Research Institute for Olympic Sports KIHU
Jyväskylä

Problems of overreaching in endurance sport

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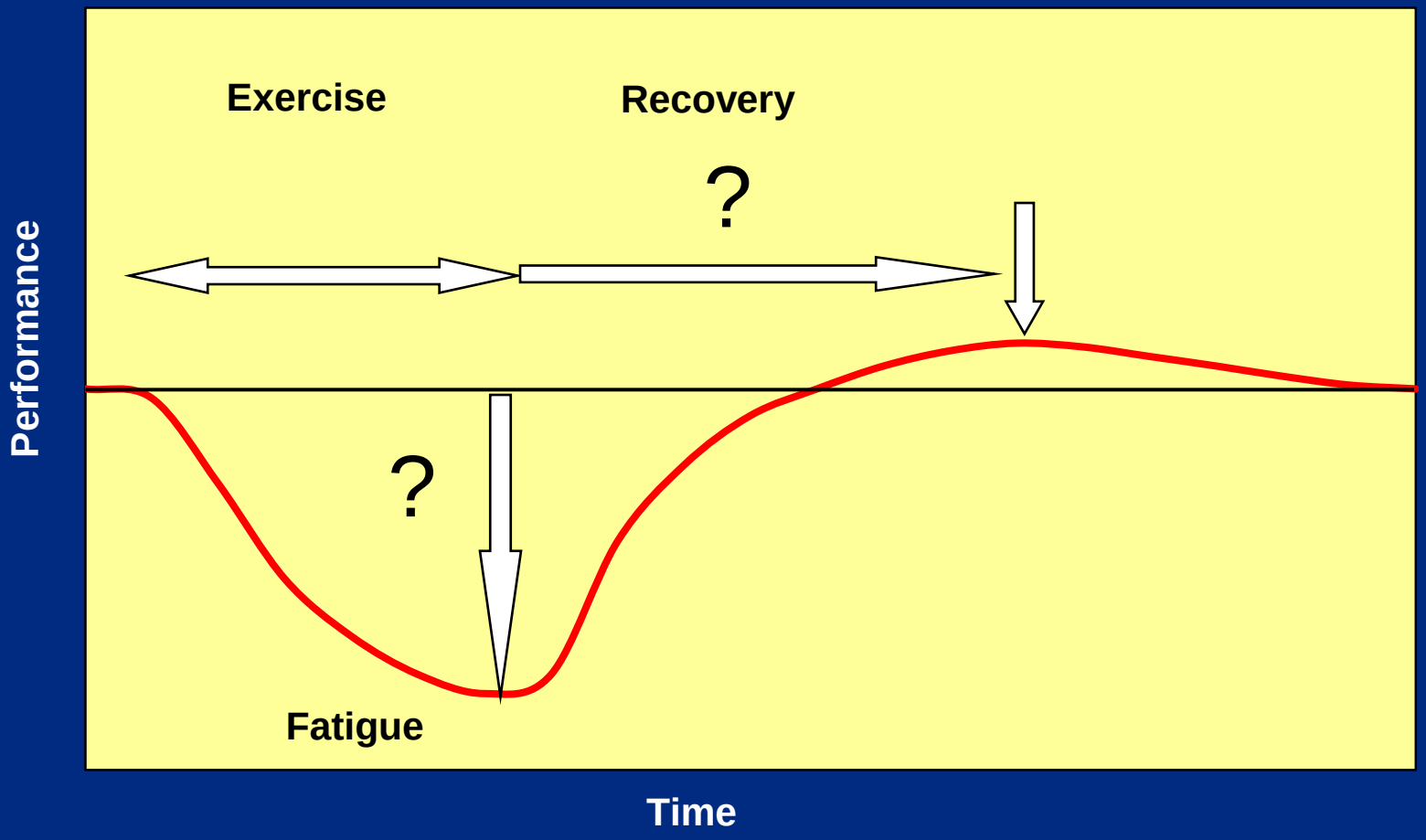
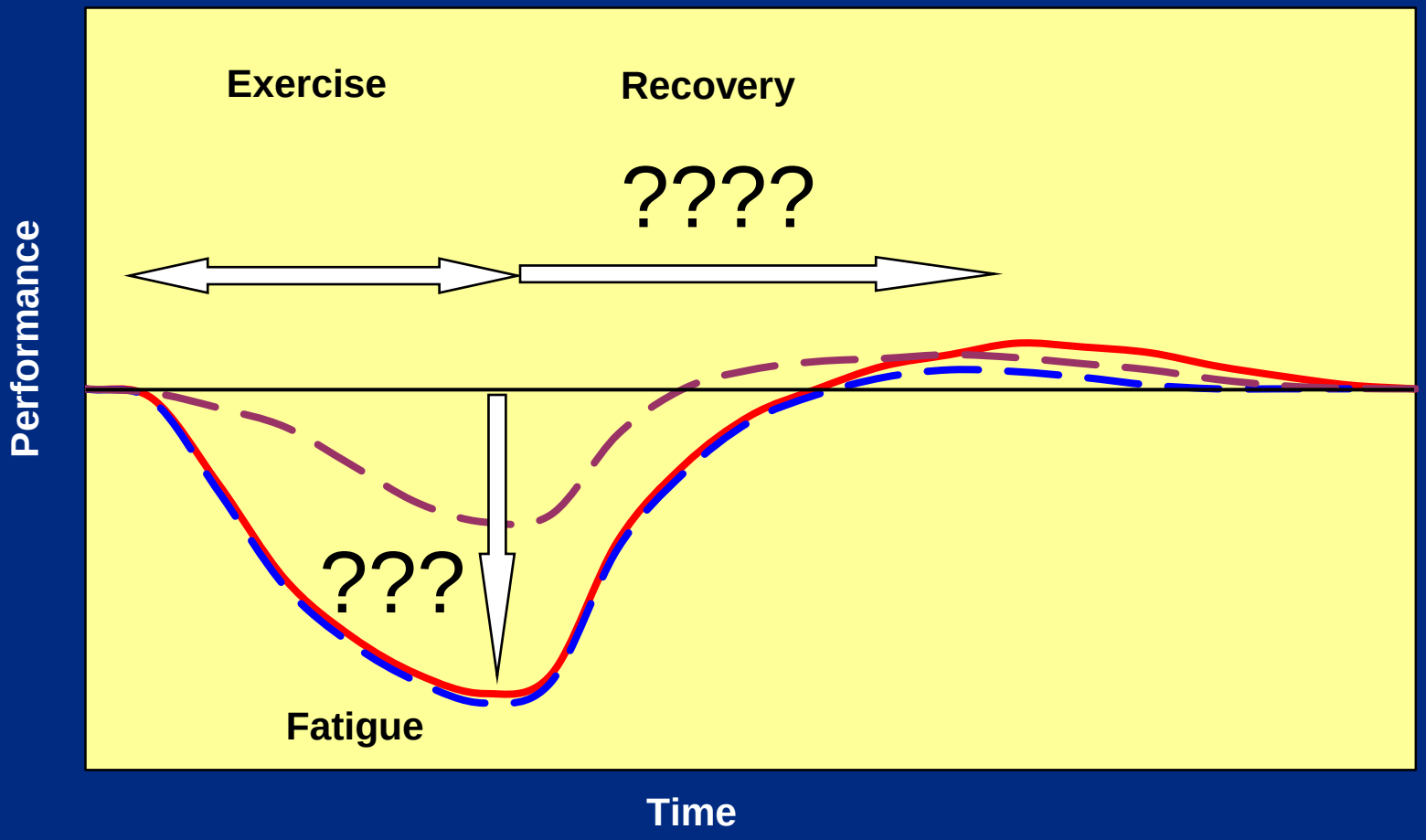
Problems of overreaching in endurance sport

