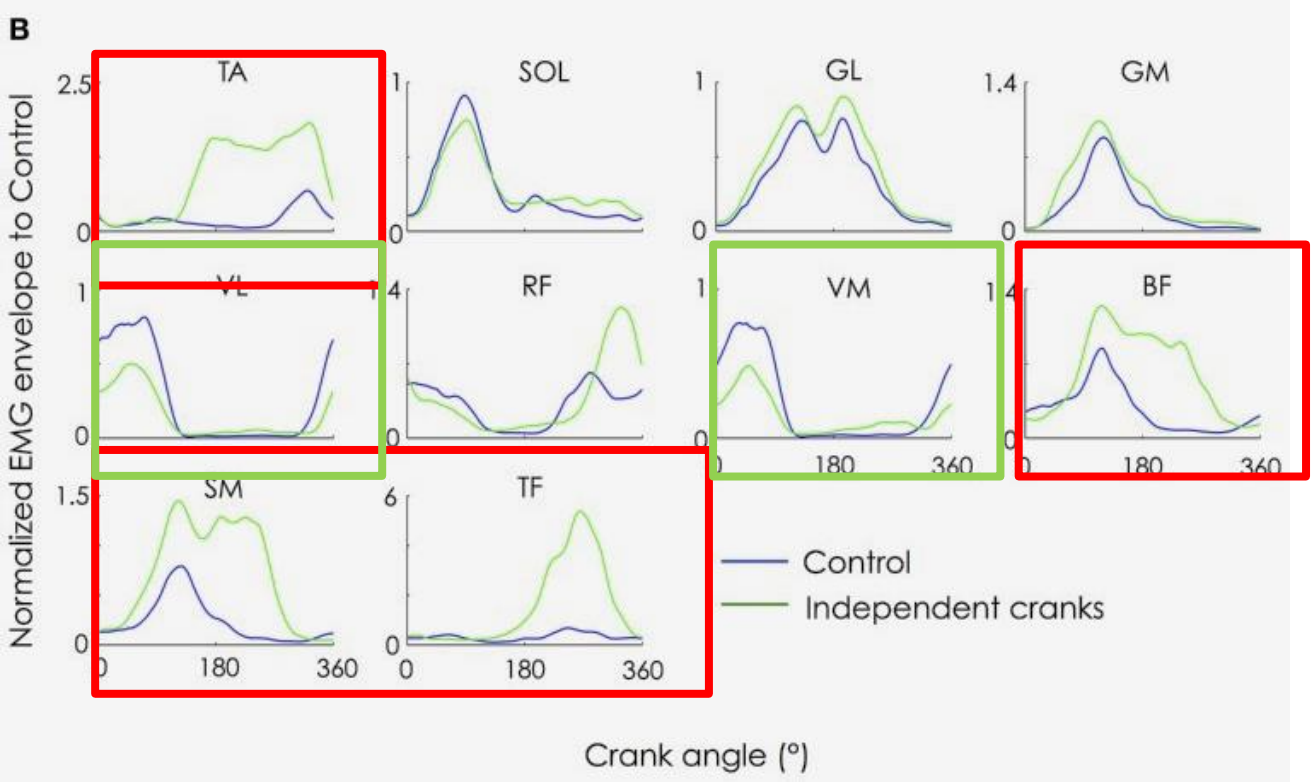




➡ Exemple: Powercranks system

All flexors:
Pulling action (hip):
High strength training

BDC and initial phase of upstroke (hamstrings)
Technique



Again: which long-term effect ? *(Fernandez-Pena et al. 2009)*

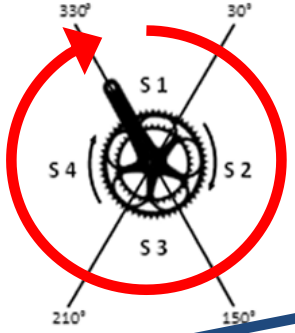
Slight alteration: increase of hamstring...
But: stabilization in time? Improvement of IE?

Cyclic task = one crank cycle (0 à 360°)

Amplitude

Pedal displacement

System bike+cyclist displacement



Frequency - duration

Cadence - pedaling rate

Crank length

Gear ratio

Joints angle

Muscles length

Force applied on the pedals

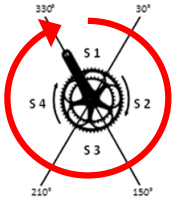
Muscle force

Pedal velocity

Shortening velocity of the muscles

Activation dynamics

A lot of muscles : « muscle coordination »



Choice of the gear ratio

Net crank torque

Pedaling rate

External power (crank)

A lot of commercial devices…!!

Crank

Wheel

Pedal

External power output ecological measurement - performance

Power: simple but still very useful parameter on the field!

Submaximal exercice

Power profile : critical power, MAP

Power demand and distribution,

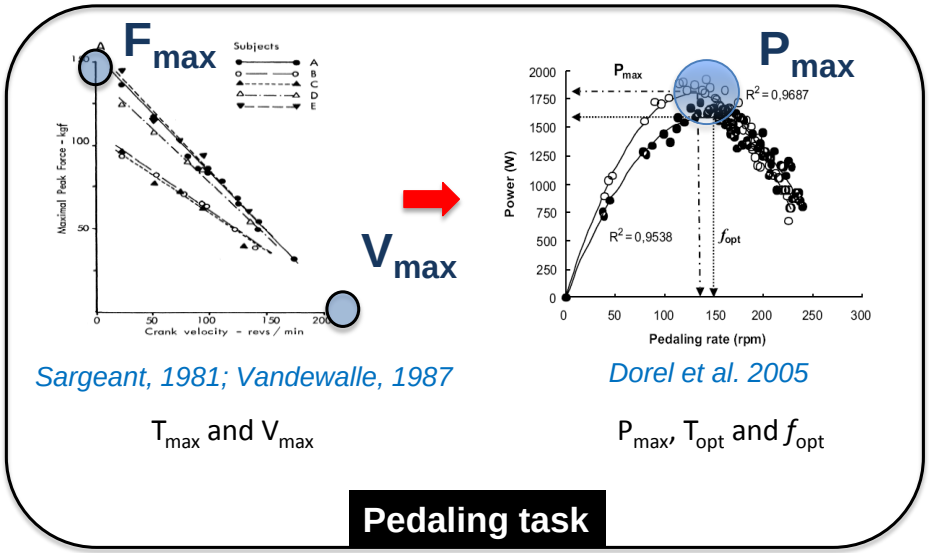
SCx: aerodynamics field measurement

Road, off-road, and endurance track cycling

Sprint cycling

Force-velocity

power-velocity relationships



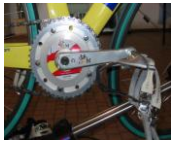
►Indexes of muscle function of lower limbs

►On specific performance?

