HIGH-INTENSITY TRAINING

Yann LE MEUR[1]

[1] French Institute of Sport, Paris, France

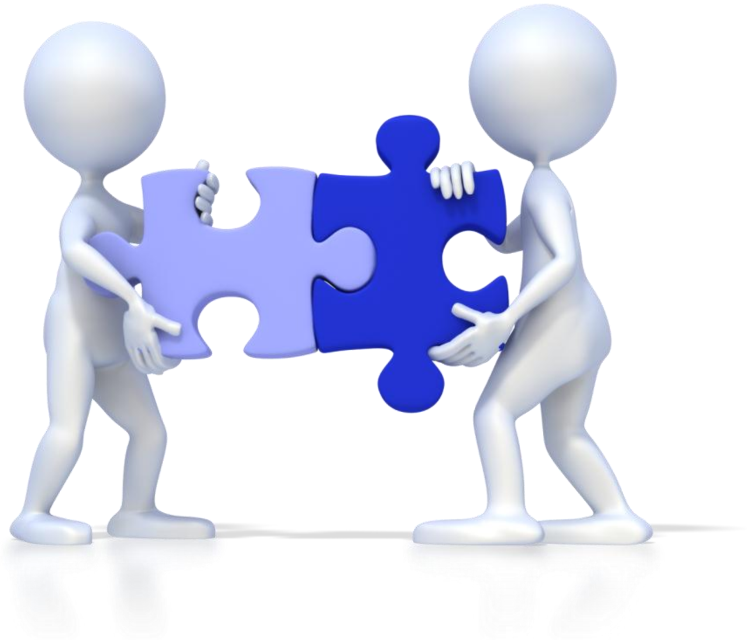
Jornadas de actualización en rendimientio deportivo
Vittoria-Gasteiz, 12th September 2015

@YLMSportScience

Introduction

Introduction

Potential of varying quantities of both high-intensity interval training and continuous high-volume, low intensity training on performance in highly trained athletes



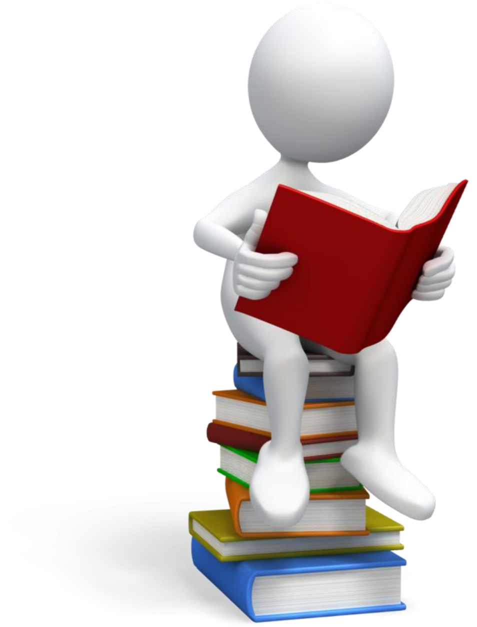
HIT involves repeated short-to-long bouts of rather high-intensity exercise interspersed with recovery periods

A little history of HIT

1920's - Paavo NURMI

14 minutes 36 seconds (5000m)

Short interval training at an intensity superior to a specific velocity such as 6 × 400m in 60 seconds inside a slow run of 10 to 20km in the woods



1950's – Emil ZATOPEK (5k – marathon)

4x Olympic champion & WR holder

100x 400m at 1min12s

HIT-induced adaptations

Cardiovascular adaptations

Adaptations to the heart itself

↗ Left ventricular chamber size
↗ Wall thickness
↗ Myocardial contractility
↗ Ventricular compliance

Decrease in total peripheral resistance

↘ Capillary & arteriole vasodilatation

Neuromuscular adaptations

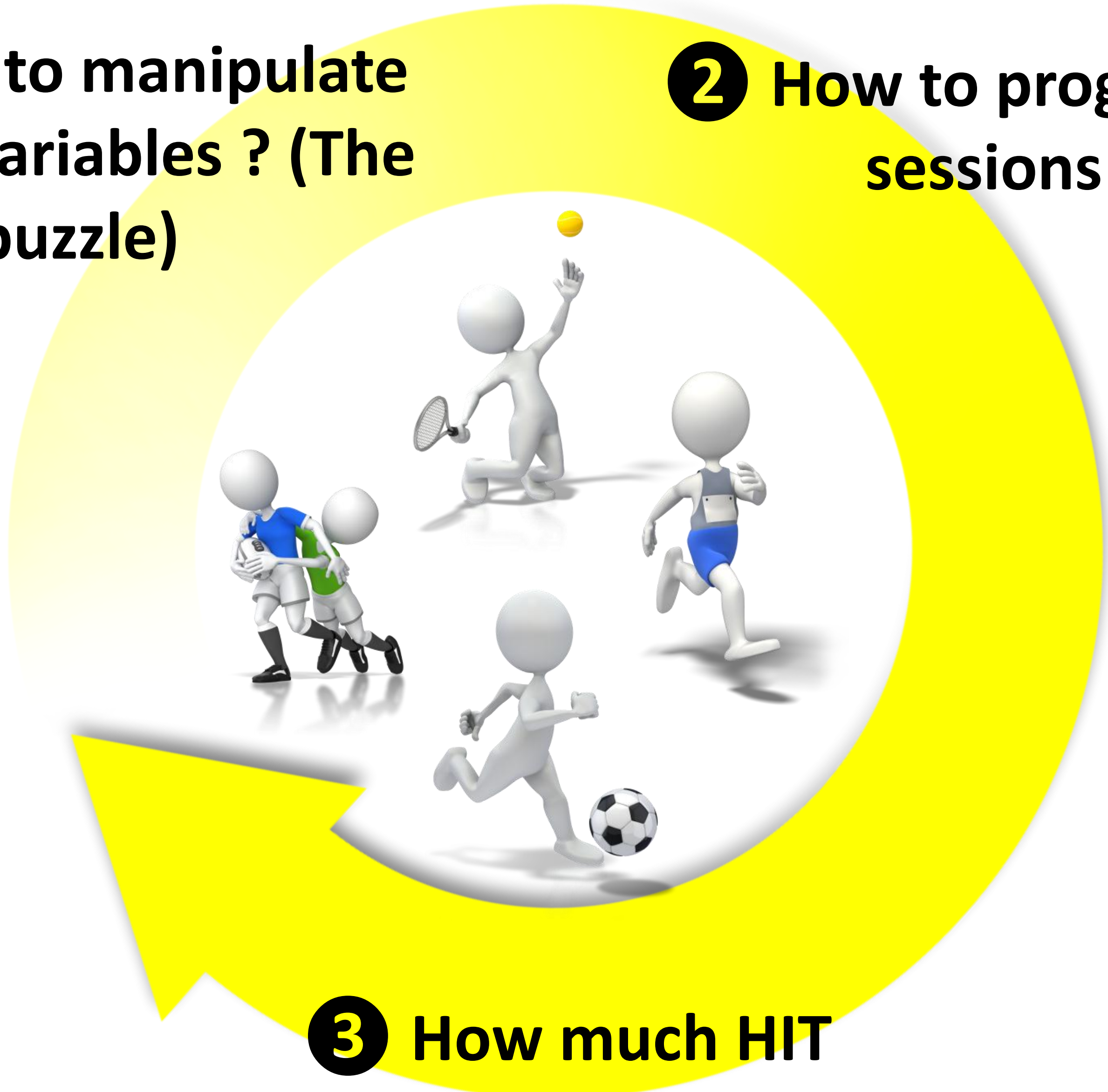
More fatigue resistant fast twitch fibres
↗ Oxidative capacity
↗ Lactate endling

HIT-induced adaptations

❶ Improved endurance performance
❷ Improved repeated-sprint performance
❸ Increased tolerance to overload periods

❶ How to manipulate the HIT variables ? (The puzzle)

❷ How to program HIT sessions ?



❸ How much HIT is enough ?

HOW TO MANIPULATE THE HIT VARIABLES ? (THE PUZZLE)

The following section is an illustrated summary of this review

Sports Med (2013) 43:313–338
DOI 10.1007/s40279-013-0029-x

REVIEW ARTICLE

High-Intensity Interval Training, Solutions to the Programming Puzzle

Part I: Cardiopulmonary Emphasis

Martin Buchheit · Paul B. Laursen

Sports Med (2013) 43:927–954
DOI 10.1007/s40279-013-0066-5

REVIEW ARTICLE

High-Intensity Interval Training, Solutions to the Programming Puzzle

Part II: Anaerobic Energy, Neuromuscular Load and Practical Applications

Martin Buchheit · Paul B. Laursen

HIT FORMAT

❶ Long intervals (≥ 45s)

❷ Short intervals (< 45s)

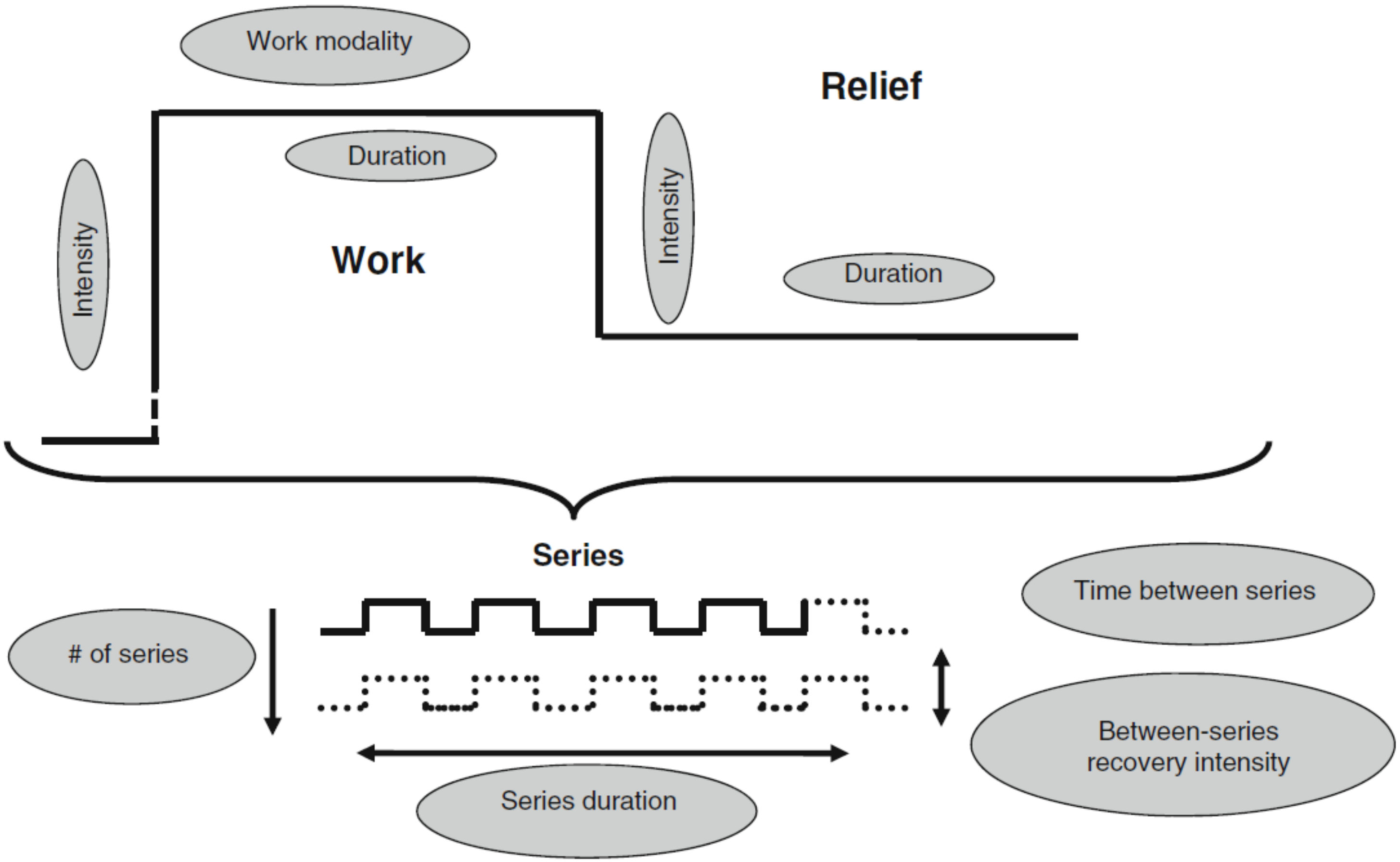
❸ Repeated-sprint training

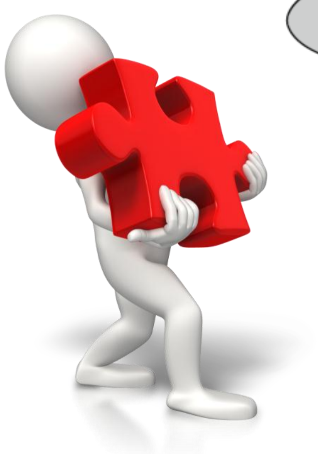
≤10 s, all-out sprints,interspersed with recovery periods

❹ Sprint interval training

20–30 s all-out sprints, interspersed with recovery periods

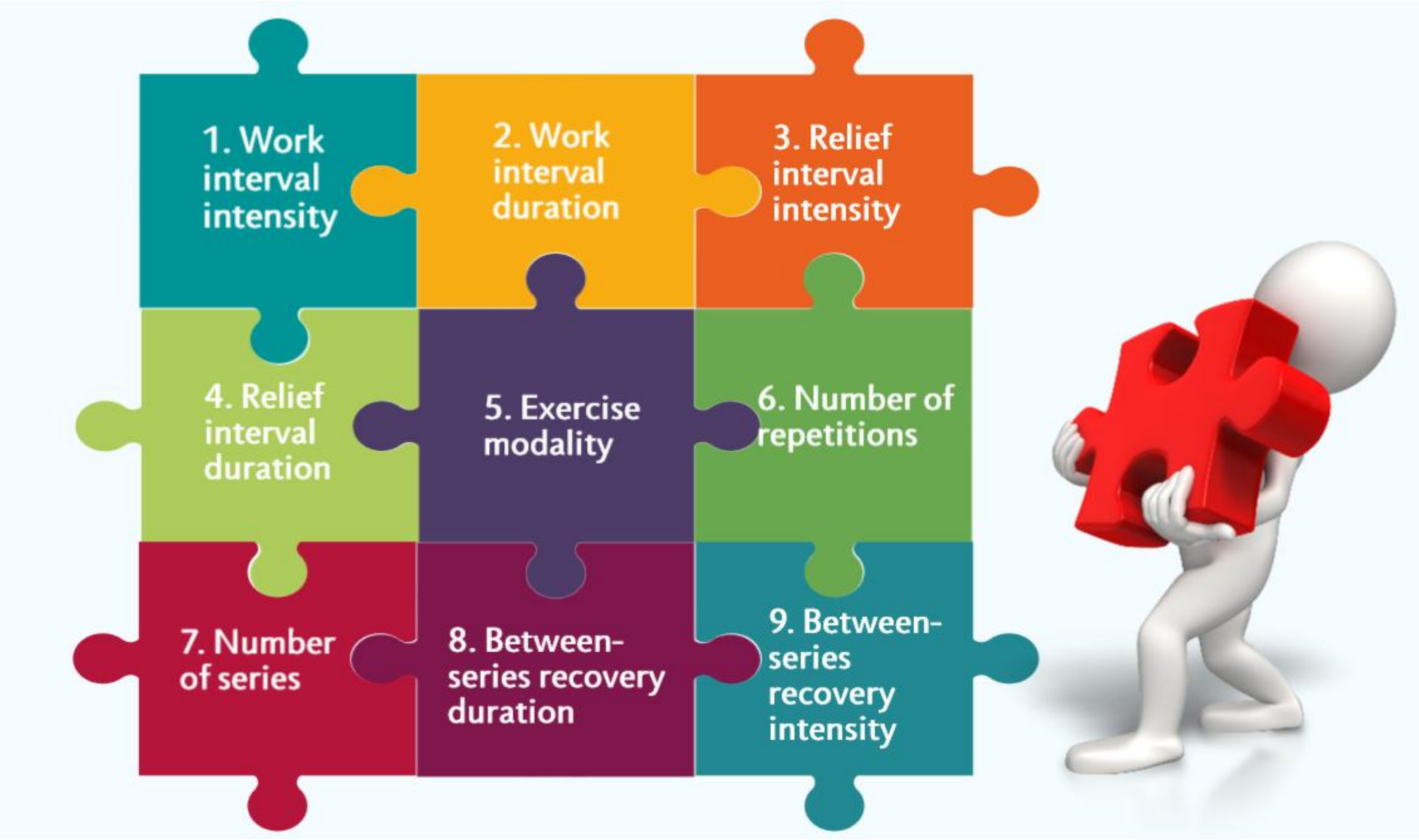
5x (3min [90% vVO2max], r = 90s [0%])





Buchheit & Laursen, 2013

Prescribtion of HIT consists of the manipulation of at least 9 variables; any of each has a likely effect on the acute metabolic & neuromuscular response

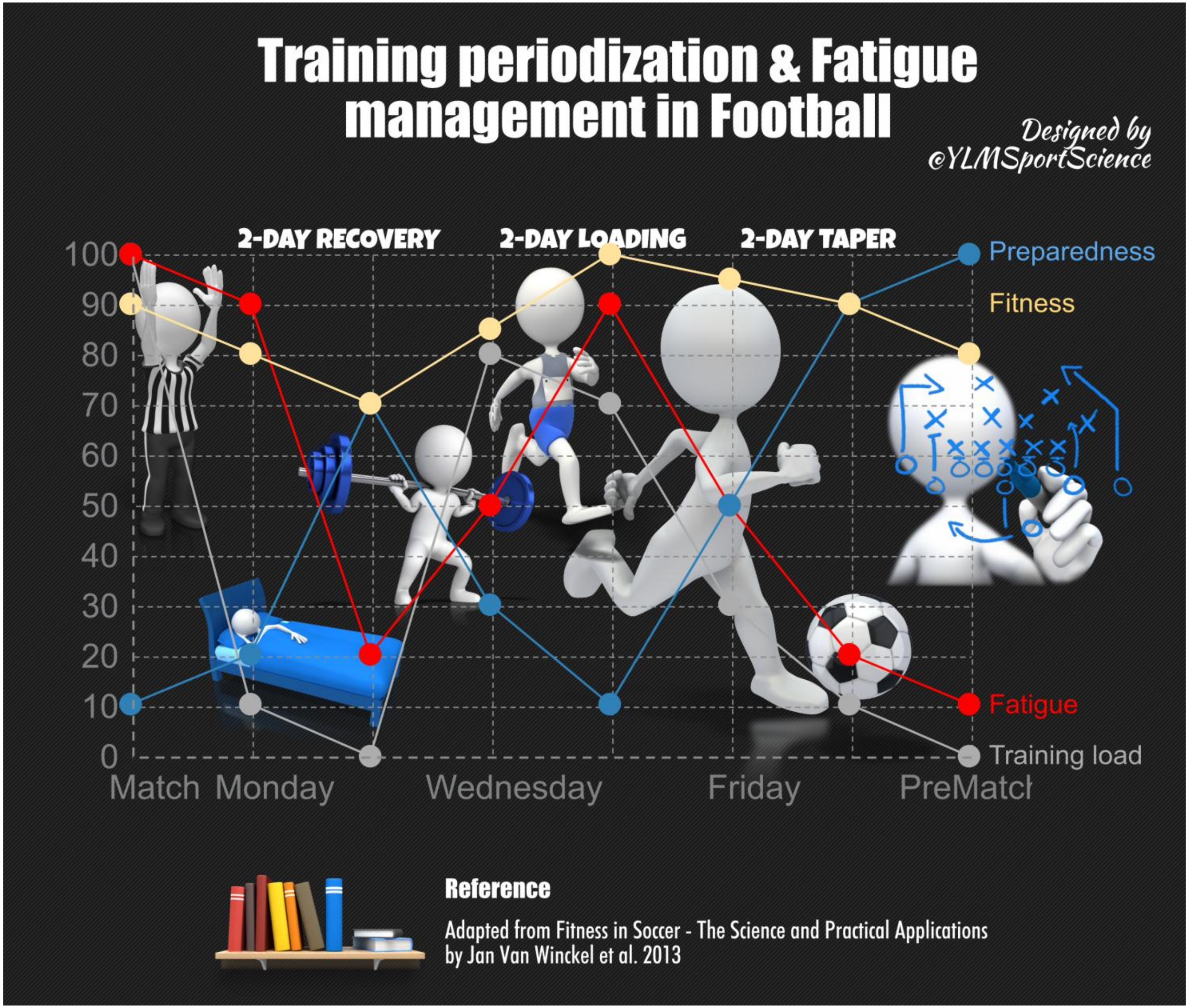


Manipulating HIT: the puzzle

« The ability of the coach to understand the isolated acute responses to various HIT formats may assist with selection of the most appropriate HIT session to apply, at the right place and time»

Buchheit & Laursen, 2013

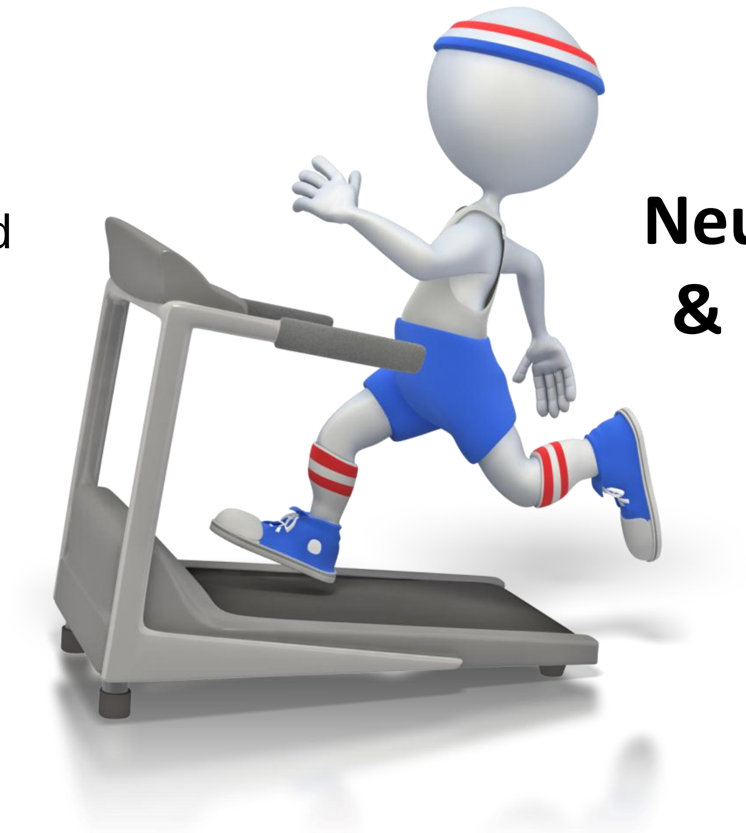
An example



Training periodization & Fatigue management in Football
Designed by @YLMSportScience
2-DAY RECOVERY
2-DAY LOADING
2-DAY TAPER
100
90
80
70
60
50
40
30
20
10
0
Match
Monday
Wednesday
Friday
PreMatch
Preparedness
Fitness
Fatigue
Training load
Reference
Adapted from Fitness in Soccer - The Science and Practical Applications by Jan Van Winckel et al. 2013

Metabolic demands

(1) splitting of the stored phosphagens;
(2) anaerobic glycolytic energy production;
(3) the oxidative metabolism

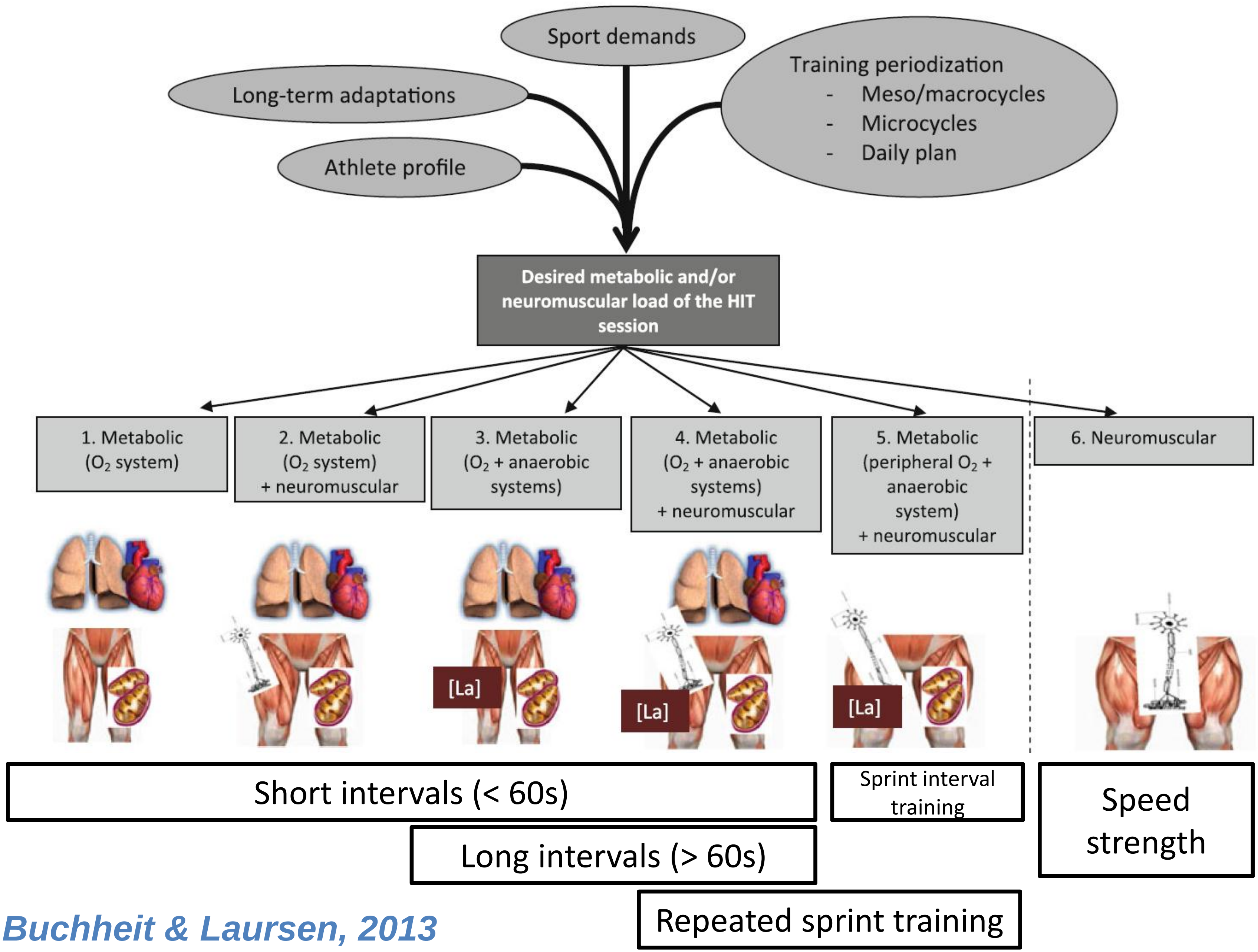


Neuromuscular load & Musculoskeletal strain

Primary variables of interest: VO_2, cardiovascular work, stored energy and cardiac autonomic stress