1. Basic principle of training adaptation
2. Factors determining training load
3. Useful methods for determination of training load
4. Monitoring training induced stress and recovery
5. Conclusions / future directions

Basic principle of training adaptation



Basic principle of training adaptation



Basic principle of training adaptation

Overtraining example: male XC-skier

Incremental test on a treadmill

Time of testing	November	January
Body mass (kg)	70,1	70,3
Body fat (%)	8,1	8,2
VO_{2max} (ml/kg/min)	83	72
$VO_{2demand}$ (ml/kg/min)	85	74
HR_{max} (bpm)	182	177
Lactate peak (mM)	11,7	7,6
AnT VO_2 (ml/kg/min)	61	61
AnT $VO_{2demand}$ (ml/kg/min)	60	58
AnT HR (bpm)	161	164
AnT lactate (mM)	2,6	2,7
AerT VO_2 (ml/kg/min)	50	48
AerT $VO_{2demand}$ (ml/kg/min)	49	47
AerT HR (bpm)	142	144
AerT lactate (mM)	1,8	1,3
Hb (g/l)	172	170
Hct (%)	51	51
HR supine / standing (bpm)	58 / 78	49 / 78

Decreased VO_{2max} and performance

Decreased HR max

Lower lactate max

Lower lactate at aerobic threshold

Lower resting heart rate

Overtraining example: female 400 m runner

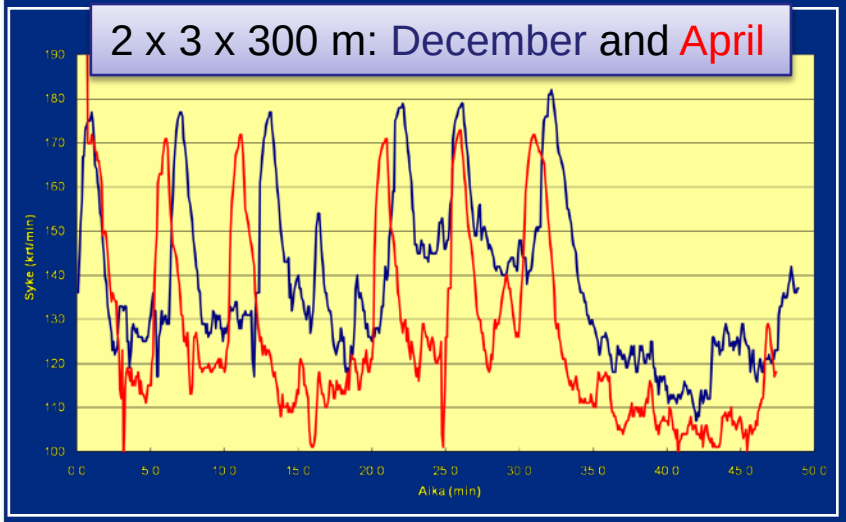
MART on a track

Time of testing	December	April
V_{max} (m/s)	8,11	8,06
Lactate peak (mM)	15,7	13,9
V_{13mM} (m/s)	7,76	7,92
V_{10mM} (m/s)	7,38	7,40
V_{7mM} (m/s)	6,80	6,86
V_{5mM} (m/s)	6,22	6,46
V_{3mM} (m/s)	5,36	5,55
CMJ (cm)	46,2	45,5
V_{30m} (m/s)	8,96	8,77

