

HIGH-INTENSITY TRAINING



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WHAT MAKES A
CHAMPION?

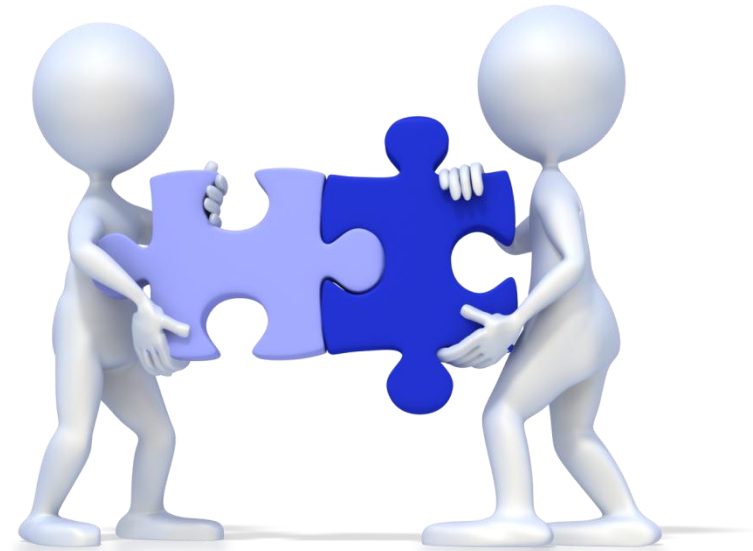




*No Pain,
No Gain*



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



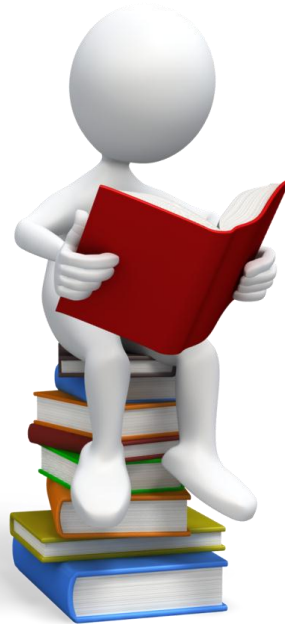
HIT involves repeated short-to-long bouts of rather high-intensity exercise interspersed with recovery periods



1920's - Paavo NURMI

14 minutes 36 seconds (5000m)

Short interval training at an intensity superior to a specific velocity such as $6 \times 400\text{m}$ 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



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 ending

- 1 Improved endurance performance**
- 2 Improved repeated-sprint performance**
- 3 Increased tolerance to overload periods**



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

2 How to program HIT sessions ?



3 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



1 Long intervals
(≥ 45 s)

2 Short intervals
(< 45s)

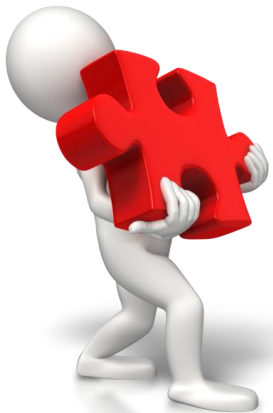
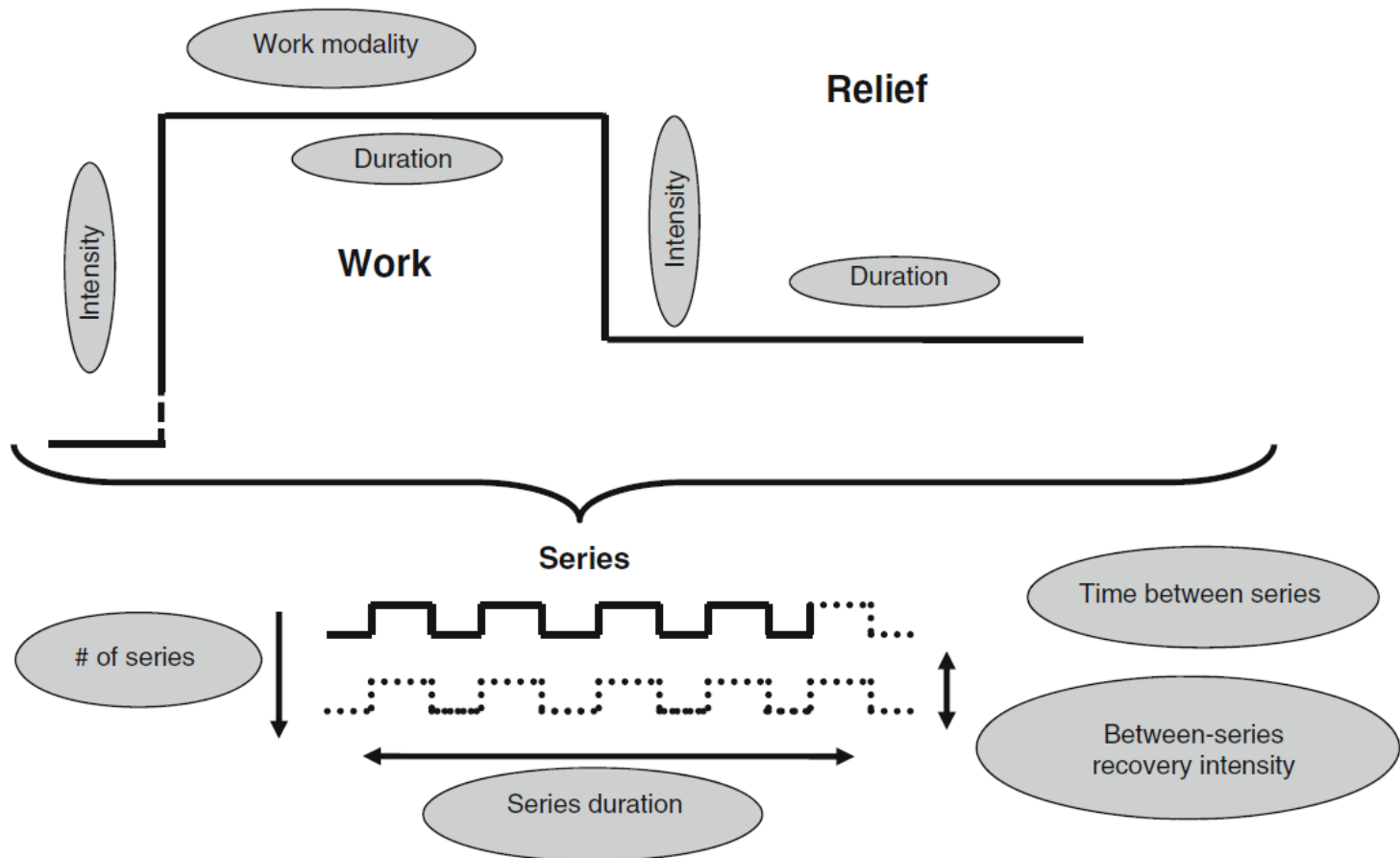


3 Repeated-sprint training
 ≤ 10 s, all-out sprints, interspersed with recovery periods

4 Sprint interval training
20–30 s all-out sprints, interspersed with recovery periods

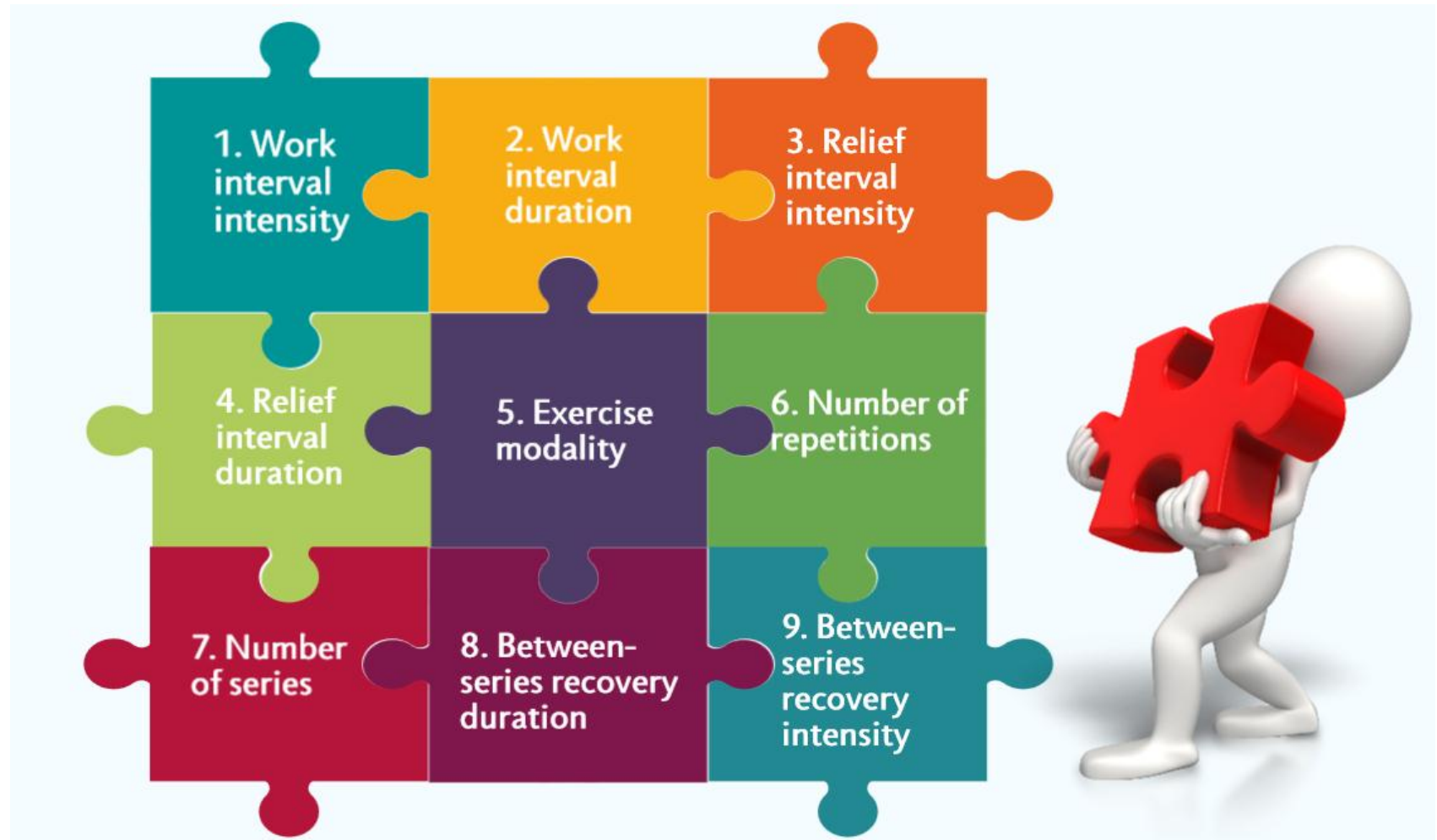
The pieces of the puzzle

5x (3min [90% vVO₂max], r = 90s [0%])



The pieces of the puzzle

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



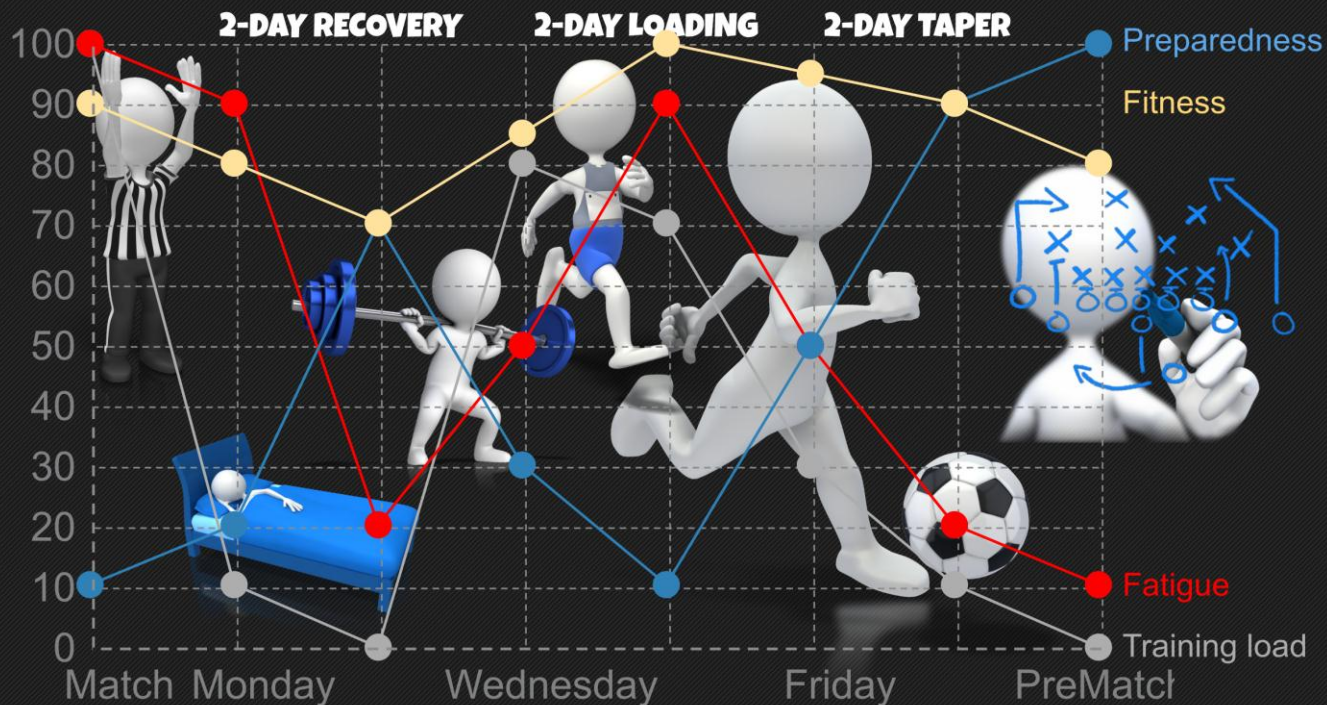
« The ability of the coach to understand the isolated acute responses to various HIT formats may assist with selection of the most appropriate HIT session to apply, at the right place and time»

Buchheit & Laursen, 2013



Training periodization & Fatigue management in Football

Designed by
@YLM Sport Science



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

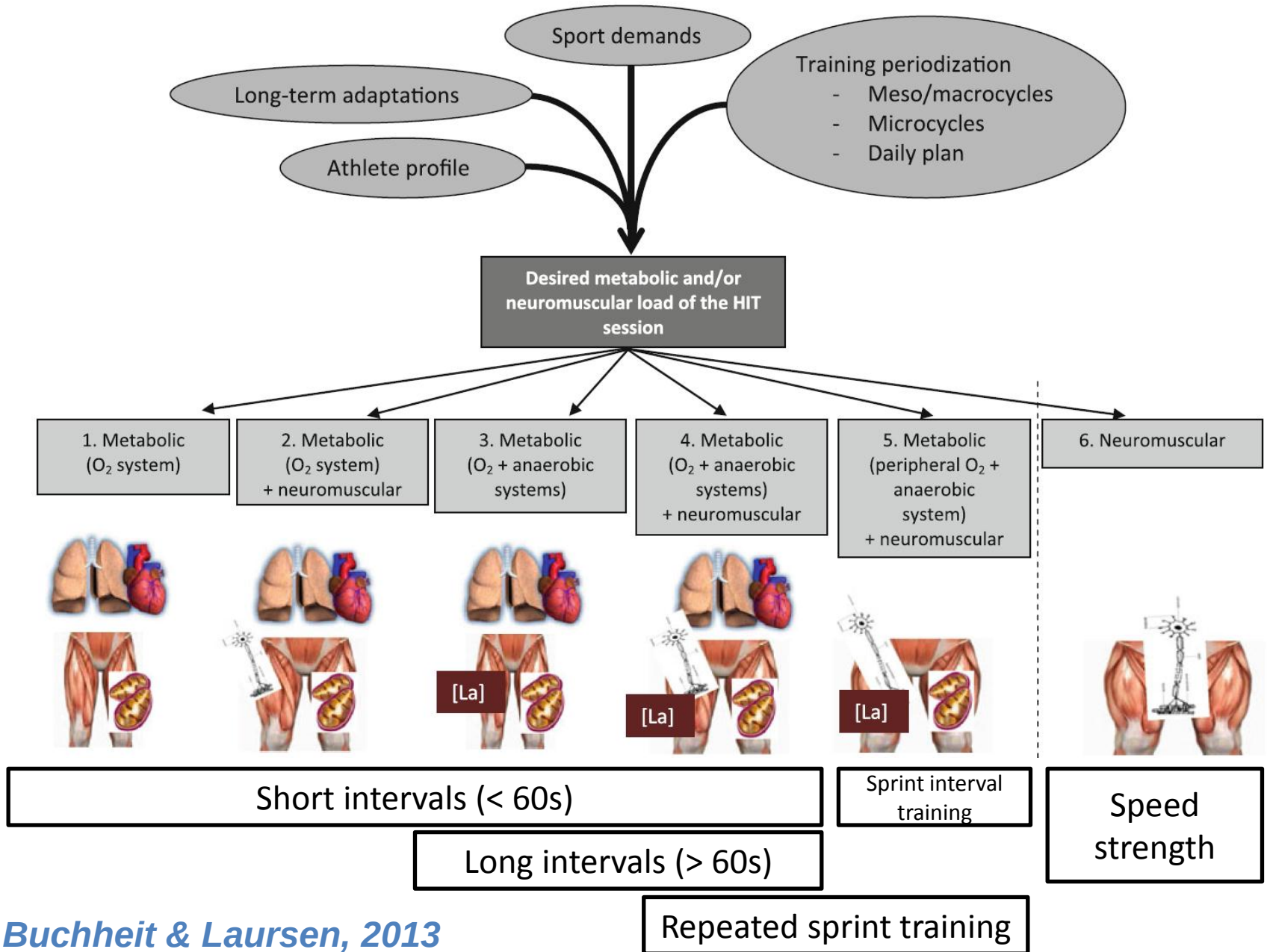


Neuromuscular load & Musculoskeletal strain

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



1 Long intervals
($\geq 45s$)

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

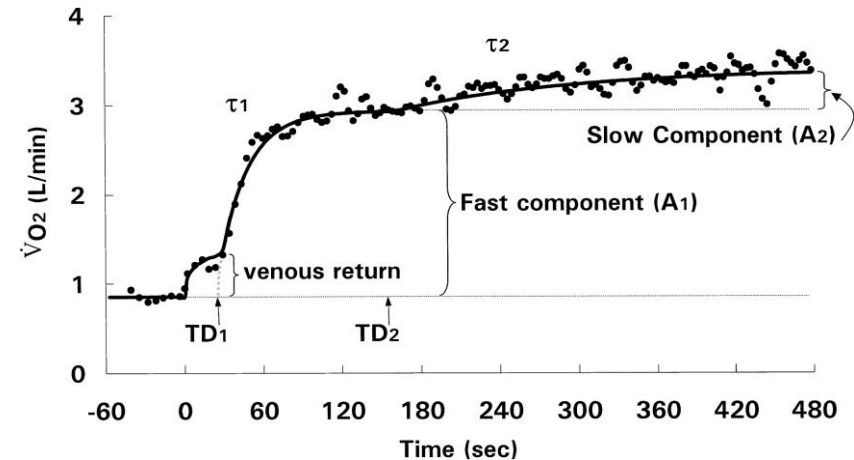


**How to maximize the
time spent at or near
 VO_{2max} during HIT
sessions ?**

Exercise intensity & interval duration

1 Exercise Intensity

Work intensities of $\geq 90\%$ $\dot{V}O_{2\max}$ are recommended for maximizing $TV\dot{O}_{2\max}$ during long intervals



2 Interval duration

Option 1

Time needed to reach $\dot{V}O_{2\max}$
+ 1 or 2 min



Option 2

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

3 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 $\text{VO}_{2\text{max}}$ 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