Secondary variables of interest: anaerobic glycolytic energy contribution & neuromuscular load/musculoskeletal strain

Manipulating HIT



Buchheit & Laursen, 2013

HIT FORMAT

❶ Long intervals (≥ 45s)

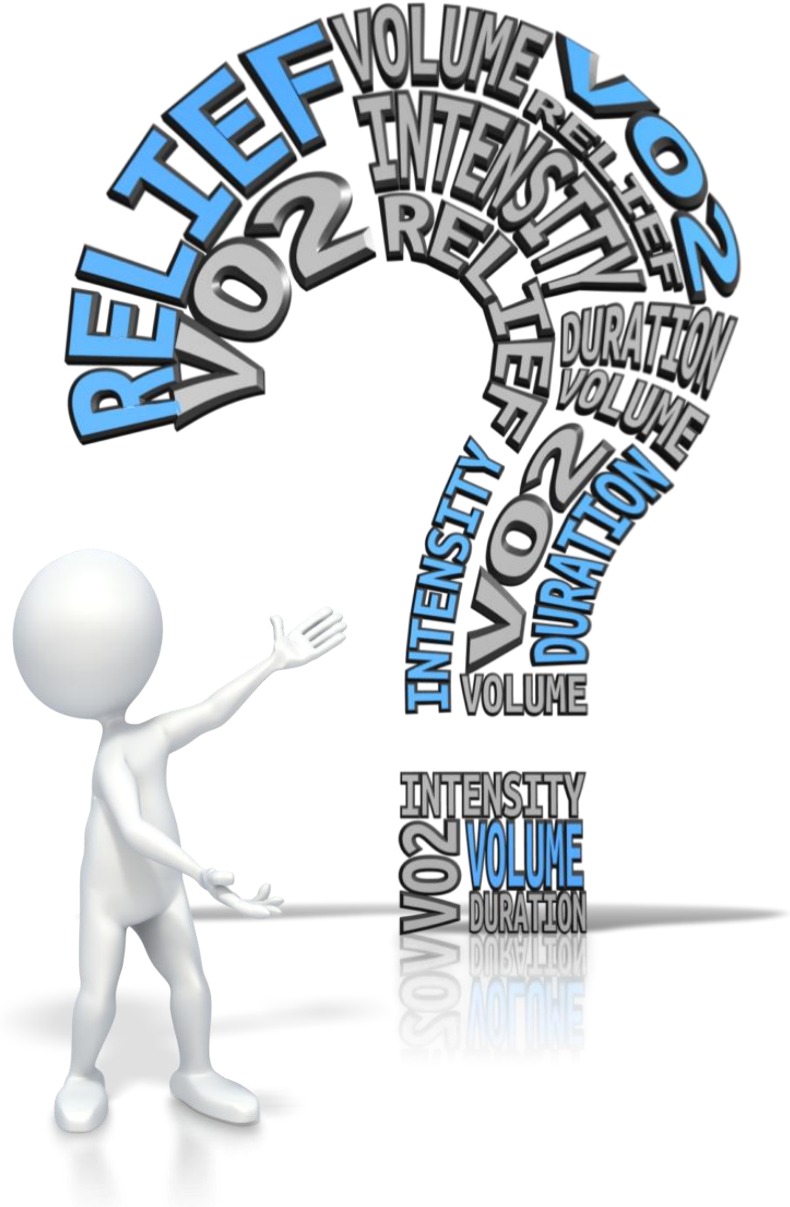
❷ Short intervals (< 45s)

❸ Repeated-sprint training

≤10 s, all-out sprints,interspersed with recovery periods

❹ Sprint interval training

20–30 s all-out sprints, interspersed with recovery periods

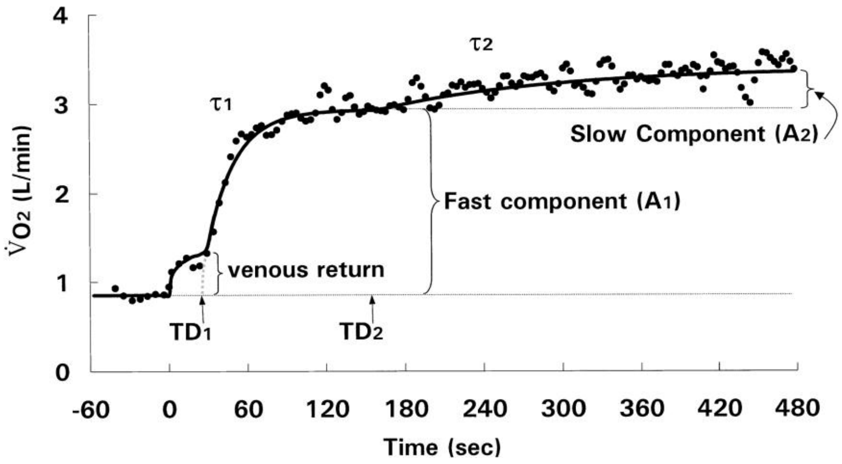


How to maximize the time spent at or near VO_{2max} during HIT sessions ?

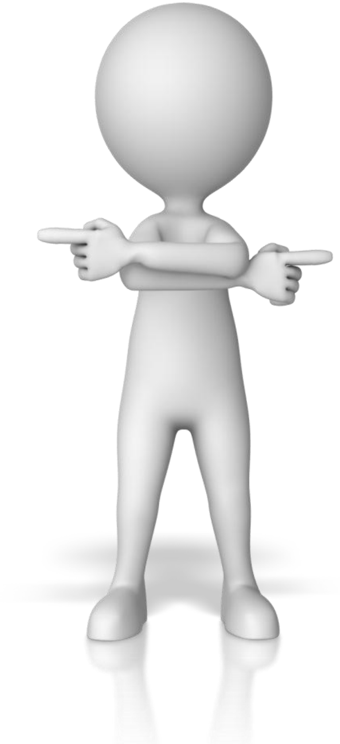
Exercise intensity & interval duration

❶ Exercise Intensity

Work intensities of ≥90% vVO2max are recommended for maximizing TVO_{2max} during long intervals



❷ Interval duration



Option 1

Time needed to reach VO_{2max} + 1 or 2 min

Option 2

≥ 2–3 min and adjust in accordance with the athlete's training status (with the less trained performing lower training loads, but longer intervals)

❸ Relief duration & intensity

Maximizing work capacity during subsequent intervals (by increasing blood flow to accelerate muscle metabolic recovery)

Maintaining a minimal level of VO_2 to reduce the time needed to reach VO_{2max} during subsequent intervals

Recovery: active or passive?

Active recovery can

↘ Muscle oxygenation,
↘ PCr resynthesis (O_2 competition)
↗ Anaerobic system engagement during the following effort

May negate subsequent interval performance when recovery < 3min

Passive recovery is recommended when the relief interval is less than 2–3 min in duration

Volume of HIT with long intervals

❹ Volume of HIT

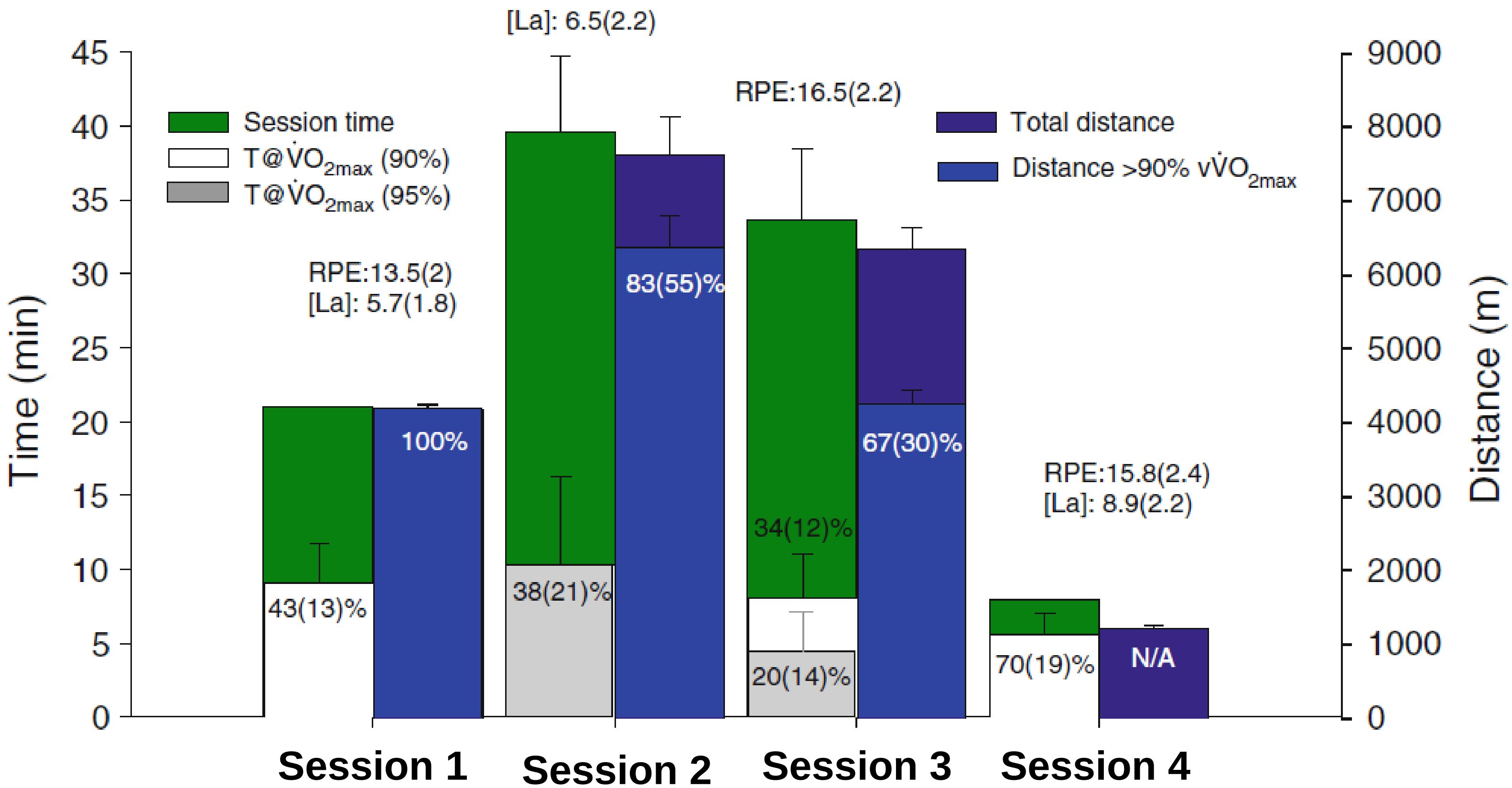
Cumulated high-intensity ([90% v/pVO2max) exercise time during typical sessions in well trained athletes has been reported to be

- 6x 2min
- 5x 3min
- 4x 4min
- 6x 4min
- 4x 6min
- 5x 6min

From 10 min > 90 % to 4–10 min > 95 % at VO2max

Total session volume should enable athletes to spend between 5 (team and racket sports) and 10 (endurance sports) min > 90% VO_{2max}

Volume of HIT with long intervals



Session 1: 5x (3min [90% vVO_{2max}], r = 90s [0%])
Session 2: 5x (5min [92% vVO_{2max}], r= 2.5min [46% vVO_{2max}])
Session 3: 3x (2x(2min [100% vVO_{2max}], r = 2min [50% vVO_{2max}]))
Session 4: 3min45 [SSG] / 30s[0%] / 3min45 [SSG]

❺ Anaerobic glycolytic energy contribution

While HIT with long intervals is likely the best format for adapting cardiopulmonary function, blood lactate accumulation (and likely anaerobic glycolytic energy contribution) will still reach high levels (end-session values >10 mmol/L)

Increased by

↗ Intensity
↗ Interval duration
↘ Recovery interval (when the duration of the exercise interval is fixed)

1 Long intervals (≥ 45s)

2 **Short intervals (< 45s)**

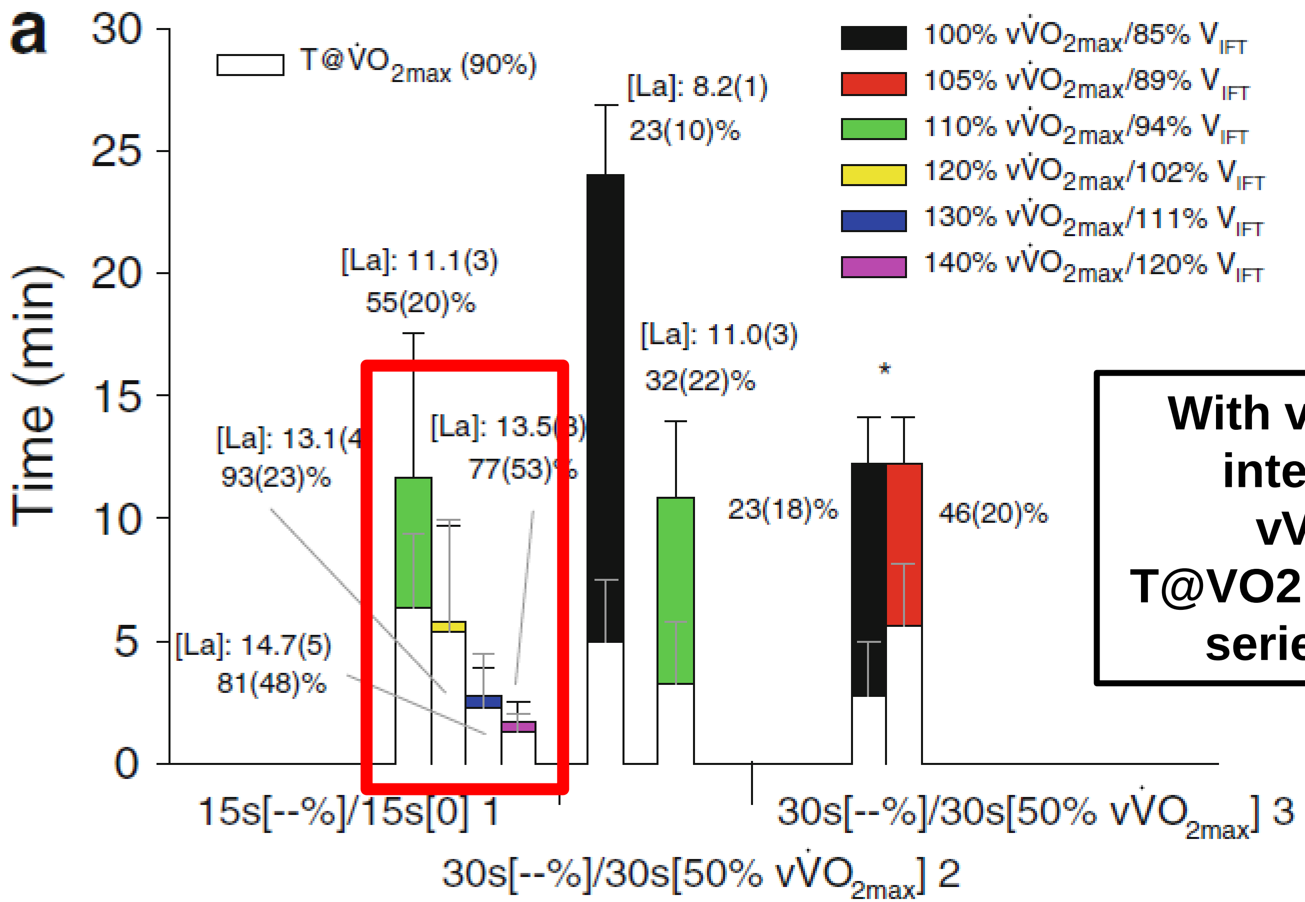
3 Repeated-sprint training

≤10 s, all-out sprints,interspersed with recovery periods

4 Sprint interval training

20–30 s all-out sprints, interspersed with recovery periods

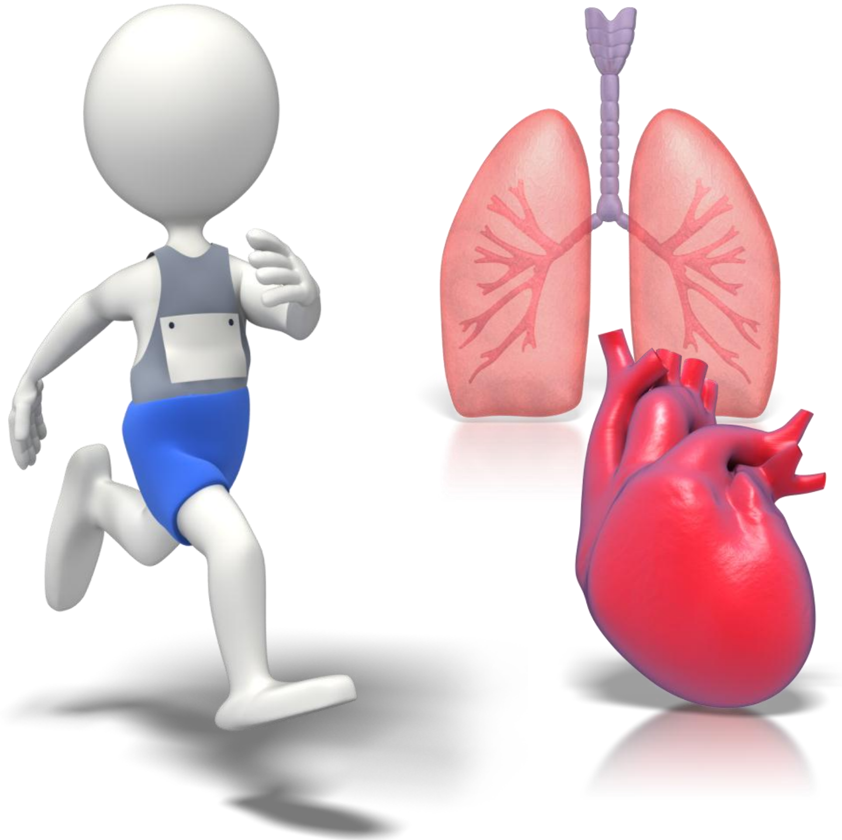
❶ Exercise Intensity



With very-high-exercise intensities (>120 % vVO2max), total T@VO2max for a given HIT series is usually low

Selection of a work bout intensity that ranges between 100 % and 120 % of vVO2max may be optimal to elicit high VO_2 responses

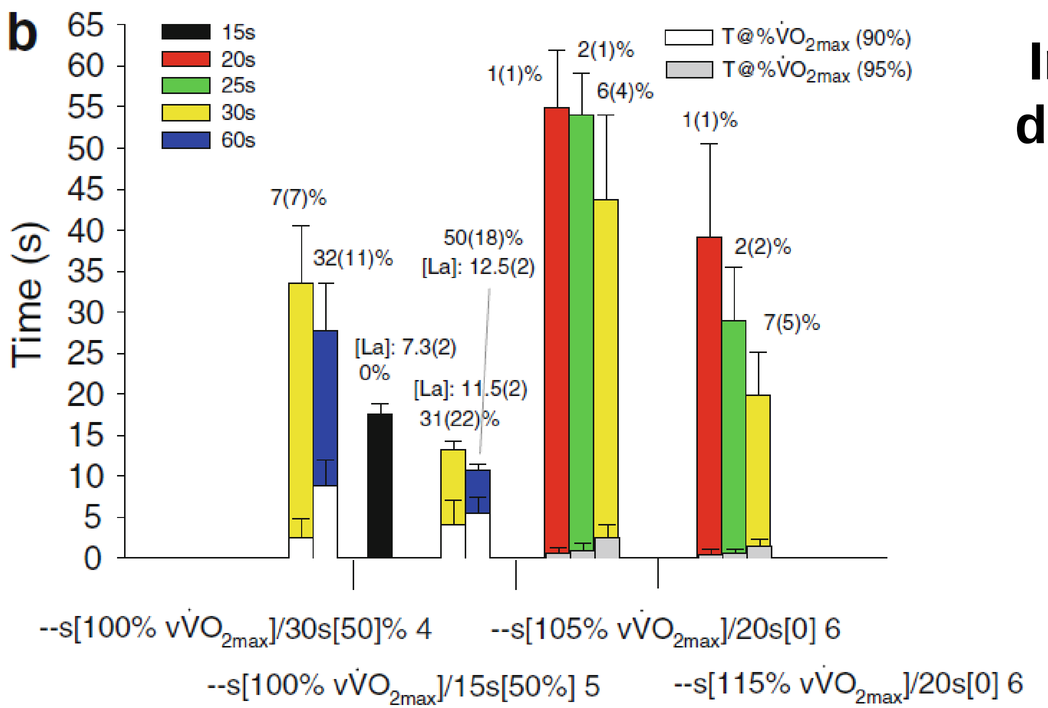
❷ Interval duration



During very short runs (<10 s)

- ATP requirements in working muscle are met predominantly by oxidative phosphorylation
- Recovery: oxymyoglobin stores rapidly restored ► cardiopulmonary responses of such efforts are relatively low, unless exercise intensity is set at a very high level

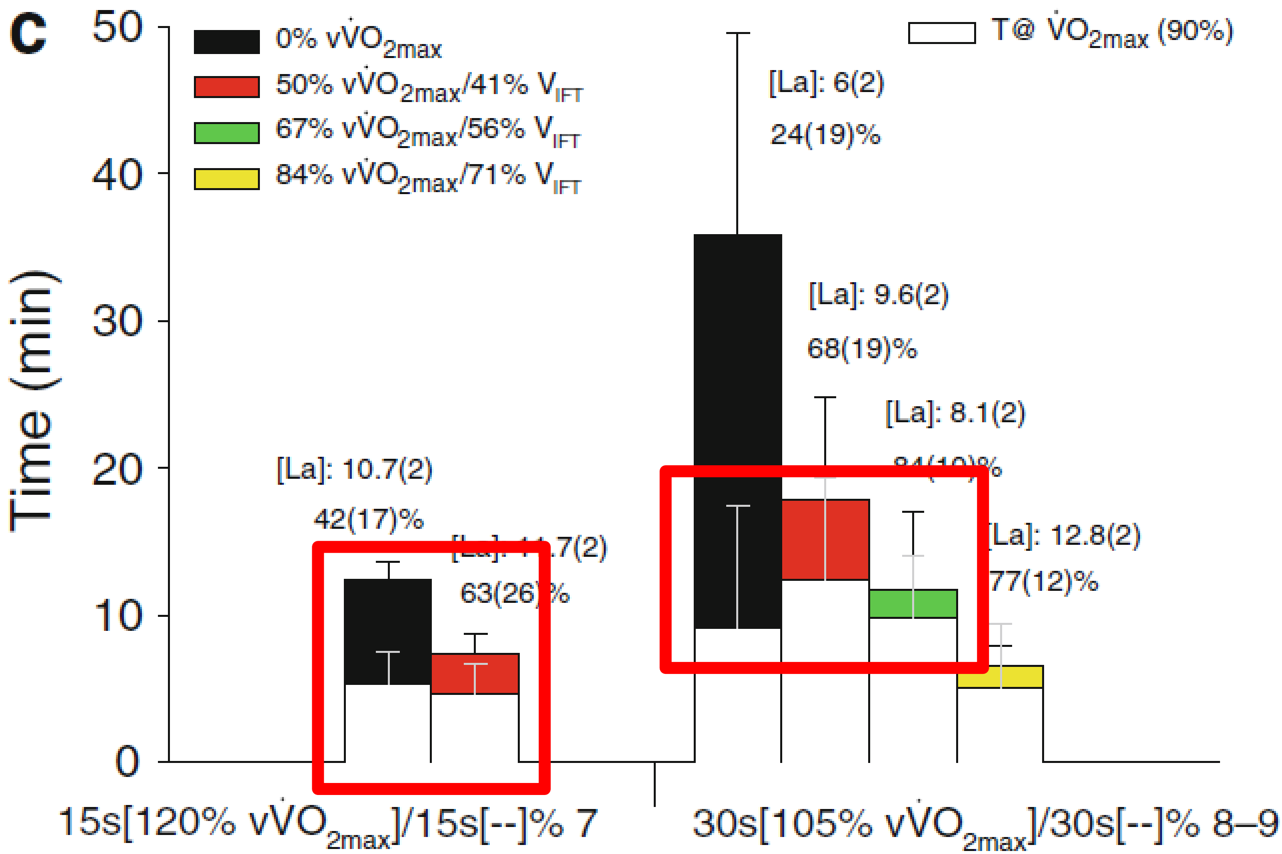
Work intervals >10 s appears to be required to elicit high VO_2 responses during HIT involving short intervals (100–120 % vVO_{2max})