Lower peak lactate

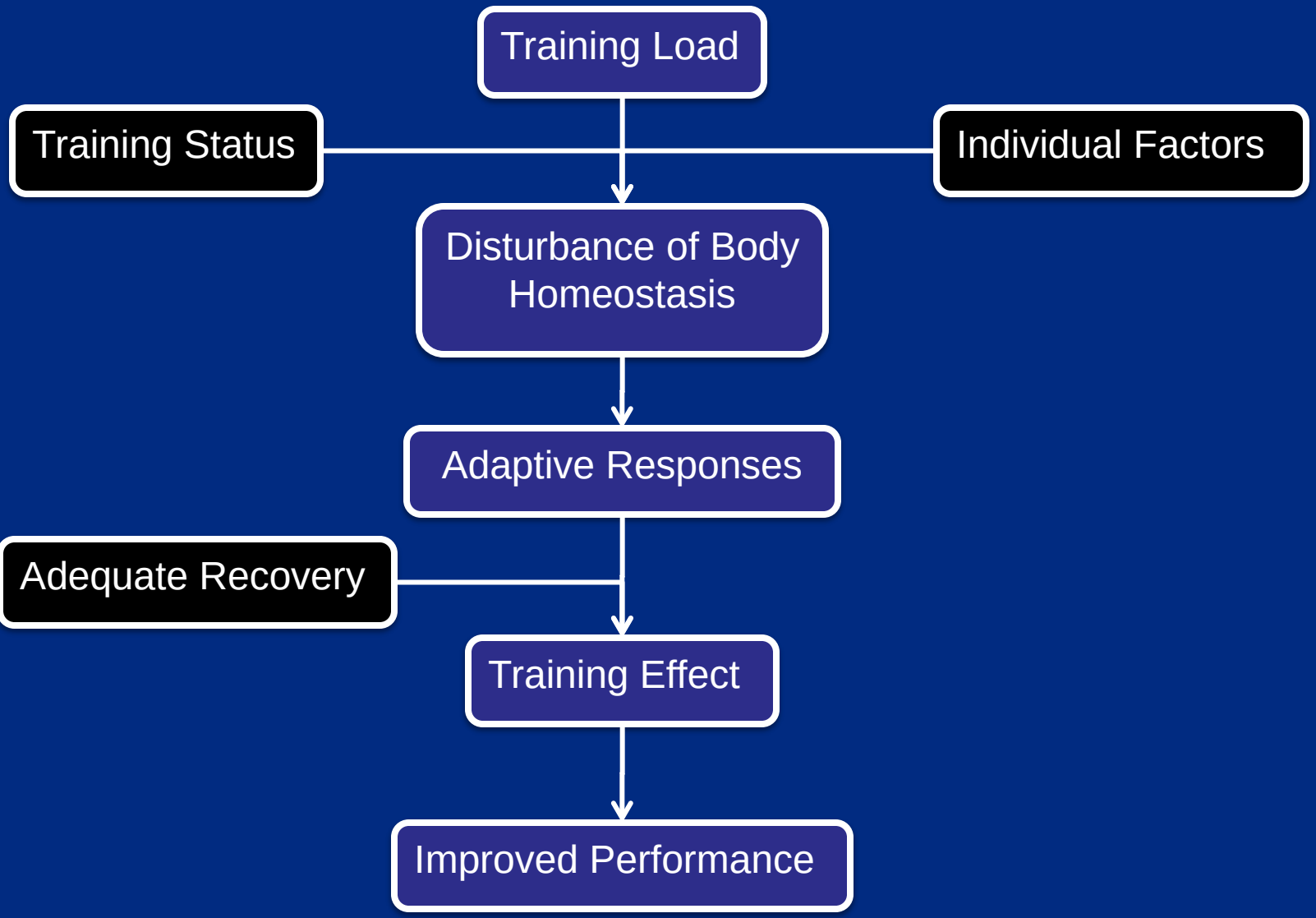
Improved velocity at low lactate levels

Decreased max velocity



Decreased exercise and recovery HR, decreased blood lactate values increased rating of perceived exertion

Model of training and training adaptation



Factors determining training load

- Exercise intensity
- Duration of exercise
- Training frequency
- Recovery periods within the training session
- Exercise mode
- Physiological properties of an athlete: endurance vs. sprint type
- Training background
- Training state
- External conditions

→ Exercise induced fatigue and training adaptation is a complex phenomenon and is affected by multiple factors, which can not be totally controlled

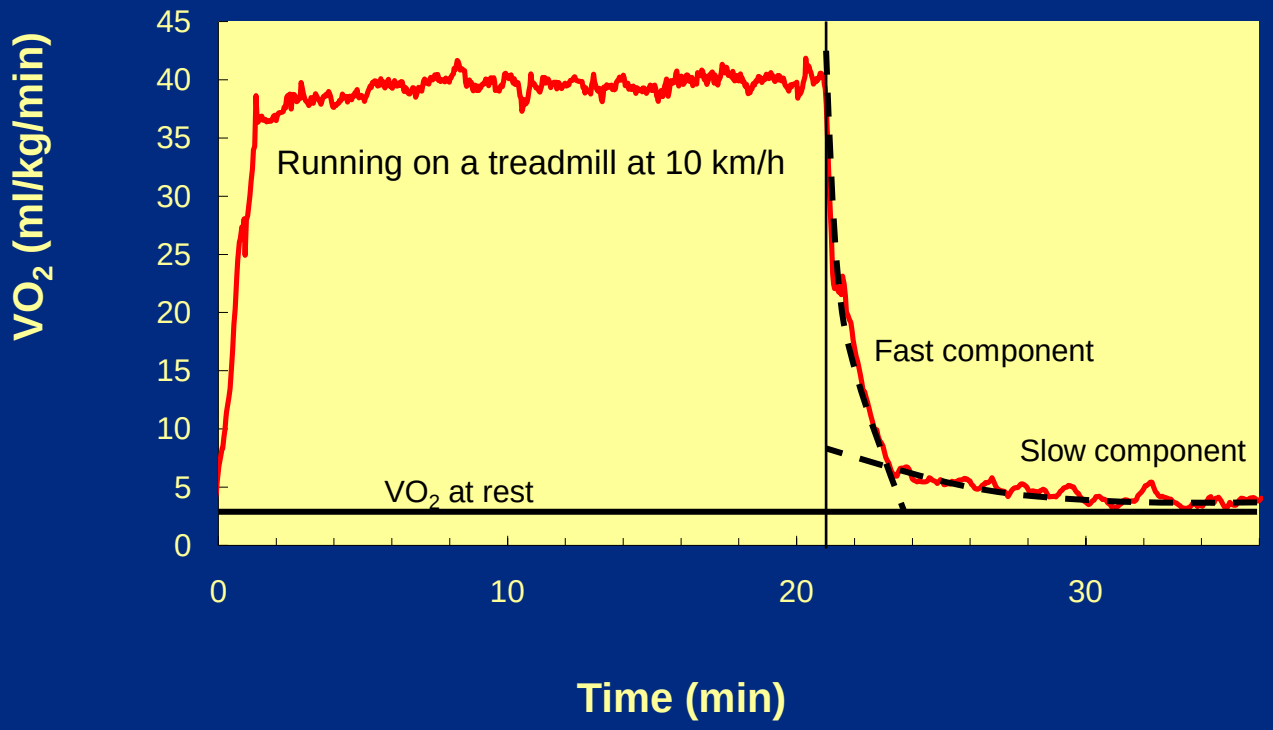
Properties of an objective tool for measuring training load in elite athletes