4 Volume of HIT

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

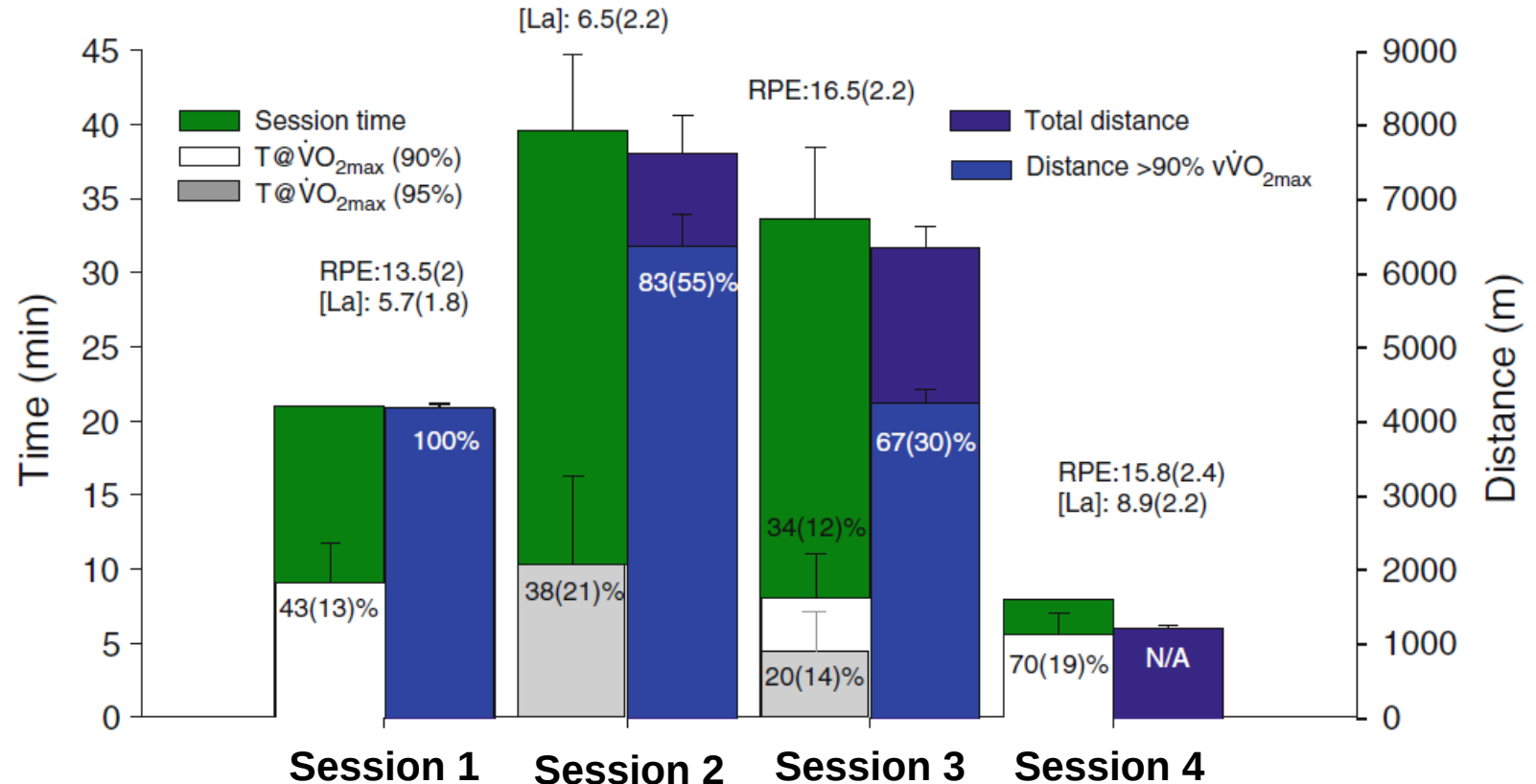
- 6x 2min
- 5x 3min
- 4x 4min
- 6x 4min
- 4x 6min
- 5x 6min

**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% VO₂max**



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]

5 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
($\geq 45s$)

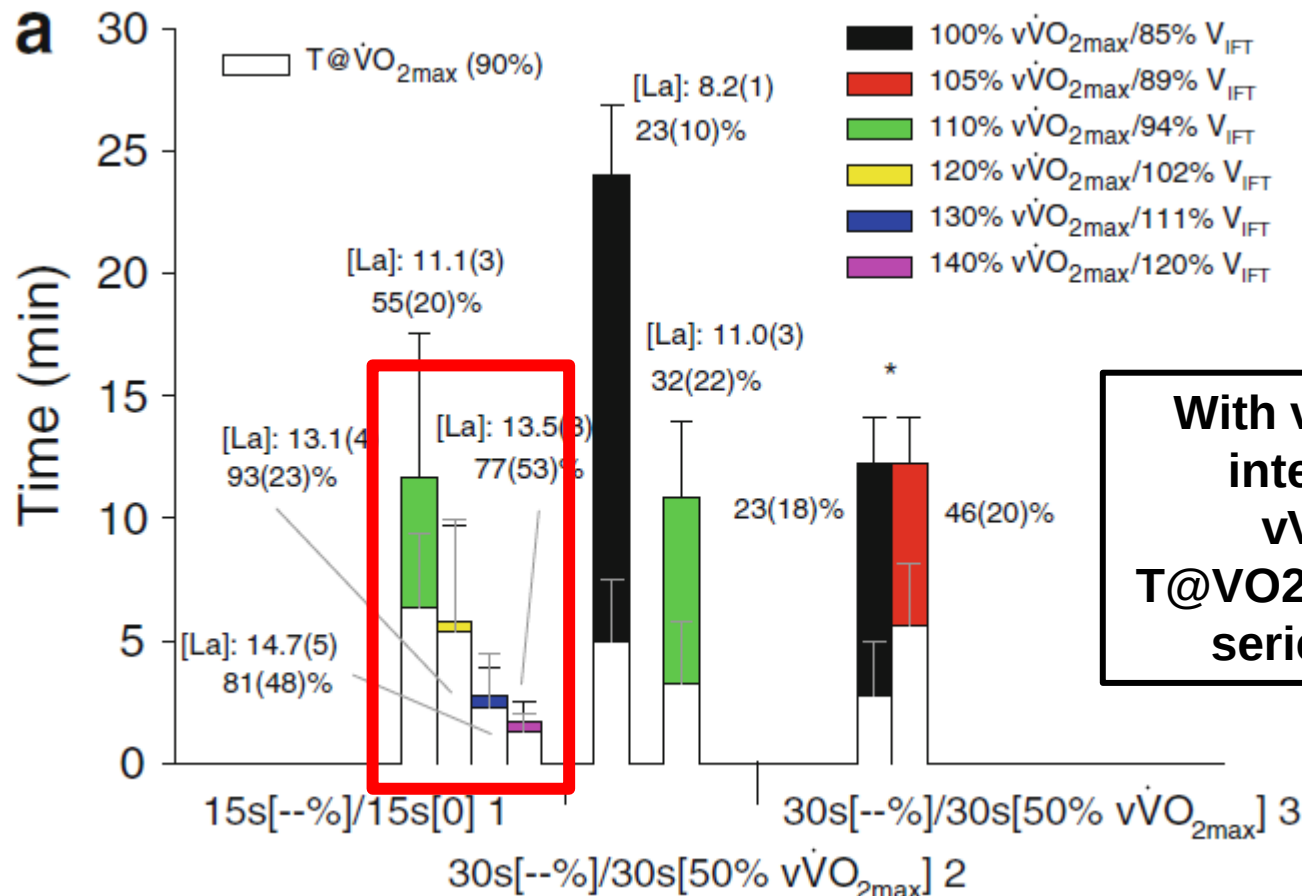
2 Short intervals
($< 45s$)



3 Repeated-sprint training
 ≤ 10 s, all-out sprints, interspersed with recovery periods

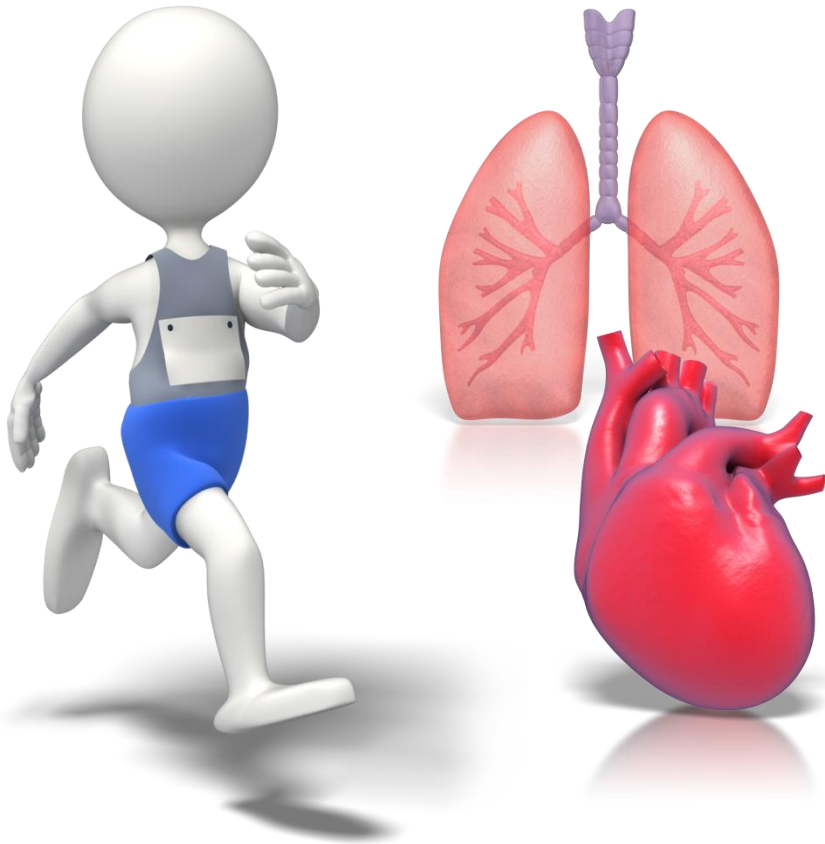
4 Sprint interval training
20–30 s all-out sprints, interspersed with recovery periods

1 Exercise Intensity



Selection of a work bout intensity that ranges between 100 % and 120 % of $\dot{V}O_{2max}$ may be optimal to elicit high $\dot{V}O_2$ responses

2 Interval duration

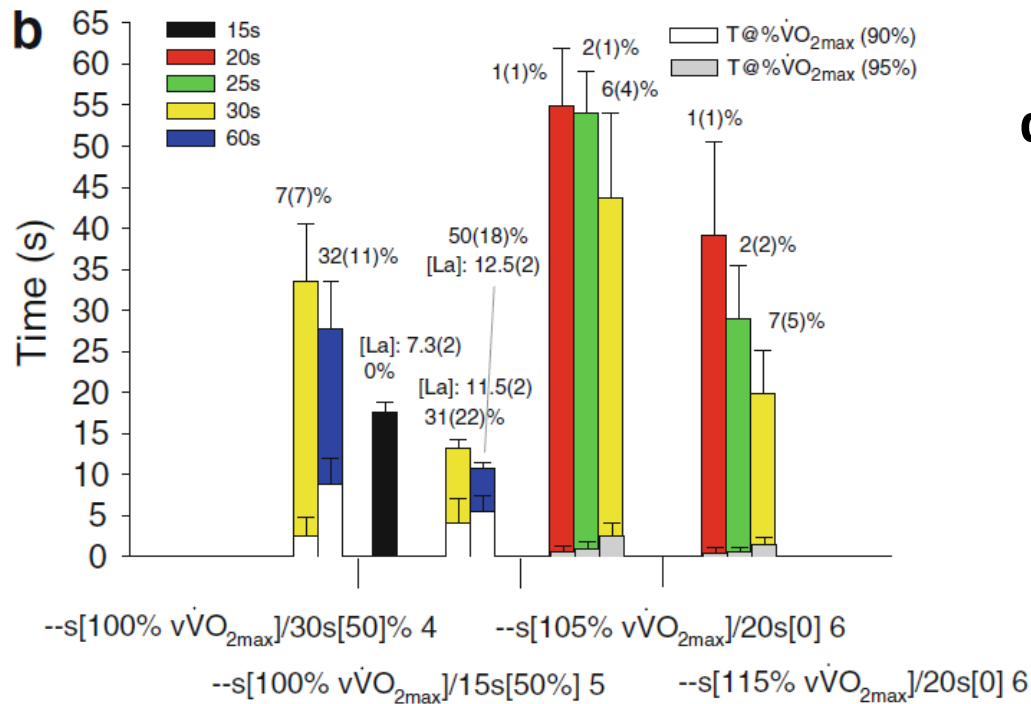


During very short runs (<10 s)

- 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 % $v\text{VO}_{2\text{max}}$)

Work interval duration

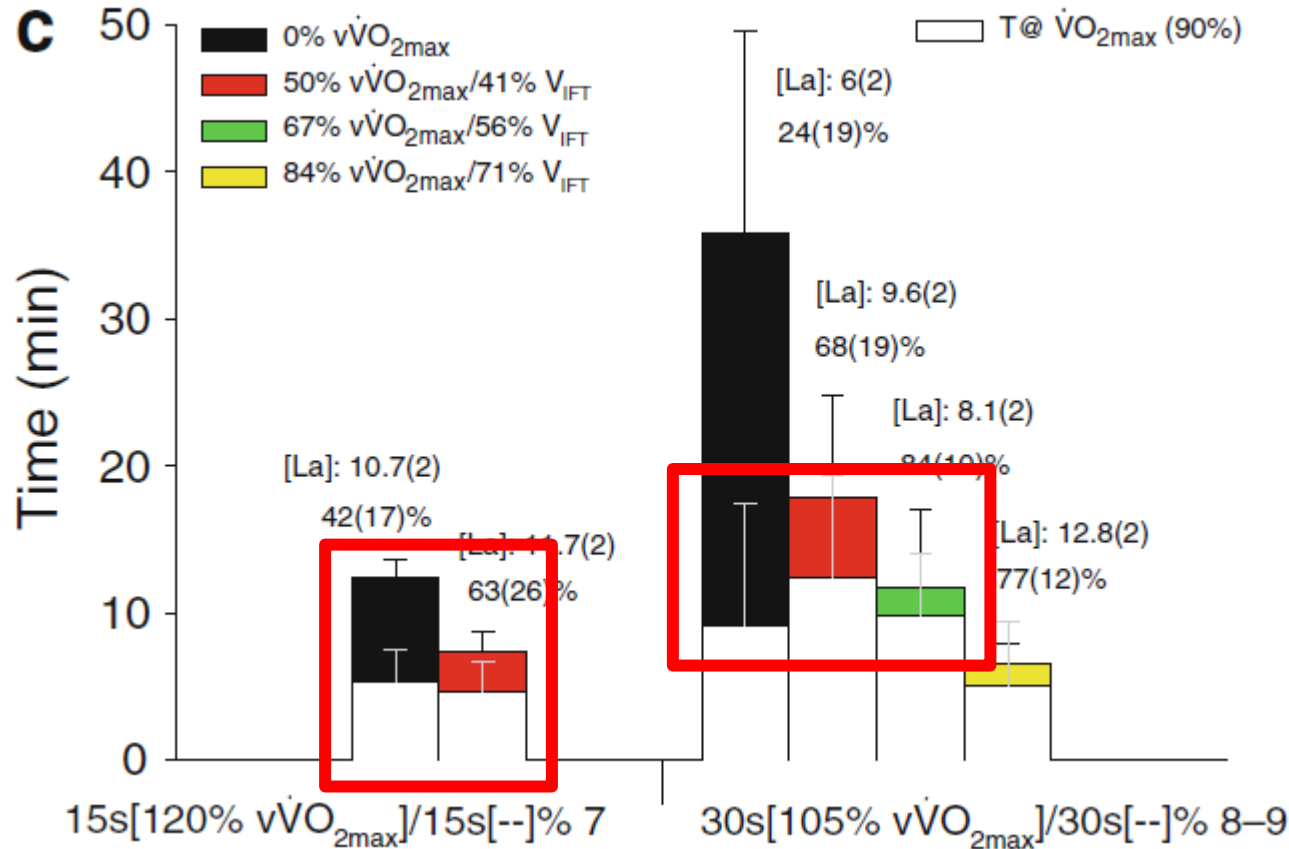


Increasing the work interval duration, while keeping work relief intervals constant increases $T@VO_{2max}$

Longer work intervals (e.g. 30 s/30 s vs. 15 s/15 s) are preferred for individuals with slow VO_2 kinetics (i.e. older/less trained), or for exercising on a bike



3 Relief duration & intensity



15s / 15s: absolute $T@VO_{2max}$ might not differ between active and passive recovery conditions

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

4 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}

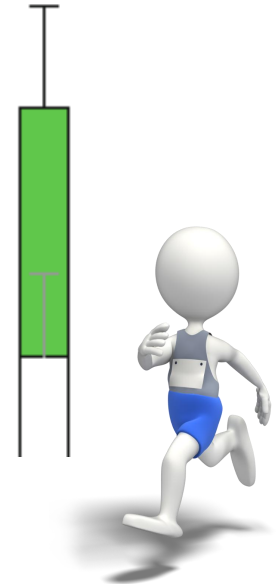
➤ Example for an endurance athlete:

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



T@VO2max/total
exercise time ratio

[La]: 11.0(3)
32(22)%



➤ Example for team sports athletes:

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

5 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)

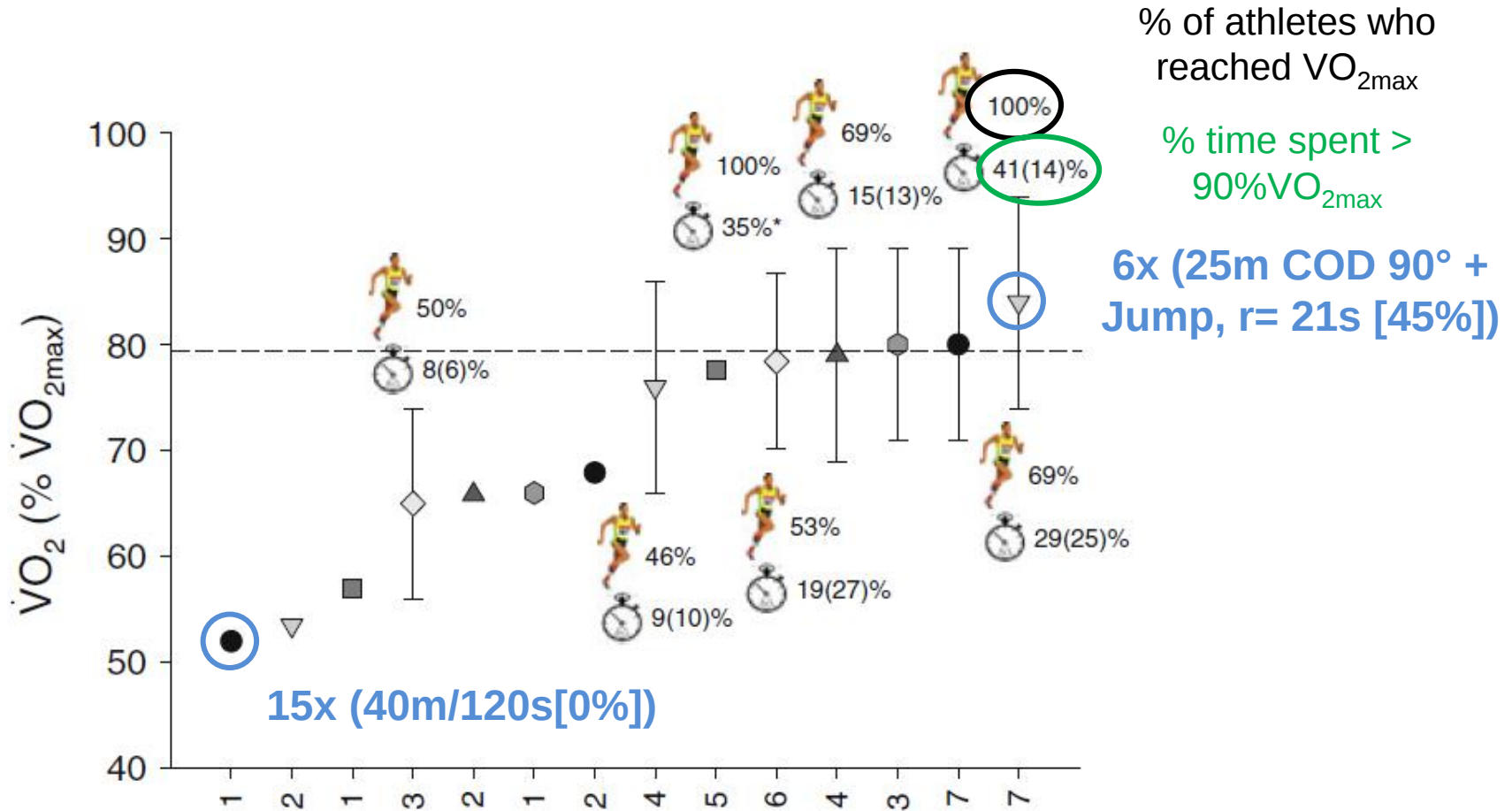
1 Long intervals
($\geq 45\text{s}$)

2 Short intervals
($< 45\text{s}$)



3 Repeated-sprint training
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4 Sprint interval training
20–30 s all-out sprints, interspersed with recovery periods