Some power-velocity characteristics are related to world-class performance (200 m sprint): P_{max}/A_p, f_{opt}

(Dorel et al. 2005)

During sprint performance: net power measurement remains very useful ….

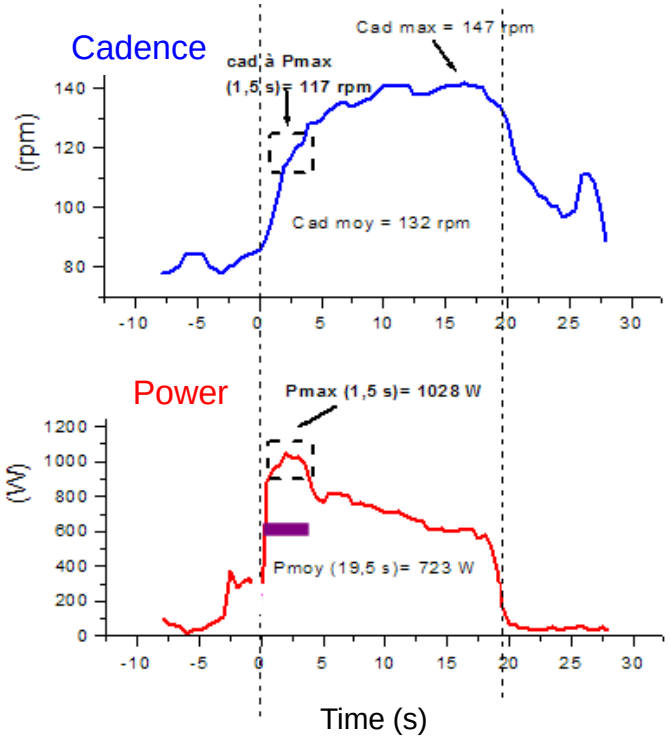


Ecologically!!

Optimizing and control training

Training: the different qualities: Force, power, velocity
Controlling: involvement - fatigue

► Power session

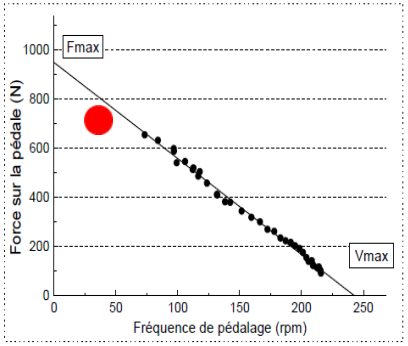


During sprint performance: net power measurement remains very useful ….

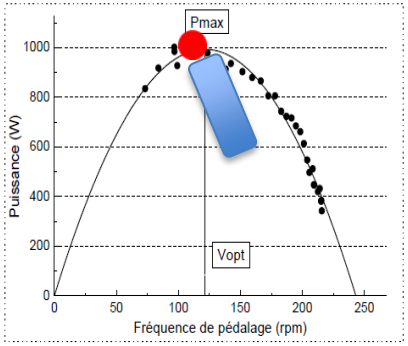
Optimizing and control training

Training: the different qualities: Force, power, velocity
Controlling: involvement - fatigue

▶ Force session

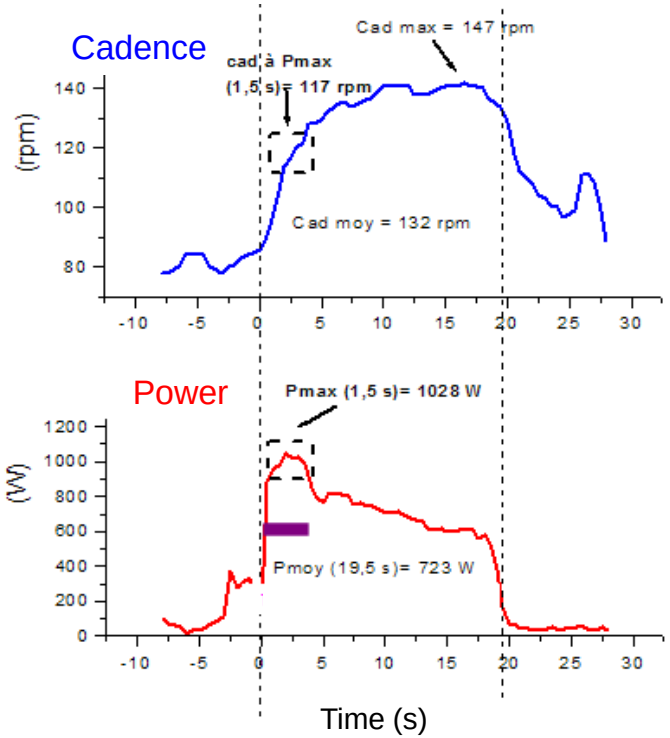


Pmax
power-velocity endurance



Résultats individuels							
Vmax (rpm)	Fmax (N)	Fmax (N/kg)		Vopt (rpm)	Pmax (W)	Pmax (W/kg)	Pmax PIC (W)
243	950	16.4		122	993	17.1	1013

▶ Power session

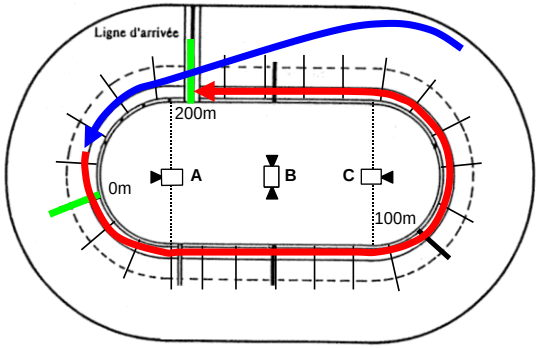


During sprint performance: net power measurement remains very useful ….