- Sensitive to changes
- Practical and easy to use
- Non-invasive
- Cheap to use
- Should answer to the following questions:
  - How hard was the training session?
  - How long does it take to recover?
  - How does fatigue accumulate during the particular training period?

How hard was the training session? The determination of training load

- Heart rate
  - Average heart rate
  - Heart rate distribution in different intensity zones
  - TRIMP = Time x ΔHR ratio x y (Banister 1991)
  - Heart rate recovery
  - Heart rate variability
- RPE
  - Session Load = Duration x RPE (Foster et al. 2001, JSCR)
- Blood lactate
- EPOC

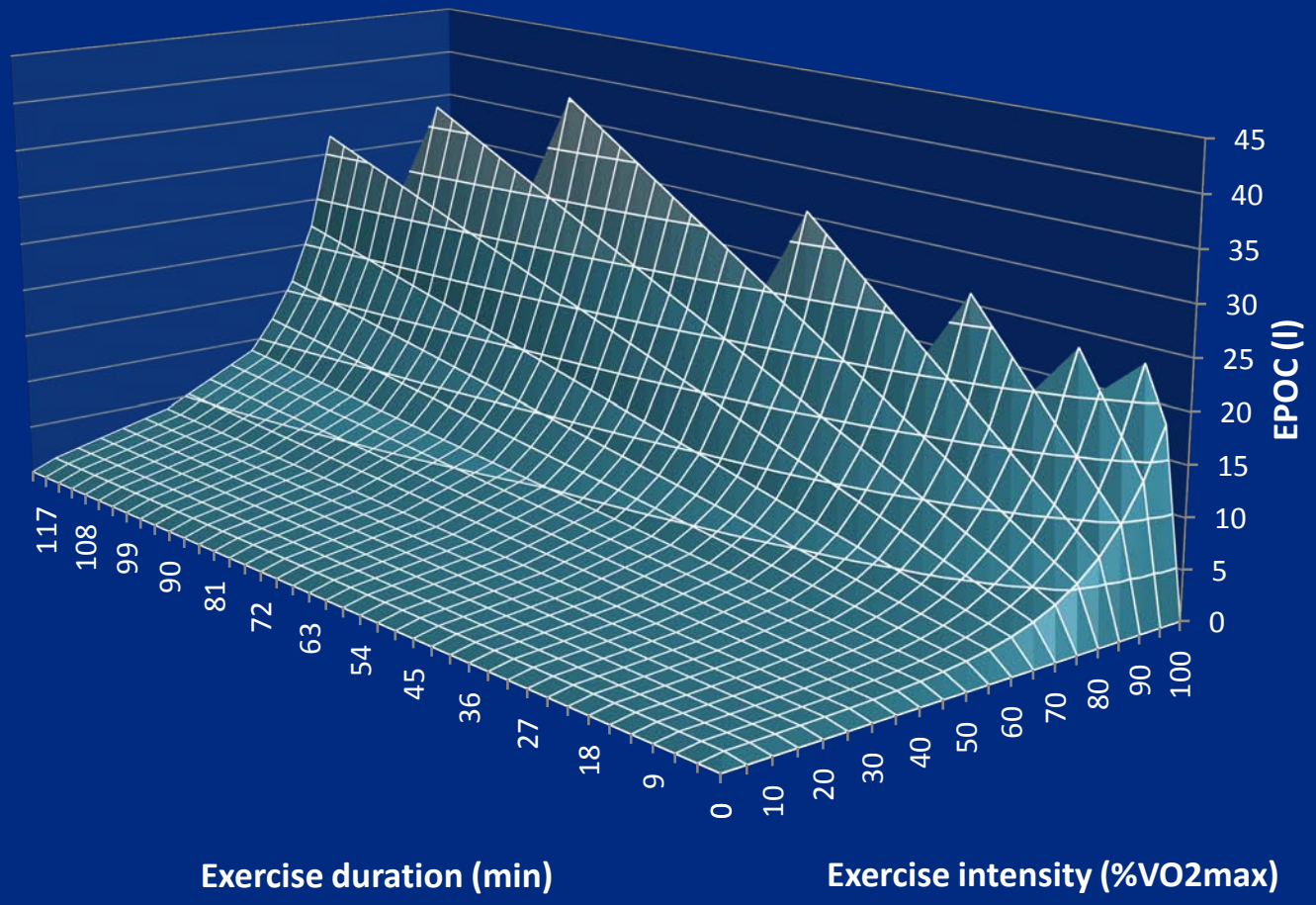
EPOC
Excess Post-exercise Oxygen Consumption