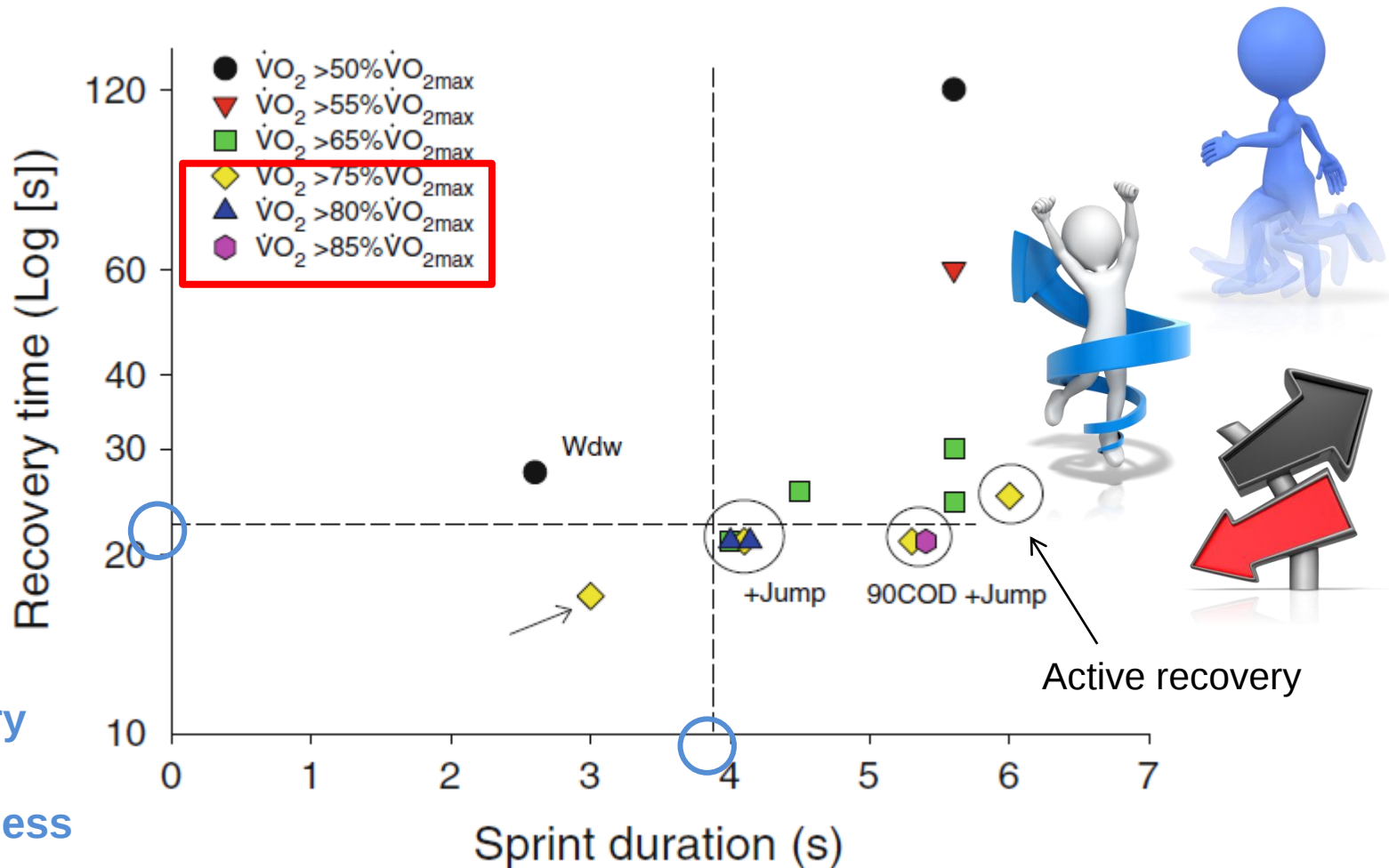


$\dot{V}O_{2max}$ is often reached and sustained for 10–40 % of the entire RSS duration (i.e. ~2-3 min when 3 blocks is programmed)

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



1 Recovery should be active and less than 20 s



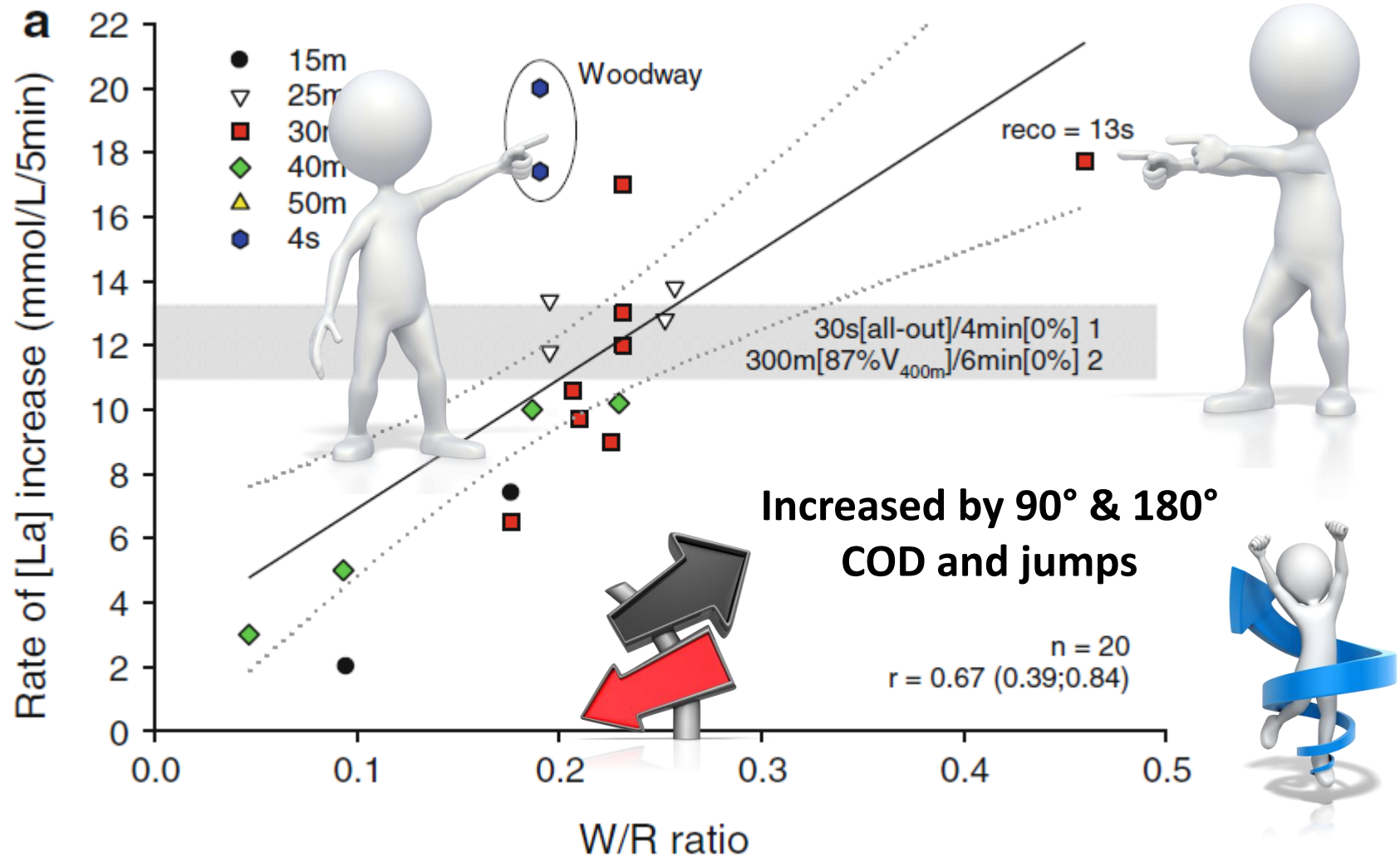
2 Sprints/efforts should last at least 4 s

3 Include change of direction and/or jumps after sprinting



$T@VO_{2max}$ 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

1 Long intervals
($\geq 45\text{s}$)

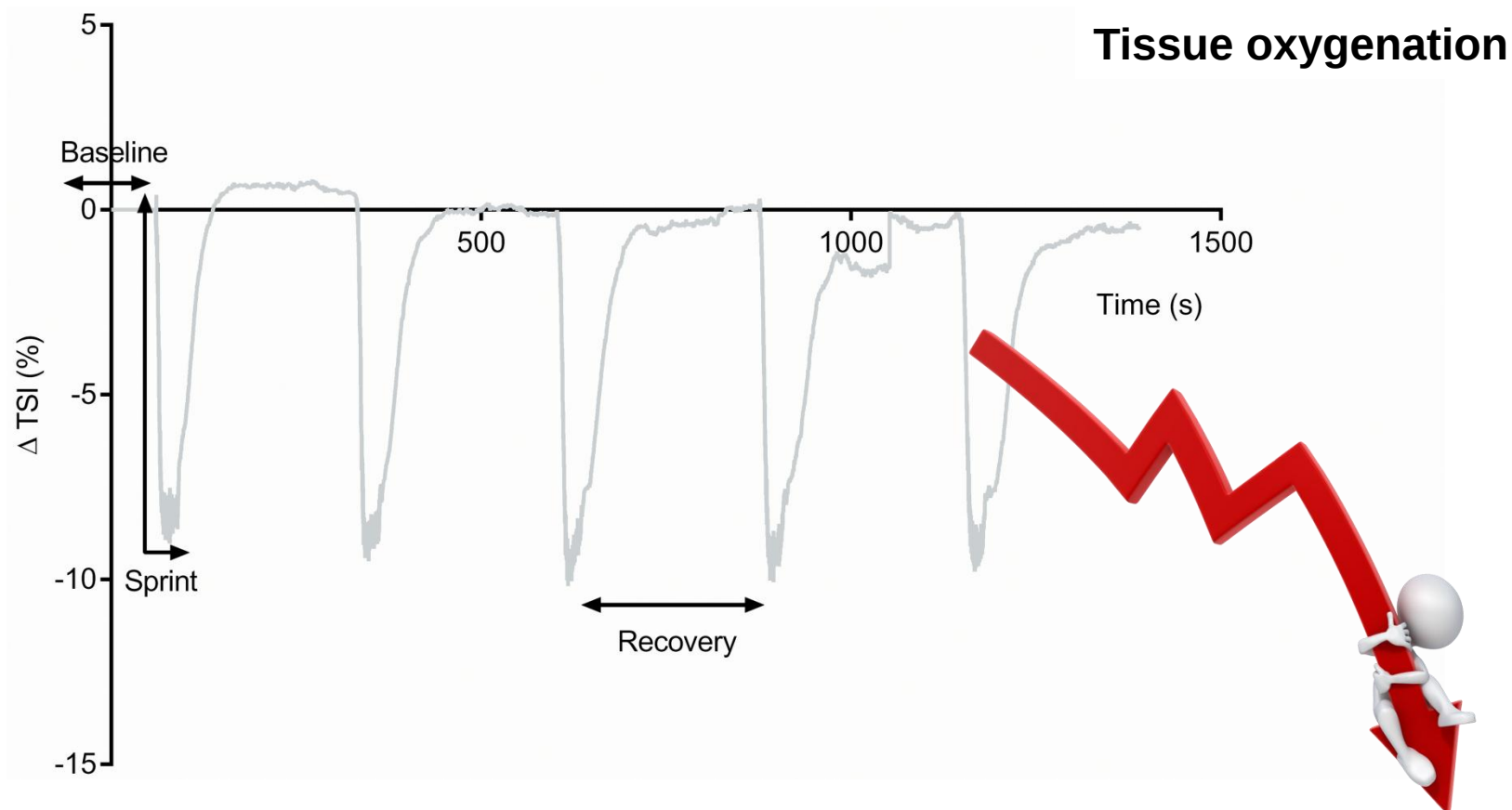
2 Short intervals
($< 45\text{s}$)



3 Repeated-sprint training
 $\leq 10\text{ s}$, all-out sprints, interspersed with recovery periods

4 Sprint interval training
20–30 s all-out sprints, interspersed with long recovery periods

- Very short T@VO₂max (no values > 90% VO₂max in some athletes),
- But very high muscle O₂ 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



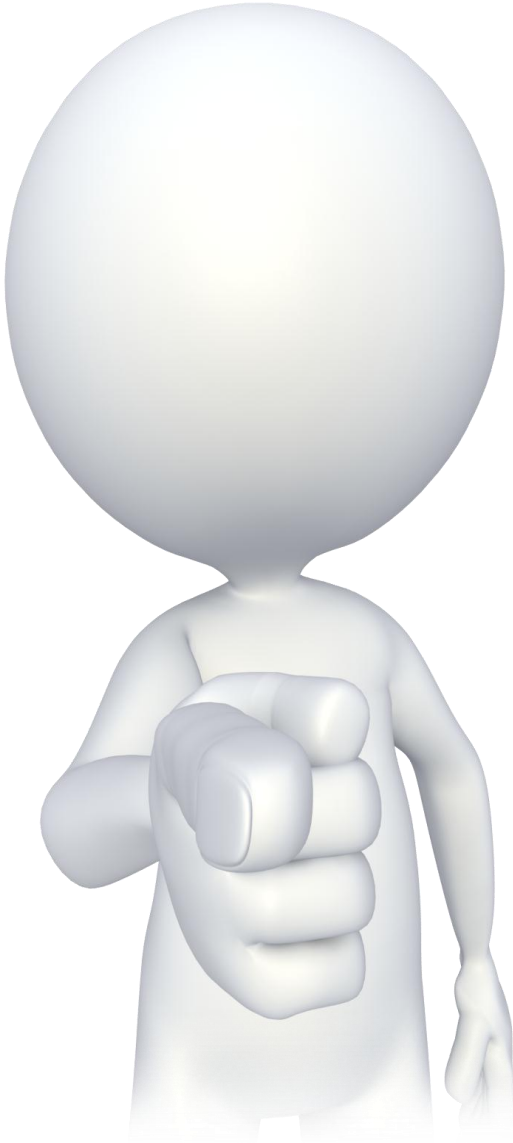


SIT sequences are associated with high NM demands:

- ↳ 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?**

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

- ➊ Most HIT formats, when properly manipulated, can enable athletes to reach VO_{2max} ,
- ➋ However, important between-athlete and between-HIT format differences exist with respect to $T@VO_{2max}$,
- ➌ RSS and SIT sessions allow for a limited $T@VO_{2max}$ compared with HIT that involve long and short intervals,
- ➍ 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,
- ➎ The methods of maximizing long-term VO_{2max} development and performance adaptations using different forms of HIT sessions is still to be determined



⑥ 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);

⑦ 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



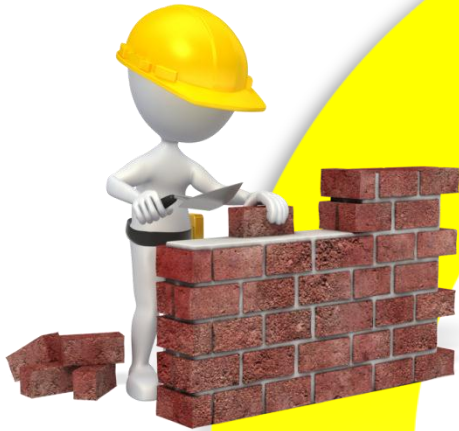
Too much of a good thing?

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



Understanding HIT-induced fatigue

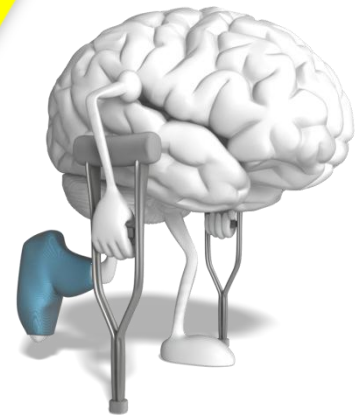
② MUSCLE DAMAGES



③ RESTORE

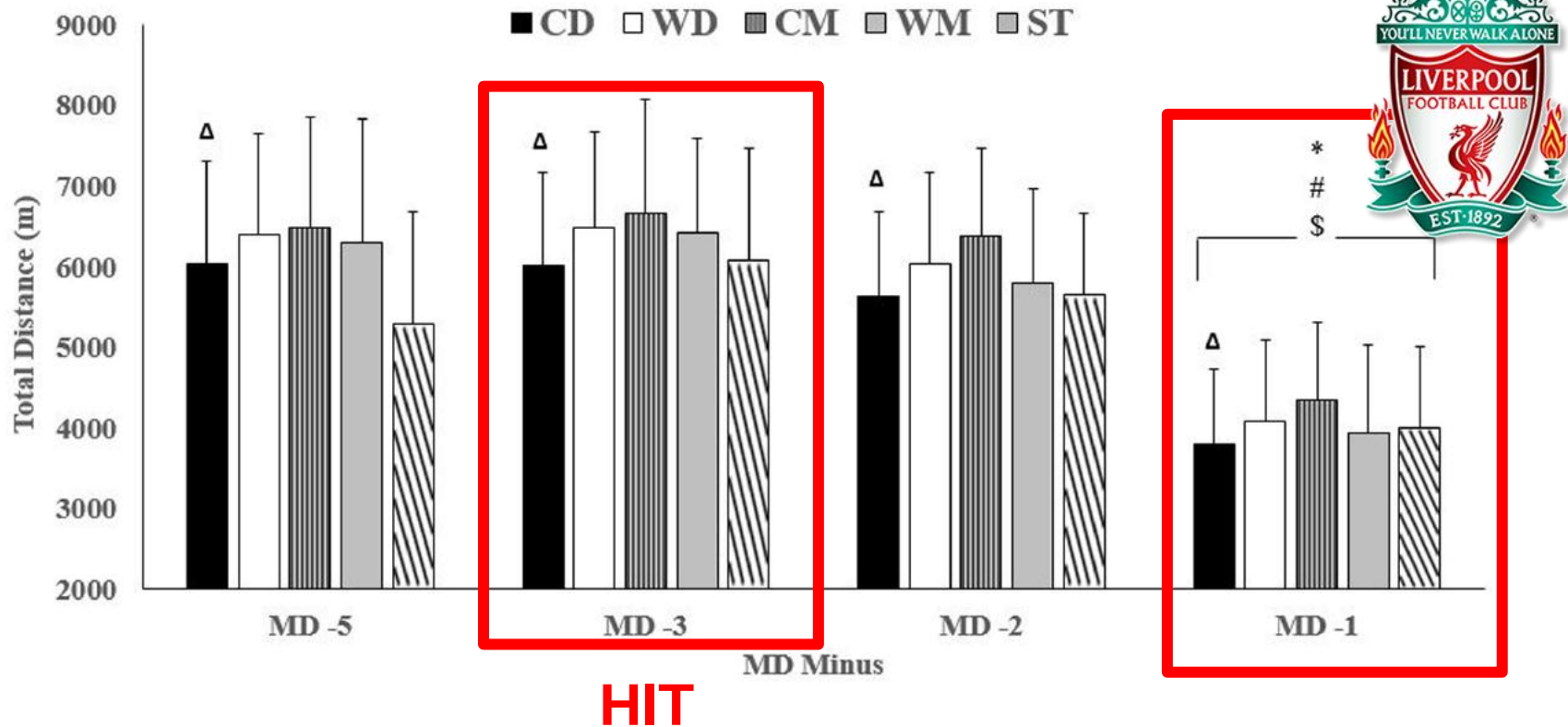


① ANS PERTURBATIONS



Understanding HIT-induced fatigue

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



MON	TUE	WED	THUR	FRI	SAT	SUN
MD-5	O	MD-3	MD-2	MD-1	MD	O

d) In-Season MD Minus Training Comparison

Understanding HIT-induced fatigue

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

Alistair Brownlee

Typical training week Feb 2012

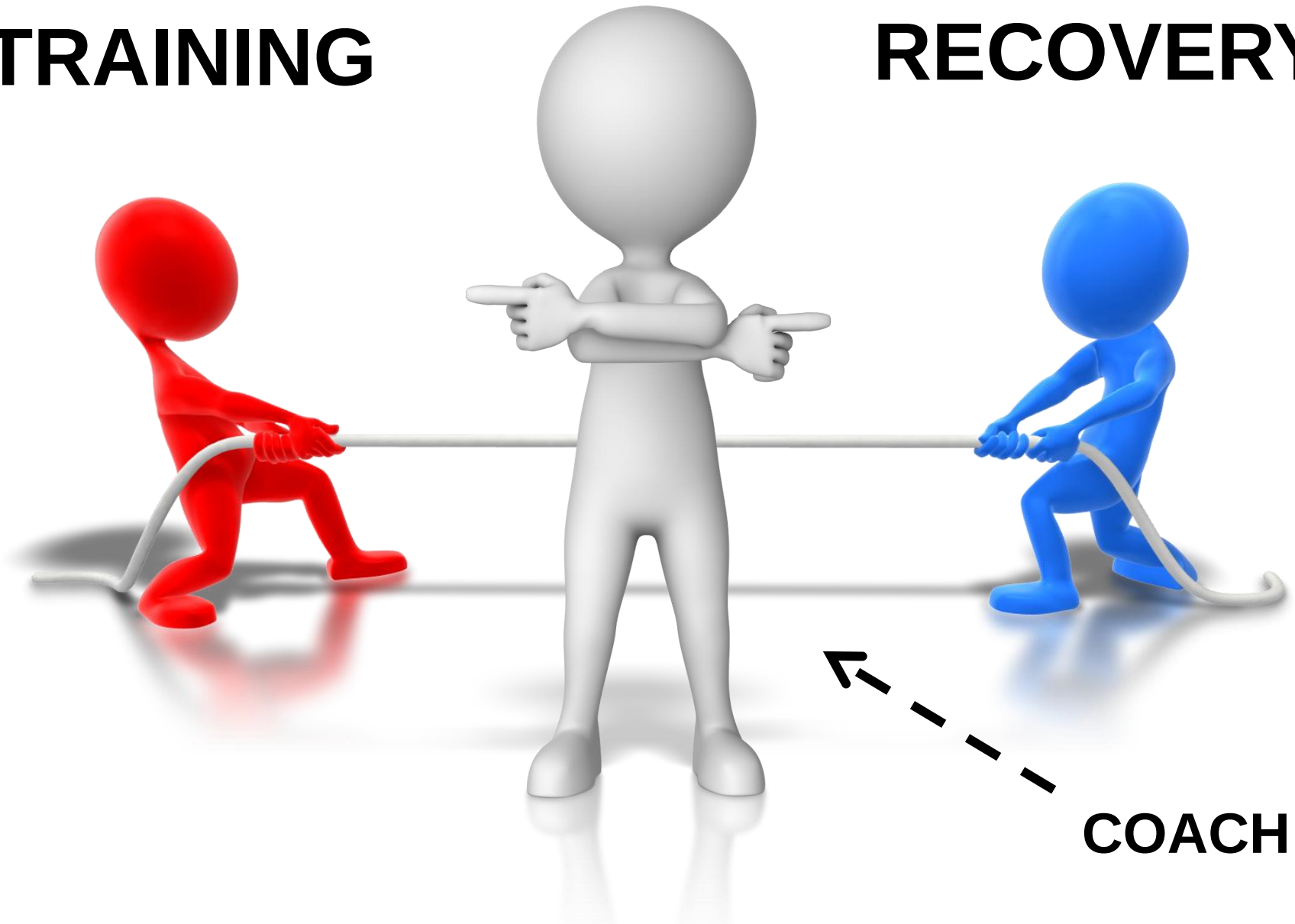


steady/aerobic		tempo/hard/interval			S&C/physio	
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
80 min steady run 120bpm	Easy Swim	Easy swim	Fast swim	Easy swim	Run session 30 mins hard 160bpm	4 hrs easy bike
Drills S&C	40 min easy run	75 min easy run	60 min easy run	S&C	3.5 hrs easy bike	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