Optimizing top level performance in competitions

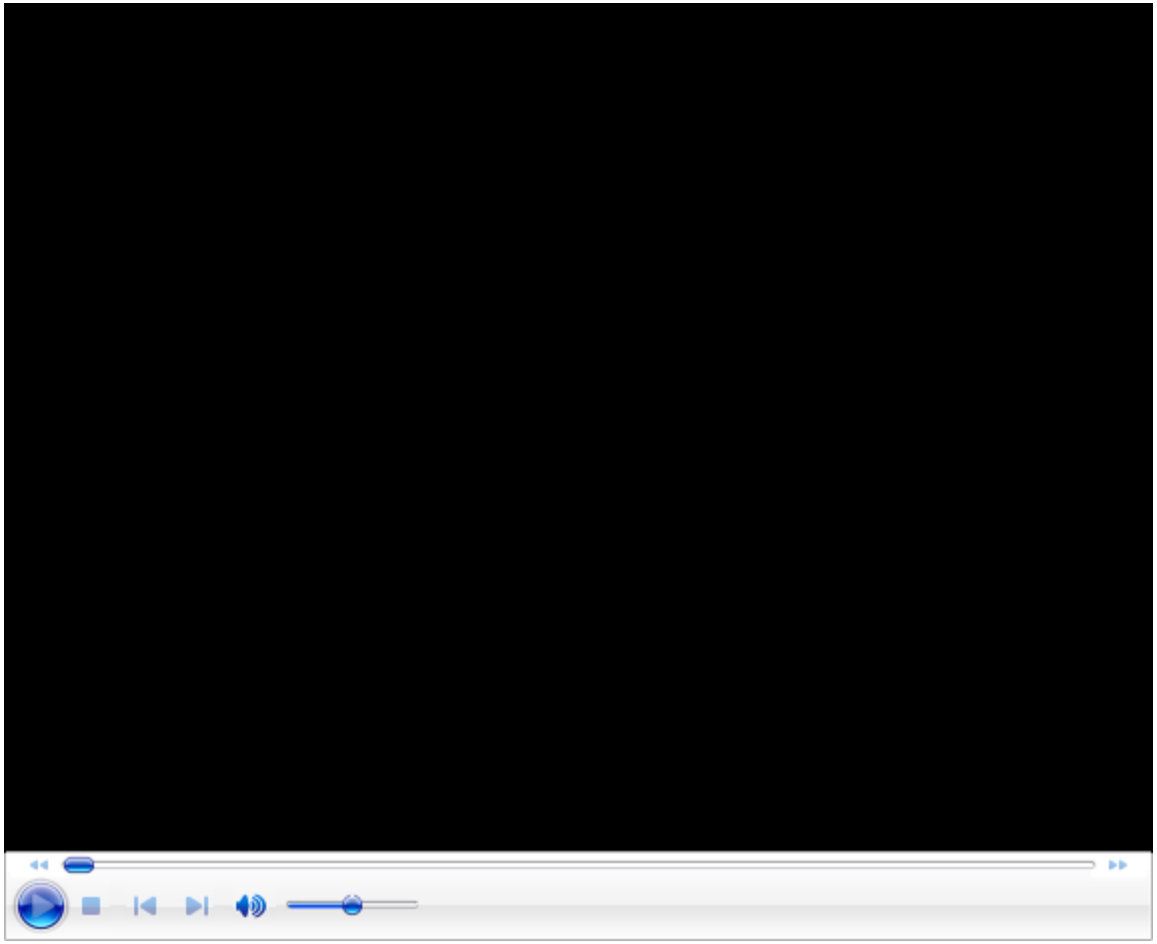
World cup - Cali

200m - Man



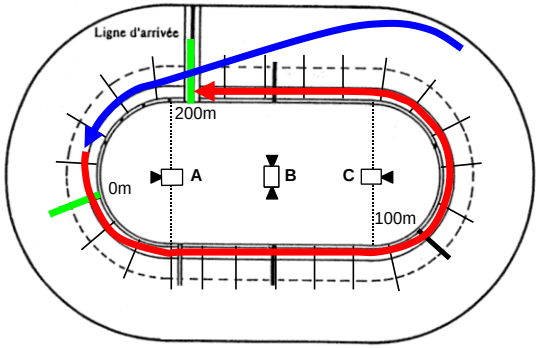
During sprint performance: net power measurement remains very useful ….

Optimizing top level performance in competitions



World cup - Cali

200m - Man



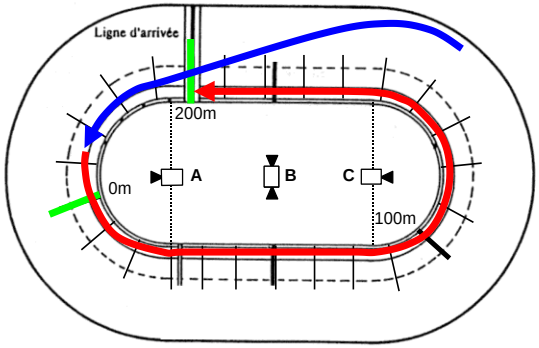
During sprint performance: net power measurement remains very useful ….