EPOC is defined as an increase in oxygen uptake above resting level after the exercise suggesting an increase in energy need

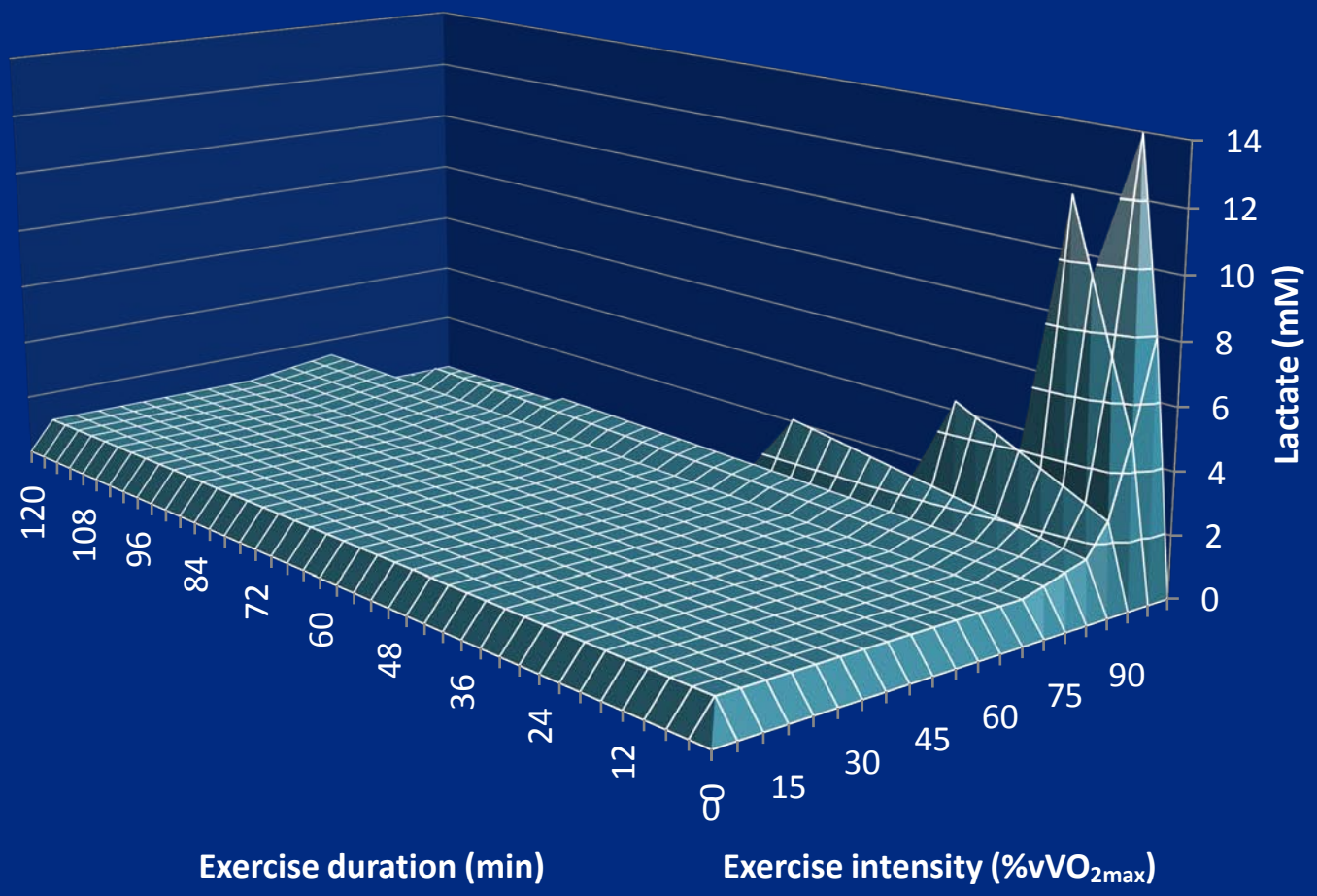
Effect of intensity and duration on EPOC