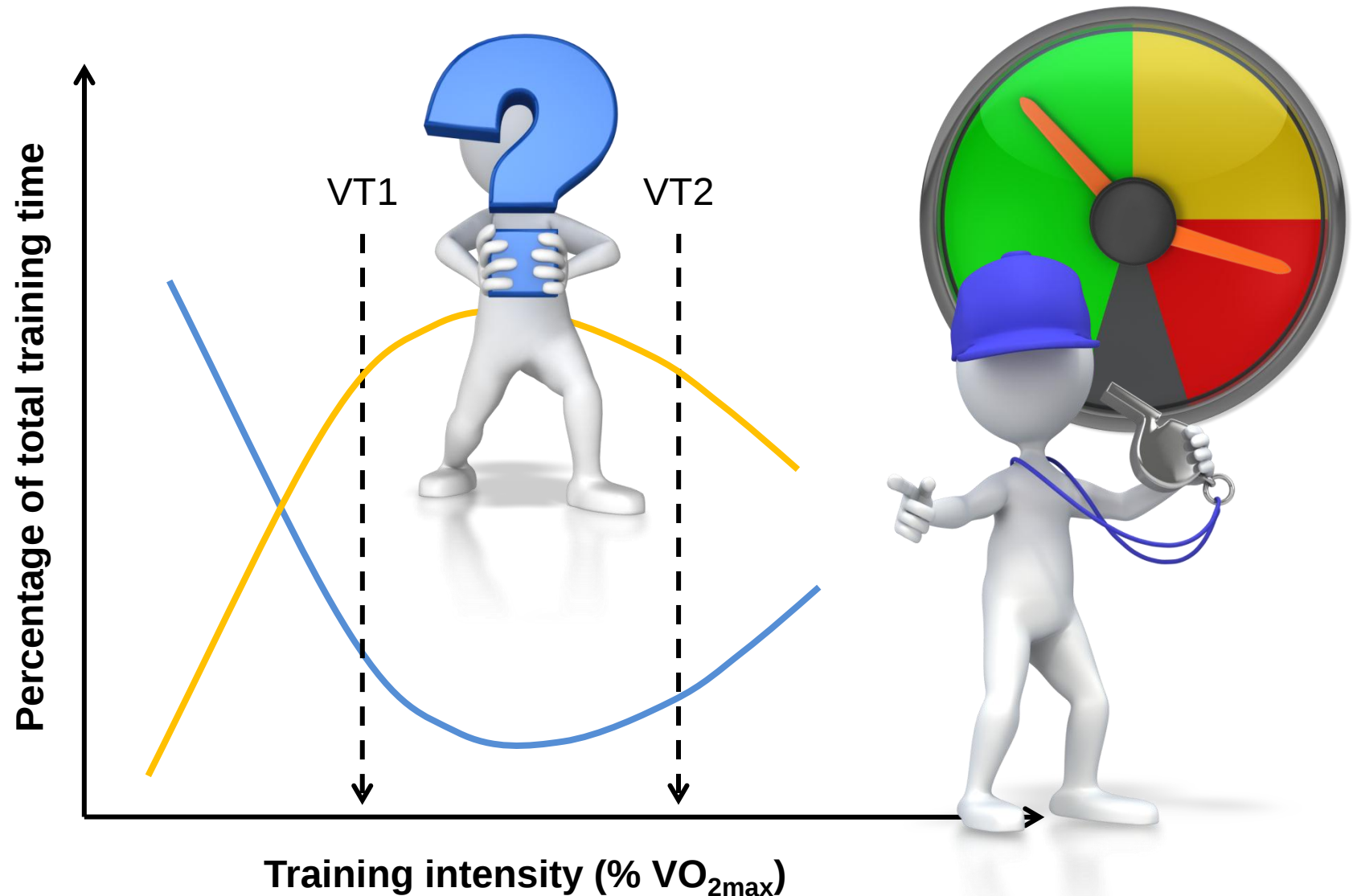
TRAINING

RECOVERY



COACH

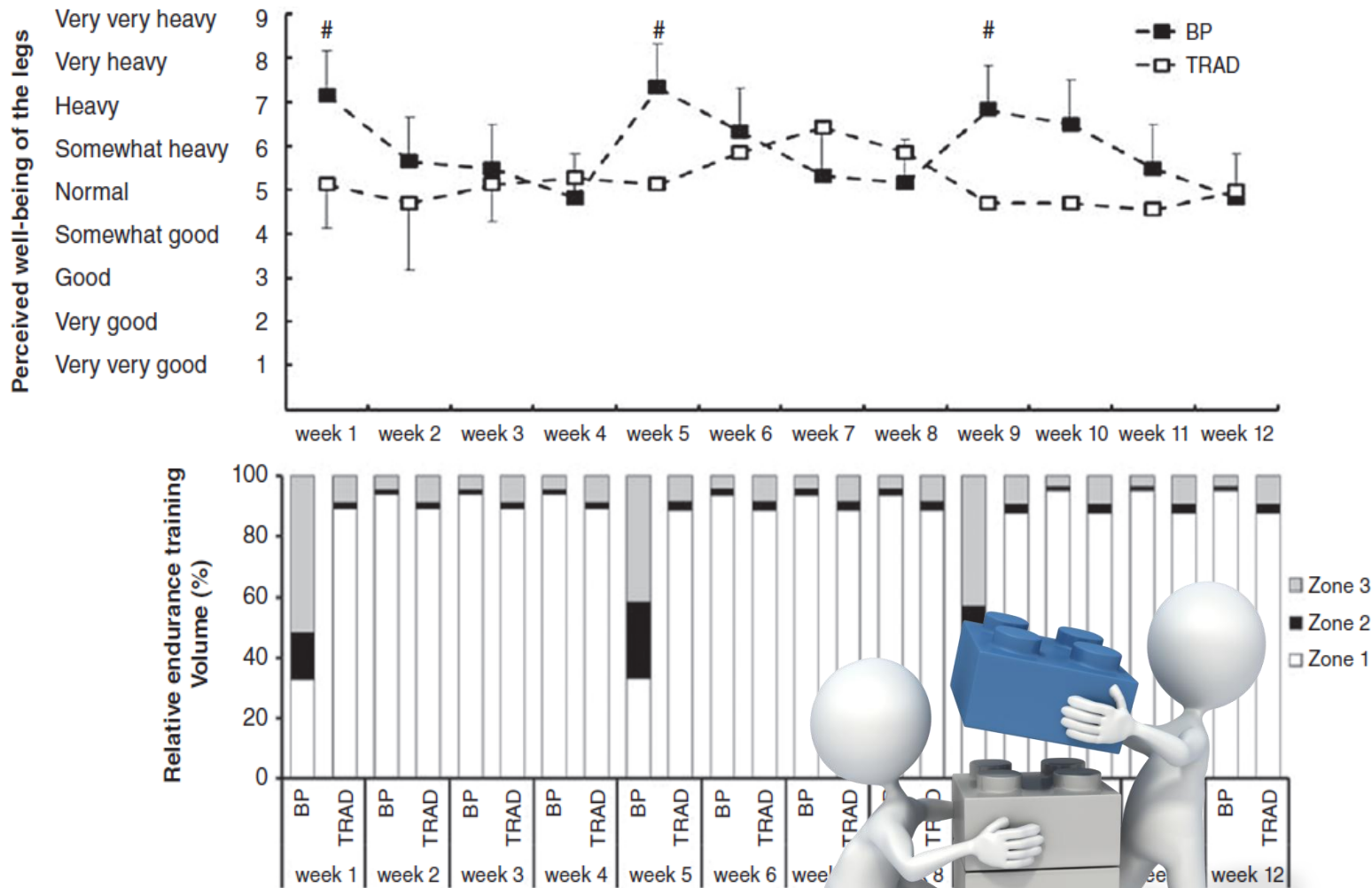
Training intensity distribution: getting the balance right!



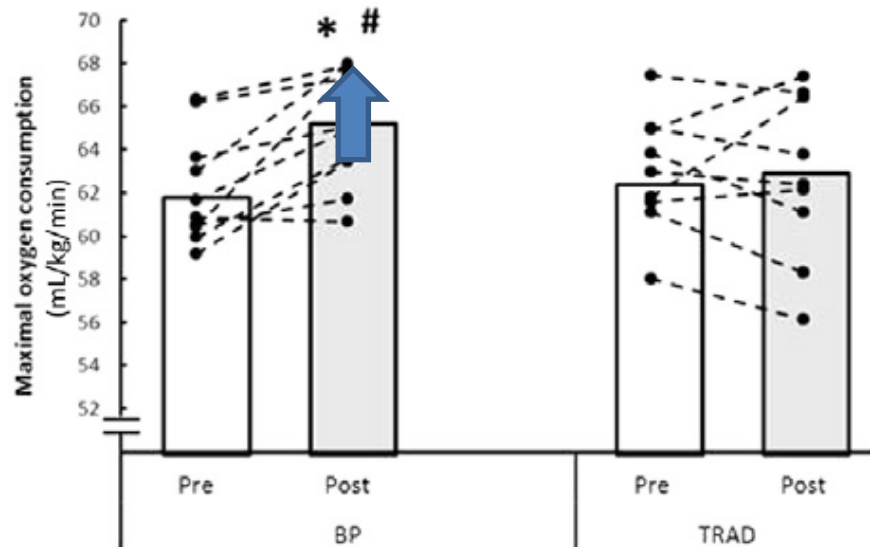
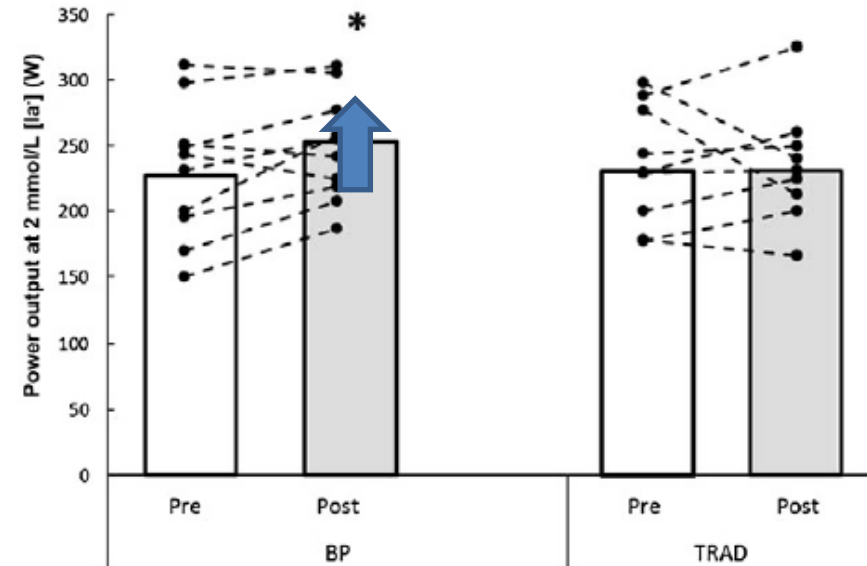
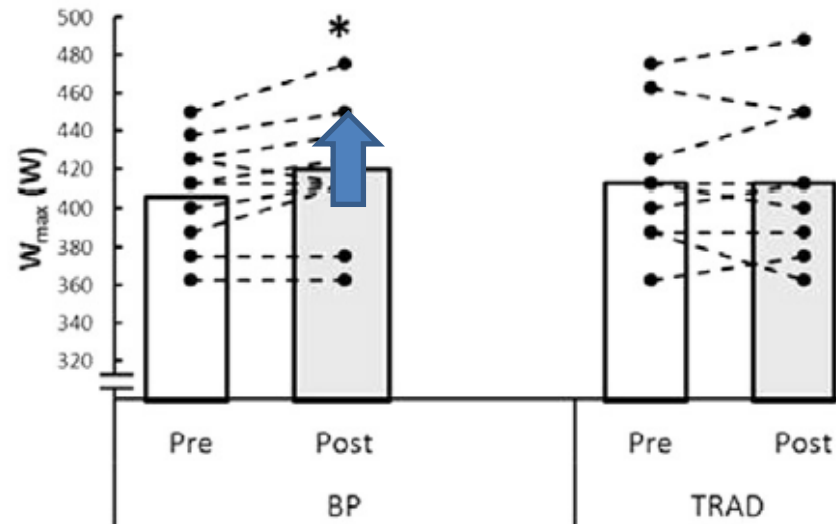
Seiler, 2010

Block periodization: Study #1

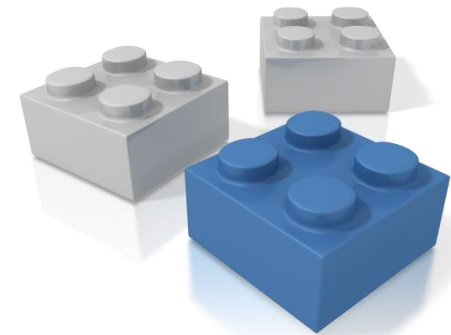
2 + 2 + 2 + 2 HIT per week versus 3 + 1 + 1 + 1 per week