Increasing the work interval duration, while keeping work relief intervals constant increases T@VO$_{2max}$

Longer work intervals (e.g. 30 s/30 s vs. 15 s/15 s) are preferred for individuals with slow VO2 kinetics (i.e. older/less trained), or for exercising on a bike

❸ Relief duration & intensity



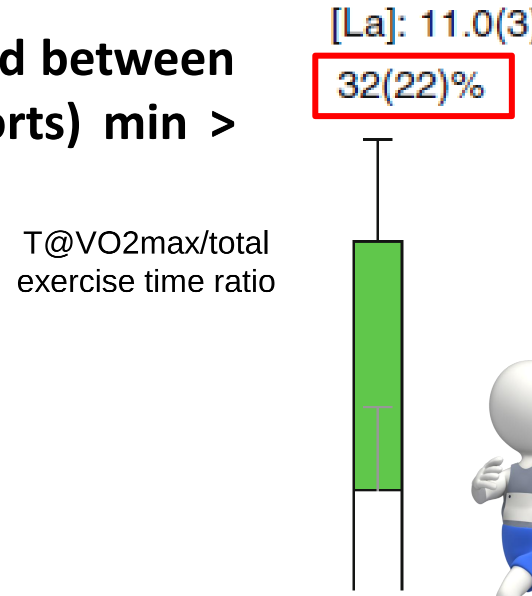
15s / 15s: absolute T@VO2max might not differ between active and passive recovery conditions

30s / 30s: relief interval intensities around 70 % vVO2max should be recommended to increase both T@VO_{2max} and the T@VO_{2max}/exercise time ratio

Series duration, Sets and T@VO2max

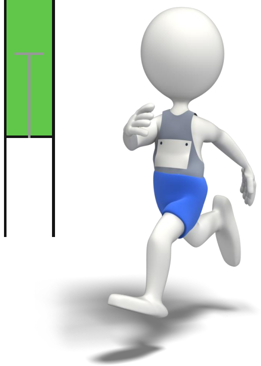
❹ Volume of HIT

Total session volume should enable athletes to spend between 5 (team and racket sports) and 10 (endurance sports) min > 90% VO_{2max}



- Example for an endurance athlete:

3x (10x 30s [110% vVO2max], r= 30s [50% vVO2max])



- Example for team sports athletes:

2x (10x 30s [110% vVO2max], r= 30s [50% vVO2max])

❺ Anaerobic glycolytic energy contribution

Increased by

↗ Work interval intensities (110/60% > 100/70% > 90/80%)
↗ Work/relief ratio (at a fixed work interval)

Anaerobic Glycolytic Energy Contribution

Field-based HIT formats with short intervals are generally associated with lower initial rates of blood lactate accumulation compared with long intervals

Neuromuscular load during Short- and Long- Intervals

Greater load associated with short intervals

Modulated by

Change of direction

Surface (hard, grass, sand)

Locomotion mode (running, cycling, rowing)

❶ Long intervals (≥ 45s)

❷ Short intervals (< 45s)

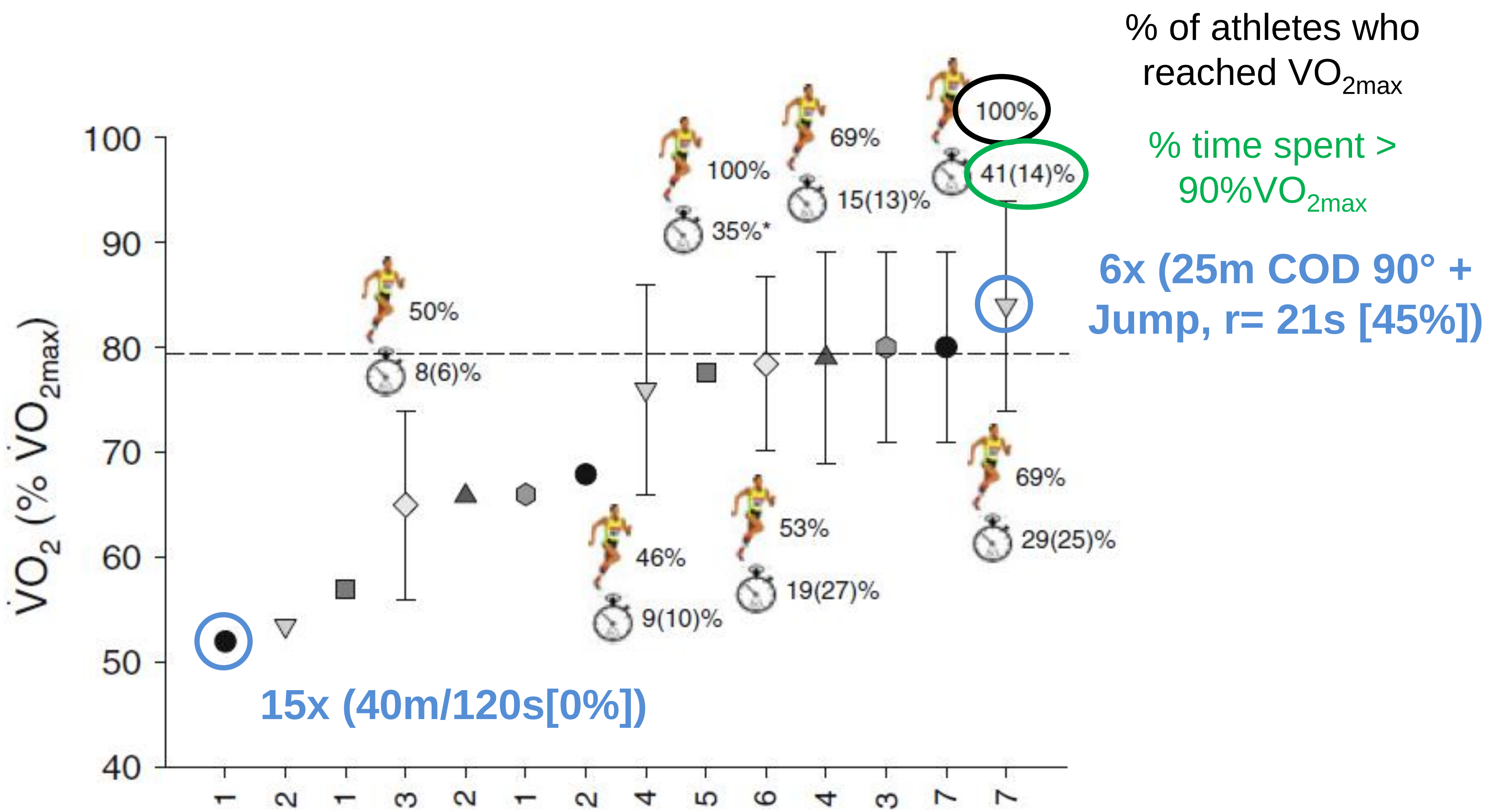
❸ Repeated-sprint training

≤10 s, all-out sprints,interspersed with recovery periods

❹ Sprint interval training

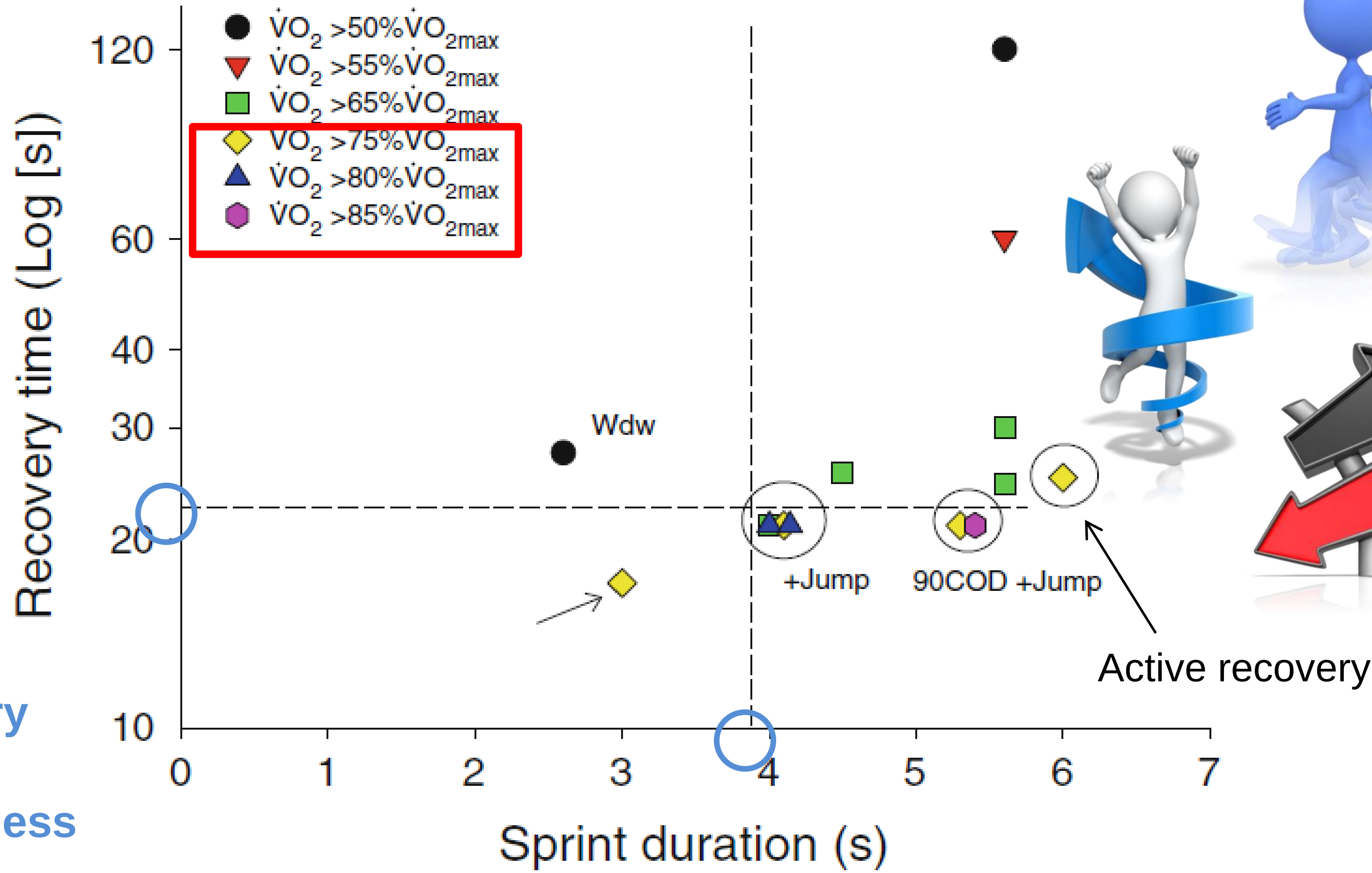
20–30 s all-out sprints, interspersed with recovery periods

RSS and T@VO_{2max}



VO_{2max} is often reached and sustained for 10–40 % of the entire RSS duration (i.e. ~2-3 min when 3 blocks is programmed)

To increase T@VO_{2max} during repeated-sprint sessions



❶ Recovery should be active and less than 20 s

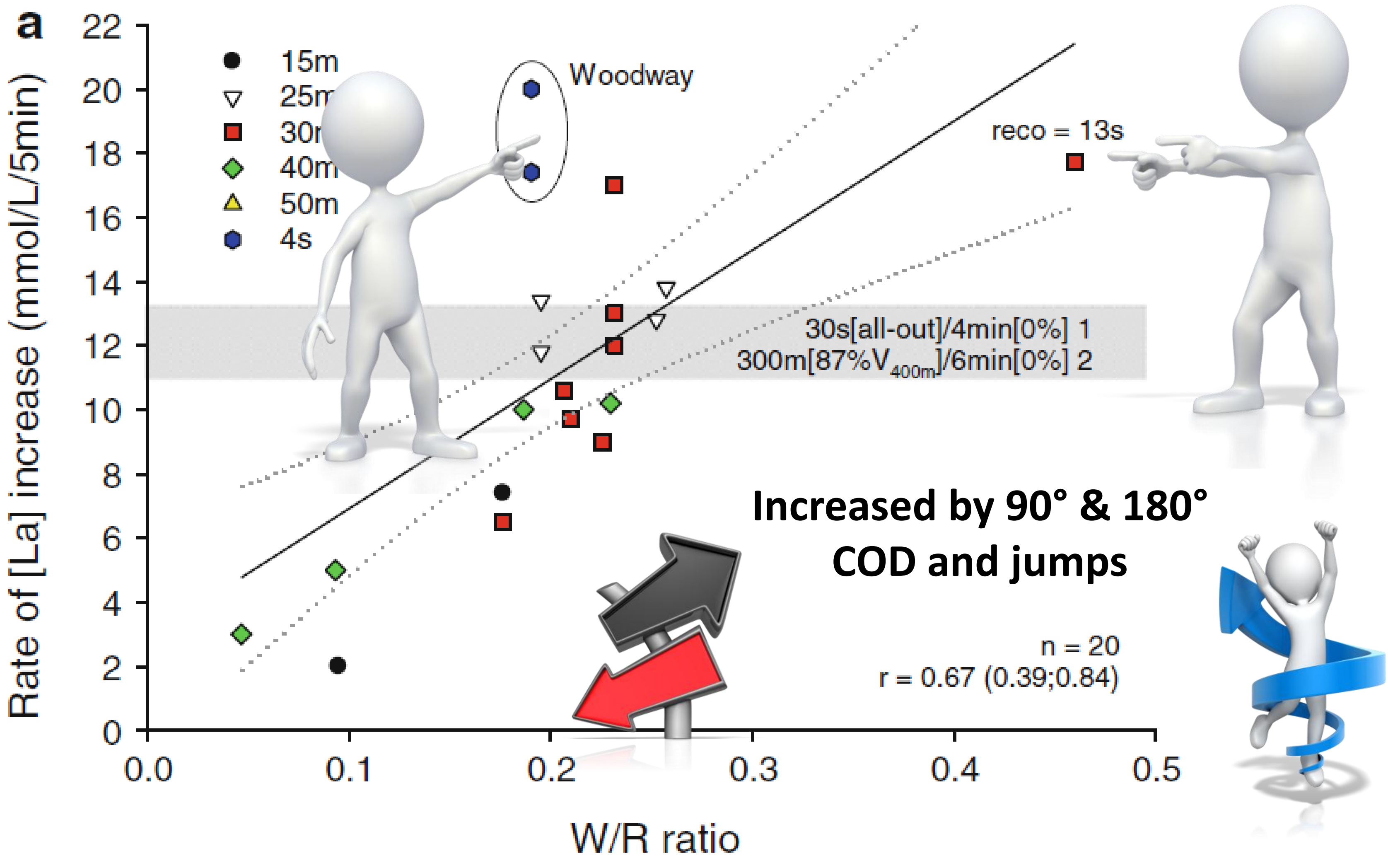
❷ Sprints/efforts should last at least 4 s

❸ Include change of direction and/or jumps after sprinting

High-interindividual variability

$T@VO_{2max}$ during repeated-sprints sequences is inversely correlated with VO_{2max} ► RSS may be questionable to apply in some athletes, especially those of high fitness

Anaerobic Glycolytic Energy Contribution



The initial rate of blood lactate accumulation during an RSS is largely correlated with its work/relief ratio, irrespective of the sprinting distance

Neuromuscular load during RSS

RSS sequences are associated with high NM demands:

↘ Speed

Change in stride pattern & running technique

Stiffness modulation

↗ Injury risk

(if not controlled)

Increased by

↗ Sprint duration

↗ Number of sprints

↘ Relief duration

↗ COD & jumps

HIT FORMAT

1 Long intervals (≥ 45s)

2 Short intervals (< 45s)

3 Repeated-sprint training

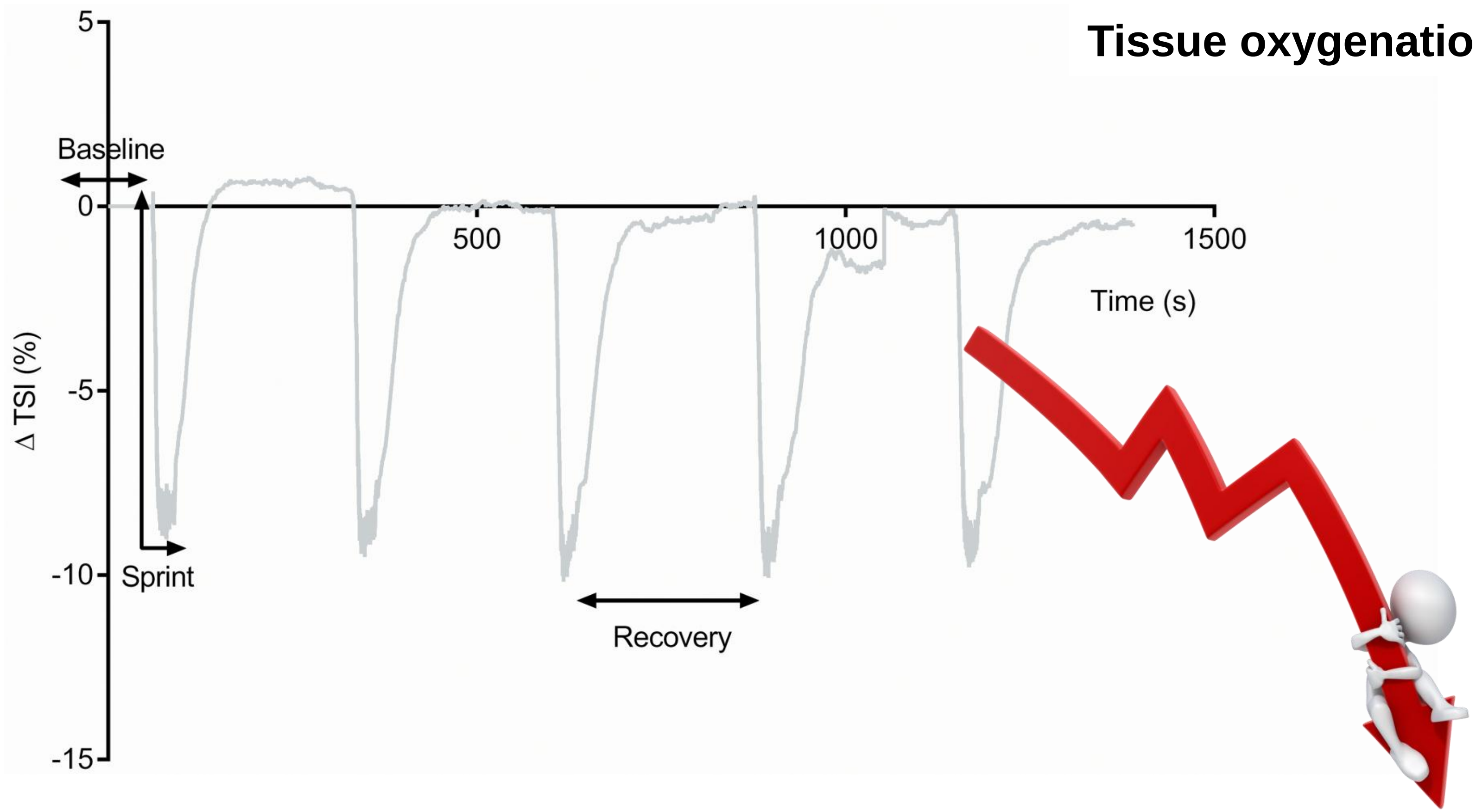
≤10 s, all-out sprints,interspersed with recovery periods

4 Sprint interval training

20–30 s all-out sprints, interspersed with long recovery periods

SIT and T@VO2max

- Very short T@VO_{2max} (no values > 90% VO_{2max} in some athletes),
- But very high muscle O_2 demand
- Progressive shift in energy metabolism during a SIT session, with a greater reliance on oxidative metabolism when sprints are repeated



Anaerobic Glycolytic Energy Contribution

- **SIT- type HIT formats are typically associated with elevated rates of blood lactate accumulation**

- **Increased by**

  ↗ Sprint duration (but < 45 s)
  ↗ Recovery duration

SIT sequences are associated with high NM demands:

↘ Speed (large)

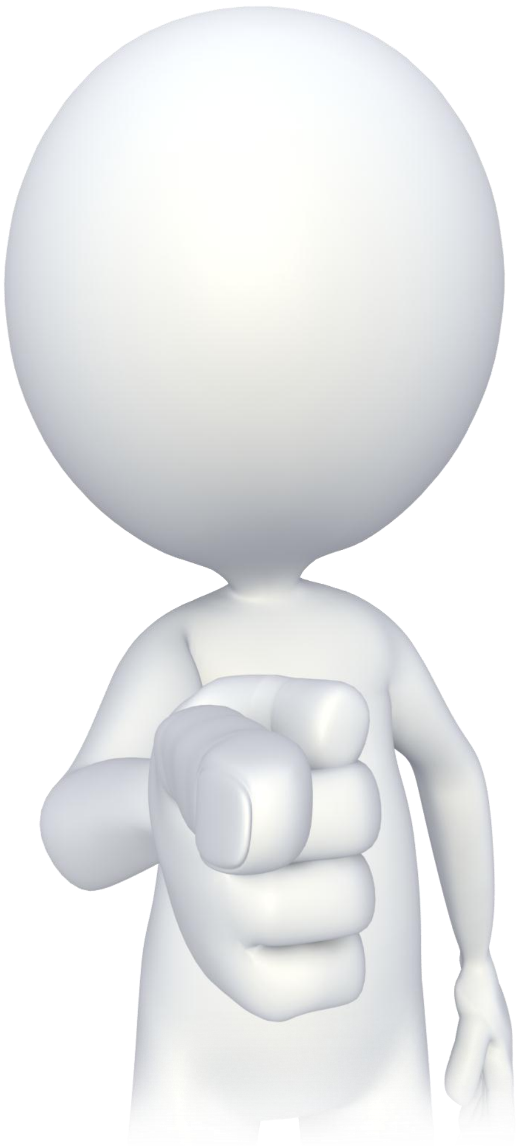
Change in stride pattern & running technique

Stiffness modulation

↗ Injury risk

(if not controlled)

It makes a lot of information to consider…



IN ONE SLIDE?