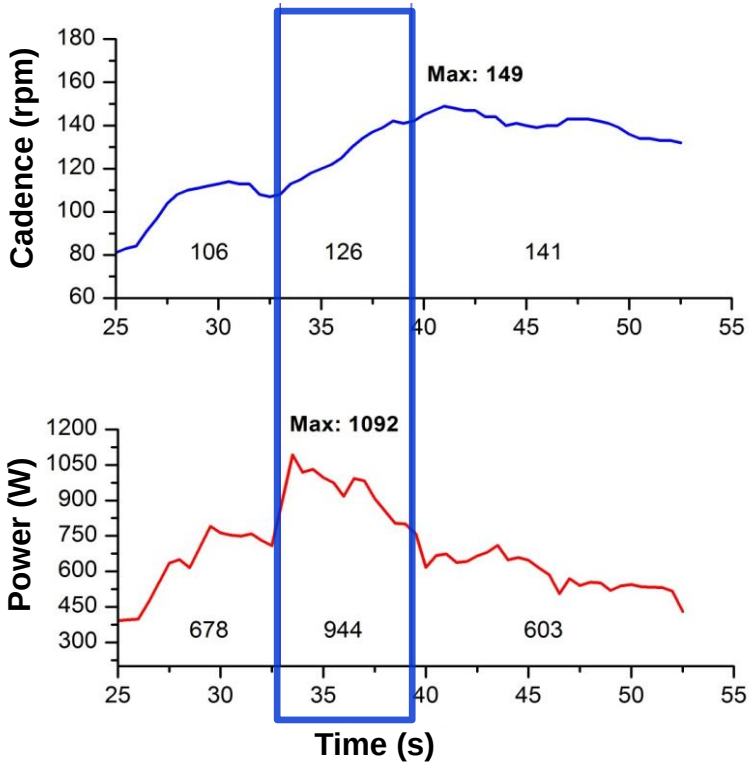
Optimizing top level performance in competitions

Acceleration phase and choice of gear ratio: 200m performance

World cup - Manchester

200m - Woman





Velocity= 105% V_{opt}

Power = 86% P_{max}

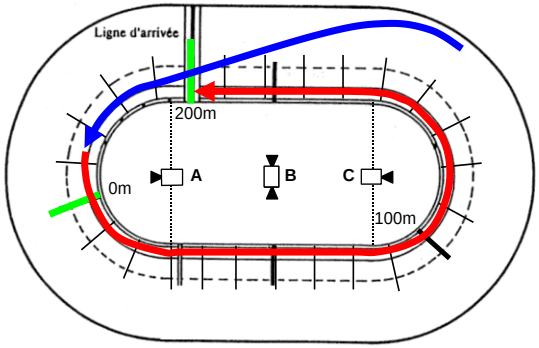
Today: net power measurement remains very useful ….

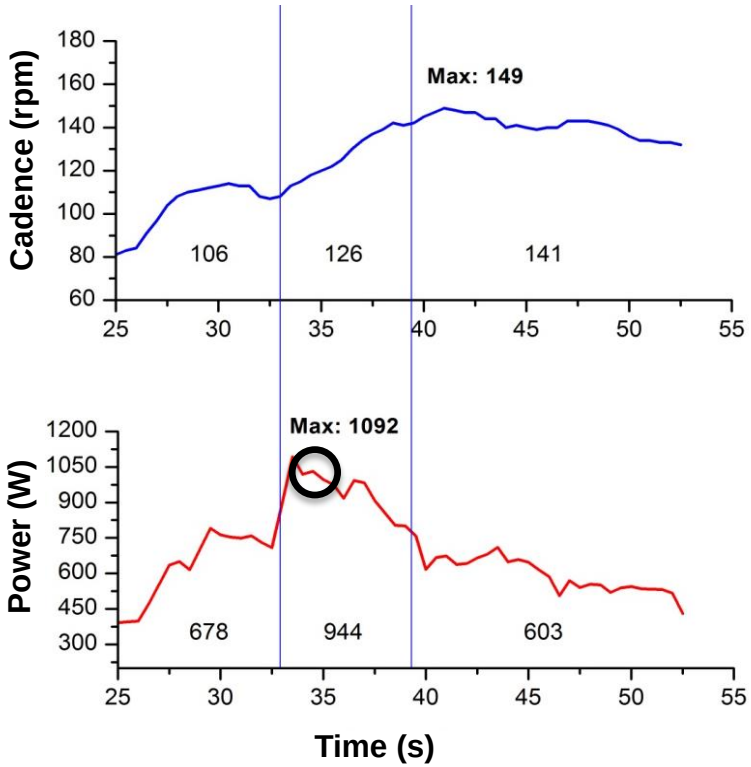
Optimizing top level performance in competitions

Acceleration phase and choice of gear ratio: 200m performance
Sprint match against
Influence of track characteristics