Study #1

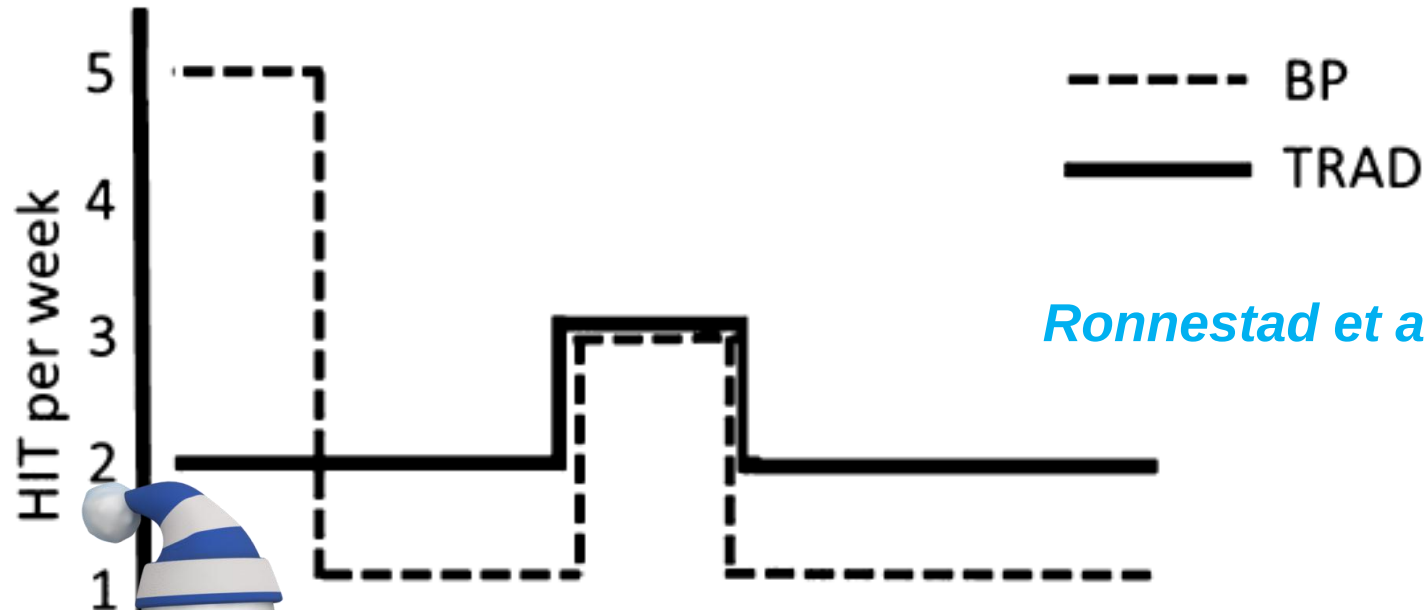


Higher improvement associated with block periodization

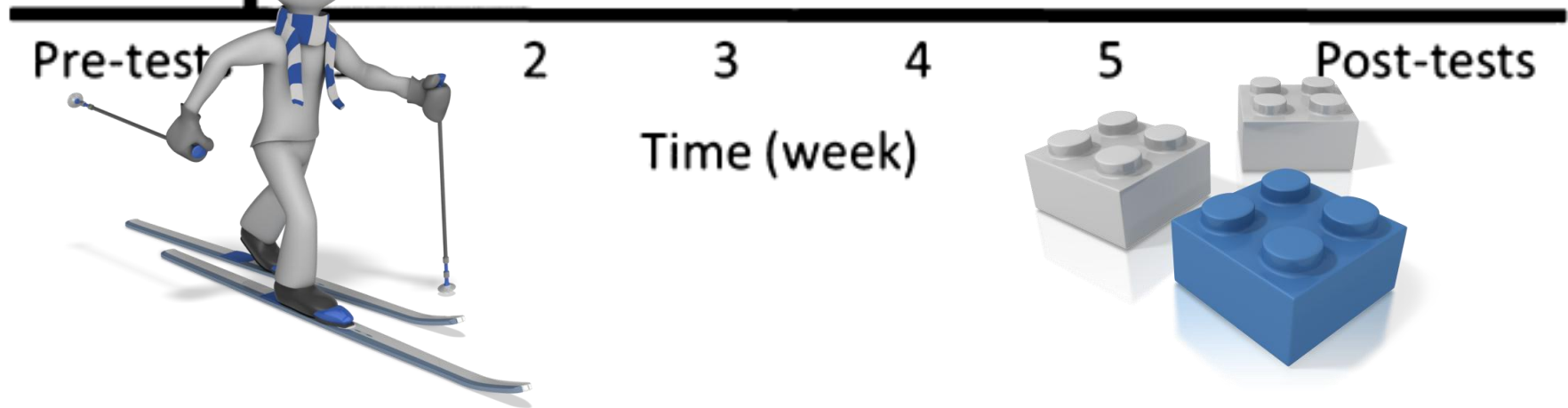


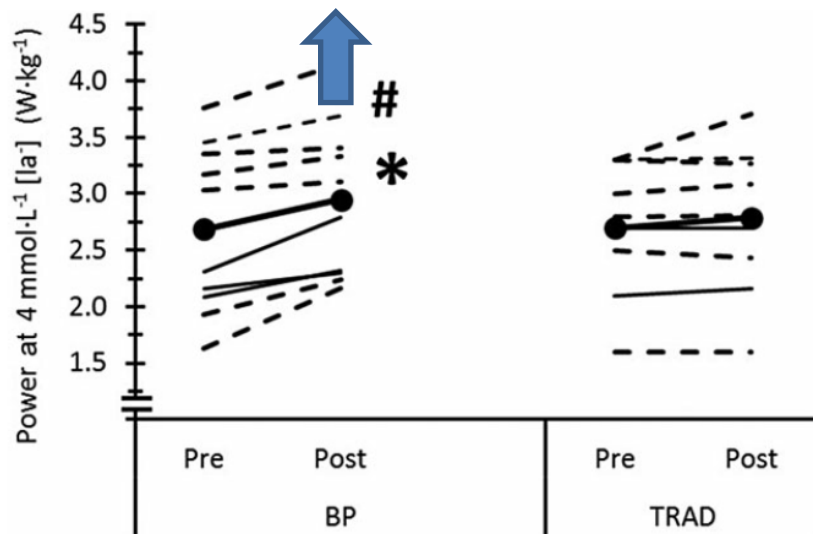
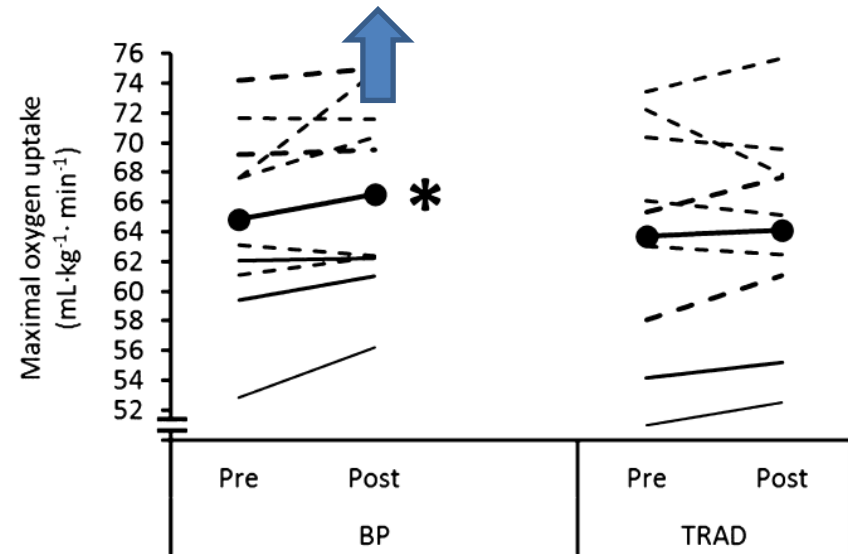
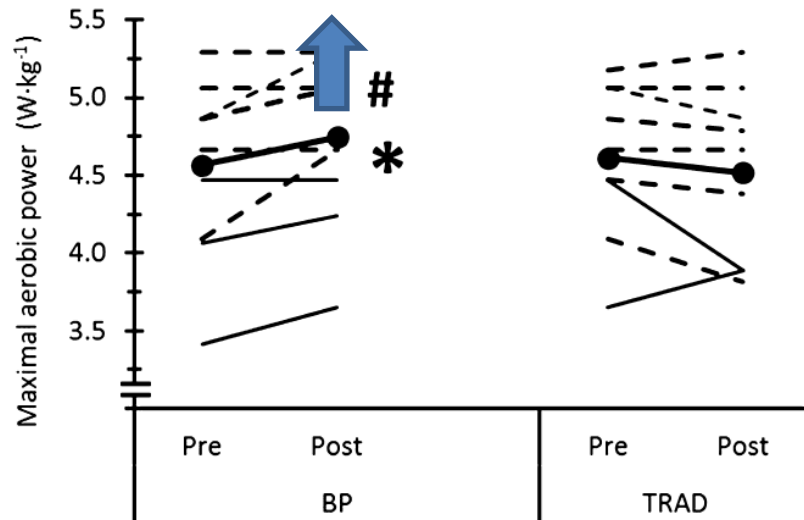
Rønnestad et al., 2013

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



Ronnestad et al., 2015





Higher improvement associated with block periodization



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_{BP2}	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 [†]
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 [†]
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	189 ± 7	189 ± 7
HR_{VT2} (beats min ⁻¹)	176 ± 7	172 ± 8	172 ± 7	176 ± 9	175 ± 6	172 ± 6	172 ± 6	172 ± 6
SR_{peak} (strokes min ⁻¹)	106 ± 4	102 ± 7	102 ± 8	108 ± 5 [£]	104 ± 4	101 ± 8	101 ± 8	101 ± 8
SR_{VT2} (strokes min ⁻¹)	86 ± 4	84 ± 3	84 ± 5	87 ± 6	87 ± 5	84 ± 6	84 ± 6	84 ± 6

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}

8.1% vs 11.0%

3.4% vs 6.2%

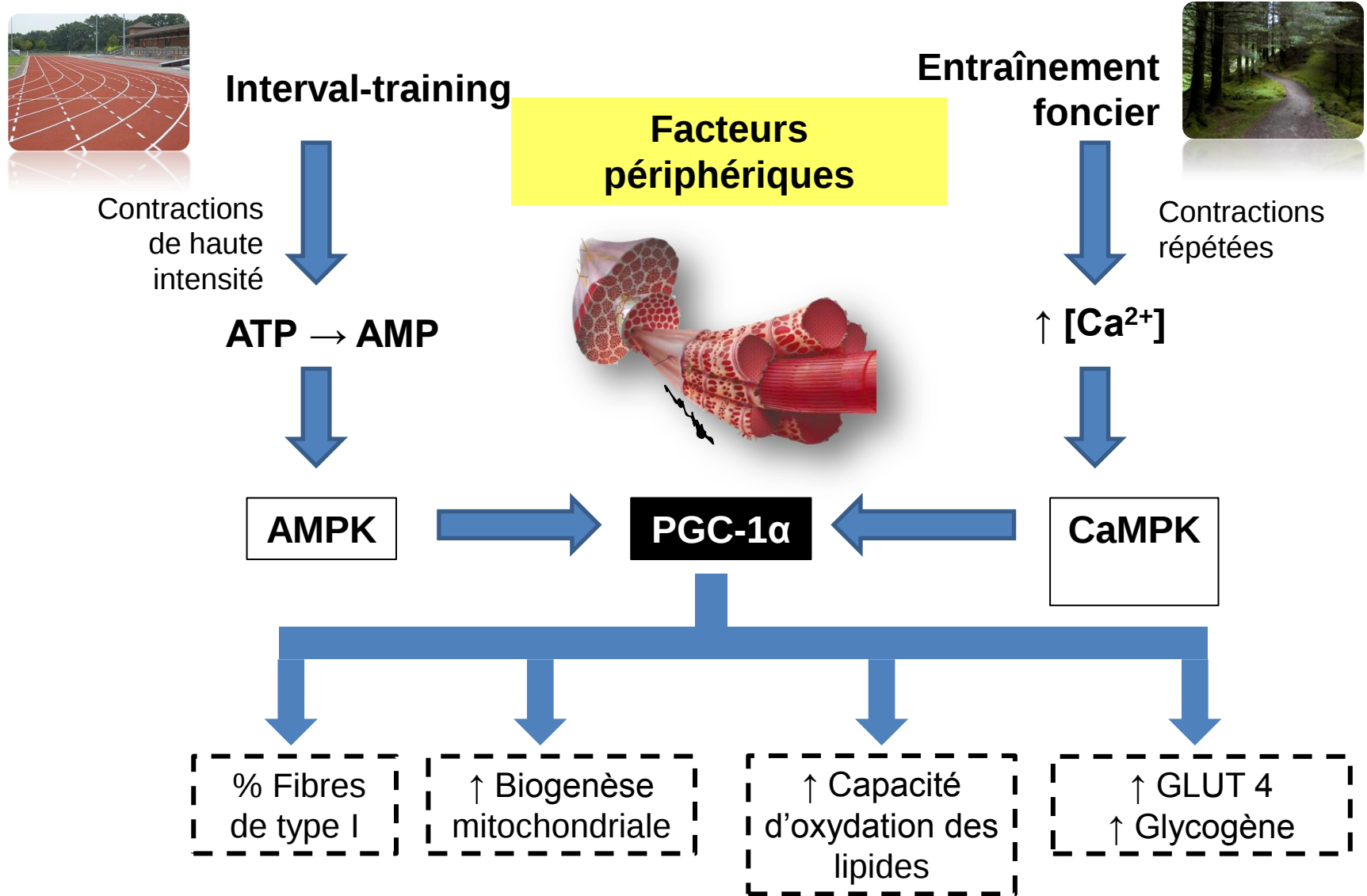
8.3% vs 14.2%



TRAINING INTENSITY DISTRIBUTION



The more HIT you do, the better?



- ① 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,
- ② ~48 h should separate HIT sessions to enable the majority of athletes to perform and train maximally,
- ③ Potential of varying quantities of high-intensity each week regularly (block periodization)



But always keep in mind that...

SCIENTIST

Providing general guidelines

↑ Positive response



Control

Intervention

↓ Negative response

CONCLUSION OF THE SCIENTIST

LIKELY POSITIVE EFFECT

COACH

Optimizing individual training strategies

↑ Positive response



Control

Intervention

↓ Negative response

CONCLUSION OF THE COACH

"I observe mitigated responses. I'm using it only with athletes A & B but it does not work for C & D"

IT IS NOT NECESSARILY CONTRADICTIONARY!

Sport Science Infographics by @YLMSSportScience

Classique Carte Magazine Mosaïque Barre Latérale Instantané Chronologie



Créé par @YLMSSportScience. Modèle Dynamic Views. Fourni par @Bloggier.

How does sleep loss influence your performance?



By @YLMSSportScience



1 A reduction in sleep quality and quantity could result in an autonomic nervous system imbalance, simulating symptoms of the overtraining syndrome



2 Growth hormone, which is fundamental to tissue regeneration and growth is released during phases of deep sleep



3 1.7 times greater risk of being injured in athletes who sleep < 8 hours per night



6 When sleep is reduced to less than 7 h in healthy adults, cognitive performance is poorer in tests for alertness, reaction time, memory, and decision making



4 Increases in pro-inflammatory cytokines following sleep loss could promote immune system dysfunction

5 Sleep loss is associated with slower and less accurate cognitive performance



7 Sufficient sleep should be obtained following training sessions, as the perceptual and motor learning processes continue into and throughout subsequent sleep



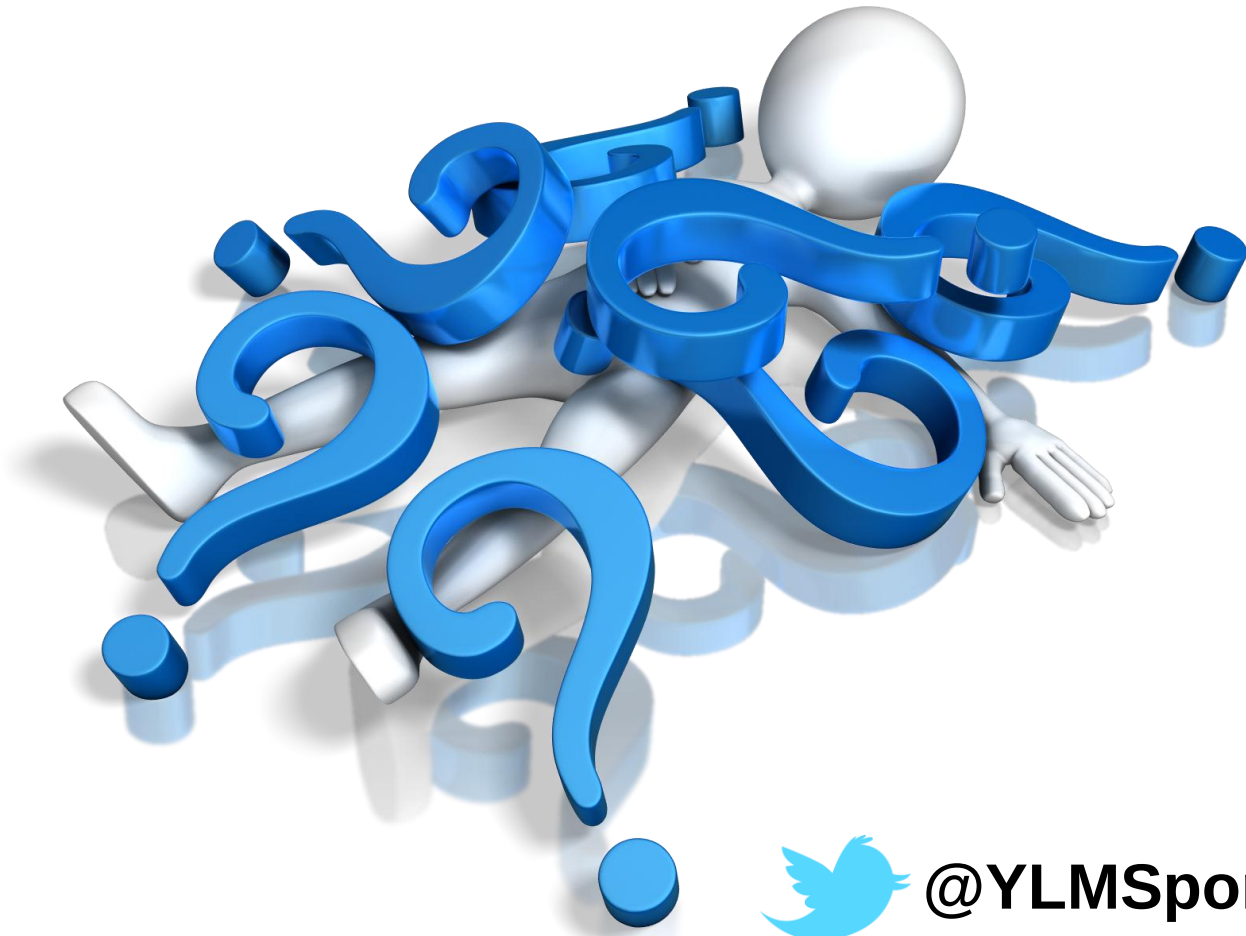
8 2-hour exposure to light exposure to light from self-luminous electronic displays can suppress melatonin by about 22% and affect sleep

Recent evidence suggests that most athletes sleep far less than either 8h per night



Reference: Le Meur, Skein & Duffield
In Recovery for Performance in Sport, Human Kinetics, 2013

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, $r = 2\text{--}4$ min)**

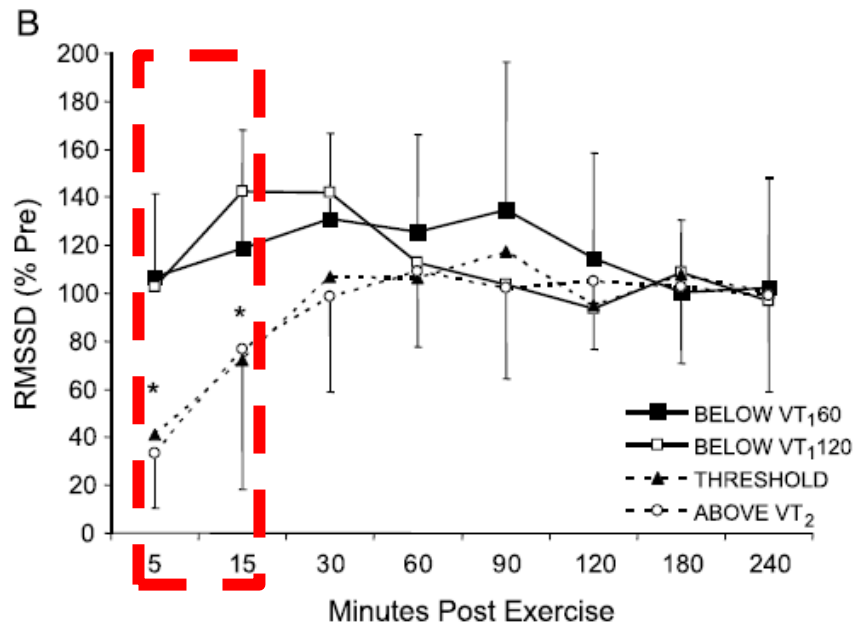
Training intensity & ANS perturbations

9 coureurs très entraînés ($72 \pm 5 \text{ mL} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$, $14 \pm 3 \text{ h} \cdot \text{sem}^{-1}$)

8 coureurs entraînés ($60 \pm 5 \text{ mL} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$, $7 \pm 1 \text{ h} \cdot \text{sem}^{-1}$)

4 exercices: 60min à 60% $\text{VO}_{2\text{max}}$ ($< \text{SV1}$), 120min à 60% $\text{VO}_{2\text{max}}$ ($< \text{SV1}$), 20min echft puis 30min à SV2 (80-85% $\text{VO}_{2\text{max}}$), 20min echft puis 6x3min à 95-100% $\text{VO}_{2\text{max}}$, $r=2\text{min}$.

Test HRV allongé Pré et Post (+5min, 15min, +30min, +1h, +2h, +3h, +4h).



Les exercices en dessous du SV1 ($\leq 120\text{min}$) ne causent pas perturbations importantes du système neuro-végétatif chez des sportifs très entraînés.

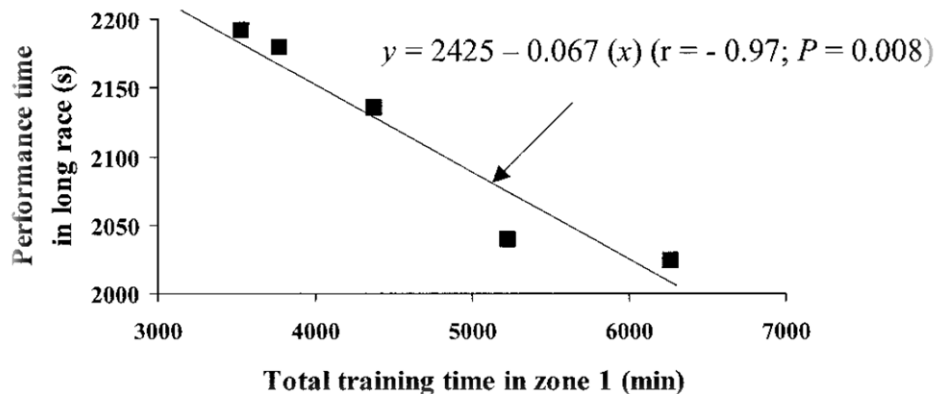
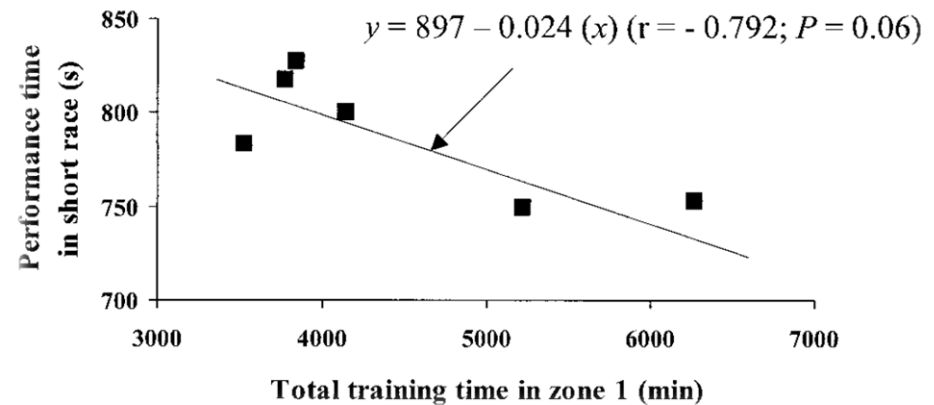
Seiler et al., 2007

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.

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%.

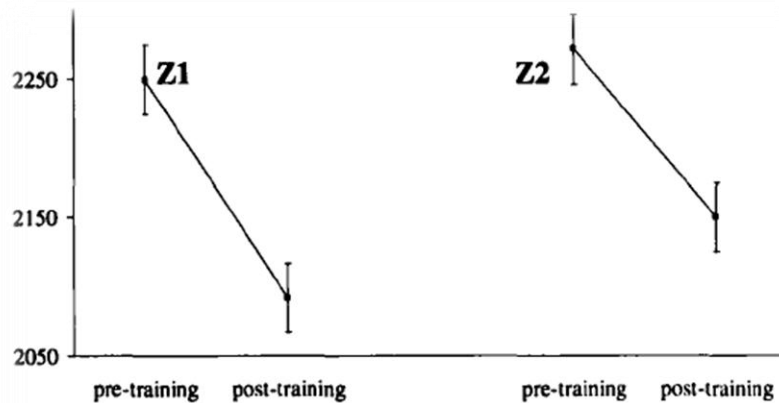


FIGURE 1. Change in performance after the training period during the simulated 10.4-km cross-country race in both groups.

TABLE 3. Results (mean $\pm$ 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 $\pm$ 408	8277 $\pm$ 463
Mean TRIMP.wk ⁻¹	452 $\pm$ 23	460 $\pm$ 26
Total time in zone 1 (min)	5246 $\pm$ 396	3830 $\pm$ 215*
Total time in zone 2 (min)	779 $\pm$ 116	1411 $\pm$ 95*
Total time in zone 3 (min)	502 $\pm$ 78	485 $\pm$ 65
Total % in zone 1	80.5 $\pm$ 1.8	66.8 $\pm$ 1.1
Total % in zone 2	11.8 $\pm$ 2.0	24.7 $\pm$ 1.5*
Total % in zone 3	8.3 $\pm$ 0.7	8.5 $\pm$ 1.0*

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

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 $\pm$ 13 s vs. -122 $\pm$ 7 s, $p = 0.03$).