Summary #1

HIT Forms	Intensity	Work interval duration	Recovery	Time spent at VO_{2max}	Observations
Short intervals (≤ 45 s)	100 – 120 % vVO_{2max} to elicit high VO_2 response	10 – 45 s	<30" : passive ≥ 30" : active	Endurance sports: 7 – 10 min Team sports & others: 5 – 7 min	Volume should depend of the T@VO_{2max} /exercise time ratio (cf. original paper) $[La^-]_b$: + NM load: +
Long intervals (> 45 s)	≥ 90 - 110 % vVO_{2max} to elicit high VO_2 response	Time needed to reach VO_{2max} + 1 or 2 min or ≥ 2 – 3 min	R < 3min: passive R > 3min: active		
Repeated sprint intervals	All-out	≥ 4 s if high VO_2 response is expected	R: active & ≤ 20 s if high VO_2 response is expected	~10 – 40 % of the entire RSS duration (but possibly 0% in high fitness athletes)	Can be associated with COD & jumps to elicit high VO_2 response **$[La^-]_b$: ++ to +++** **NM load: +++**
Sprint interval training	All-out	2-5s (~15 – 40 m)	> 20 s	From 0 to a few seconds…	… but elicits high muscle O_2 demand **$[La^-]_b$: +++** **NM load: +++**

Summary #2

❶ Most HIT formats, when properly manipulated, can enable athletes to reach VO_{2max},

❷ However, important between-athlete and between-HIT format differences exist with respect to T@VO_{2max},

❸ RSS and SIT sessions allow for a limited T@VO_{2max} compared with HIT that involve long and short intervals,

❹ Long intervals and/or short intervals with a work/relief ratio > 1 should enable a greater T@VO_{2max} / exercise time ratio during HIT sessions,

❺ The methods of maximizing long-term VO_{2max} development and performance adaptations using different forms of HIT sessions is still to be determined

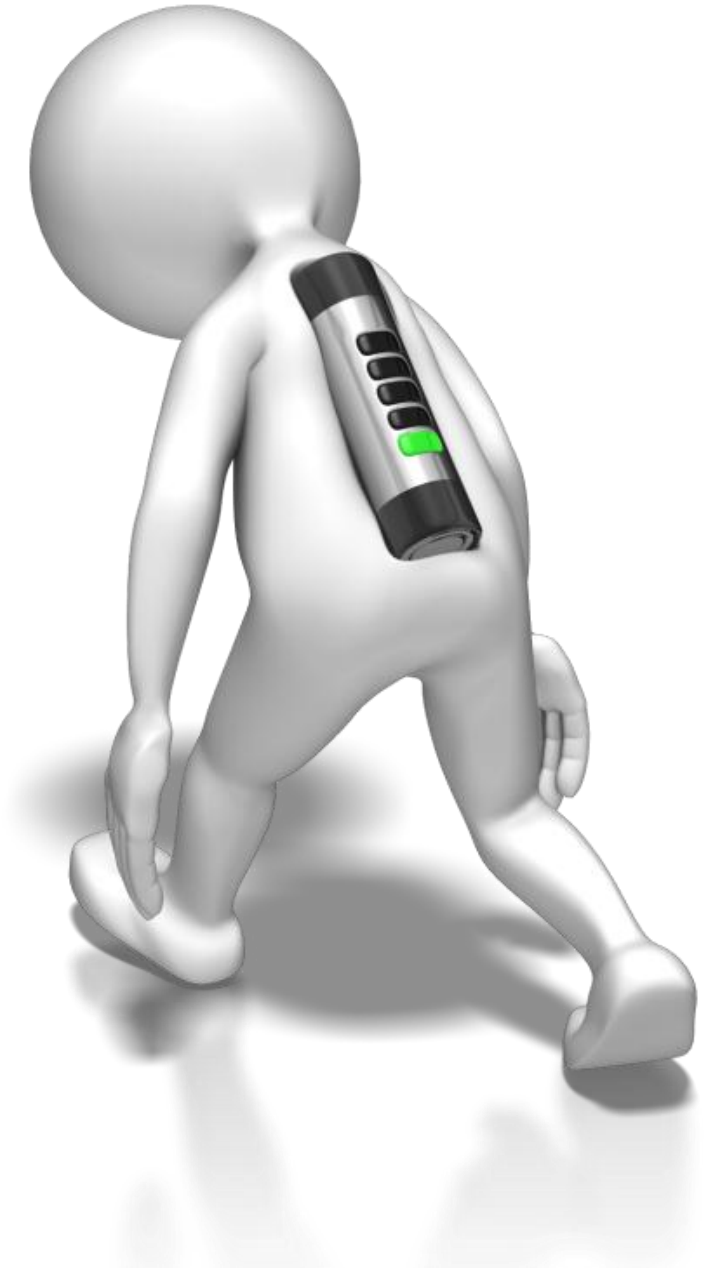
❻ Choose and balance the level of neuromuscular engagement associated with a given HIT format, based on both the expected training-induced adaptations and the acute changes in neuromuscular performance (e.g. jump performance);

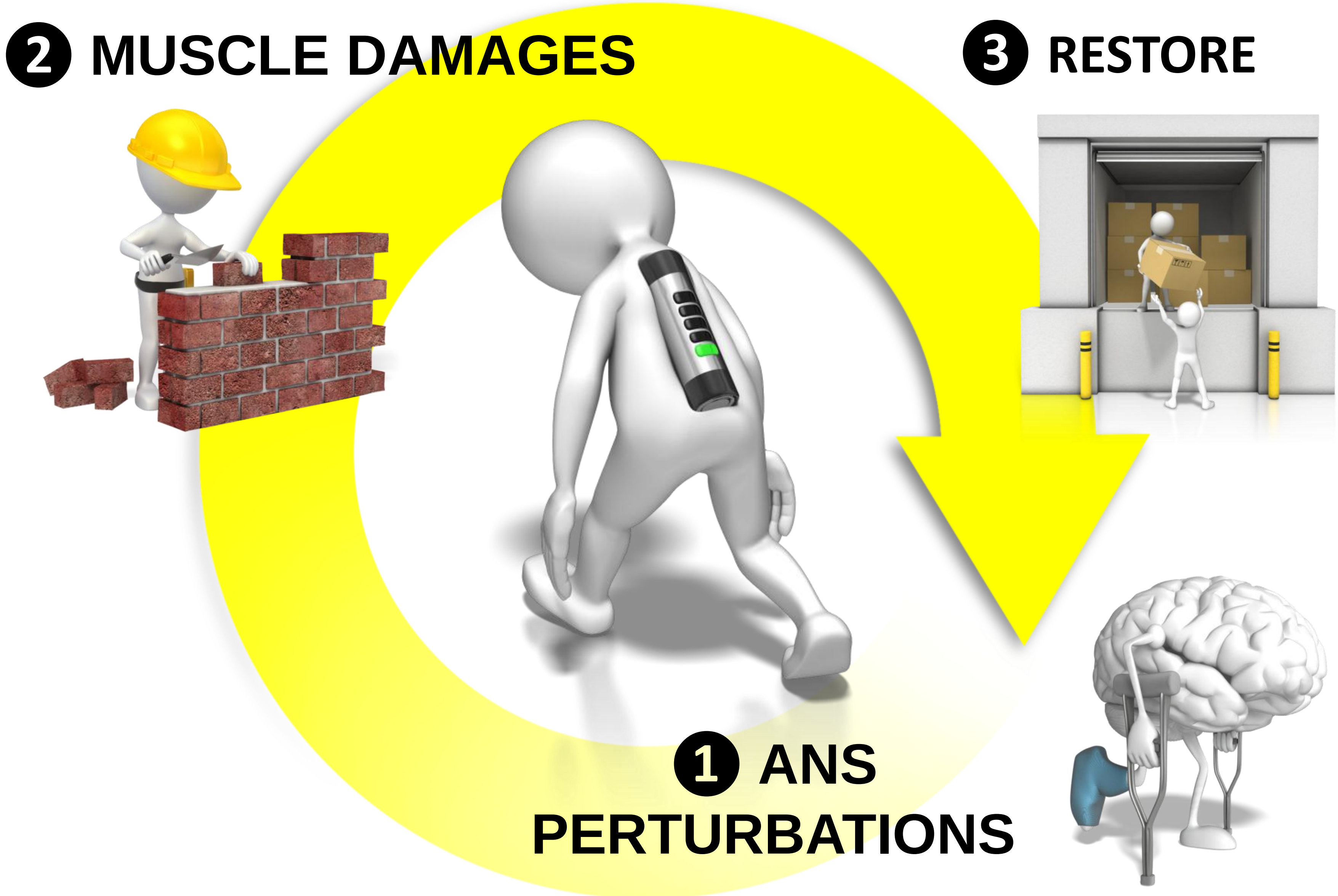
❼ Running pattern (e.g. COD, introduction of jumps during the recovery periods), exercise mode (e.g. cycling, running, bouncing) or ground surfaces (e.g. pavement, synthetic track, grass, sand, treadmill) and terrain (uphill, downhill) also may have direct implications on traumatic and overuse injury risk, and should be chosen for programming based on a risk/benefit approach.

PROGRAMMING HIT SESSIONS

Too much of a good thing?

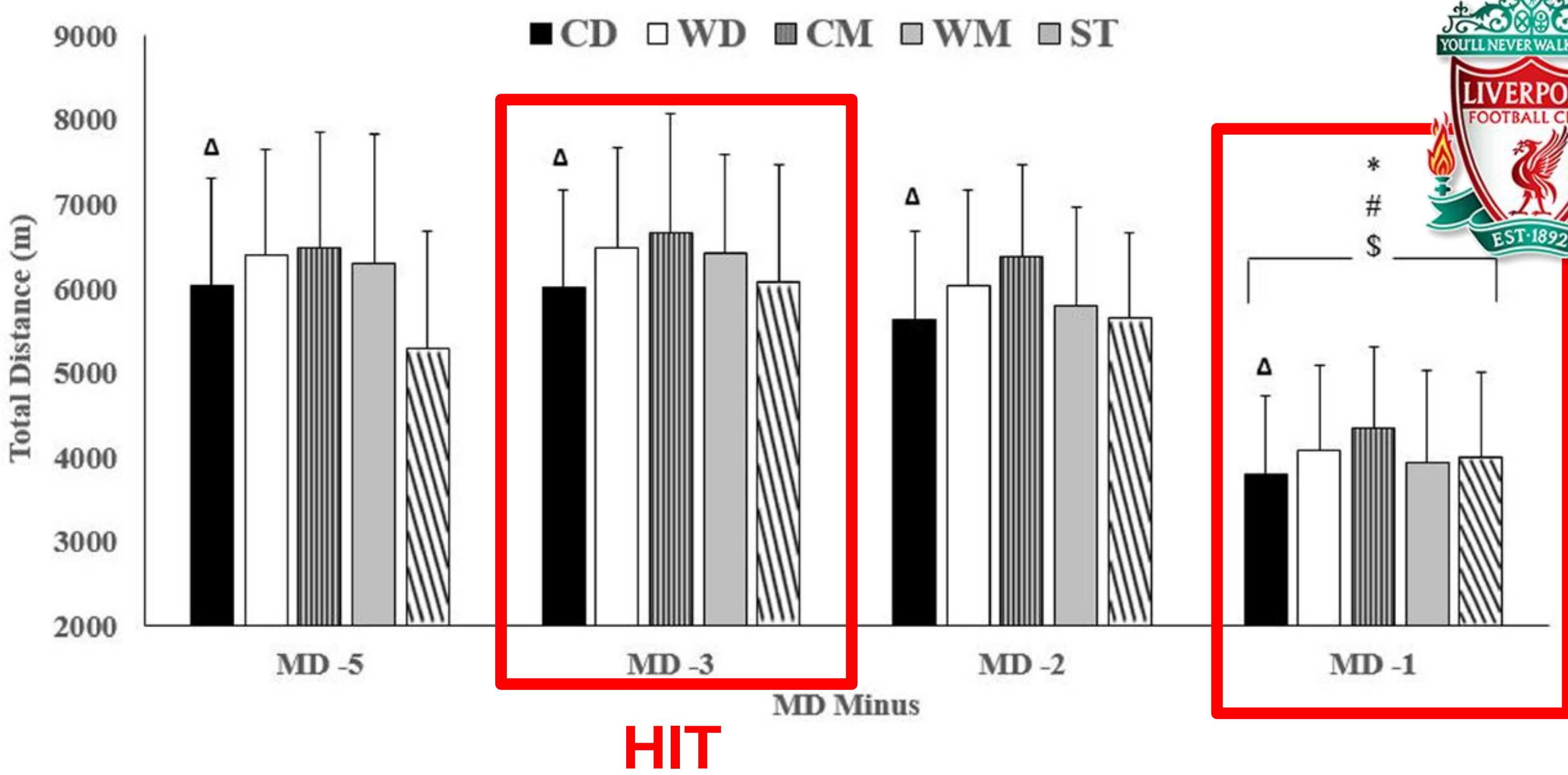
High-intensity interval training is very stressfull and may increase the risks of persistent fatigue when too many sessions are prescribed

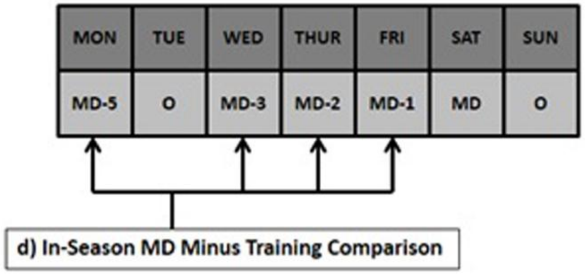



❷ MUSCLE DAMAGES
❸ RESTORE
❶ ANS
PERTURBATIONS

Understanding HIT-induced fatigue

~48 h should separate HIT sessions to enable the majority of athletes to perform and train maximally





In some exception cases, it may be different but be careful not to ask too much

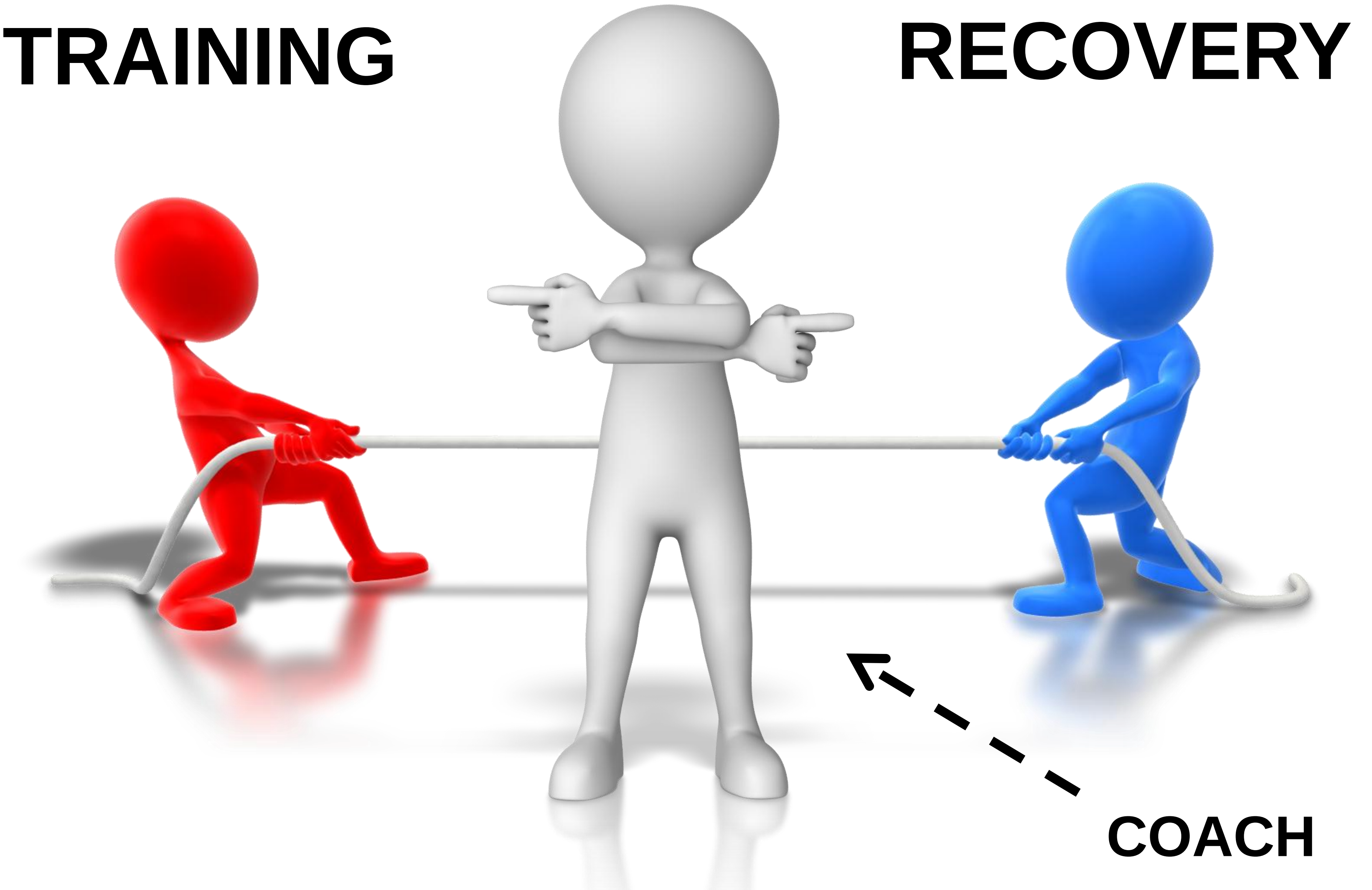
Alistair Brownlee

Typical training week Feb 2012

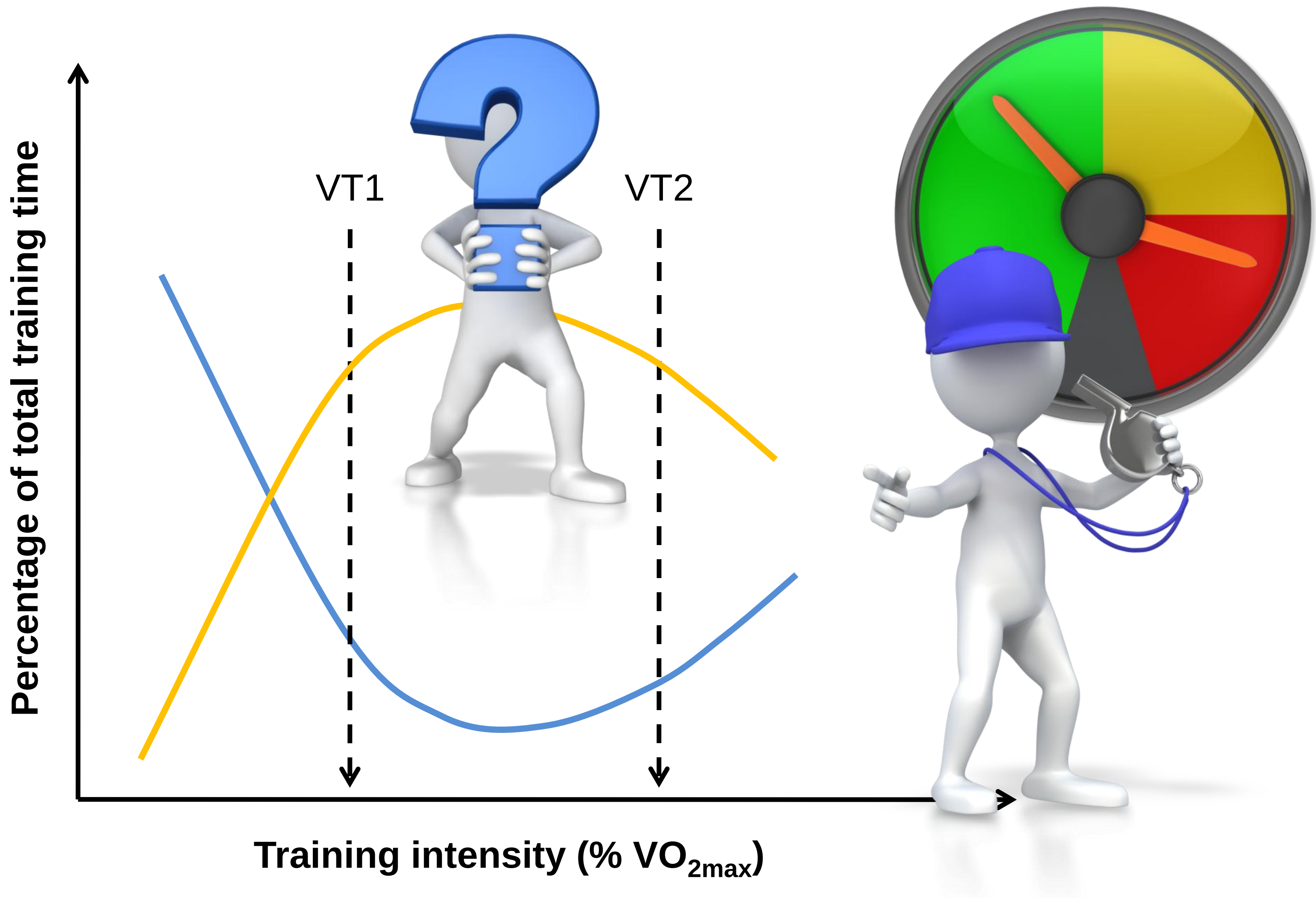
steady/aerobic   tempo/hard/interval   S&C/physio

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
80 min steady run 120bpm	Easy Swim	Easy swim	Fast swim	Easy swim	Run session 30 mins hard 160bpm	4 hrs easy bike
Drills S&C	40 min easy run	75 min easy run	60 min easy run	S&C	3.5 hrs easy bike	1hr 40 easy run
Hard Swim	1 hr easy bike	3.5 hr bike	2 hr easy bike 20 min efforts within this	60 min easy run	30 min easy run	
2 hr easy bike	Track 15 mins hard 170bpm			60 min easy bike		

By Malcolm Brown, Leeds Metropolitan University


TRAINING
RECOVERY
COACH

Training intensity distribution: getting the balance right!

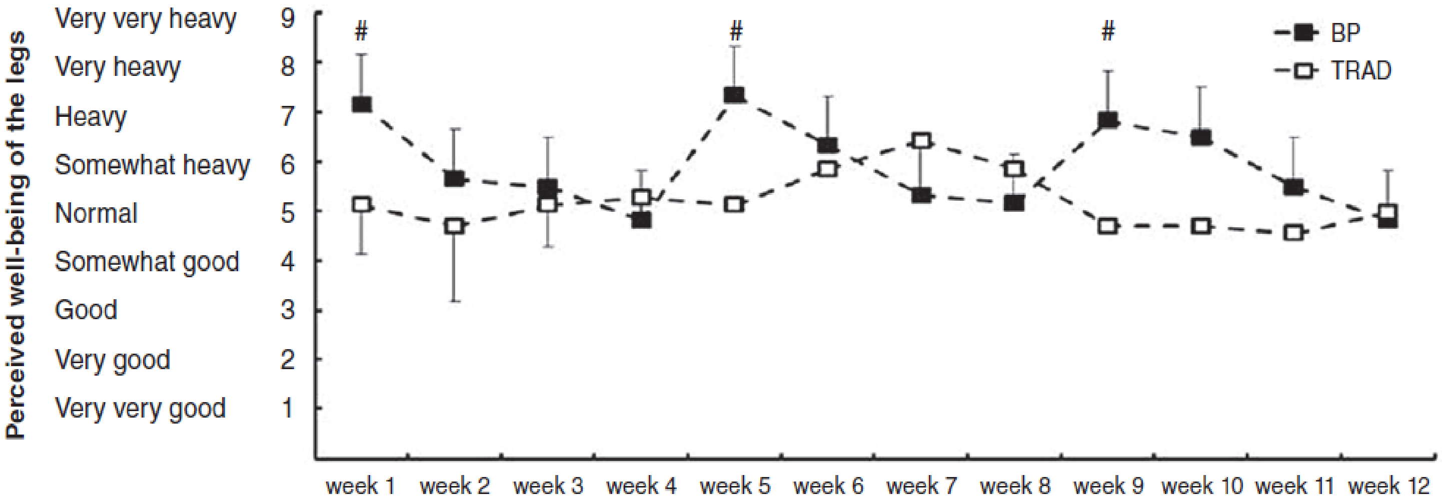


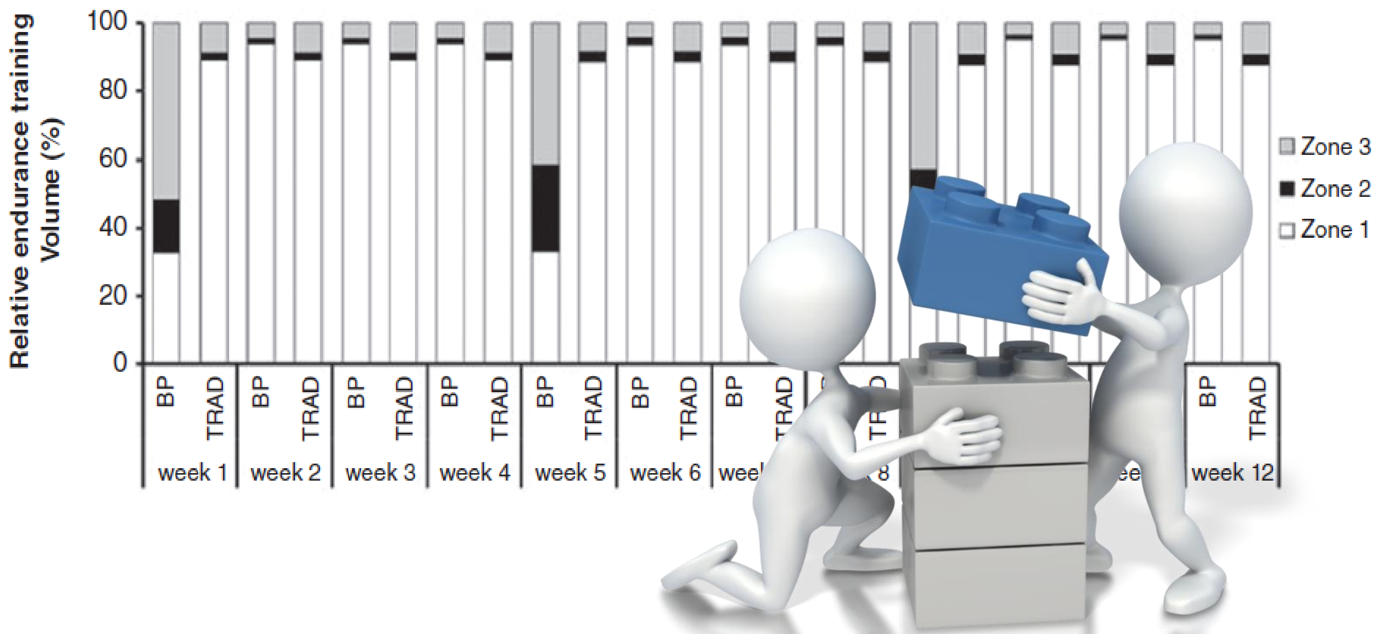
Seiler, 2010

Block periodization: Study #1

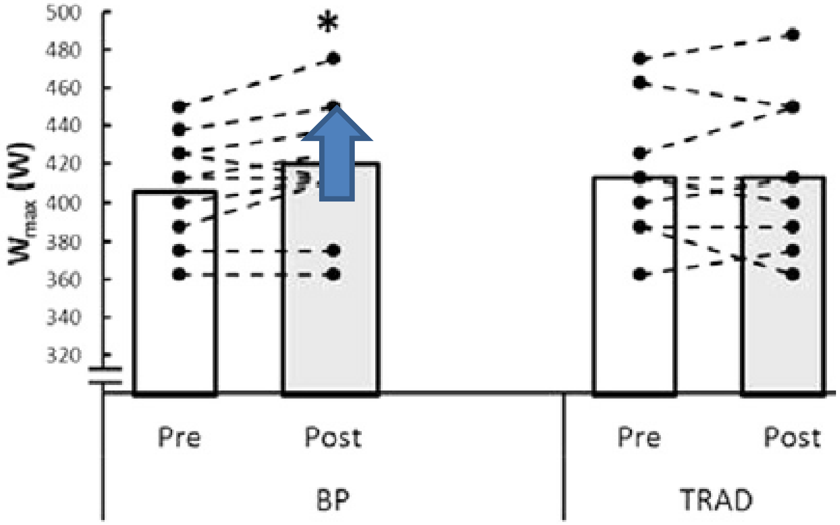
2 + 2 + 2 + 2 HIT per week versus 3 + 1 + 1 + 1 per week