World cup - Manchester

200m - Woman





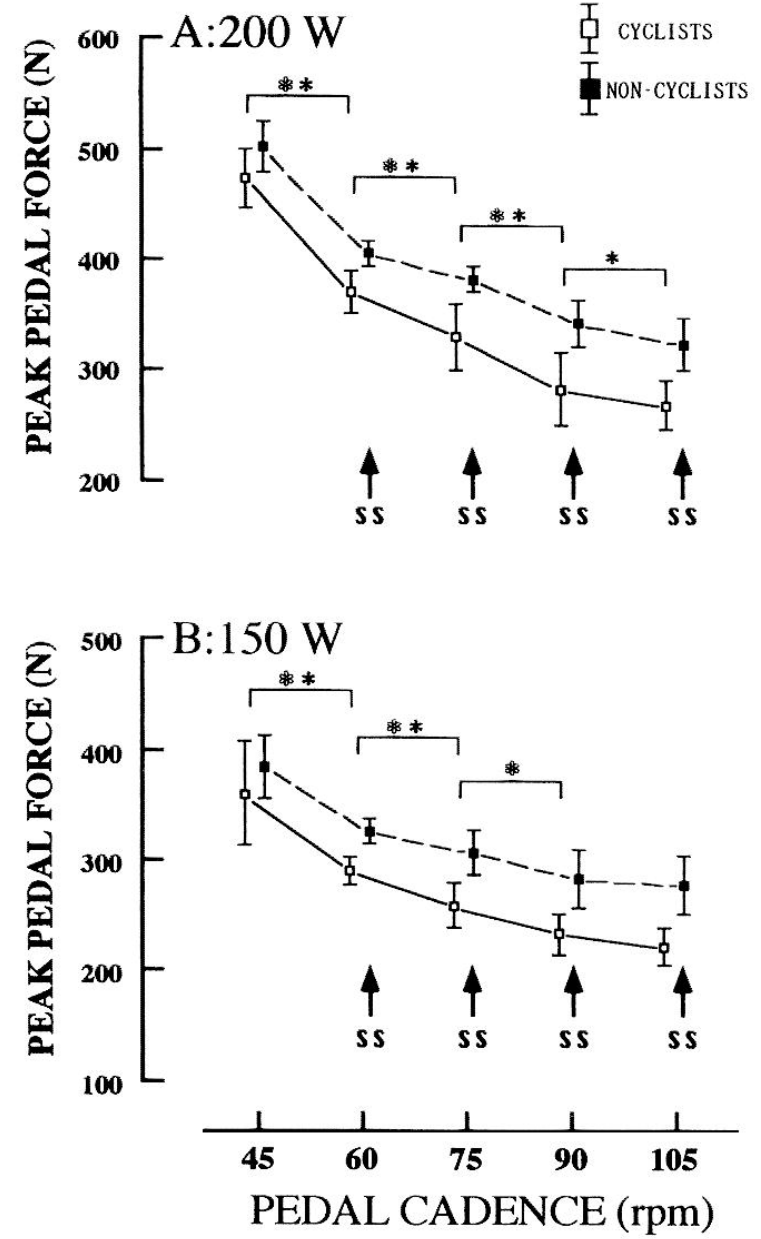
Classical objective: How to enhance the power?

Understand the biomechanics or force application over the crank cycle!

Effet de l'expertise et variabilité entre les athlè

Pas d'effet majeur de l'expertise!

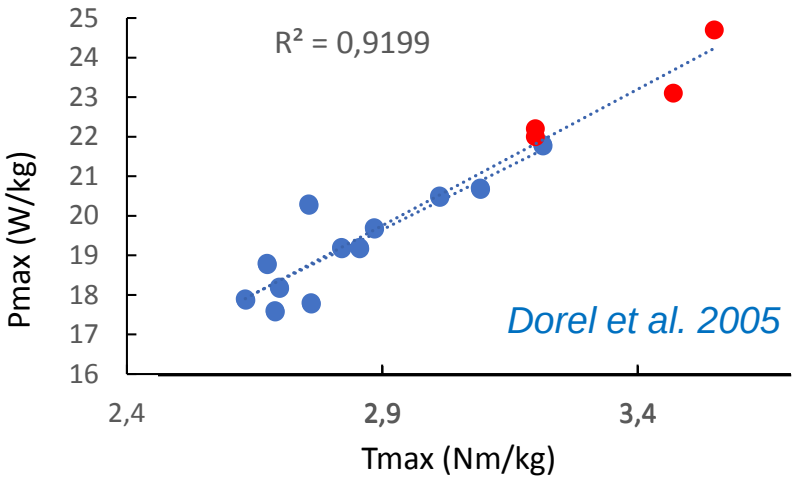
pic exercée sur les pédales plus importante pour des sédentaires à cadence et puissance identiques



Takaishi et al., 1998

« Global » muscle function : enhance maximal power?

►Maximal force of lower limbs



Role of Lean Leg Volume
(LLV-Tmax, $R^2 = 0.4$, $p < 0.01$)

►optimal velocity = 120 to 140 rpm: lower variability (or maximal velocity)

How enhance or maintain these qualities?

Training specifically in different force-velocity conditions

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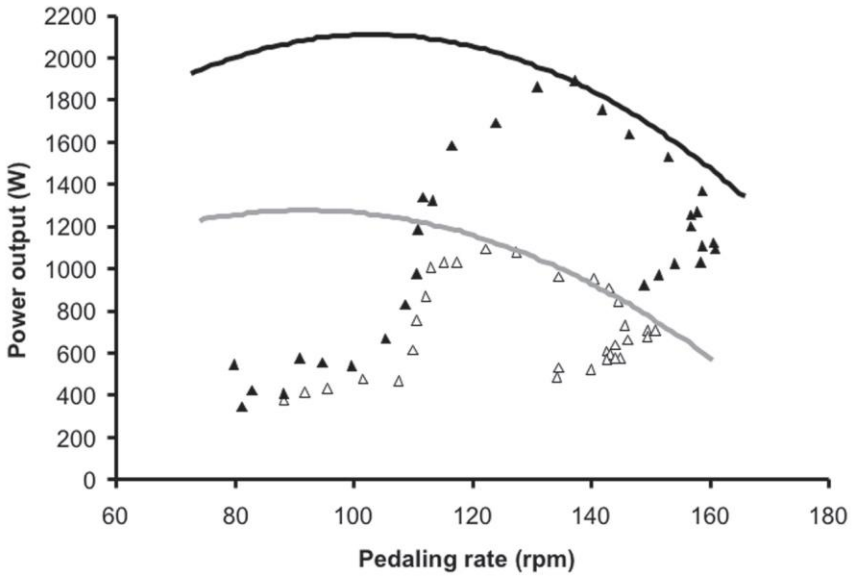