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
$\text{VO}_{2\text{max}}$ (L/min)	4.80	4.98	5.16	4.90	5.48	5.60	5.45
$\text{VO}_{2\text{max}}$ ($\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	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
v $\text{VO}_{2\text{max}}$ (km/h)	20.4	20.3	20.4	20.1	22.6	23.2	23.1
RE ($\text{mL} \cdot \text{kg}^{-1} \cdot \text{km}$)	208	214	217	210	209	206	204

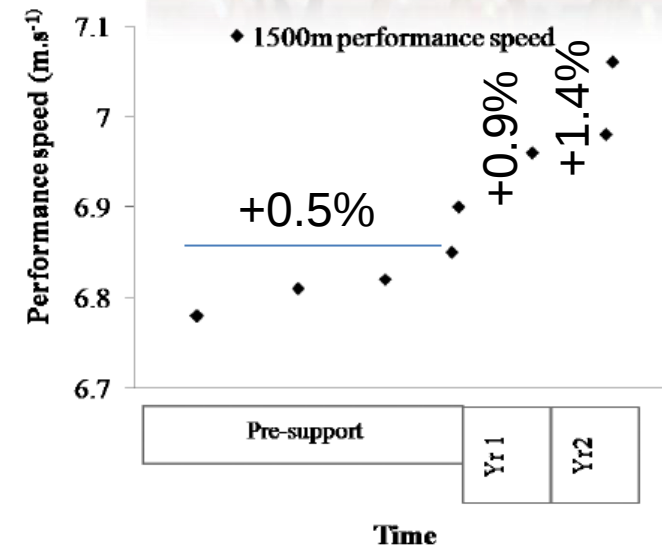
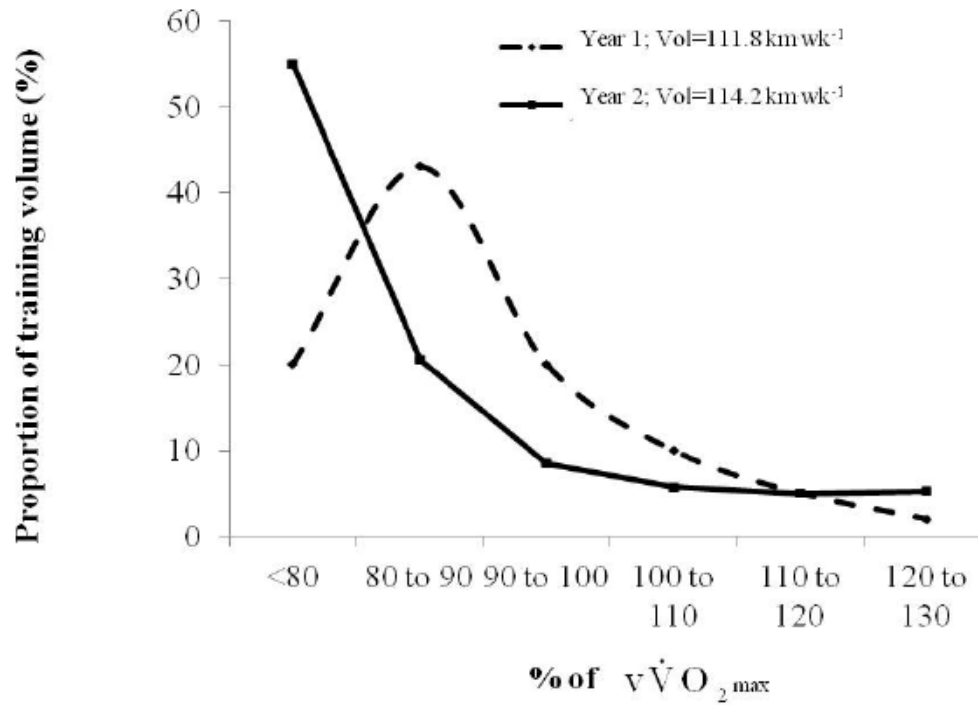
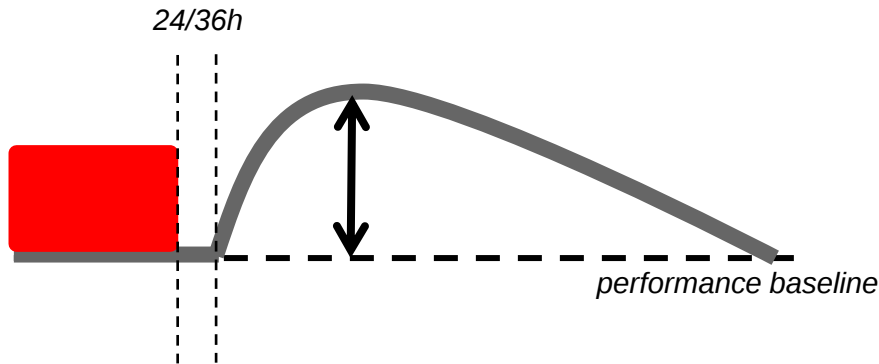


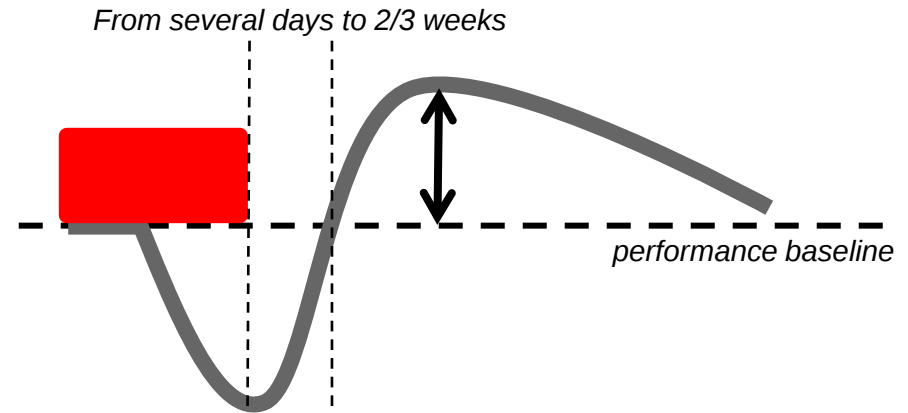
Figure 2 — The change in 1500-m performance speed during competitive races prior to physiological support and during years 1 and 2.

The different stages of training-induced fatigue

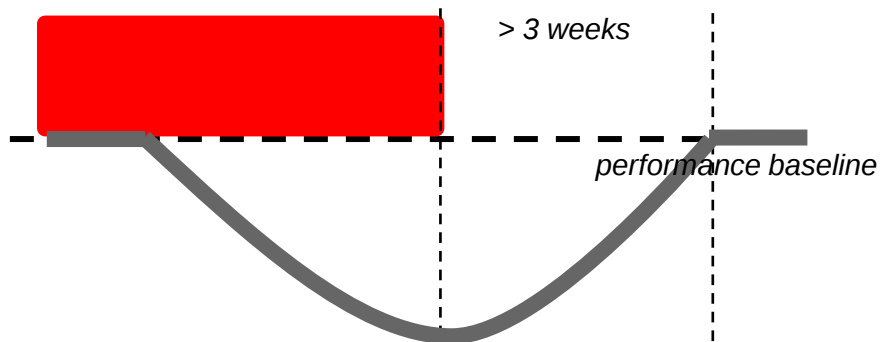
Acute fatigue



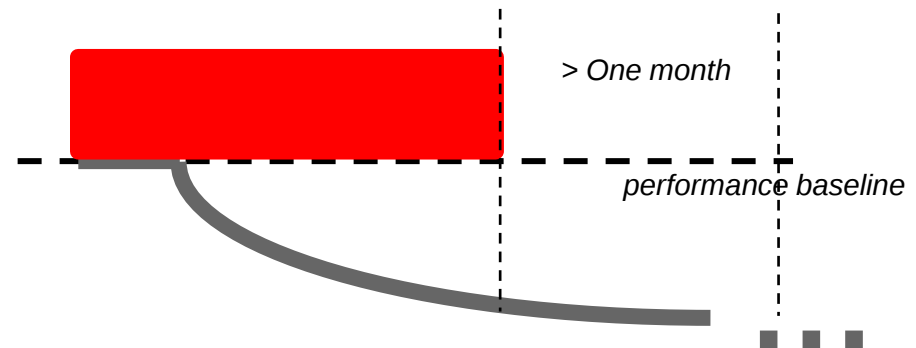
Functional overreaching

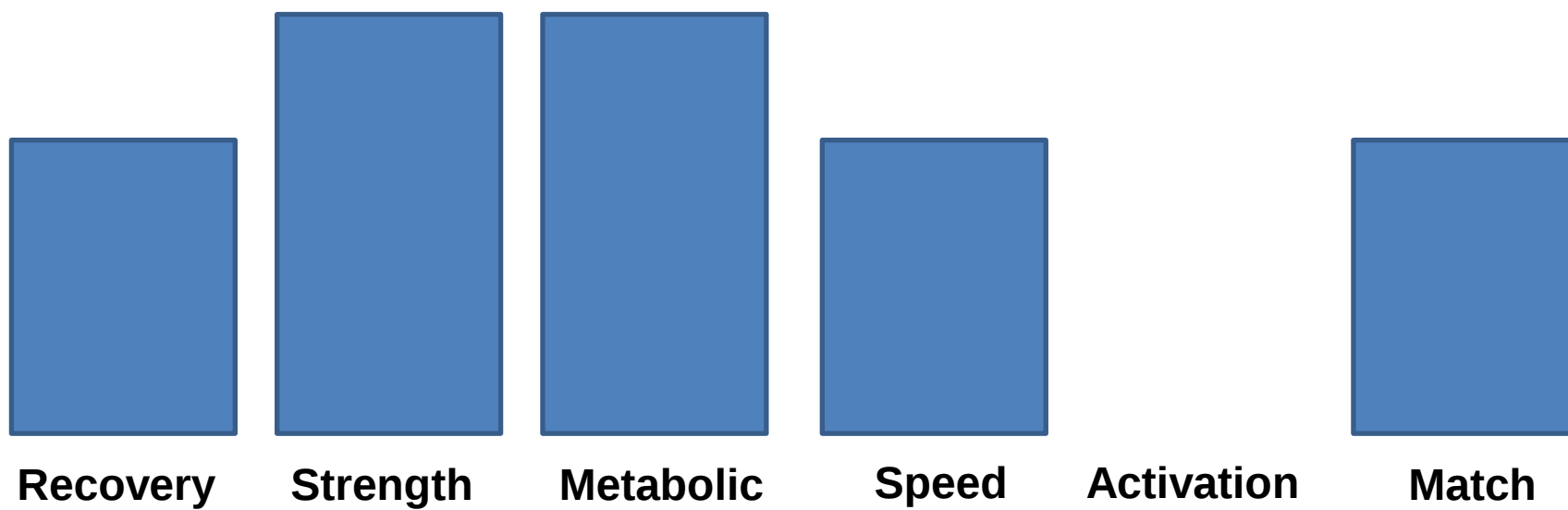


Non functional overreaching



Overtraining syndrome







**HOW MUCH IS
ENOUGH?**

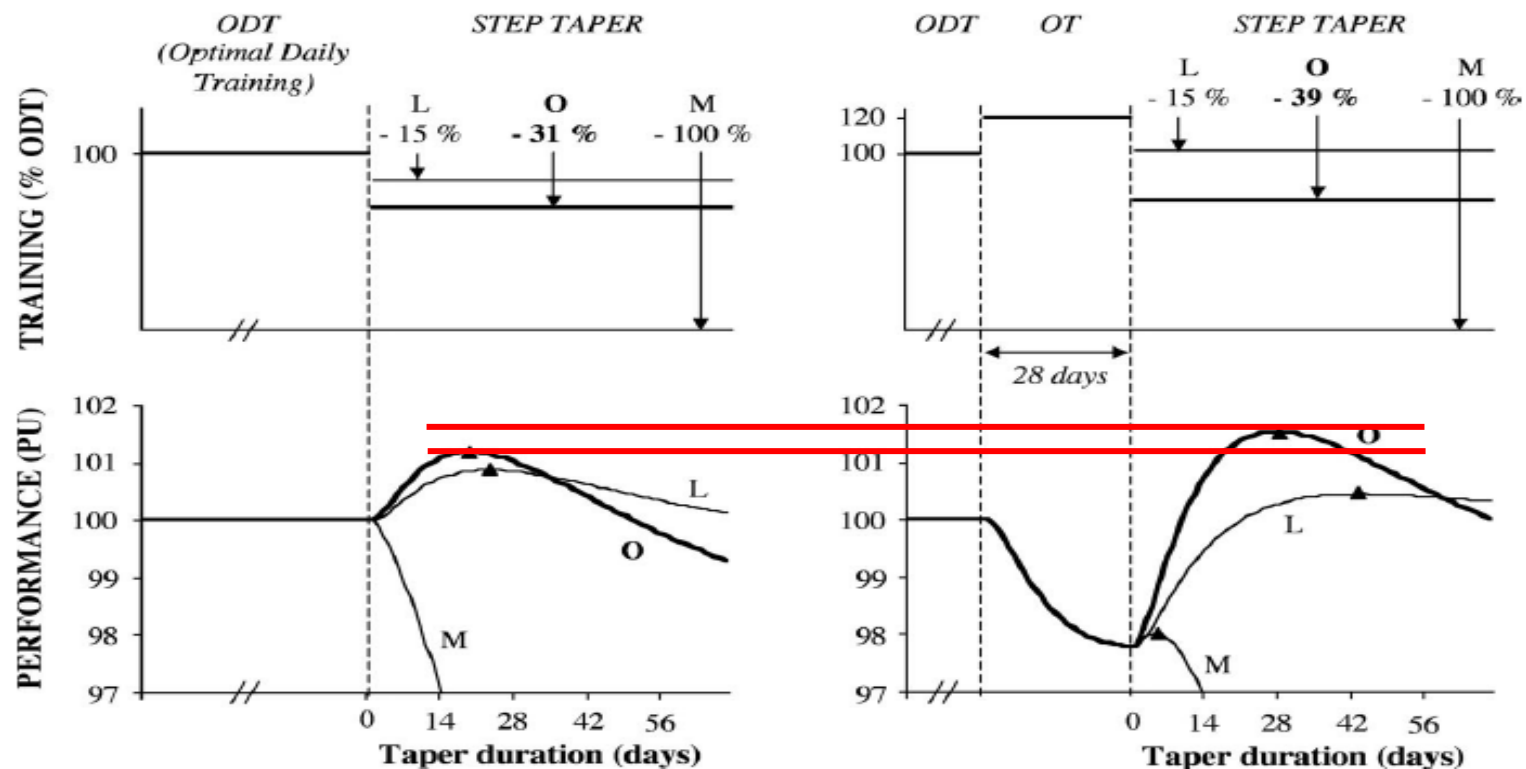
Where is the limit?



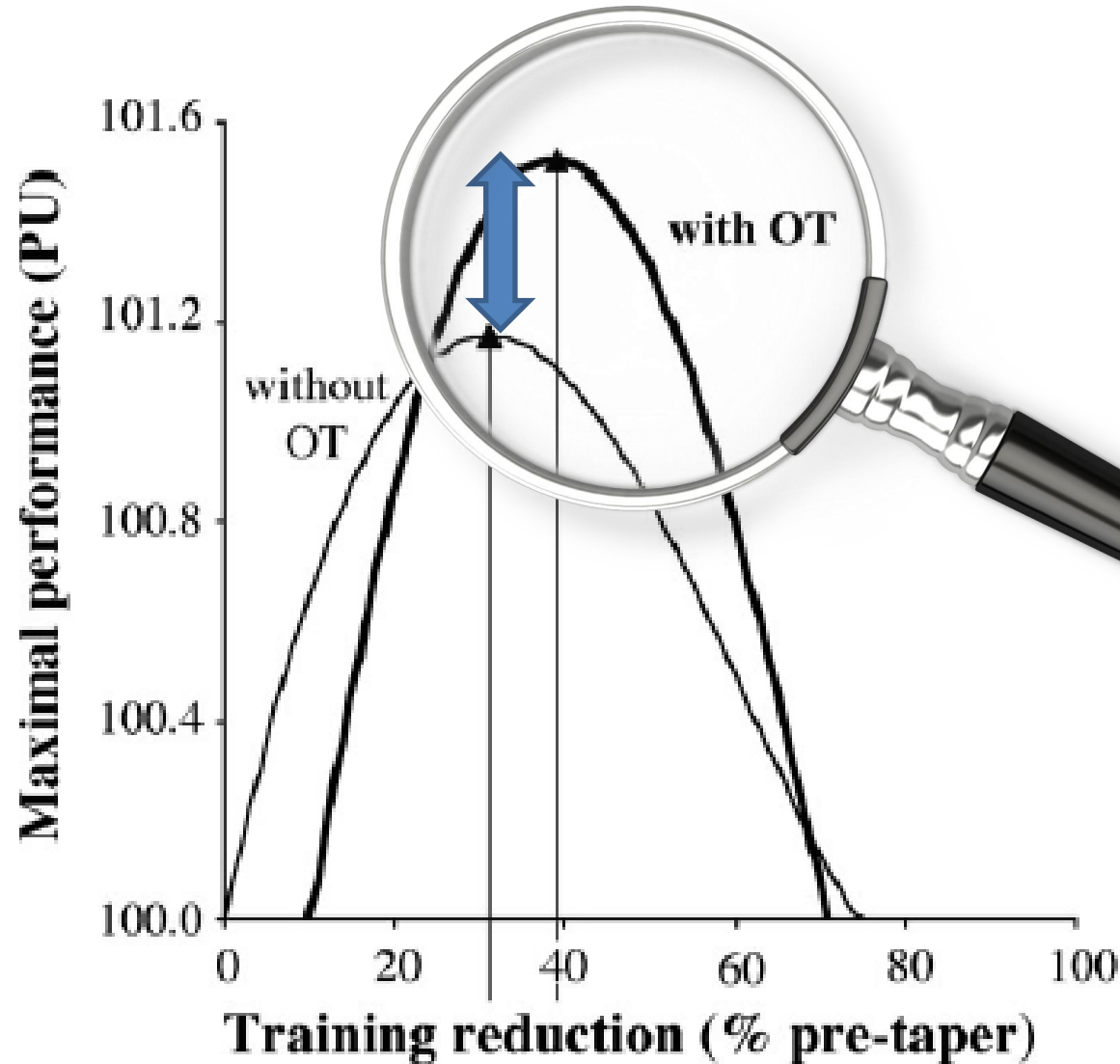
A Theoretical Study of Taper Characteristics to Optimize Performance

LUC THOMAS and THIERRY BUSSO

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



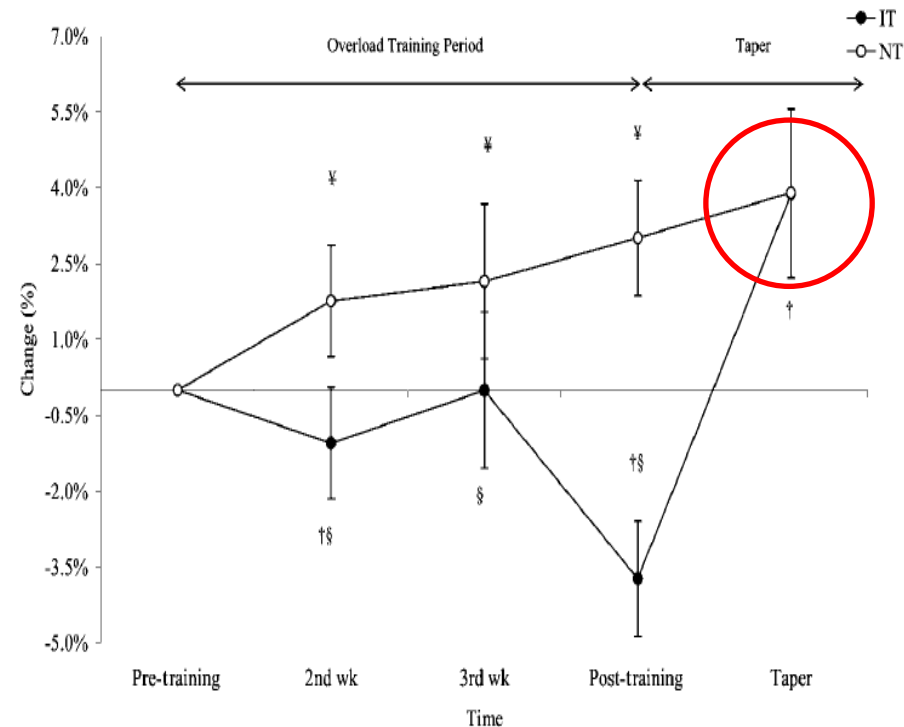
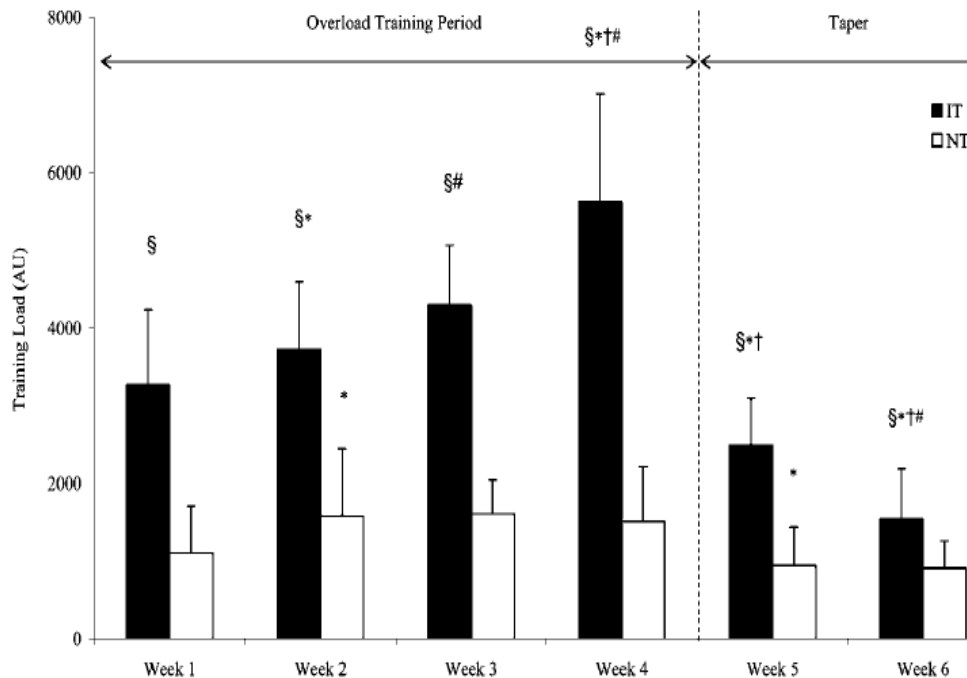
Functional overreaching, the key for supercompensation?