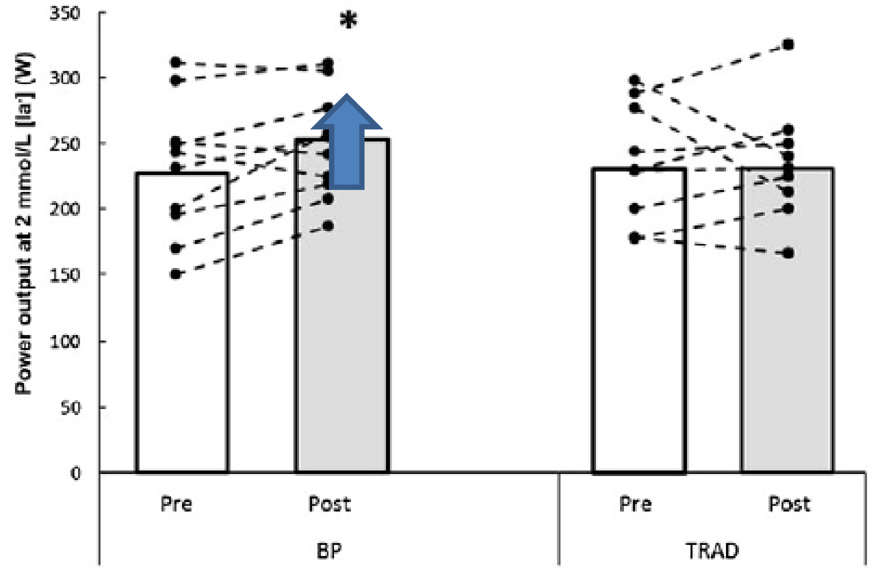
Ronnestad et al., 2013

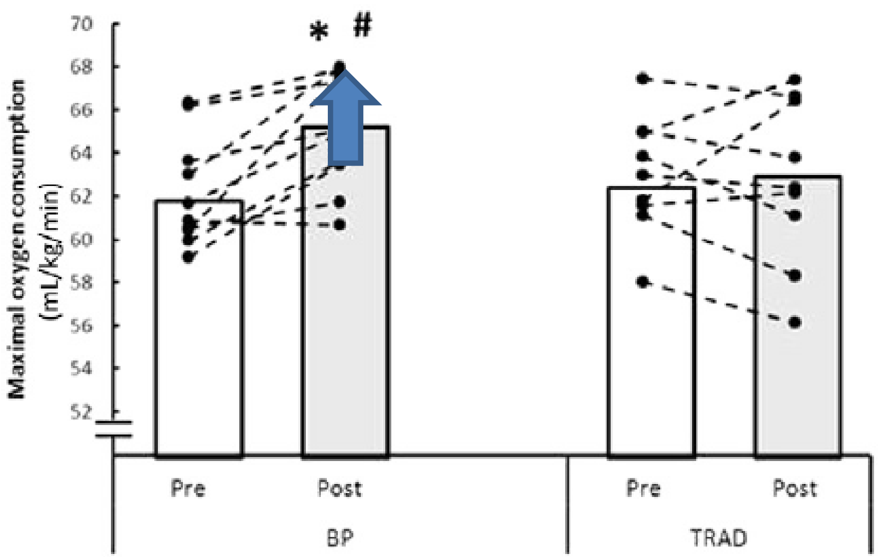




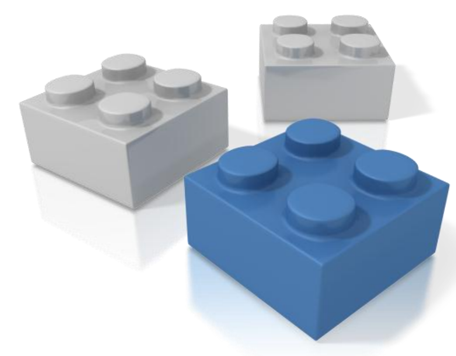
Study #1





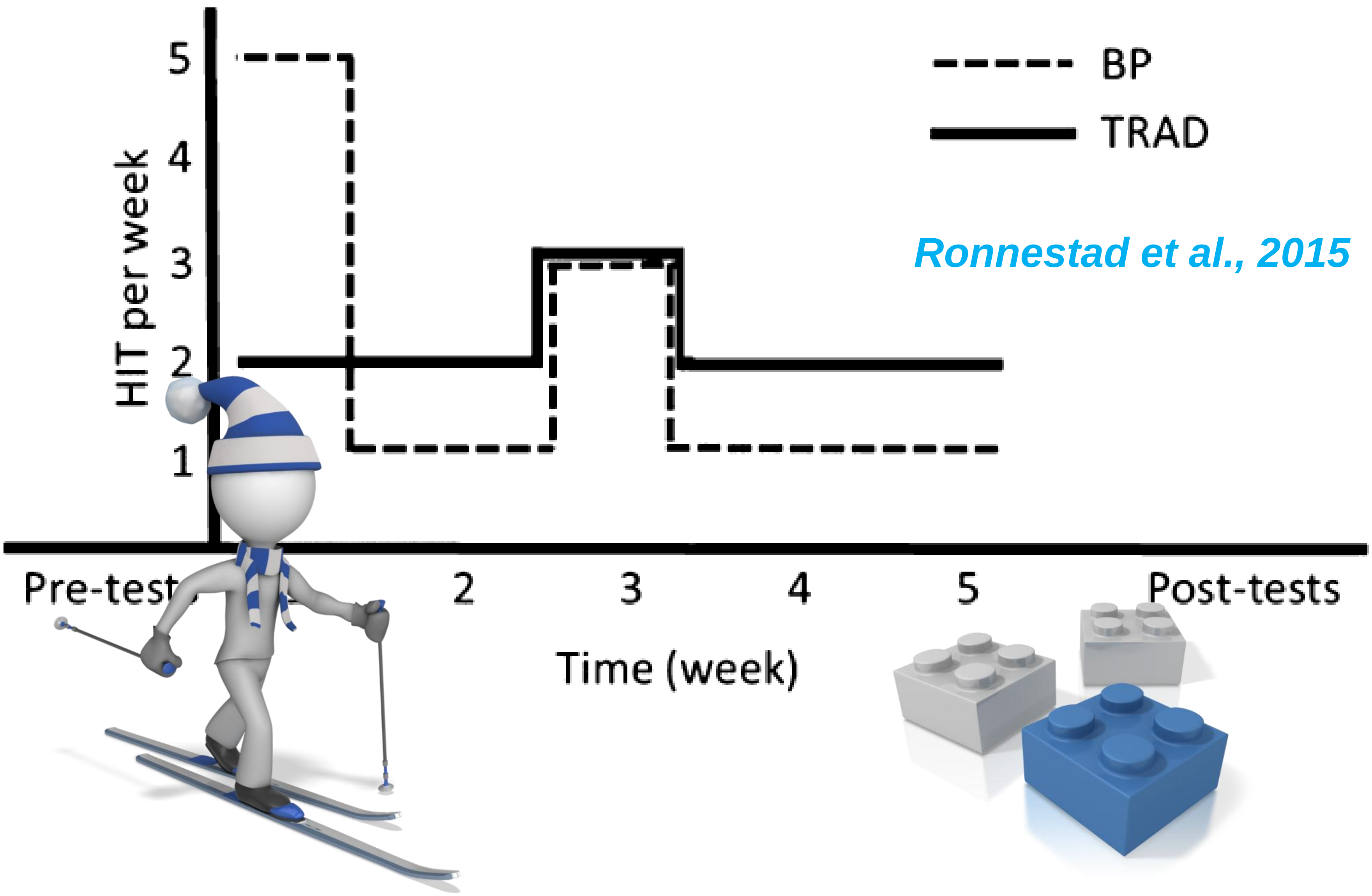


Higher improvement associated with block periodization



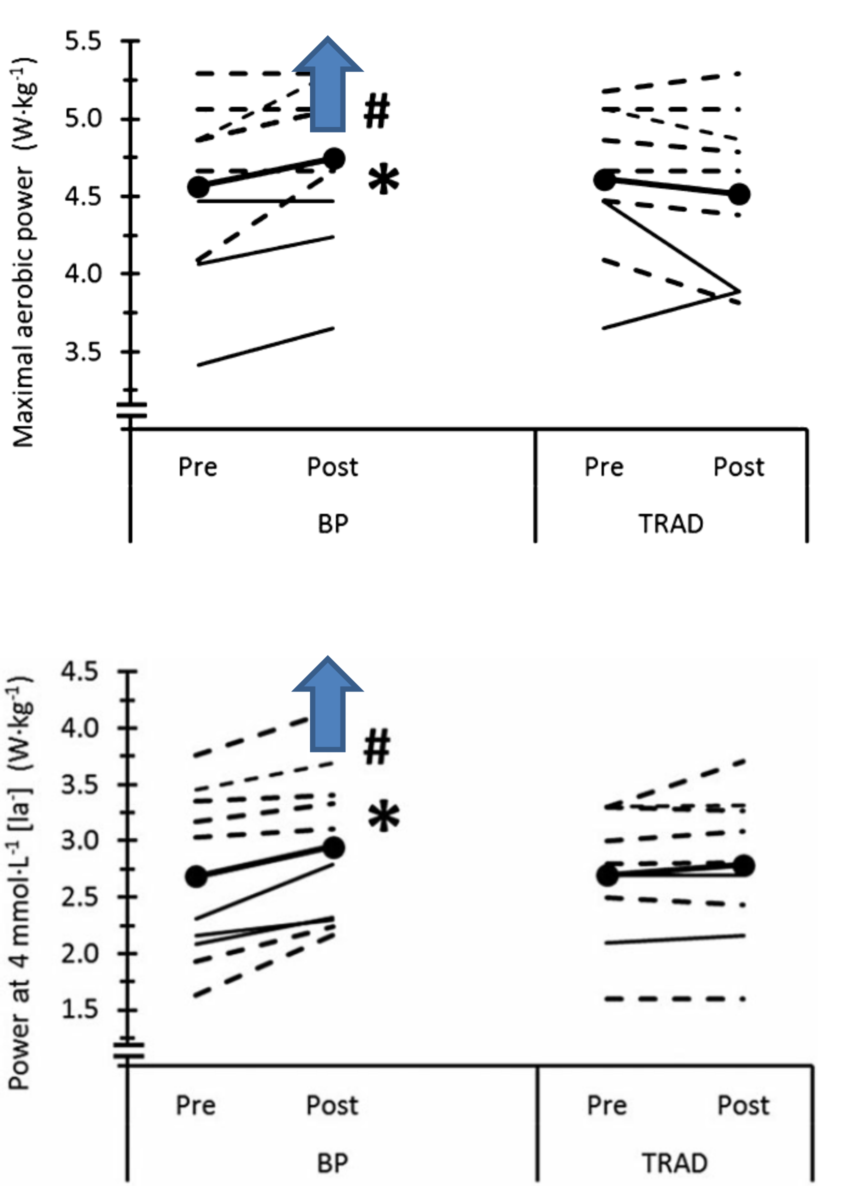
Ronnestad et al., 2013

5x 6 min > 88% HRmax, r = 3min



Ronnestad et al., 2015

Study #2



Higher improvement associated with block periodization

Ronnestad et al., 2015

Study #3

Eur J Appl Physiol (2010) 110:99–107
DOI 10.1007/s00421-010-1484-9

ORIGINAL ARTICLE

Performance changes in world-class kayakers following two different training periodization models

Jesús García-Pallarés · Miguel García-Fernández · Luis Sánchez-Medina · Mikel Izquierdo

Table 4 Changes in selected physiological and kayaking performance variables during the two training cycles

	Traditional periodization cycle				Block periodization cycle			
	T_{TP0}	T_{TP1}	T_{TP2}	T_{TP3}	T_{BP0}	T_{BP1}	T_{PB2}	T_{BP3}
VO_{2peak} (mL kg^{-1} min^{-1})	61.1 ± 2.7	64.1 ± 2.5*	68.6 ± 3.2#	67.8 ± 3.7†	62.0 ± 2.2	64.1 ± 2.7	67.3 ± 2.4#	68.1 ± 3.1†
VO_2VT2 (mL kg^{-1} min^{-1})	50.8 ± 2.4	58.6 ± 3.0*	56.6 ± 2.8	55.1 ± 2.4†	50.2 ± 2.3	56.1 ± 2.3*	53.9 ± 2.2#	54.9 ± 2.4†
VT2 (%VO_{2peak})	83.1 ± 1.1	91.4 ± 2.7*	82.5 ± 3.8#	81.3 ± 1.7	81.0 ± 3.4	87.5 ± 2.8*	80.1 ± 2.2#	80.6 ± 3.0
PS_{peak} (km h^{-1})	14.5 ± 0.3	14.8 ± 0.3*	15.0 ± 0.3	15.0 ± 0.5†	14.5 ± 0.3	14.8 ± 0.3*	15.1 ± 0.4	15.4 ± 0.3£†β
PS_{VT2} (km h^{-1})	13.5 ± 0.2	13.8 ± 0.4*	14.1 ± 0.2	14.2 ± 0.3†	13.6 ± 0.2	13.9 ± 0.2*	14.1 ± 0.2	14.2 ± 0.3†
Pw_{peak} (W)	220 ± 5	231 ± 7*	237 ± 5	240 ± 5†	218 ± 6	233 ± 7*	240 ± 4	254 ± 6£†β
Pw_{VT2} (W)	186 ± 4	196 ± 5*	205 ± 5	207 ± 5†	191 ± 6	202 ± 7*	207 ± 4	210 ± 4†
$[La^-]_{peak}$ (mmol L^{-1})	11.5 ± 4.9	11.9 ± 3.2	10.5 ± 3.5	11.7 ± 3.1	11.2 ± 3.7	12.7 ± 3.1	12.7 ± 3.4	12.0 ± 2.6
HR_{peak} (beats min^{-1})	190 ± 9	187 ± 11	188 ± 9	189 ± 4	193 ± 8	189 ± 7	[illegible]	[illegible]
HR_{VT2} (beats min^{-1})	176 ± 7	172 ± 8	172 ± 7	176 ± 9	175 ± 6	172 ± 6	[illegible]	[illegible]
SR_{peak} (strokes min^{-1})	106 ± 4	102 ± 7	102 ± 8	108 ± 5£	104 ± 4	101 ± 8	[illegible]	[illegible]
SR_{VT2} (strokes min^{-1})	86 ± 4	84 ± 3	84 ± 5	87 ± 6	87 ± 5	84 ± 6	[illegible]	[illegible]

8.1% vs 11.0%

3.4% vs 6.2%

8.3% vs 14.2%

Data are mean ± SD

* $P < 0.05$ when comparing T_{TP0} to T_{TP1} and T_{BP0} to T_{BP1}

\# $P < 0.05$ when comparing T_{TP1} to T_{TP2} and T_{BP1} to T_{BP2}

£ $P < 0.05$ when comparing T_{TP2} to T_{TP3} and T_{BP2} to T_{BP3}

† $P < 0.05$ when comparing T_{TP0} to T_{TP3} and T_{BP0} to T_{BP3}

β $P < 0.05$ when comparing T_{TP3} to T_{BP3}

TRAINING INTENSITY DISTRIBUTION

The more HIT you do, the better?

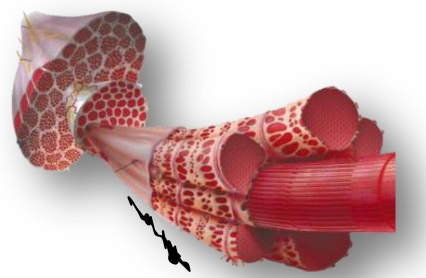
Interval-training

Contractions de haute intensité

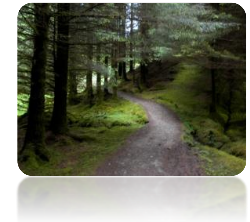
ATP → AMP

AMPK

Facteurs périphériques



PGC-1α



Entraînement foncier

Contractions répétées

↑ $[Ca^{2+}]$

CaMPK

% Fibres de type I

↑ Biogenèse mitochondriale

↑ Capacité d'oxydation des lipides

↑ GLUT 4
↑ Glycogène

Coffey & Hawley, 2007

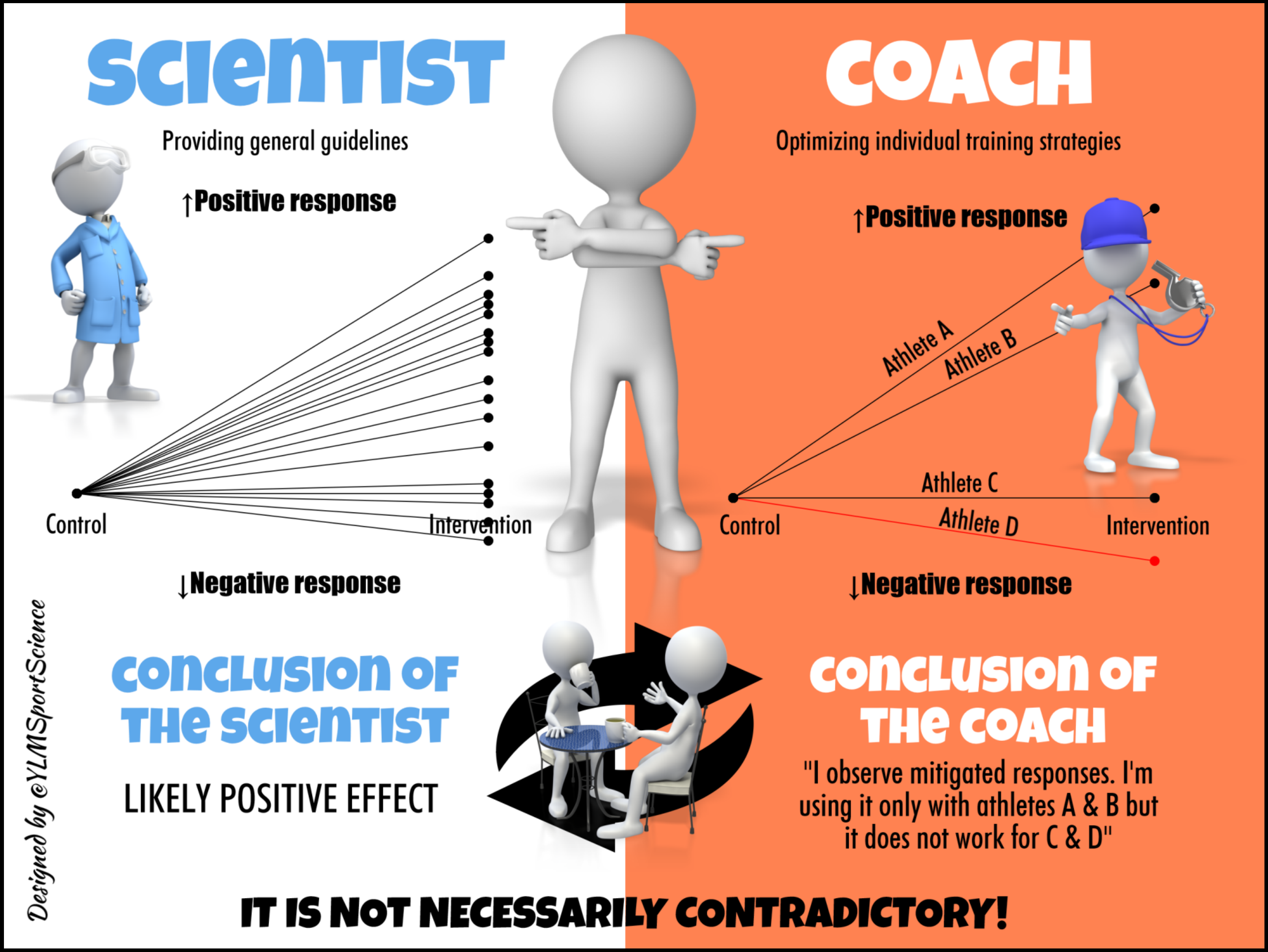
Summary #4

❶ Potential of varying quantities of both high-intensity interval training and continuous high-volume, low intensity training on performance and to reduce the risk of overreaching / injury,

❷ ~48 h should separate HIT sessions to enable the majority of athletes to perform and train maximally,

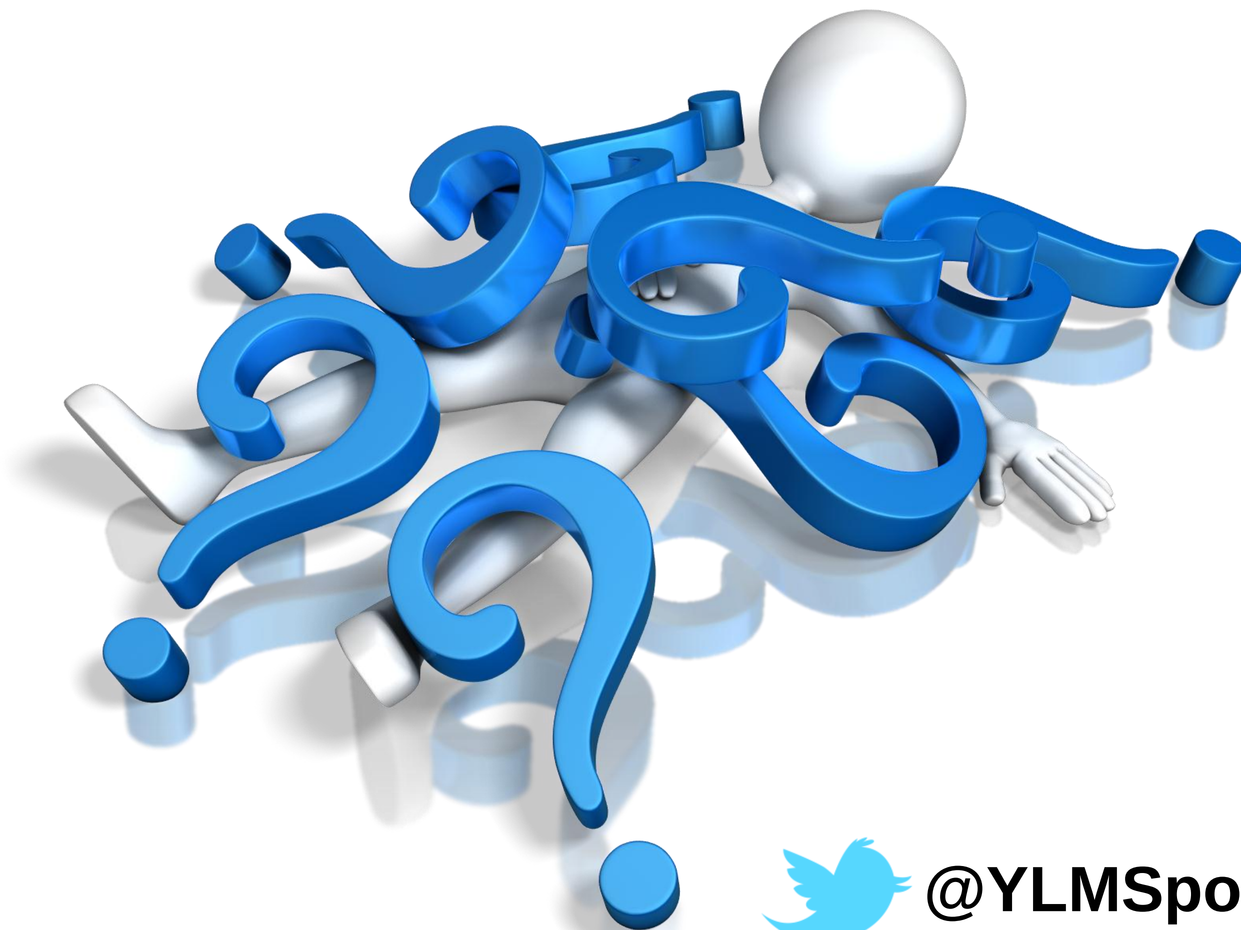
❸ Potential of varying quantities of high-intensity each week regularly (block periodization)

But always keep in mind that…



http://YLMSportScience.blogspot.fr

THANKS FOR YOUR ATTENTION



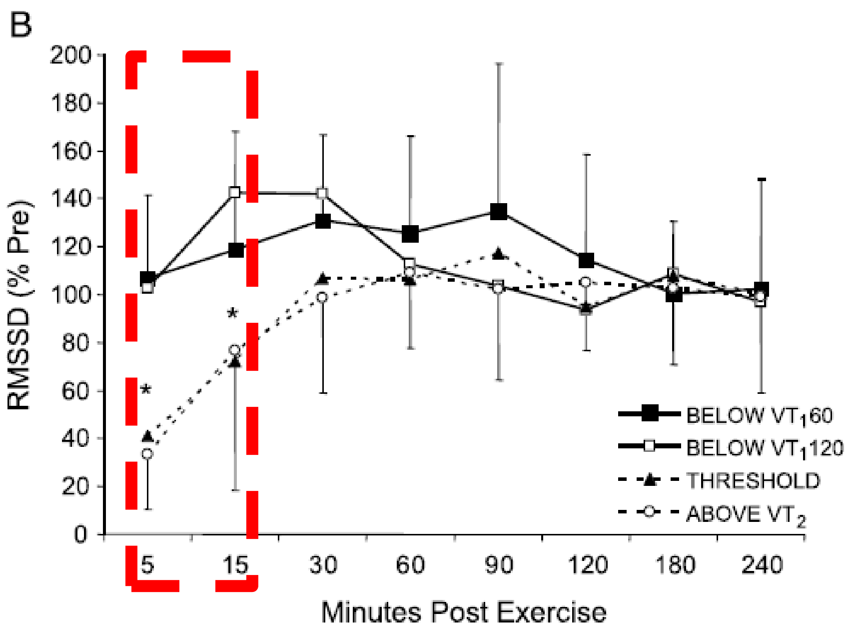
@YLMSportScience

One concept, many declensions

From long-interval training to repeated sprint training (3 – 7s sprints, r < 60 s) or sprint interval training (30 s all-out efforts, r = 2–4 min)

Training intensity & ANS perturbations

9 coureurs très entraînés (72 ± 5 $mL.min^{-1}.kg^{-1}$, 14 ± 3 $h.sem^{-1}$)
8 coureurs entraînés (60 ± 5 $mL.min^{-1}.kg^{-1}$, 7 ± 1 $h.sem^{-1}$)
4 exercices: 60min à 60% VO_{2max} (< SV1), 120min à 60% VO_{2max} (< SV1), 20min echft puis 30min à SV2 (80-85% VO_{2max}), 20min echft puis 6x3min à 95-100% VO_{2max}, r=2min.
Test HRV allongé Pré et Post (+5min, 15min, +30min, +1h, +2h, +3h, +4h).



Les exercices en dessous du SV1 (≤ 120min) ne causent pas perturbations importantes du système neuro-végétatif chez des sportifs très entraînés.