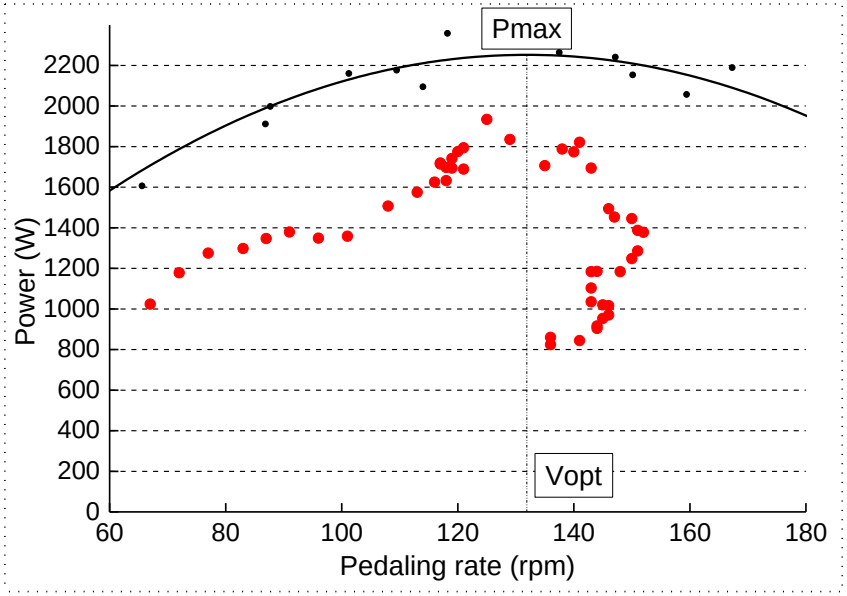

Que se passe-t-il à l'intérieur d'un cycle de pédalage?

Biomécanique d'application des forces + coordination musculaire

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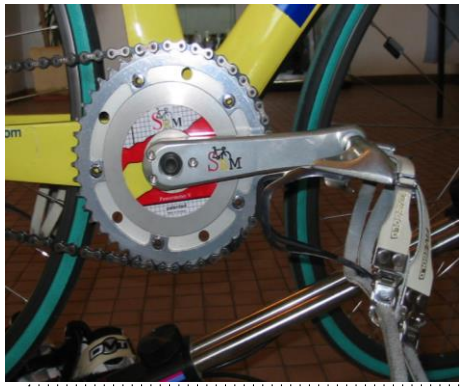
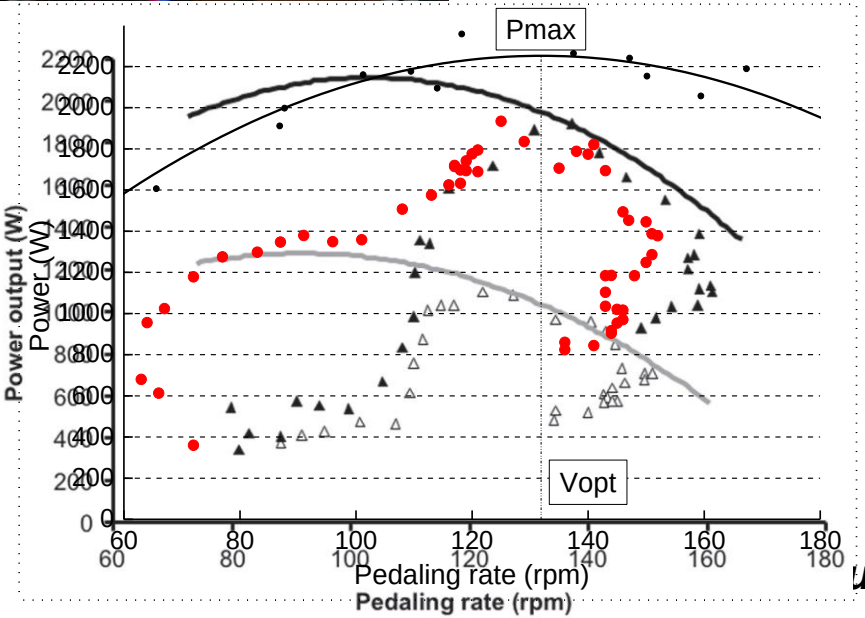
Production du moment net au pédalier



Coupe du monde 2009

200m lancé - Femme



ur d'un cycle de pédalage?

Biomécanique d'application des forces + coordination musculaire

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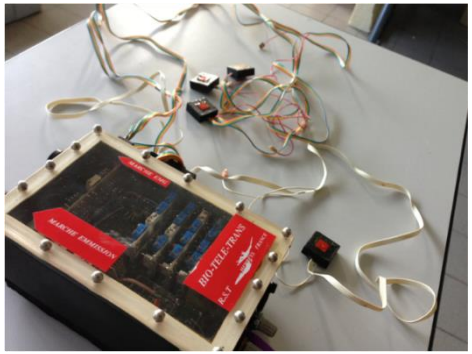
Sollicitation des groupes musculaires