(adapted from Børsheim & Bahr 2003, Sports Med)



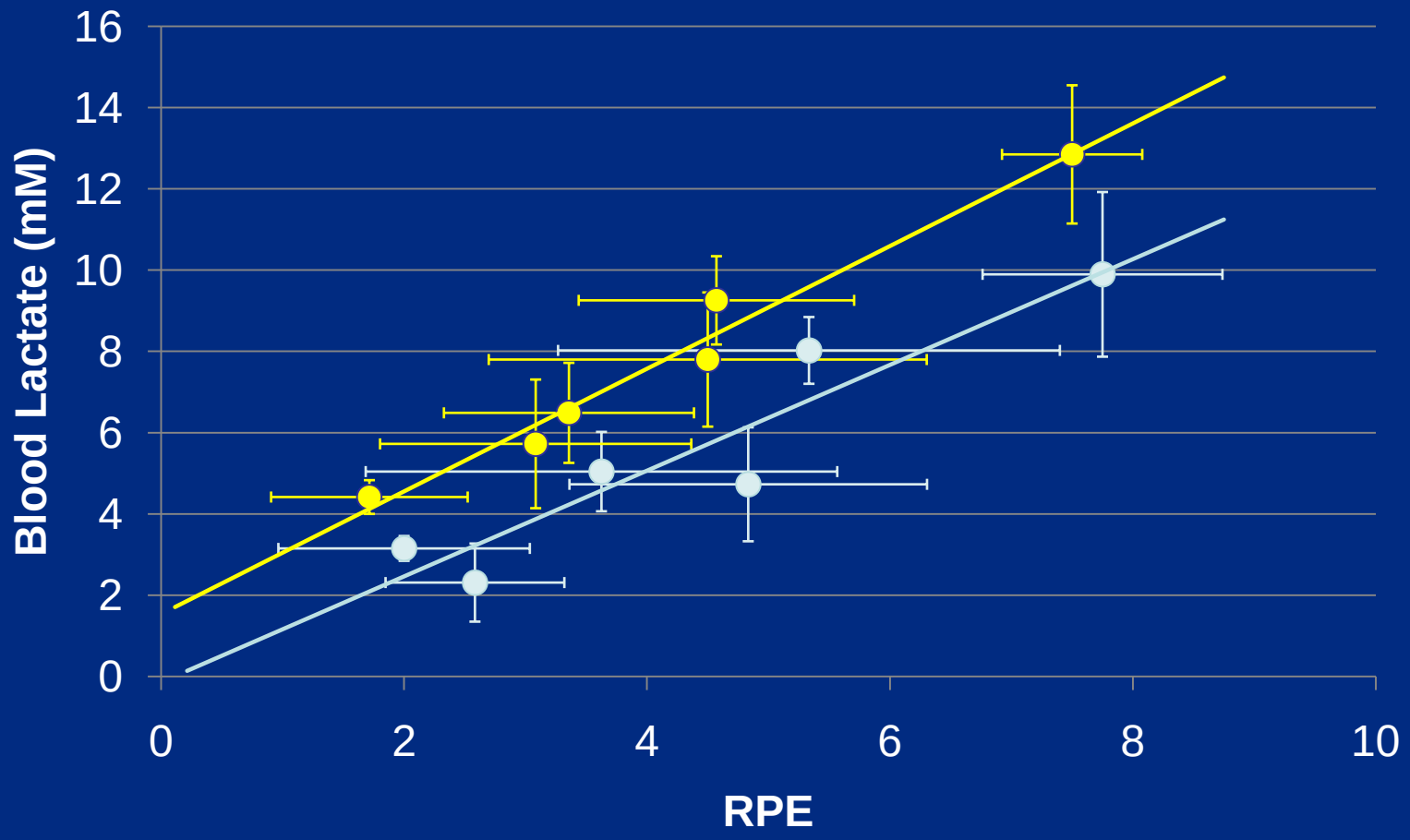
Highest EPOC values have been measured at intensity of 80% VO_{2max} and duration of 80 min in cyclists