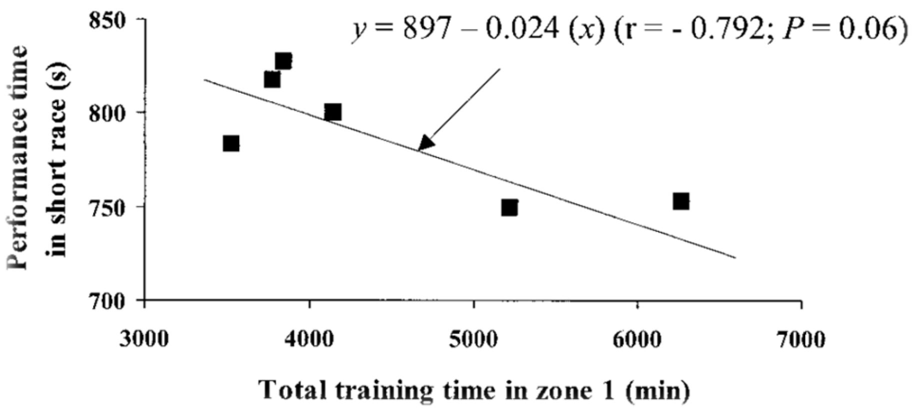
Seiler et al., 2007

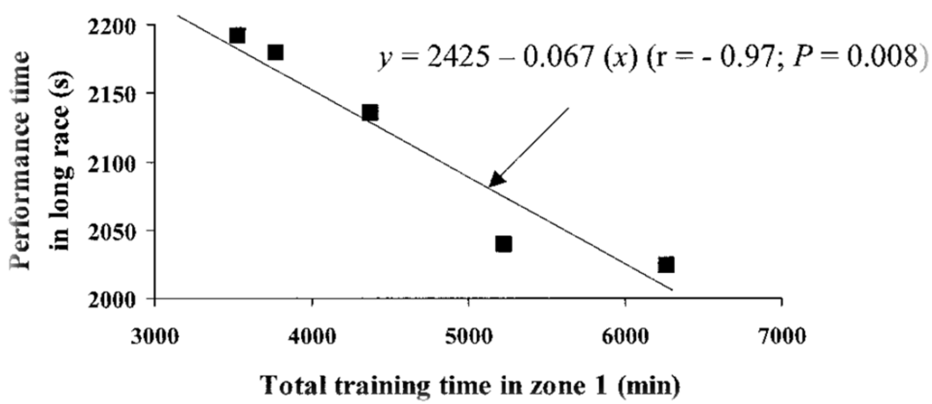
Training intensity & ANS perturbations

8 coureurs espagnols de niveau national (23 ± 2 ans, 70 ± 7 $ml.min^{-1}.kg^{-1}$).

Quantification du temps passé en zone 1, zone 2 et zone 3.

~ 70 $km.sem^{-1}$





Tendance à observer une corrélation positive entre le volume d'entraînement en zone 1 et la perf sur 4km.

Corrélation significative en prenant en compte la perf sur 10km.

Esteve-Lanao et al., 2005

Training intensity & ANS perturbations

12 coureurs espagnols de niveau national (VMA : 21.5 km.h^{-1}).

2 groupes de 6 : même charge de travail globale par semaine sur 18 semaines (niveau de performance similaire).

Distribution différente en Z1, Z2, Z3: 80%/12%/8% vs. 65%/27%/8%.

Table 3. Results (mean ± *SEM*) of training loads over the 18-week intervention period.

	Group Z1 (n = 6) goal distribution in zones 1, 2, and 3: ~80/10/10	Group Z2 (n = 6) goal distribution in zones 1, 2, and 3: ~65/25/10
Total TRIMPs	8134 ± 408	8277 ± 463
Mean TRIMP·wk^{-1}	452 ± 23	460 ± 26
Total time in zone 1 (min)	5246 ± 396	3830 ± 215*
Total time in zone 2 (min)	779 ± 116	1411 ± 95*
Total time in zone 3 (min)	502 ± 78	485 ± 65
Total % in zone 1	80.5 ± 1.8	66.8 ± 1.1
Total % in zone 2	11.8 ± 2.0	24.7 ± 1.5*
Total % in zone 3	8.3 ± 0.7	8.5 ± 1.0*

* $p < 0.01$ for Z1 vs. Z2. See text for explanation of TRIMP and zones 1, 2, and 3.

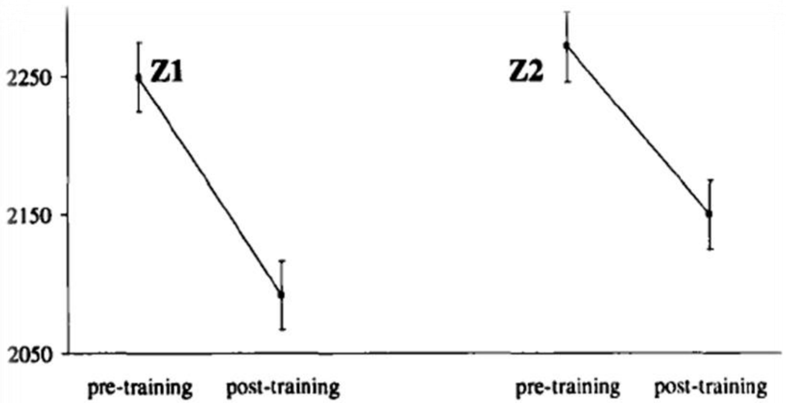


Figure 1. Change in performance after the training period during the simulated 10.4-km cross-country race in both groups.

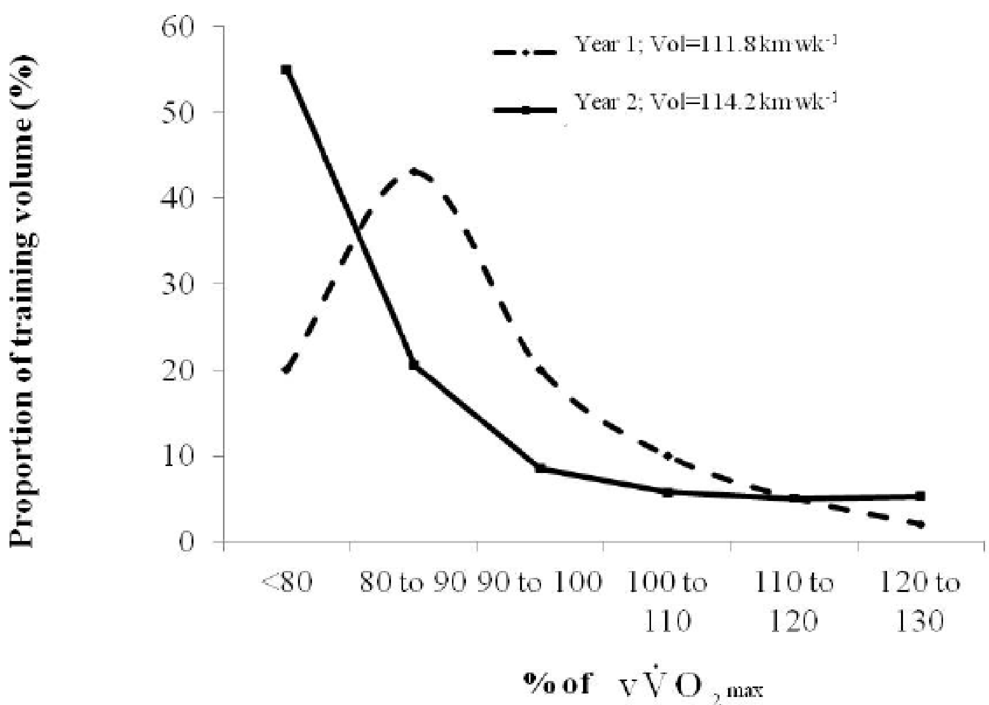
Amélioration significativement plus grande du niveau de performance sur une épreuve de 10.4km à l'issue des 18 semaines pour le groupe 80%/12%/8% (-157 ± 13 s vs. -122 ± 7 s, *p* = 0.03).

Esteve-Lanao et al., 2007

The more HIT you do, the better?

Table 1 Physiological Data Collected During Incremental Exercise to Exhaustion During 2-Year Period (T_0 was baseline) of Monitoring

Physiological Measure	Sept T_0	Nov Y 1	Mar Y 1	Sept Y 1	Dec Y 2	Mar Y 2	Sept Y 2
VO_{2max} (L/min)	4.80	4.98	5.16	4.90	5.48	5.60	5.45
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	70.5	72.4	73.8	70.5	78.6	79.6	78.5
vLT (km/h)	16.0	16.0	16.0	17.0	17.0	17.0	18.0
vVO_{2max} (km/h)	20.4	20.3	20.4	20.1	22.6	23.2	23.1
RE ($mL \cdot kg^{-1} \cdot km$)	208	214	217	210	209	206	204



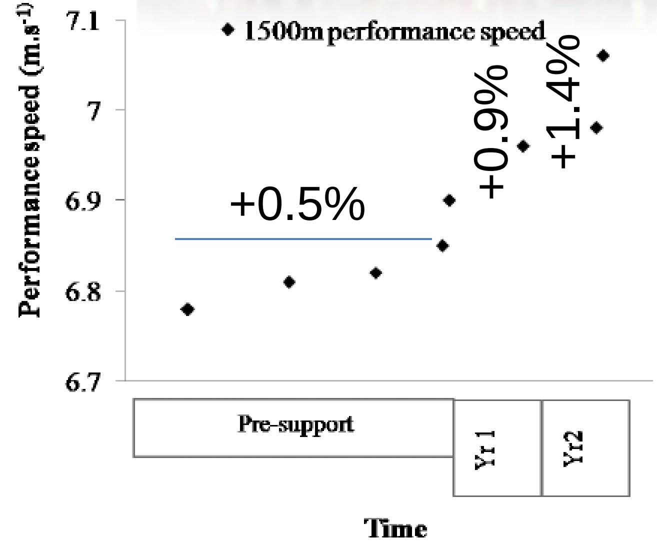
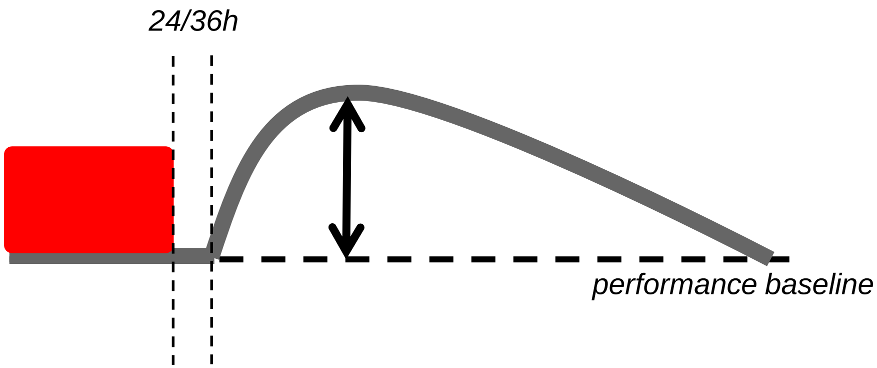


Figure 2 — The change in 1500-m performance speed during competitive races prior to physiological support and during years 1 and 2.

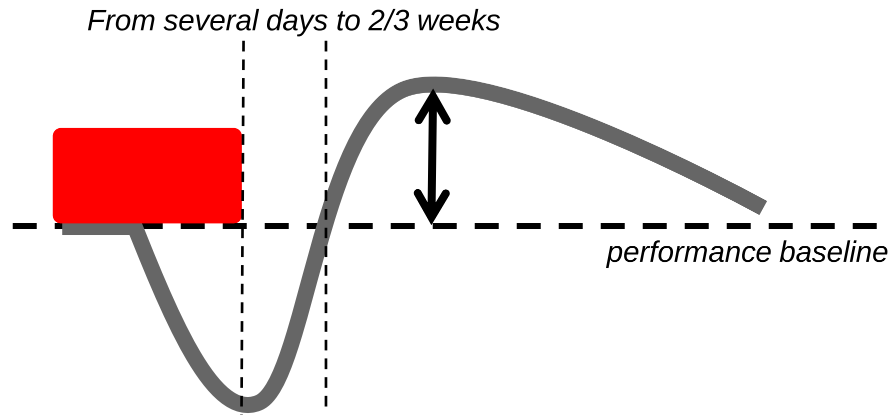
Ingham, Fudge & Pringle IJSPP 2012

The different stages of training-induced fatigue

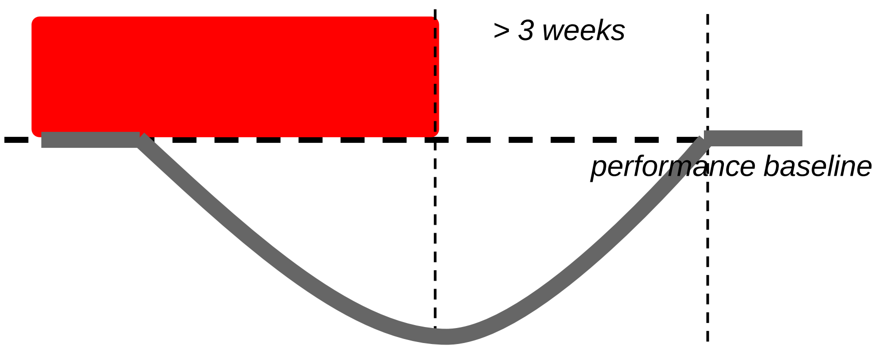
Acute fatigue



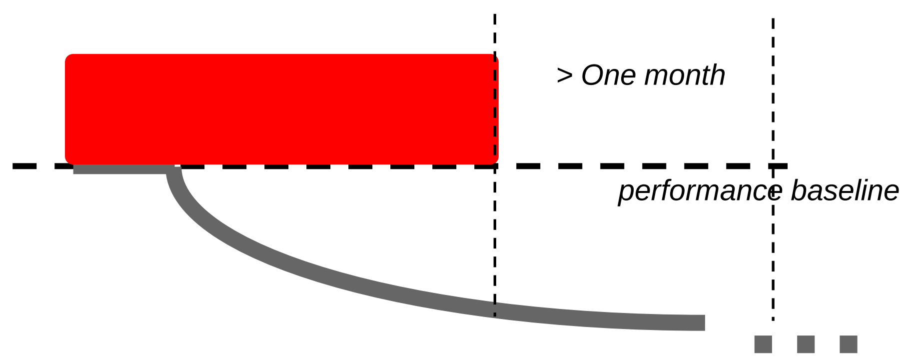
Functional overreaching

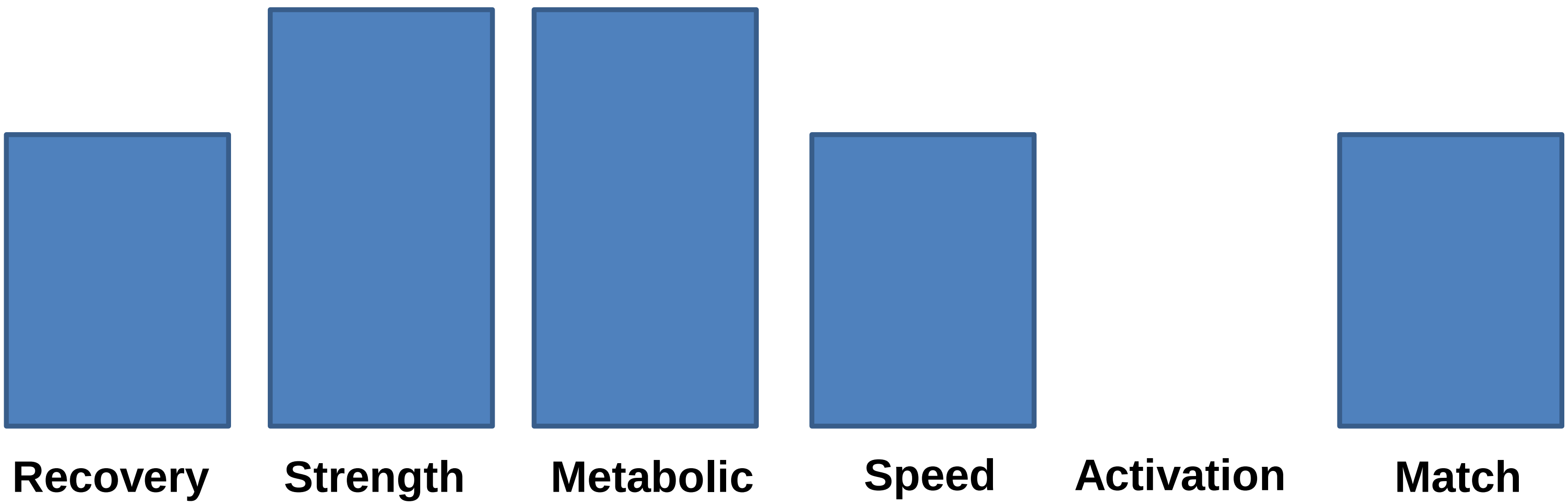


Non functional overreaching



Overtraining syndrome




Recovery
Strength
Metabolic
Speed
Activation
Match

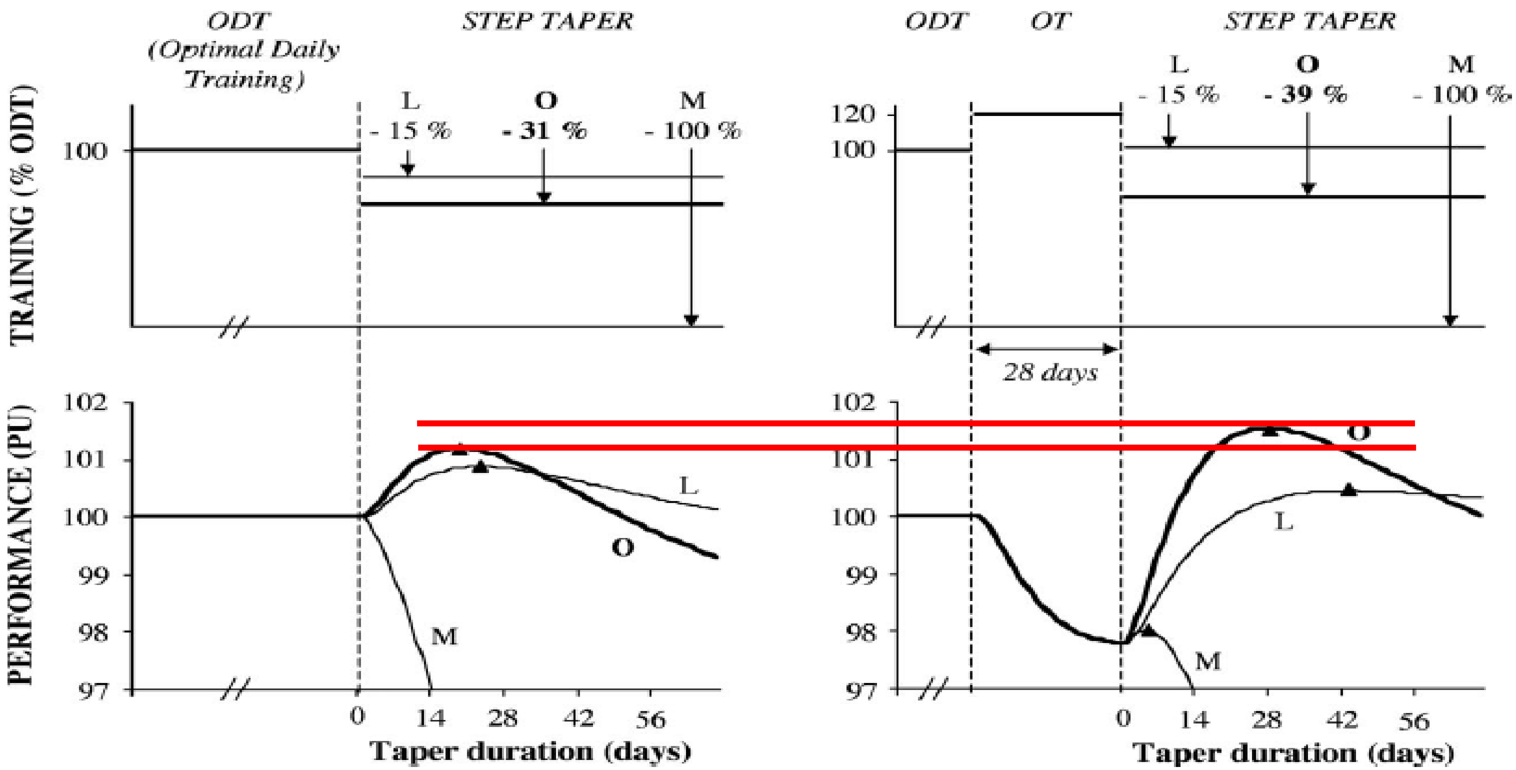
HOW MUCH IS ENOUGH?

Where is the limit?

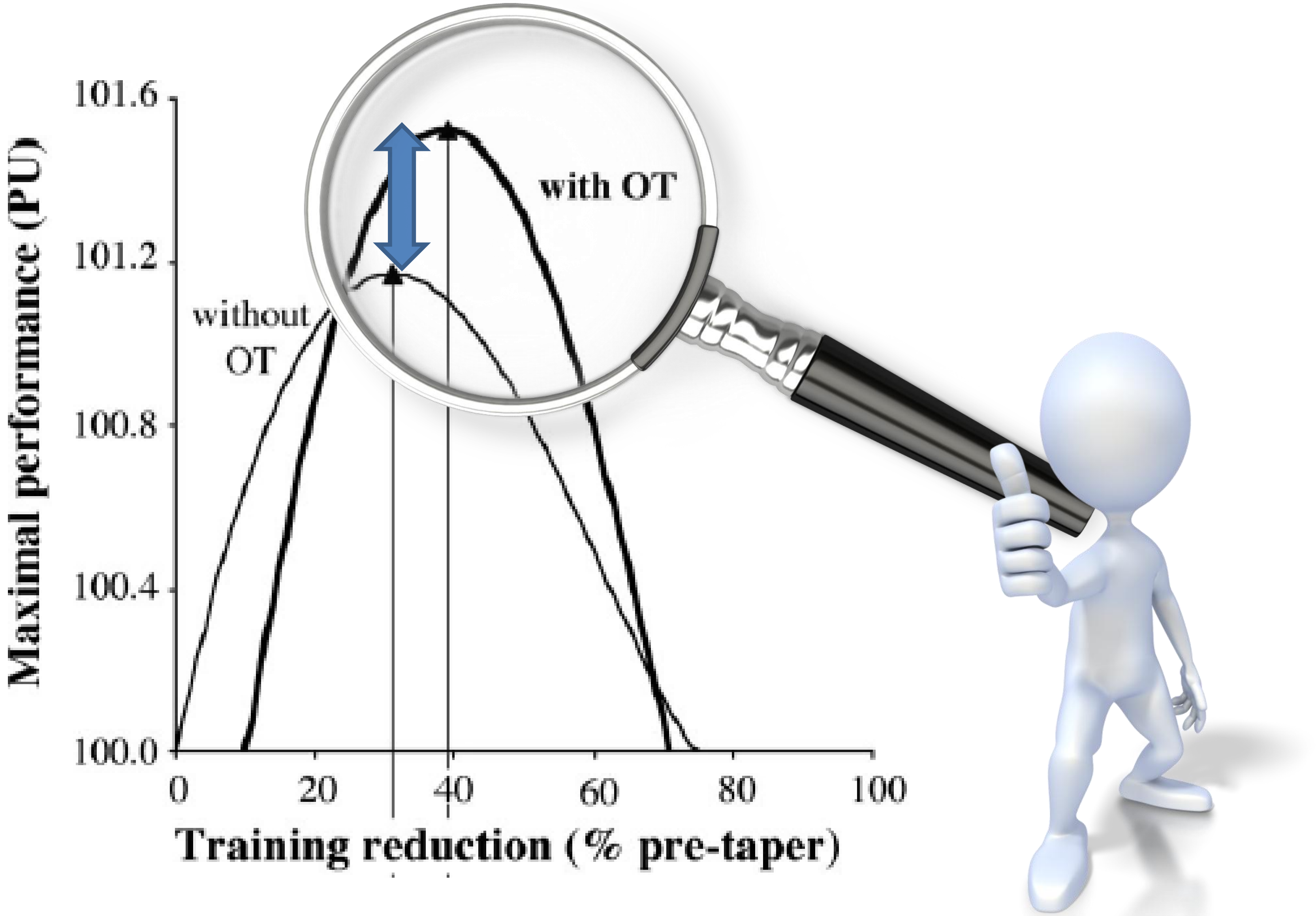
A Theoretical Study of Taper Characteristics to Optimize Performance

LUC THOMAS and THIERRY BUSSO

Research Unit of Physiology and Physiopathology of Exercise and Handicap, University of Saint-Etienne, FRANCE.



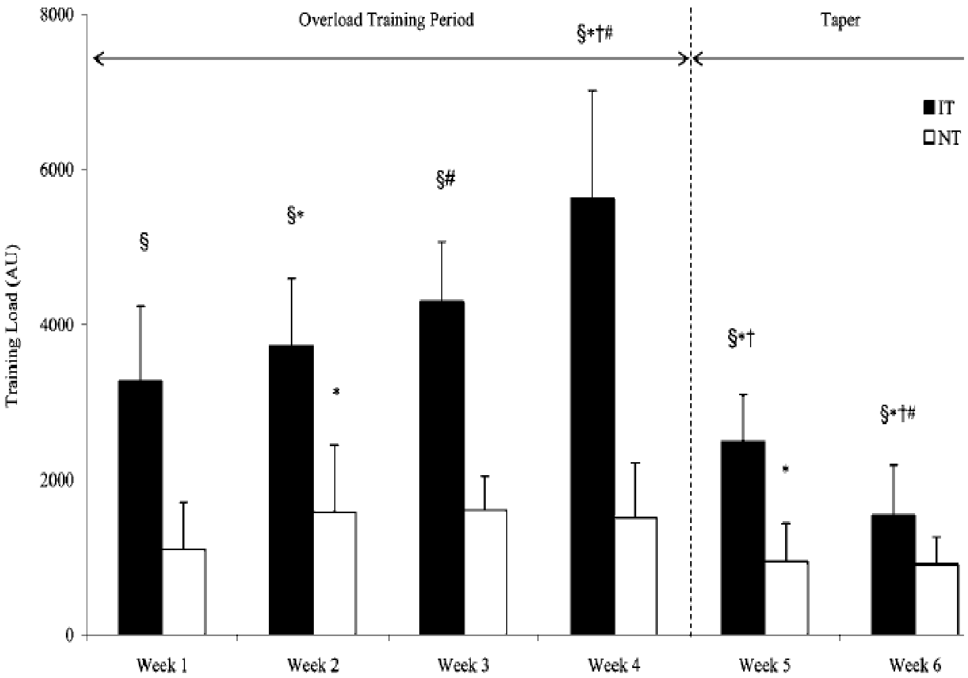
Functional overreaching, the key for supercompensation?