Exercice sous-maximal

Un outils: électromyographie de surface

Technologie WIFI



1988

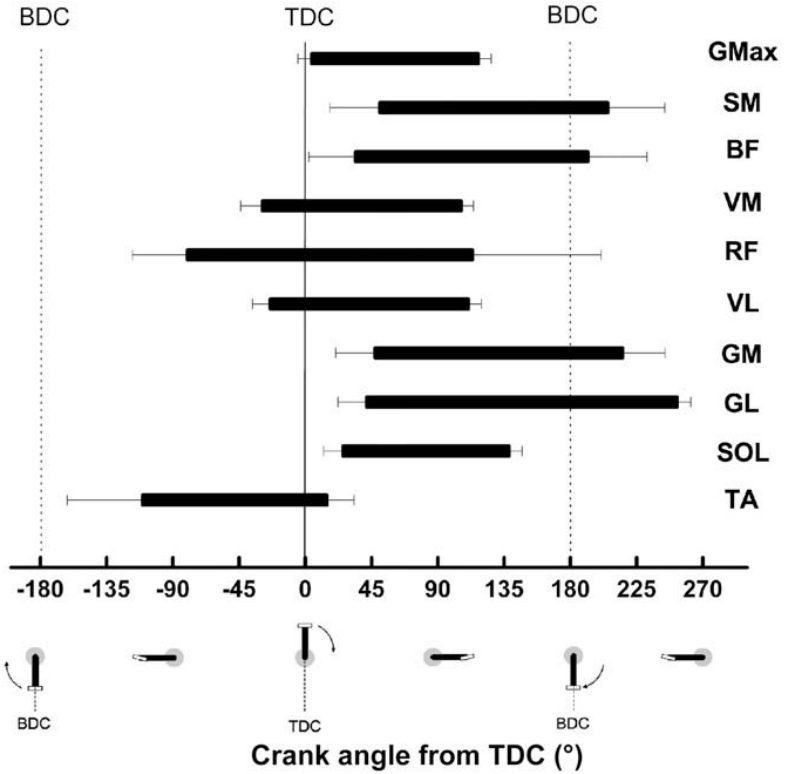
2014

Coordination intermusculaire du membre inférieur

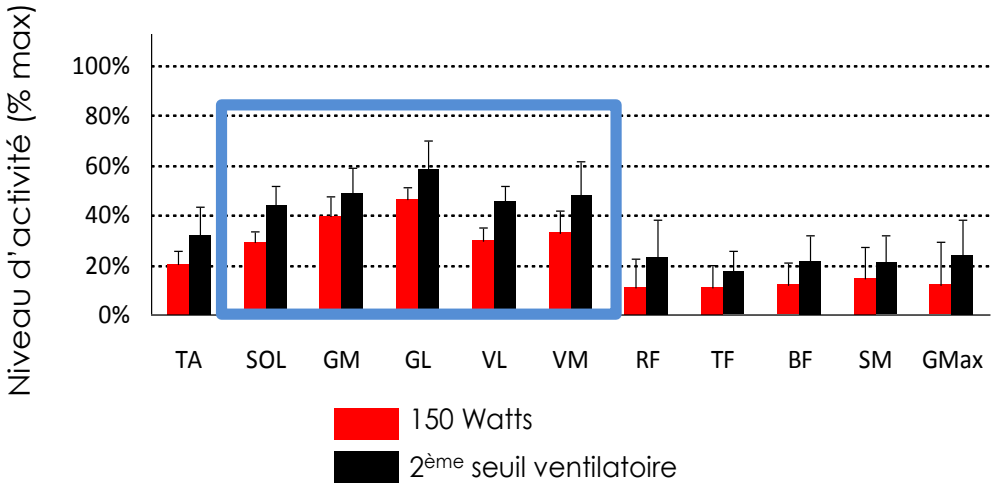
Exercice sous-maximal

Les 2 informations

Timing: séquence d'activité



Niveau d'activité = sollicitation



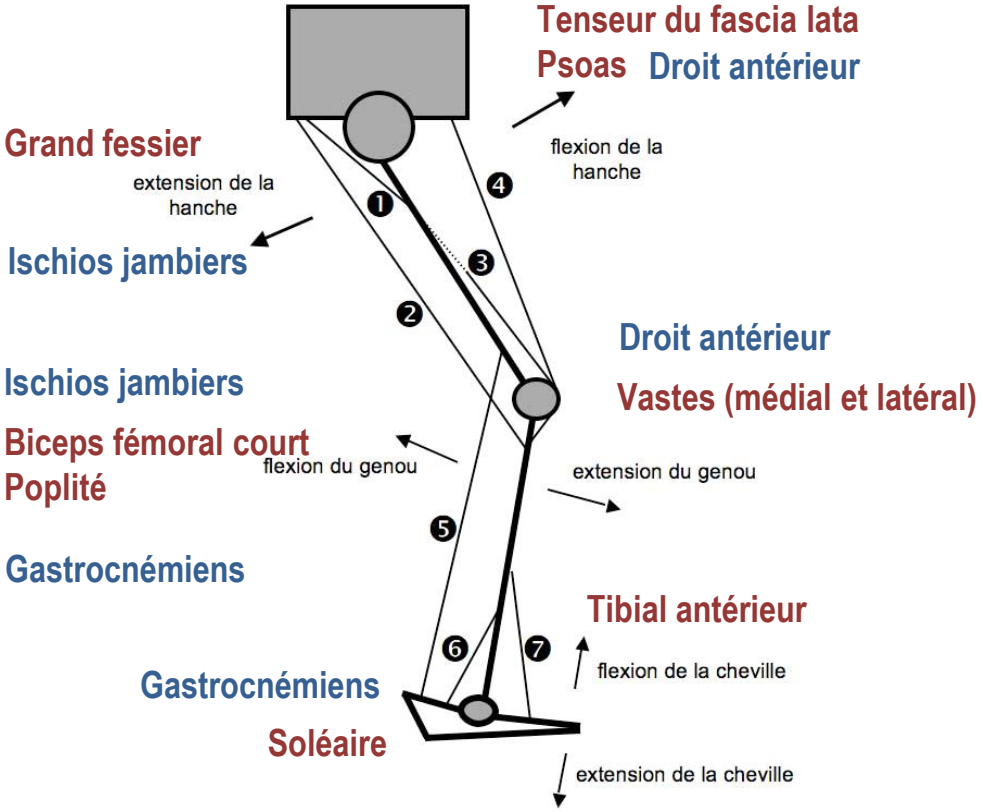
Gastrocnémiens + quadriceps : 40% max

Coordination intermusculaire du membre inférieur

Exercice sous-maximal

Plus de 20 muscles du membre inférieur

6 fonctions majeures au niveau articulaire



MAIS pour cela :
2 types de muscles

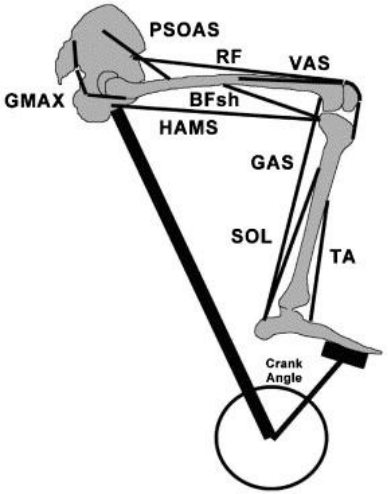
Muscle mono-articulaire
= une fonction

Muscle bi-articulaire
= deux fonctions

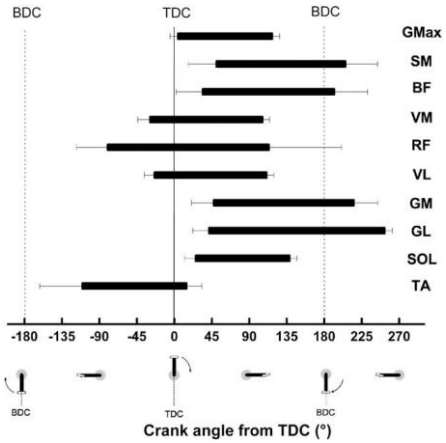
Obligation de cocontractions !

Biomechanics and neuromuscular aspect of pedaling

Circular constraint - poly-articular movement:



(Hug and Dorel 2009; Samozino et al 2007)