Functional overreaching, the key for supercompensation?

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

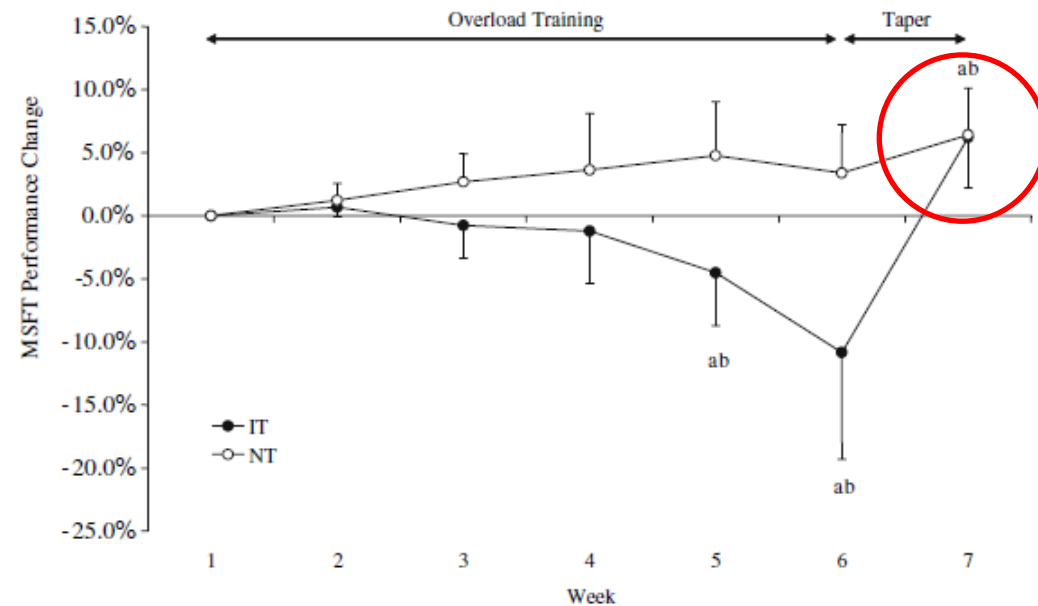
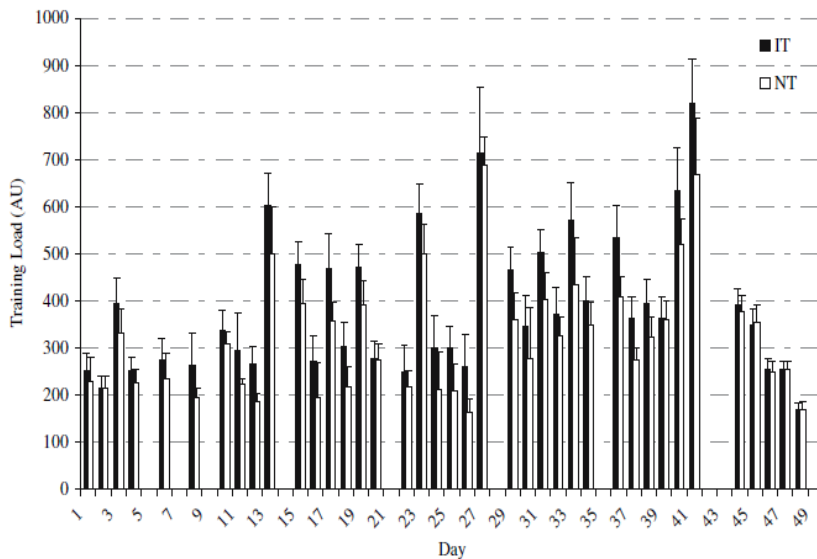
Monitoring Changes in Performance, Physiology, Biochemistry, and Psychology during Overreaching and Recovery in Triathletes



Monitoring for overreaching in rugby league players

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

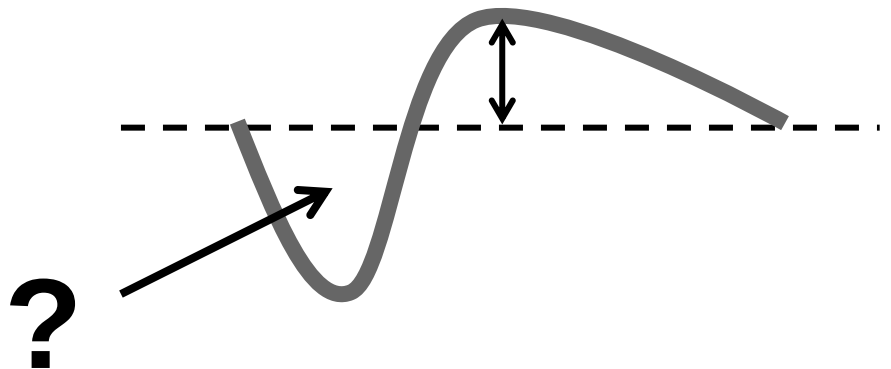
Multistage fitness test



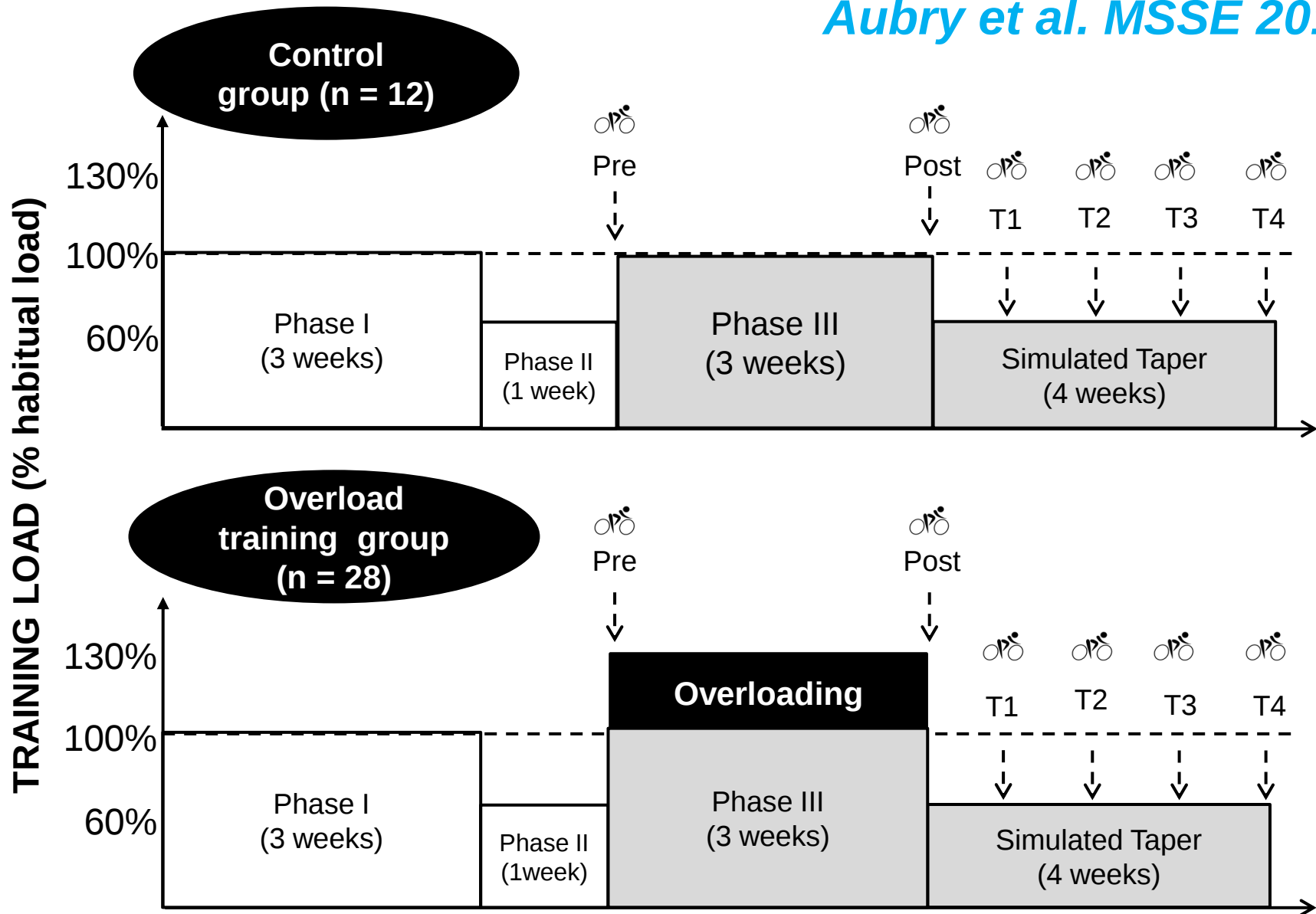
Functional overreaching, the key for supercompensation?



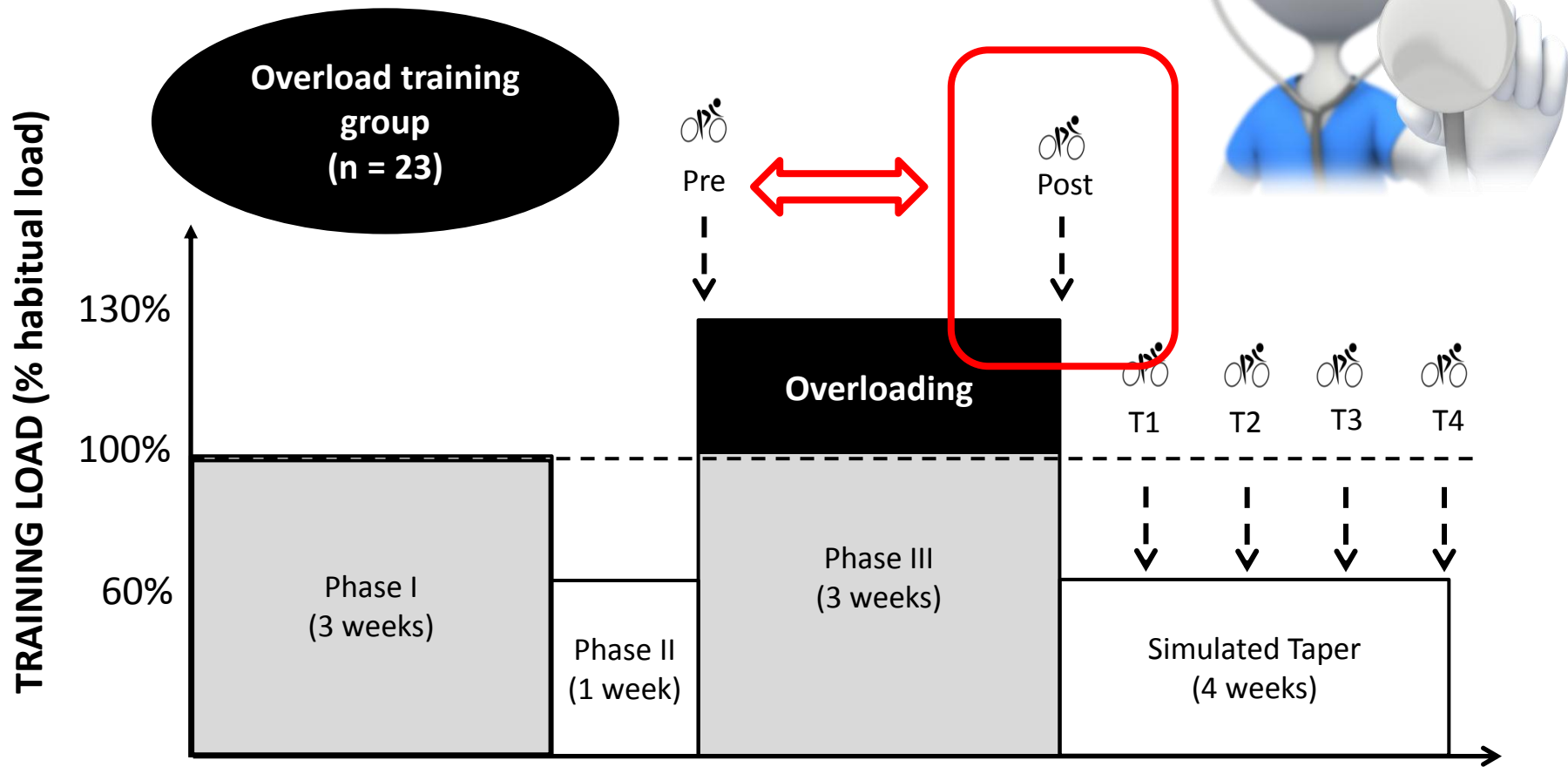
To examine whether the development of a functional overreaching state leads to greater performance supercompensation in comparison to acute fatigue strategy



Aubry et al. MSSE 2014



Functional overreaching, the key for supercompensation?