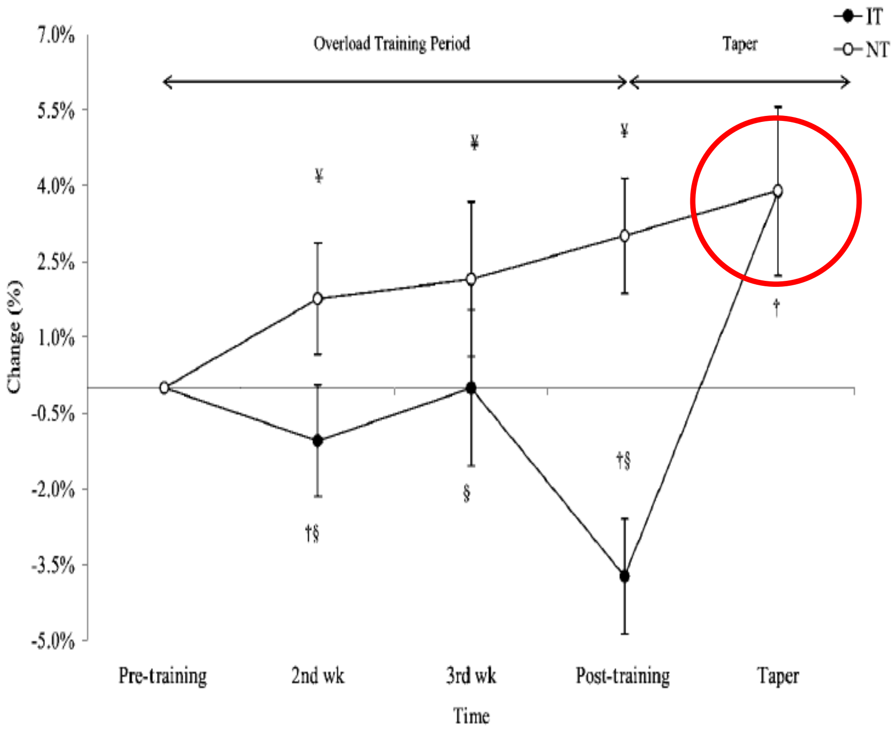


Functional overreaching, the key for supercompensation?

A. J. Coutts
L. K. Wallace
K. M. Slattery

Monitoring Changes in Performance, Physiology, Biochemistry, and Psychology during Overreaching and Recovery in Triathletes





Functional overreaching, the key for supercompensation?

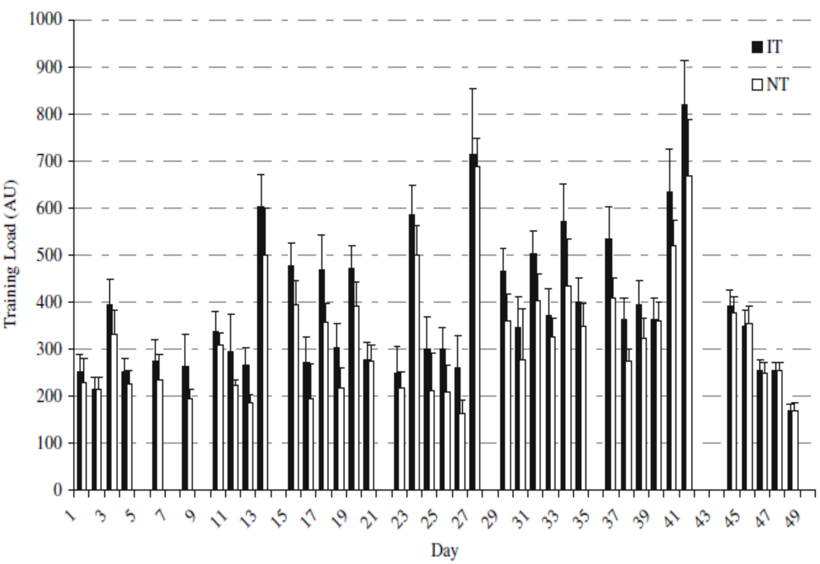
Eur J Appl Physiol
DOI 10.1007/s00421-006-0345-z

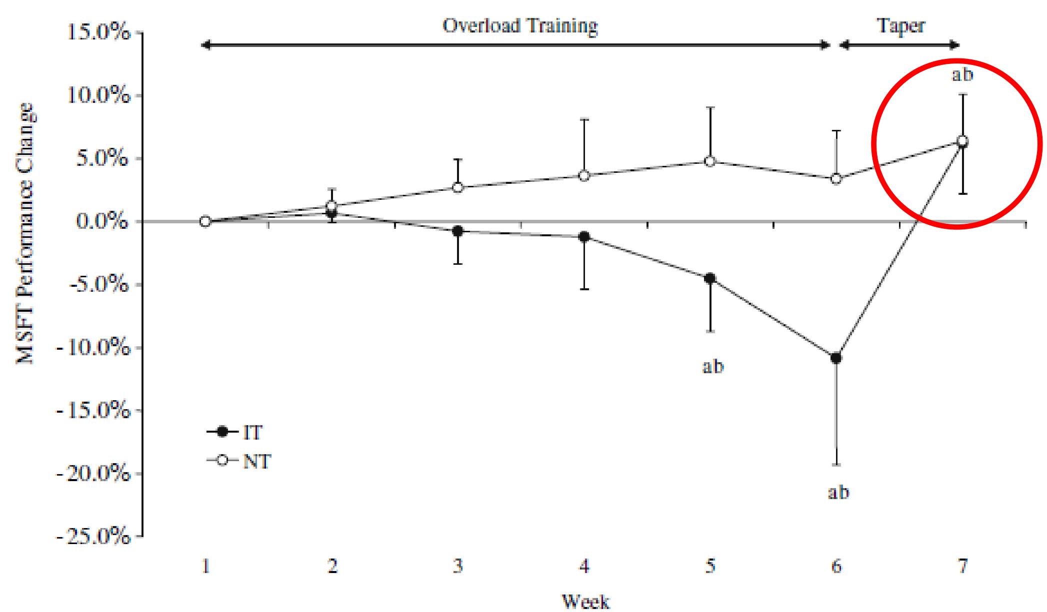
ORIGINAL ARTICLE

Monitoring for overreaching in rugby league players

Aaron J. Coutts · Peter Reaburn · Terrence J. Piva ·
Greg J. Rowsell

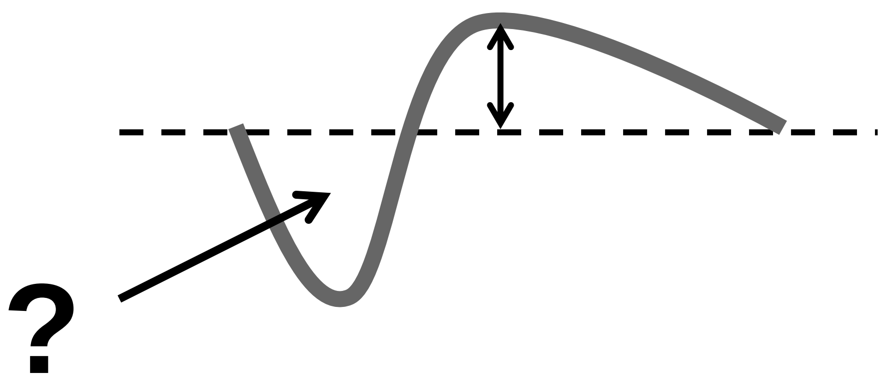
Multistage fitness test





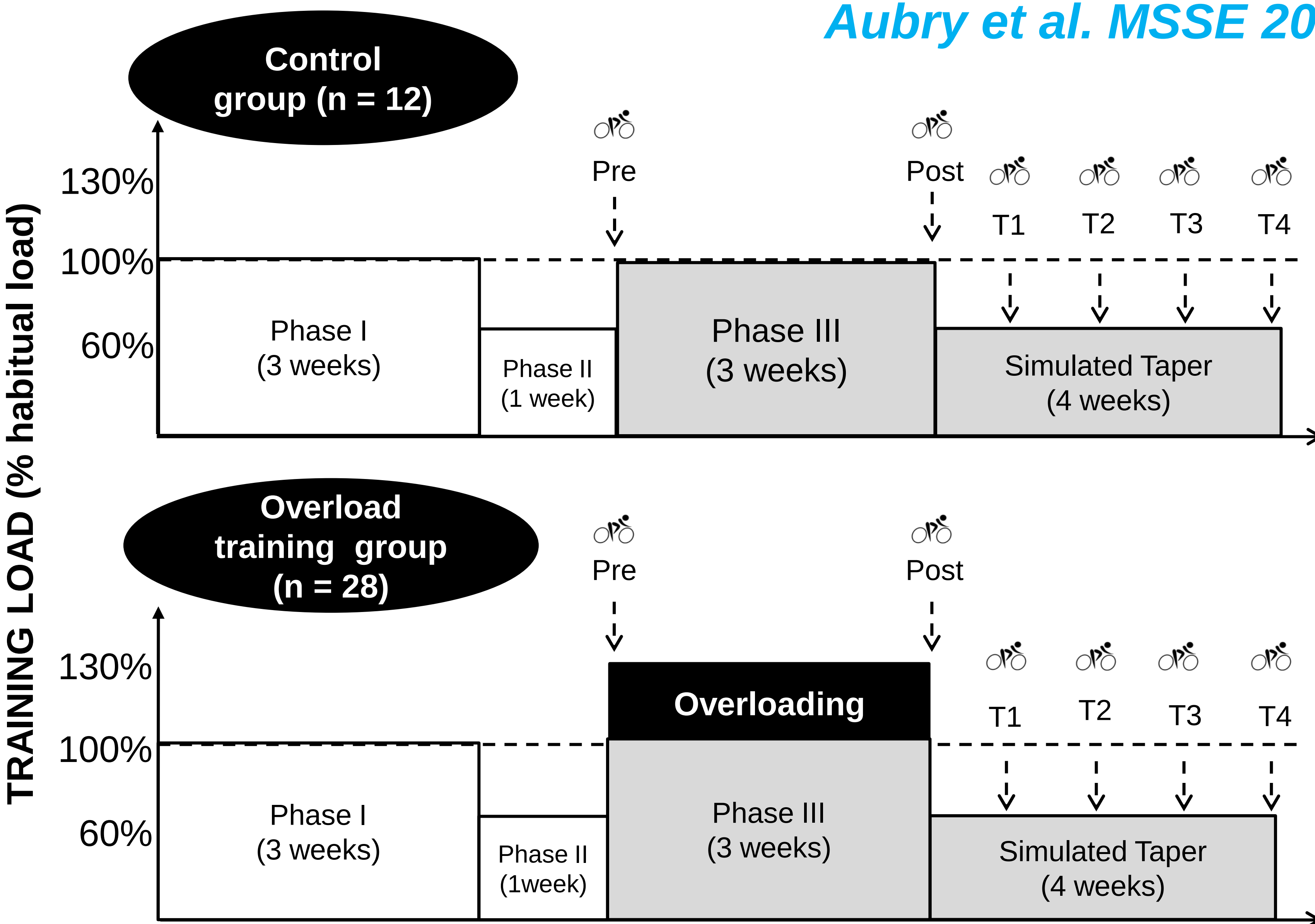
Functional overreaching, the key for supercompensation?

To examine whether the development of a functional overreaching state leads to greater performance supercompensation in comparison to acute fatigue strategy

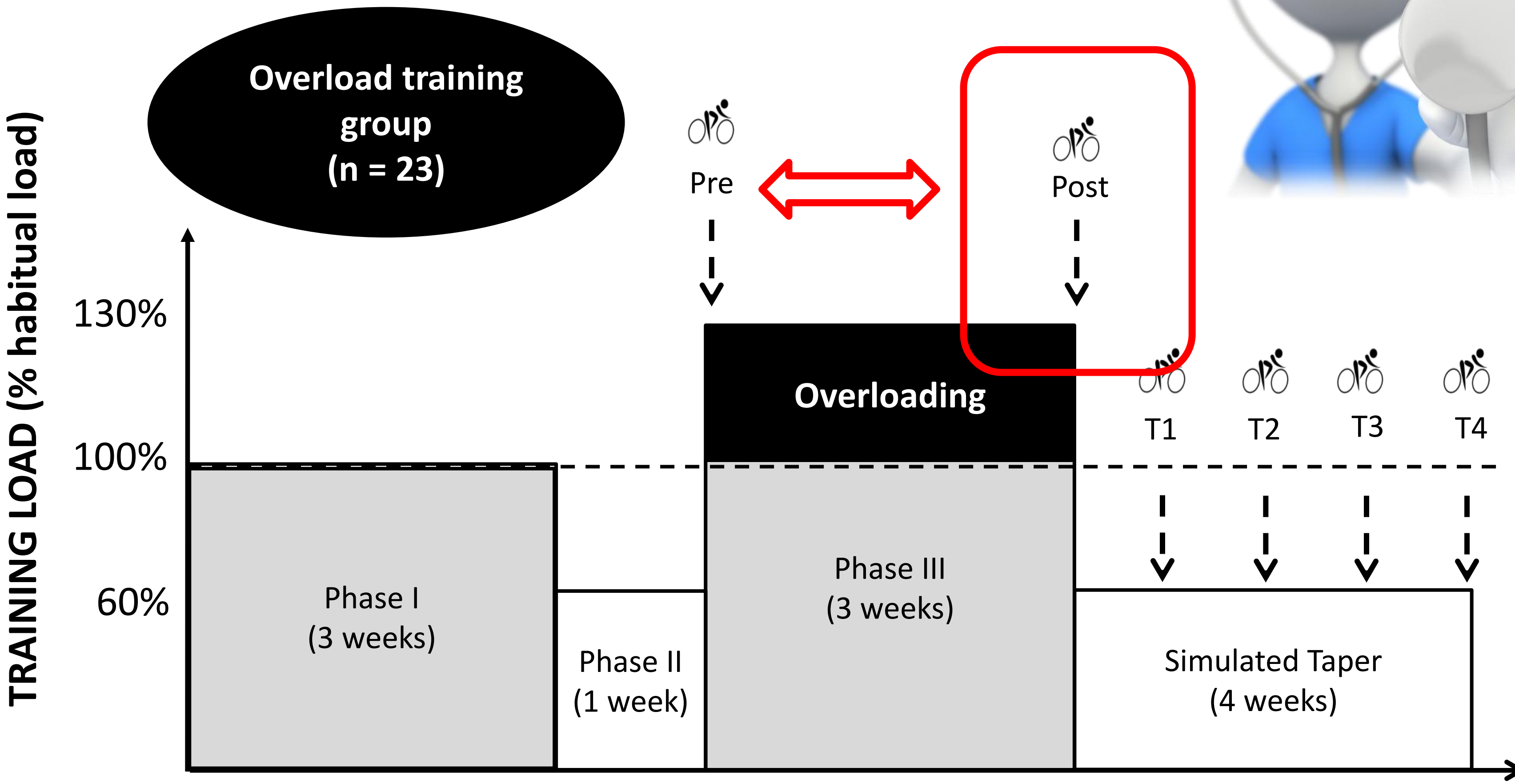


Study design

Aubry et al. MSSE 2014



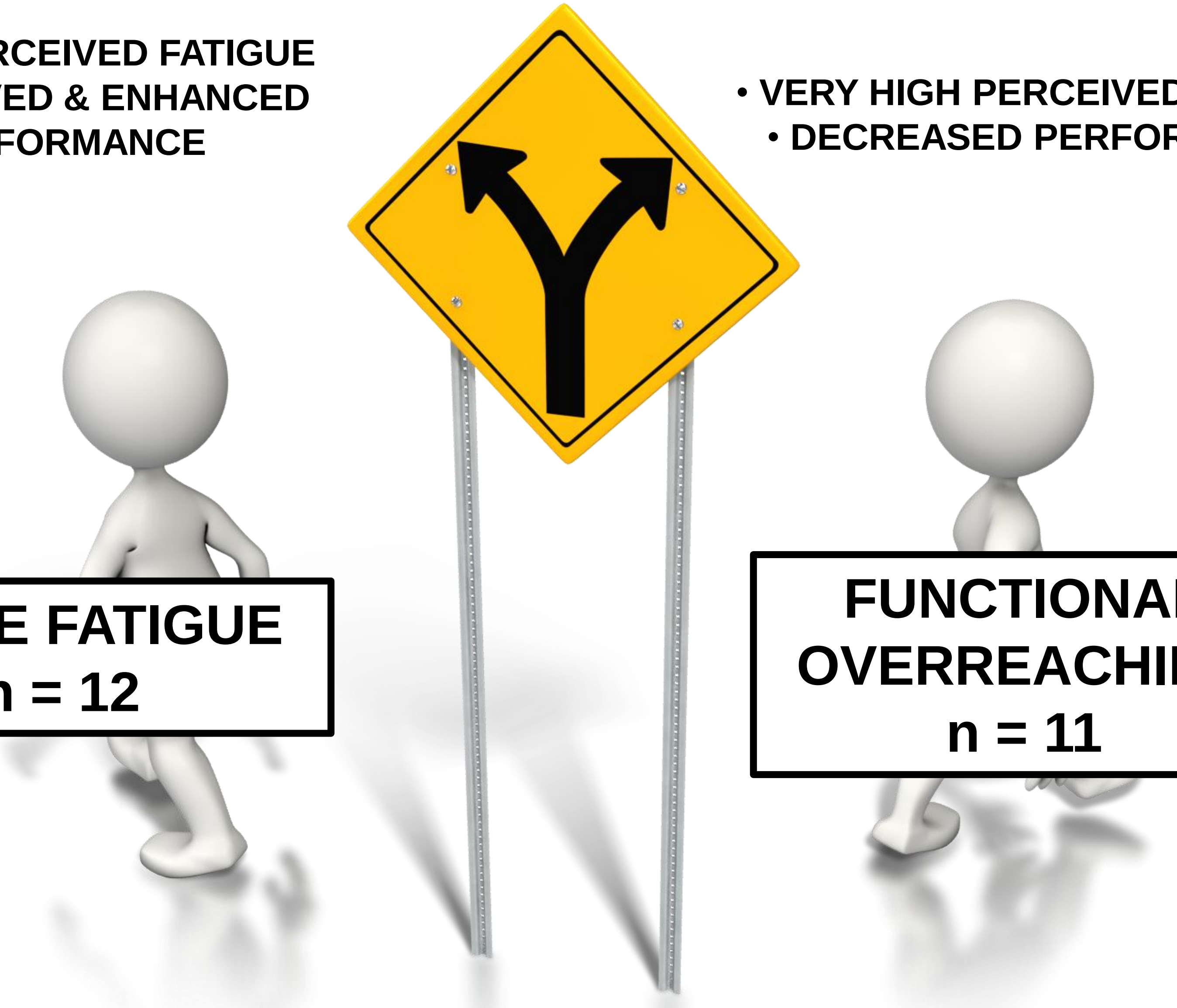
Functional overreaching, the key for supercompensation?



The overload group

- HIGH PERCEIVED FATIGUE
- PRESERVED & ENHANCED PERFORMANCE

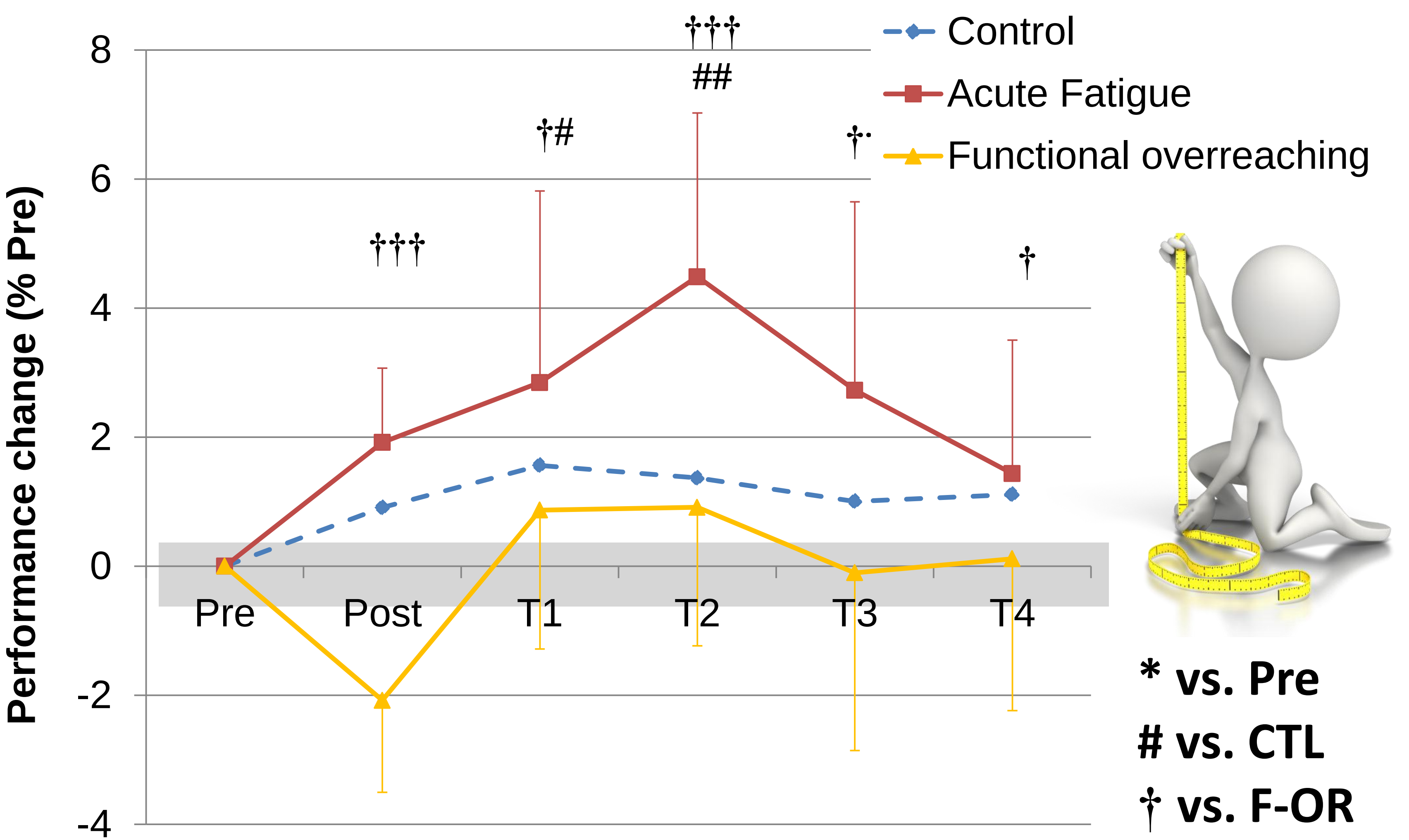
- VERY HIGH PERCEIVED FATIGUE
- DECREASED PERFORMANCE