Specificity of muscle coordination in sprint?

→ Maximal activity level?
Alteration of timing aspect?

Biomechanics and neuromuscular aspect of pedaling

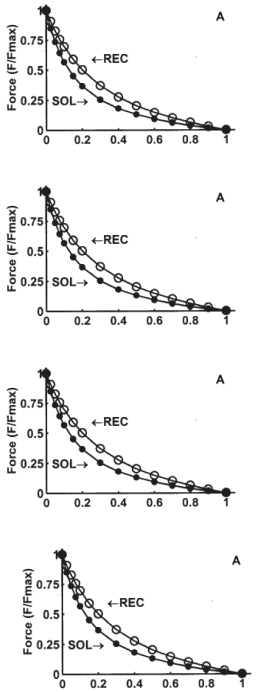
Circular constraint - poly-articular movement:

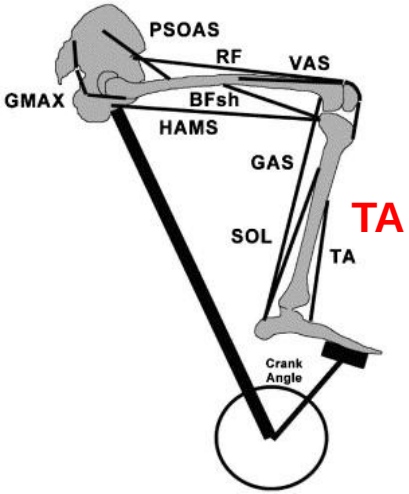
MONO GMax

MONO VL

POLY GM

POLY BF





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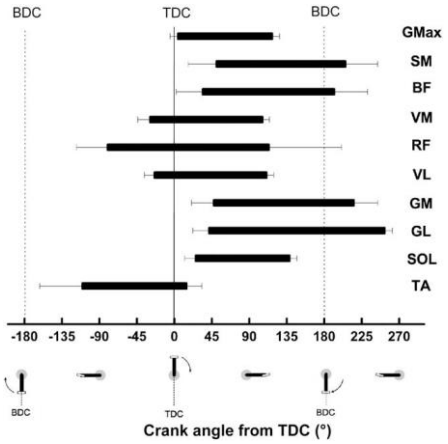


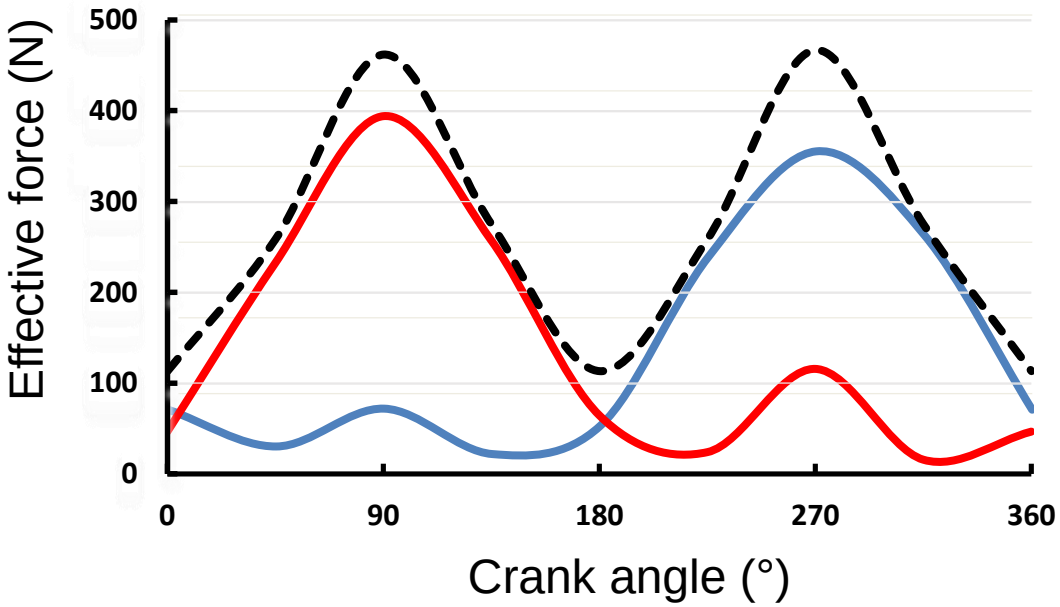
Specificity of muscle coordination in sprint?

→ Maximal activity level?
Alteration of timing aspect?

Individual muscle capacities and properties

→ Most important muscles?
Involvement and contribution?

The asymmetry of pedaling



Well balanced total effective force (net torque)

BUT !

A significant assymetry

Right LEG : downstroke ++ upstroke ++

Rigth leg = 55% **Left leg = 45%**

Asymmetry: *necessity to measure independently force on both pedals !*