- HIGH PERCEIVED FATIGUE
- PRESERVED & ENHANCED PERFORMANCE

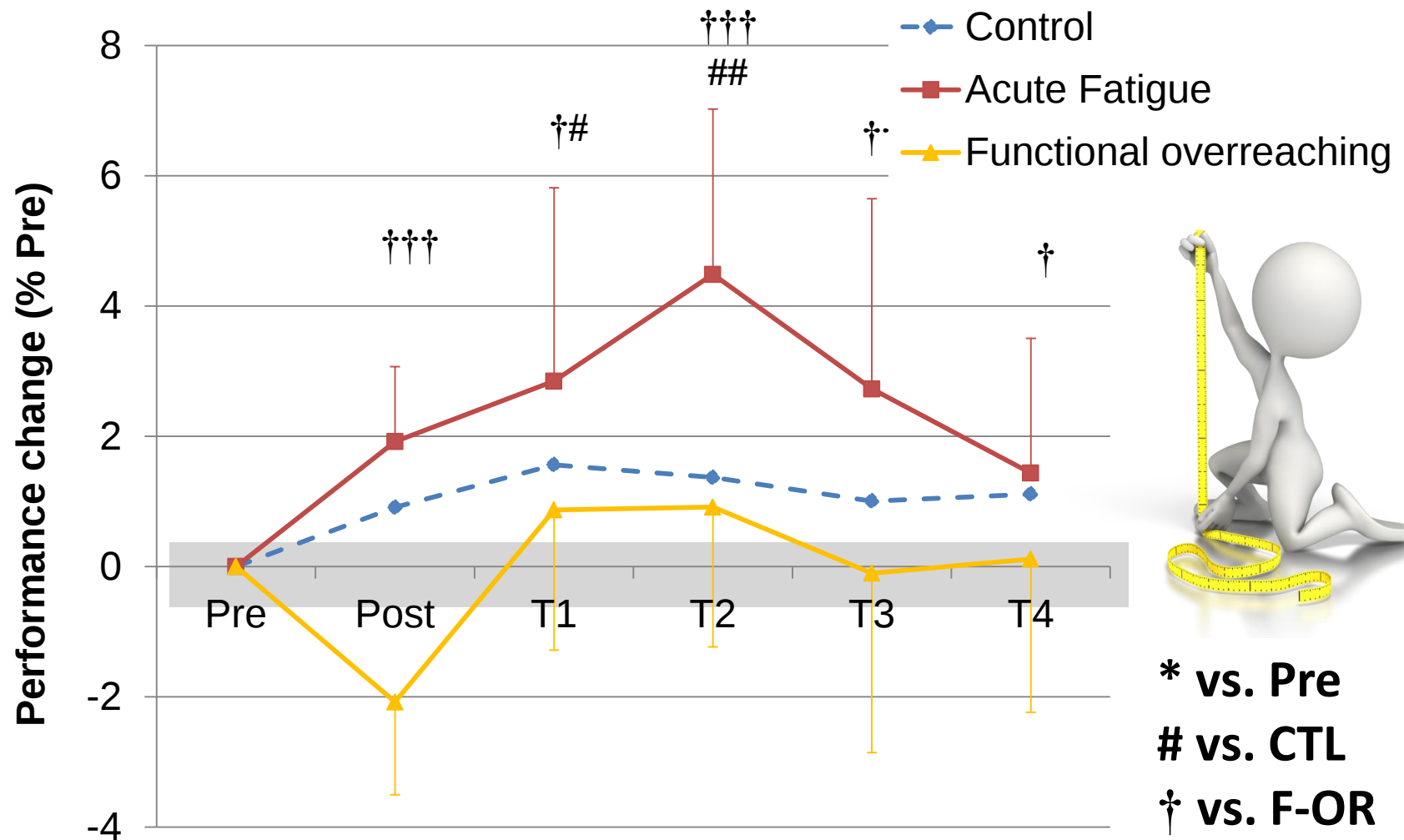
ACUTE FATIGUE
n = 12



- VERY HIGH PERCEIVED FATIGUE
- DECREASED PERFORMANCE

**FUNCTIONAL
OVERREACHING**
n = 11

The performance rebound



Physiological response



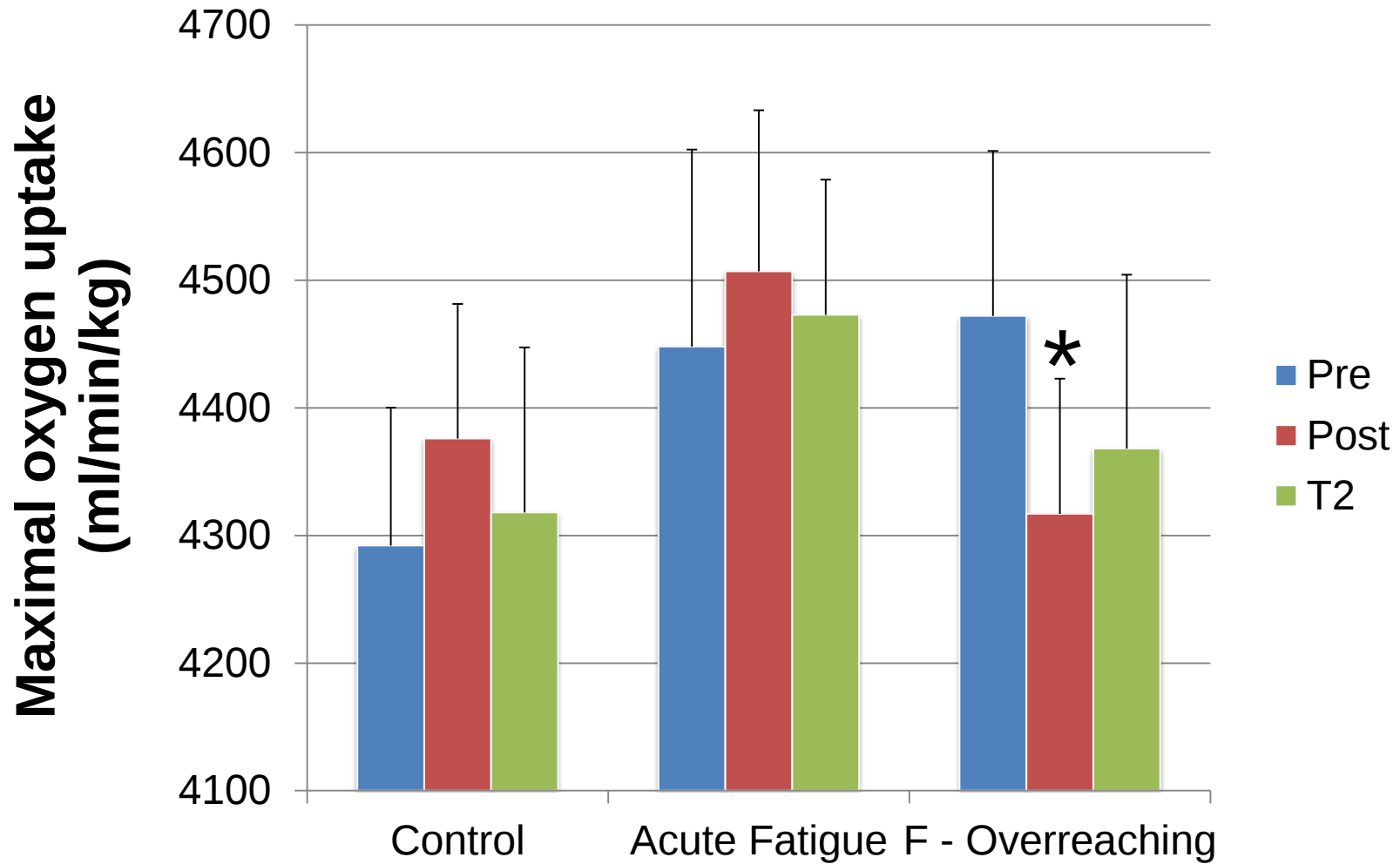
Oxygen uptake
Ventilatory parameters

Cardiac output

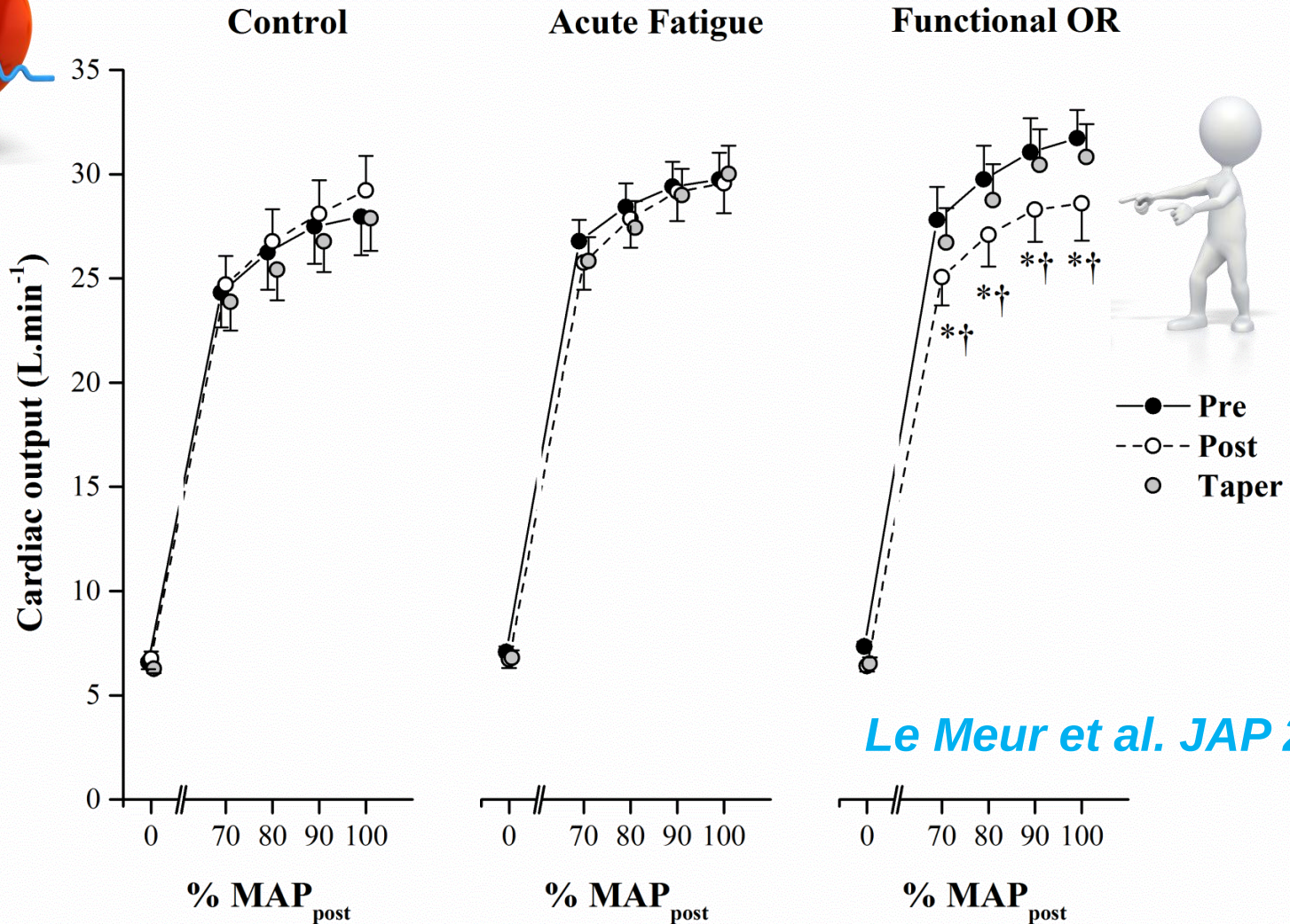
Arterial blood
pressures

Blood lactate
concentration

Plasmatic
catecholamines
concentration

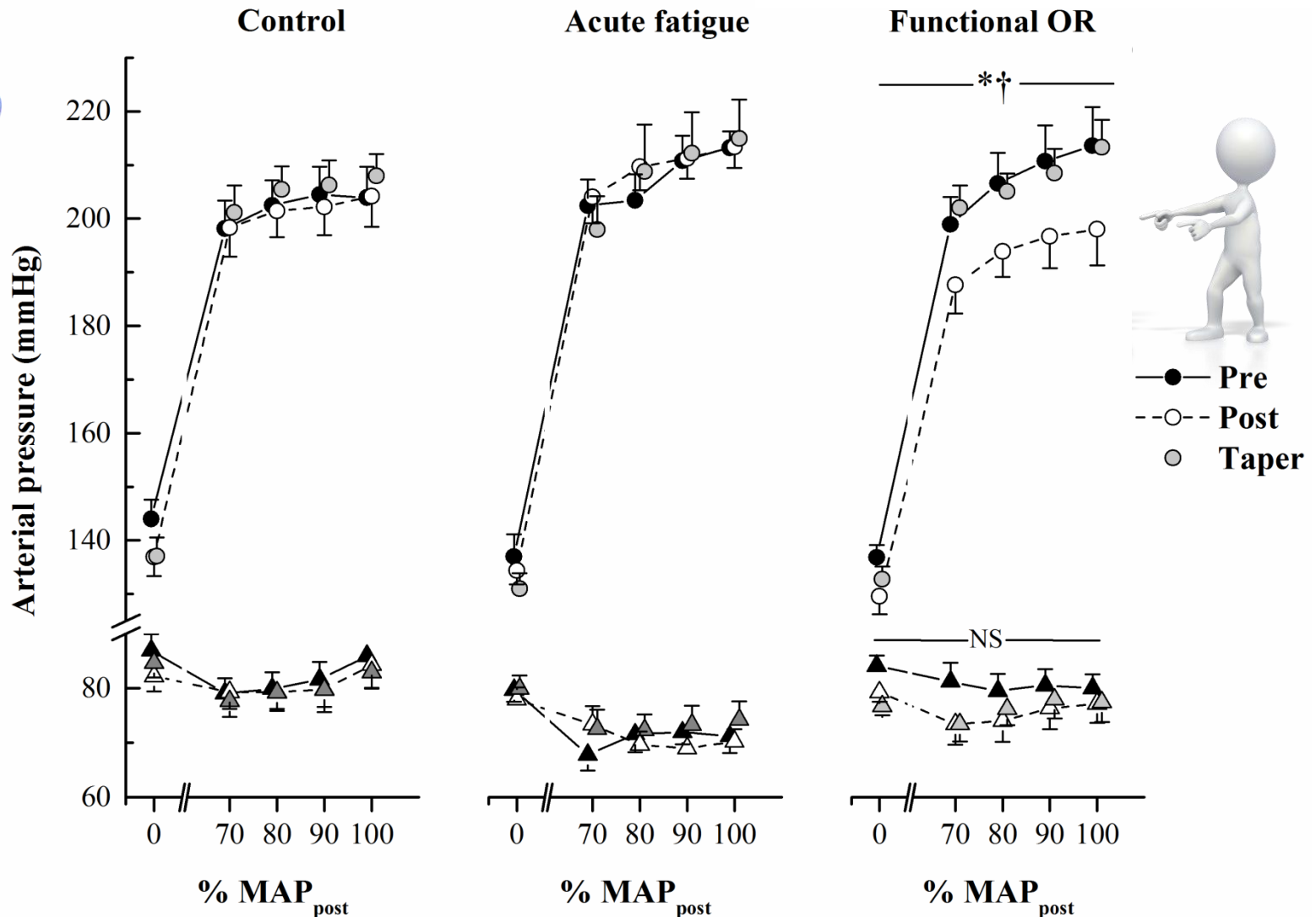


An altered cardiac response



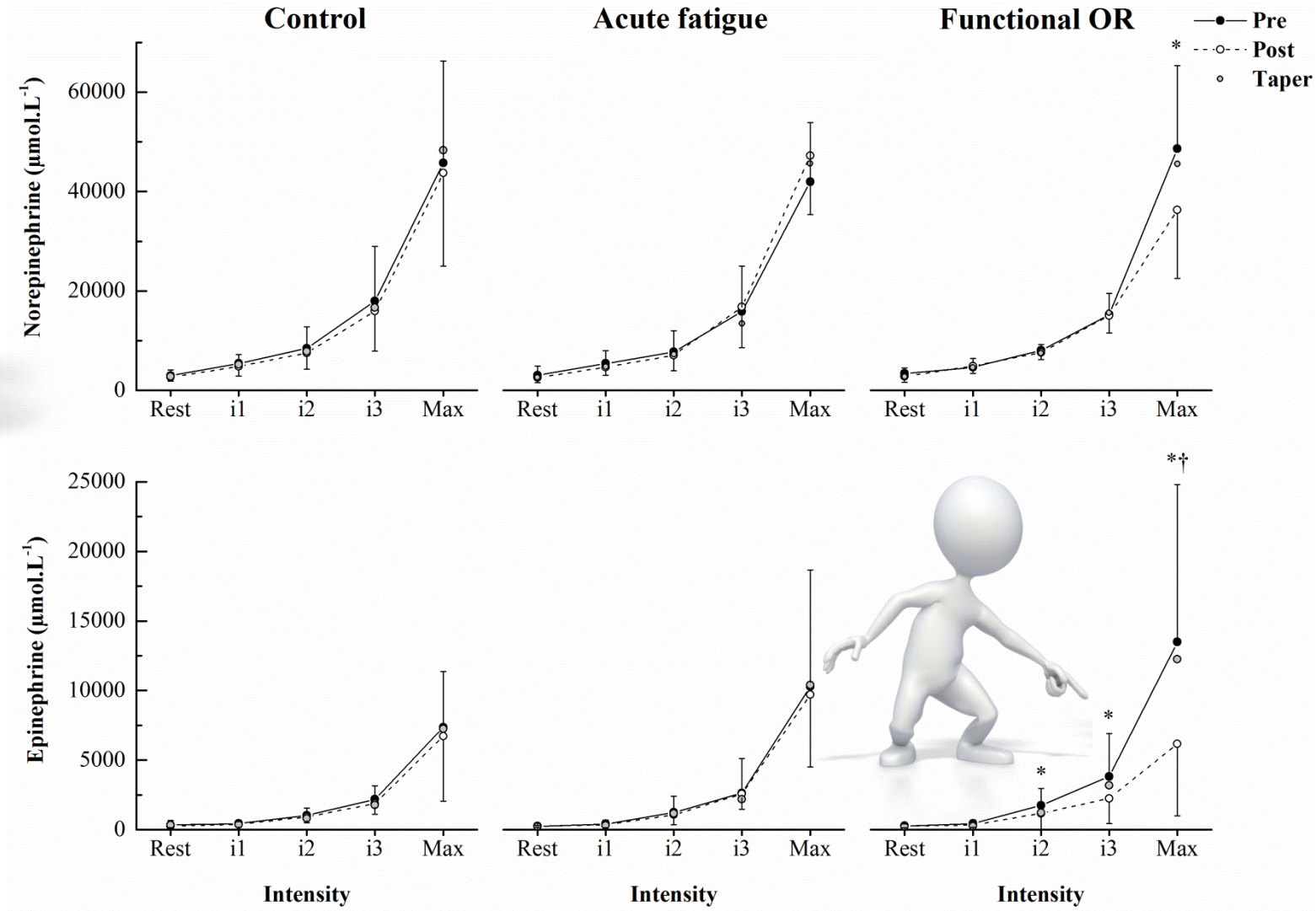
Different from Pre, $p < 0.05$; † Different from Post, $p < 0.05$

An altered cardiac response



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

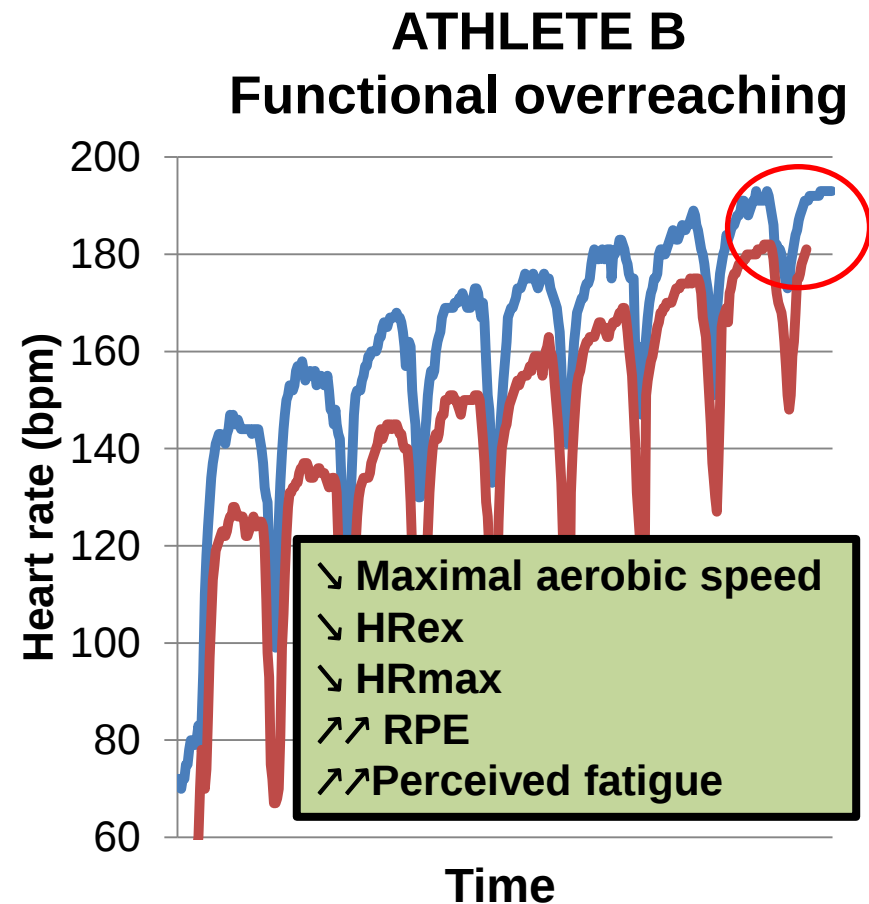
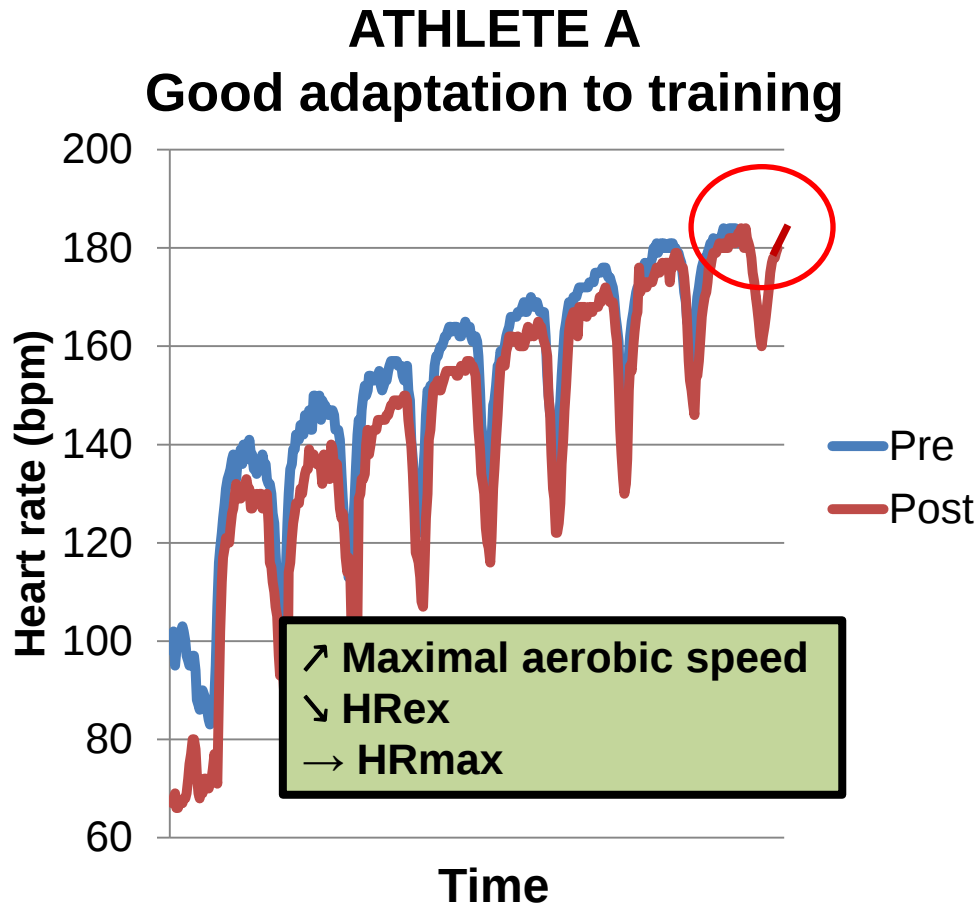
Catecholamines response



Le Meur et al. JAP 2014

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

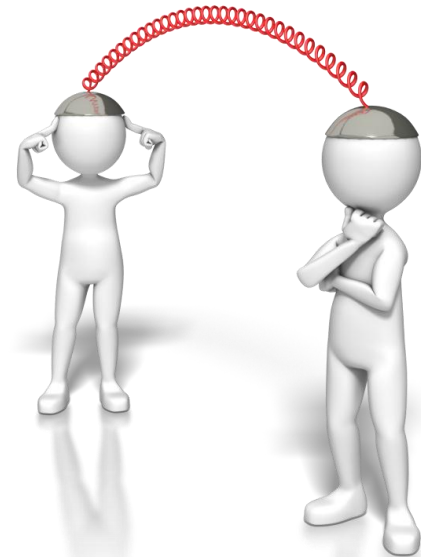
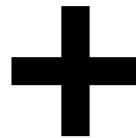
- ▶ Illustration with 2 athletes
- ▶ Same endurance-oriented overload period (+40% of habitual training load)
- ▶ Maximal incremental running test (+1km/h each 3 min, $r = 1\text{min}$)



**DEMONSTRATE EMPATHY
& ACCEPT TO REGULATE**



**MONITOR PERFORMANCE
& QUANTIFY TRAINING LOAD**



**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 interpreted **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	+++	↗	↘

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





This study showed that greater gains in performance and $\text{VO}_{2\text{max}}$ occur when the habitual training load increases before the taper... but not if there is functional overreaching

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

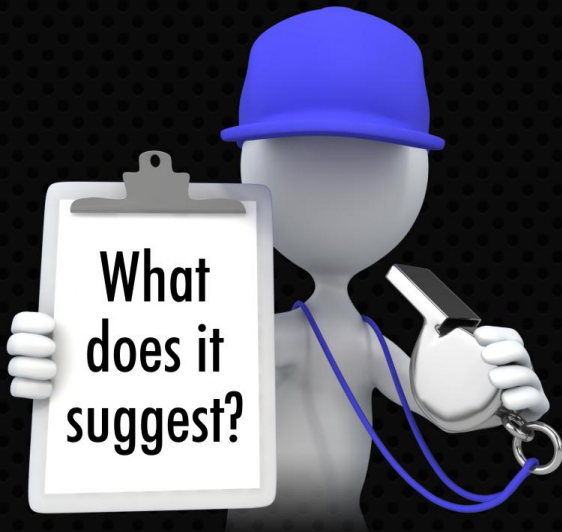
- 4** It is highly improbable that there are “best” patterns, time frames, or progression and/or loading schemes validly applicable across training contexts



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