ACUTE FATIGUE
n = 12

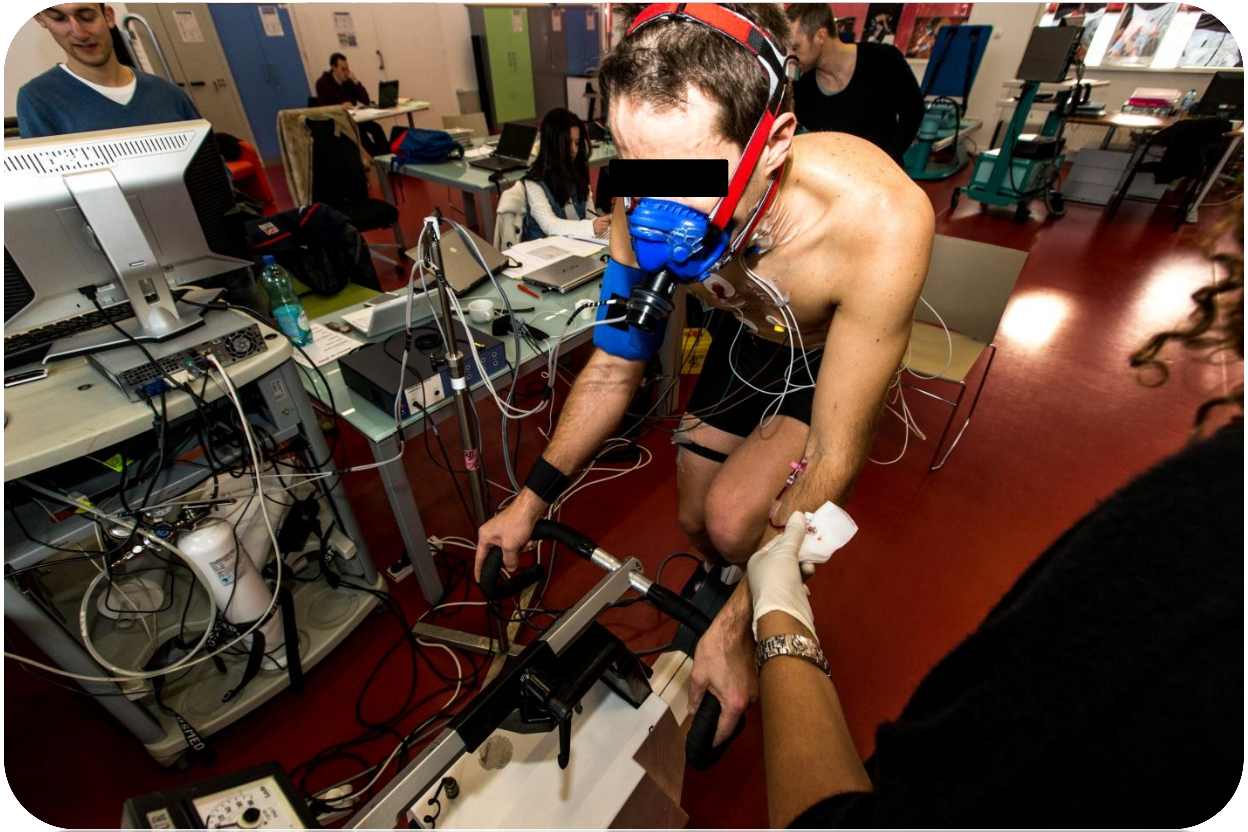
FUNCTIONAL OVERREACHING
n = 11

The performance rebound



Aubry et al. MSSE 2014

Physiological response



Oxygen uptake
Ventilatory parameters

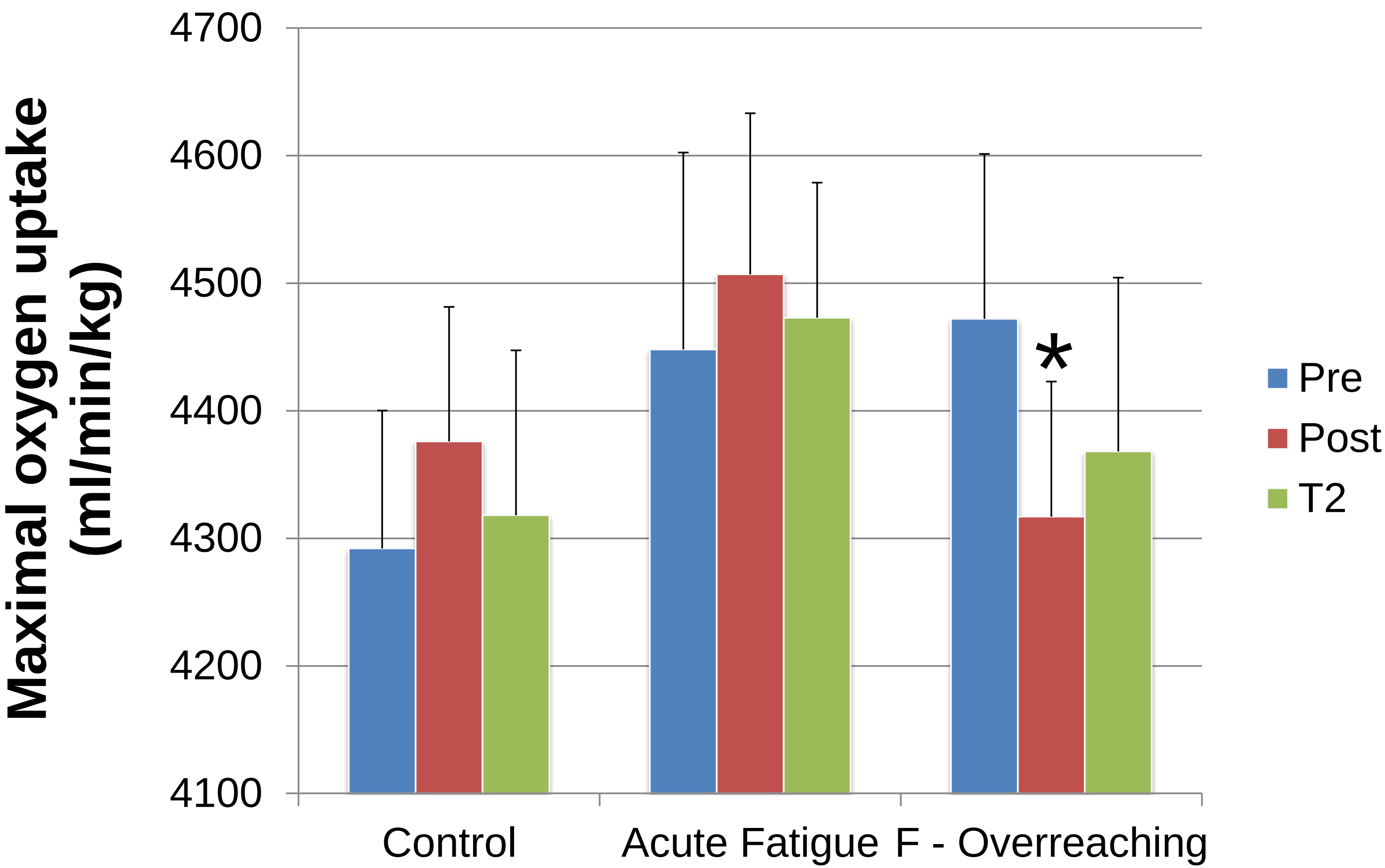
Cardiac output

Arterial blood pressures

Blood lactate concentration

Plasmatic catecholamines concentration

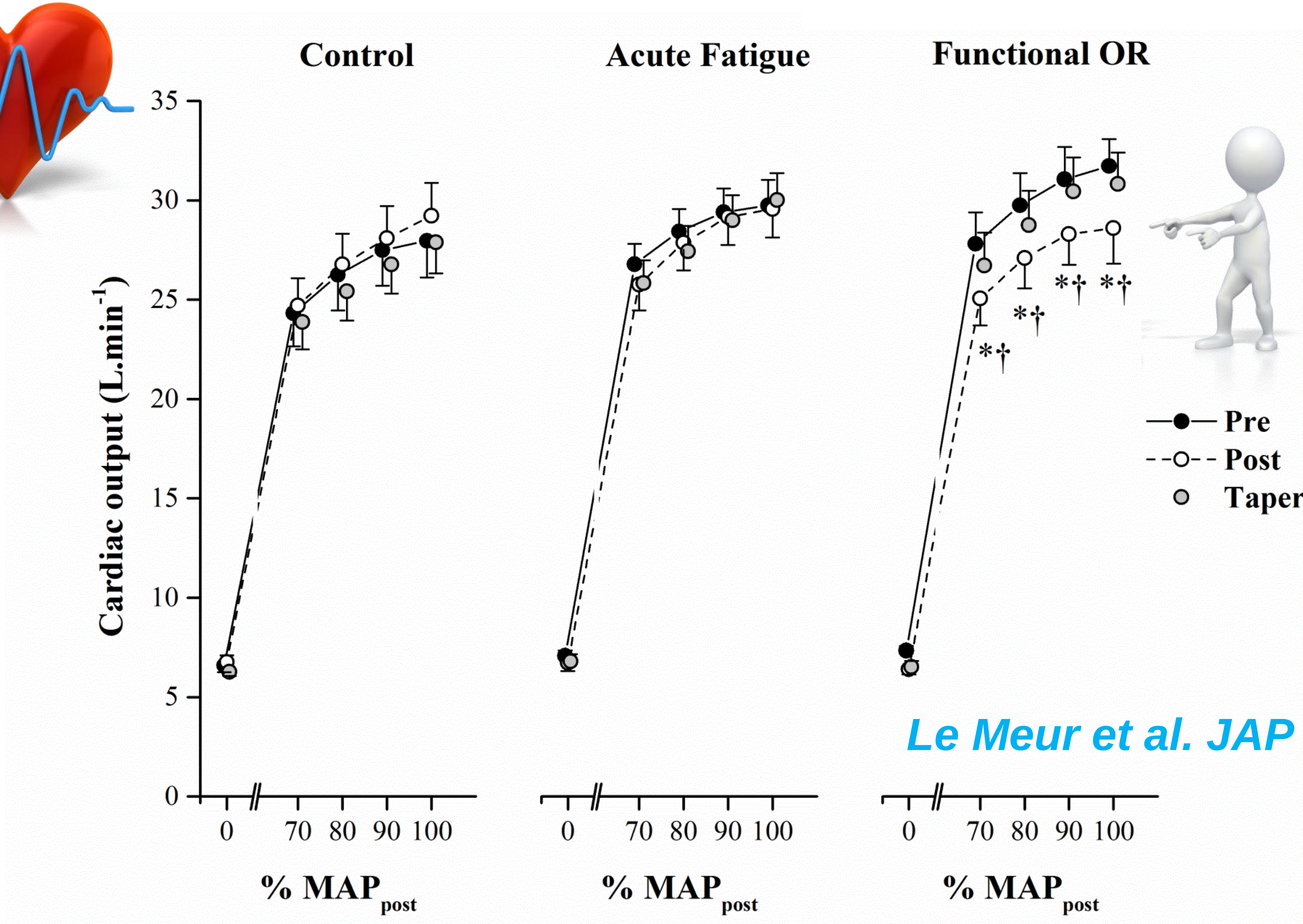
Le Meur et al. JAP 2014



Le Meur et al. JAP 2014

* Different from Pre, $p < 0.05$

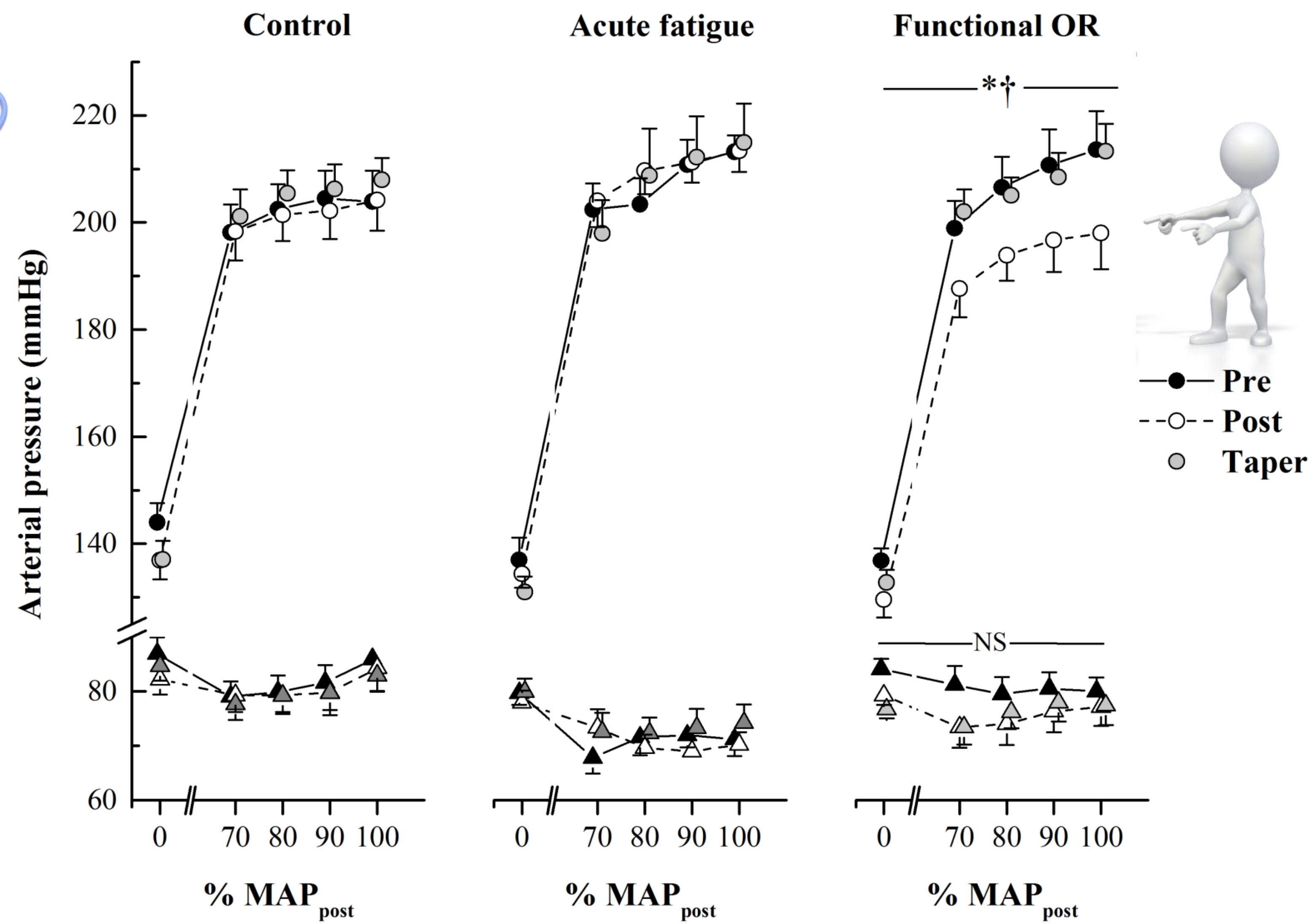
An altered cardiac response



Le Meur et al. JAP 2014

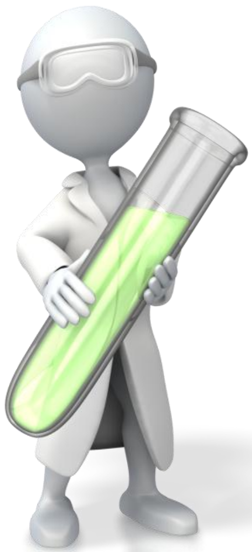
Different from Pre, $p < 0.05$; † Different from Post, $p < 0.05$

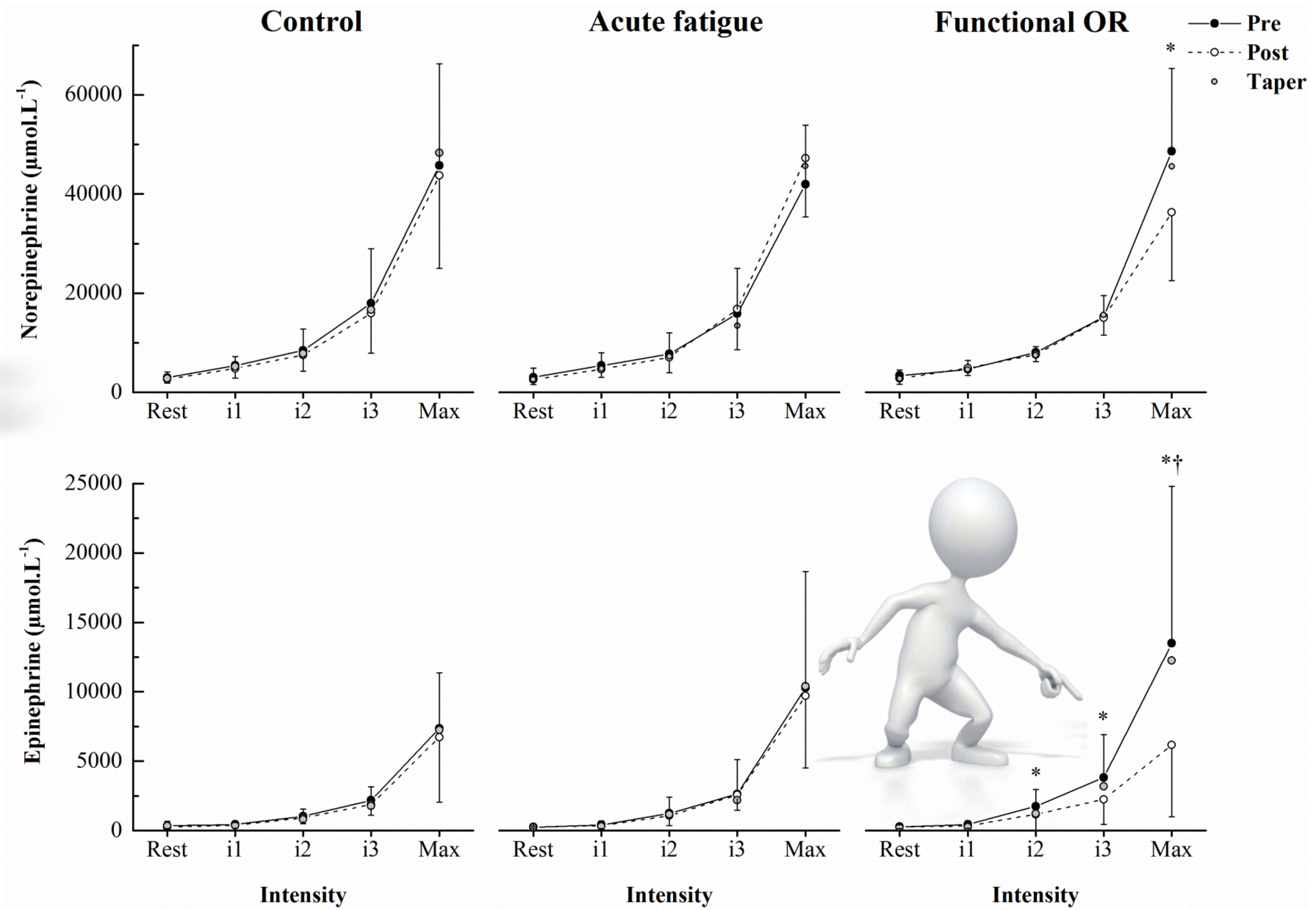
An altered cardiac response



Different from Pre, $p < 0.05$; † Different from Post, $p < 0.05$

Catecholamines response



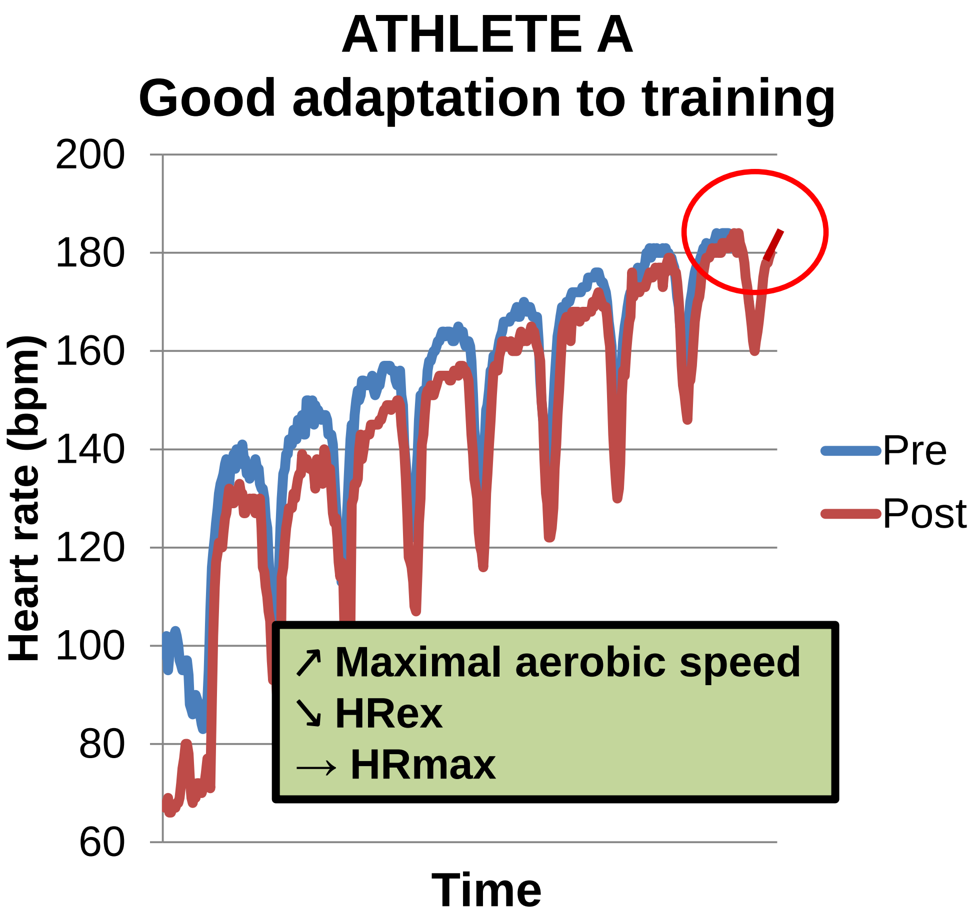


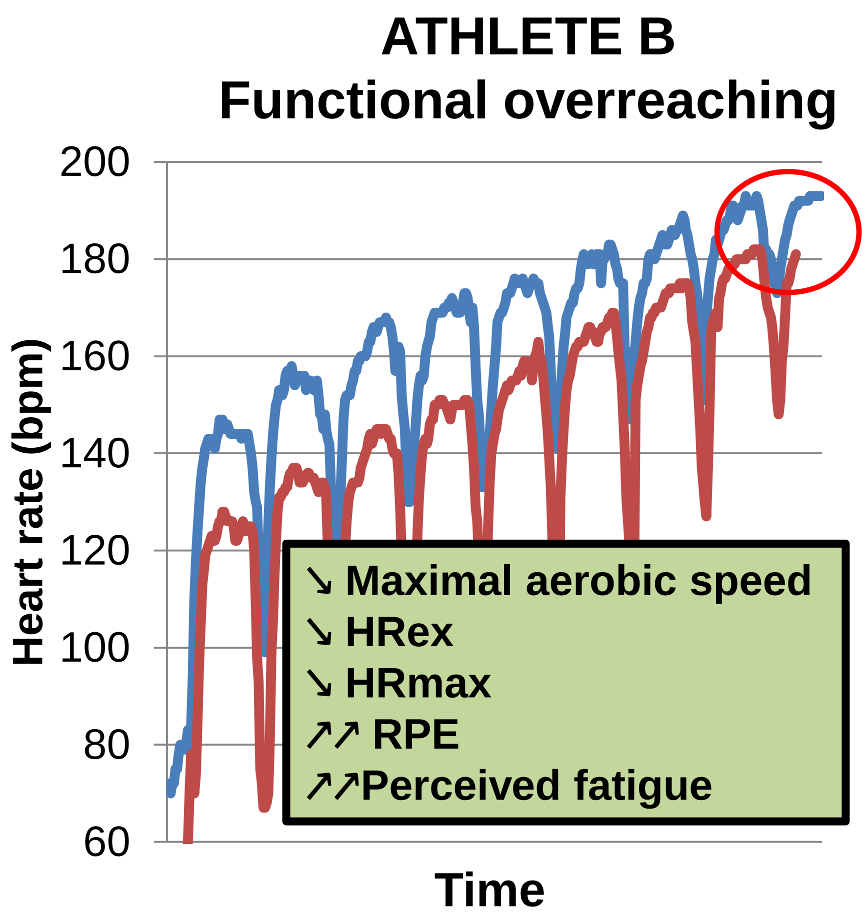
Le Meur et al. JAP 2014

Different from Pre, $p < 0.05$

† Different from Post, $p < 0.05$

- ►Illustration with 2 athletes
- ►Same endurance-oriented overload period (+40% of habitual training load)
- ►Maximal incremental running test (+1km/h each 3 min, r = 1min)



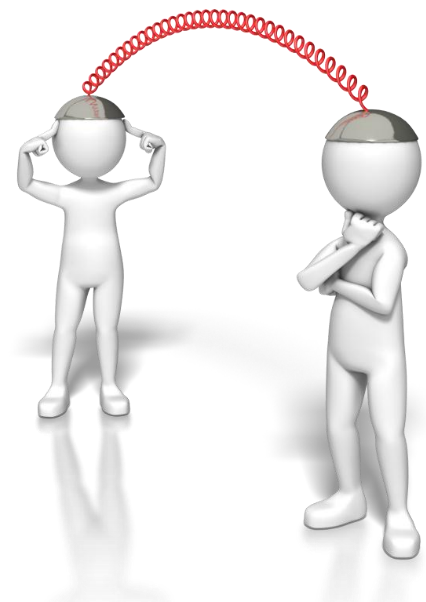


Conclusion

MONITOR PERFORMANCE
& QUANTIFY TRAINING LOAD

+

DEMONSTRATE EMPATHY
& ACCEPT TO REGULATE



DO IT SIMPLY… BUT DO IT WELL!

Resting HR and exercise HR are sensitive to changes in the training status. There likely the most usefull monitoring tools but they should always be interpretated **with other psychometric and performance markers to correctly interpret the data**

Parameters	Usefullness	Good response to training	Overreaching (intensified training)
Resting HR	++	↘	↘
Resting HRV	Difficult to implement with a squad		
HRex	++	↘	↘
HRR	(+)	↗	↗
HRmax	++	=	↘
RPE	+++	↘	↗
Perceived fatigue	+++	normal	High to very high
Performance	+++	↗	↘

HR monitoring

Parameters	Usefullness	Good response to training	Overreaching (intensified training)
Resting HR	++	↘	↘ Uusitalo et al. 1998 Hedelin 2000 Le Meur 2013 & 14
HRex	++	↘	↘ Lehmann 1991 Hedelin 2000 Bosquet 2001 Coutts 2007 Dupuy 2012 Le Meur 2013 & 14
HRR	(+)	↗	↗ Dupuy 2012 Thompson 2015 Under review

Conclusion

This study showed that greater gains in performance and VO_{2max} occur when the habitual training load increases before the taper… but <u>not if there is functional overreaching</u>

But always keep in mind that…

OBSERVATIONS

1. Individual athletes will respond differently, to one another, to identical training sessions
2. Identical sessions performed by an individual will always elicit a unique training response, for that athlete, depending on transient functional states of component subsystems
3. Group-based patterns and observations may be highly misleading when generalized to individuals
4. It is highly improbable that there are “best” patterns, time frames, or progression and/or loading schemes validly applicable across training contexts

But always keep in mind that…

Such reasoning suggests a shift from the historical ideal of preordained "best" training structures toward a philosophy characterized by an adaptive readiness to respond to emerging "information"

PRACTICAL IMPLICATIONS

1. Deviation from the preplanned path is desirable, should be actively sought, and the training management system designed to facilitate, rather than suppress, consistent modulation.
2. A crucial component of effective training processes is the systematic capture and review of pertinent data that are then employed to drive future direction.

By John Kiely, International Journal of Sport Physiology and Performance, 2012