Effect of intensity and duration on B-La



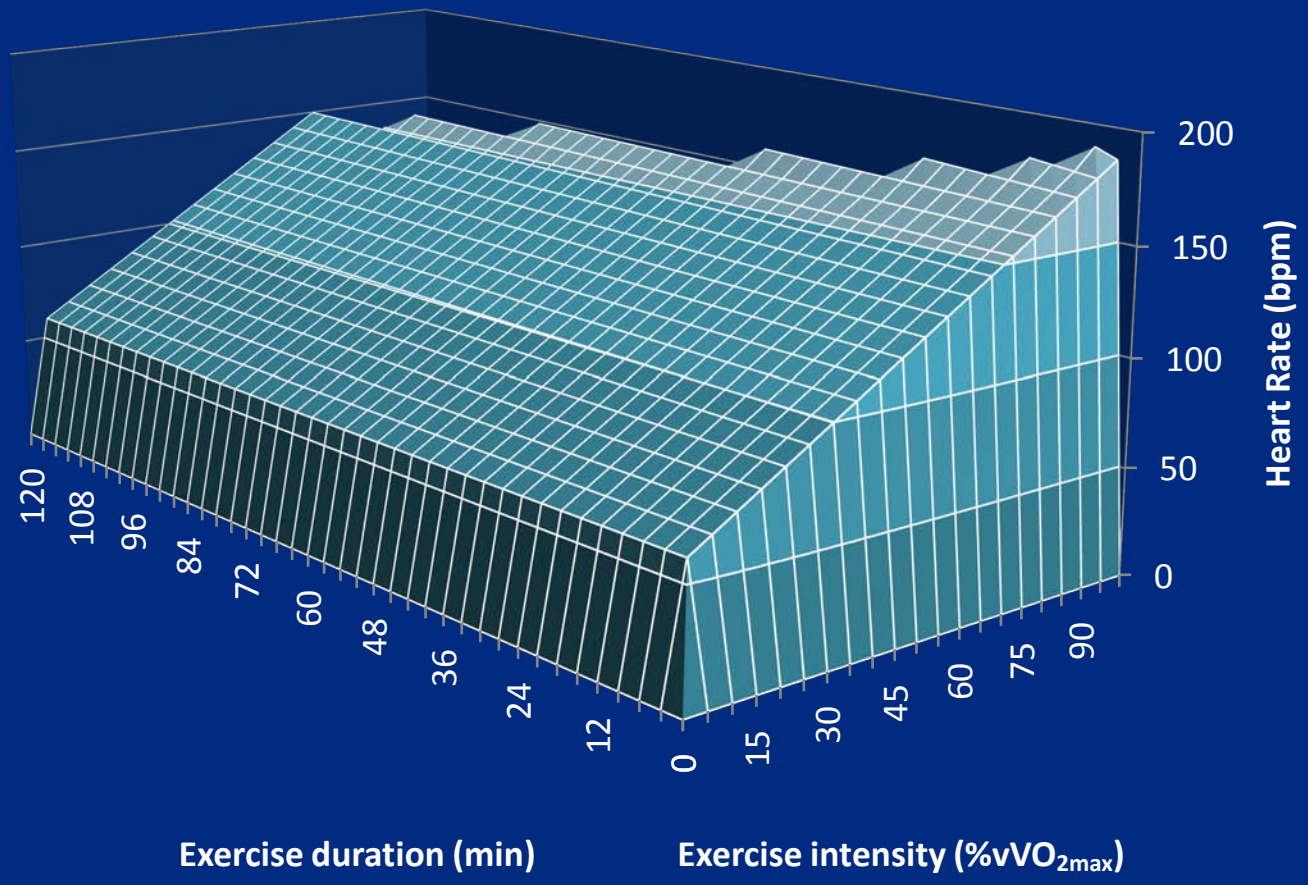
Highest B-La values have been measured after maximal exercises of durations of 2 – 5 min

Relationship between B-La and RPE after short sprints in sprint and distance runners

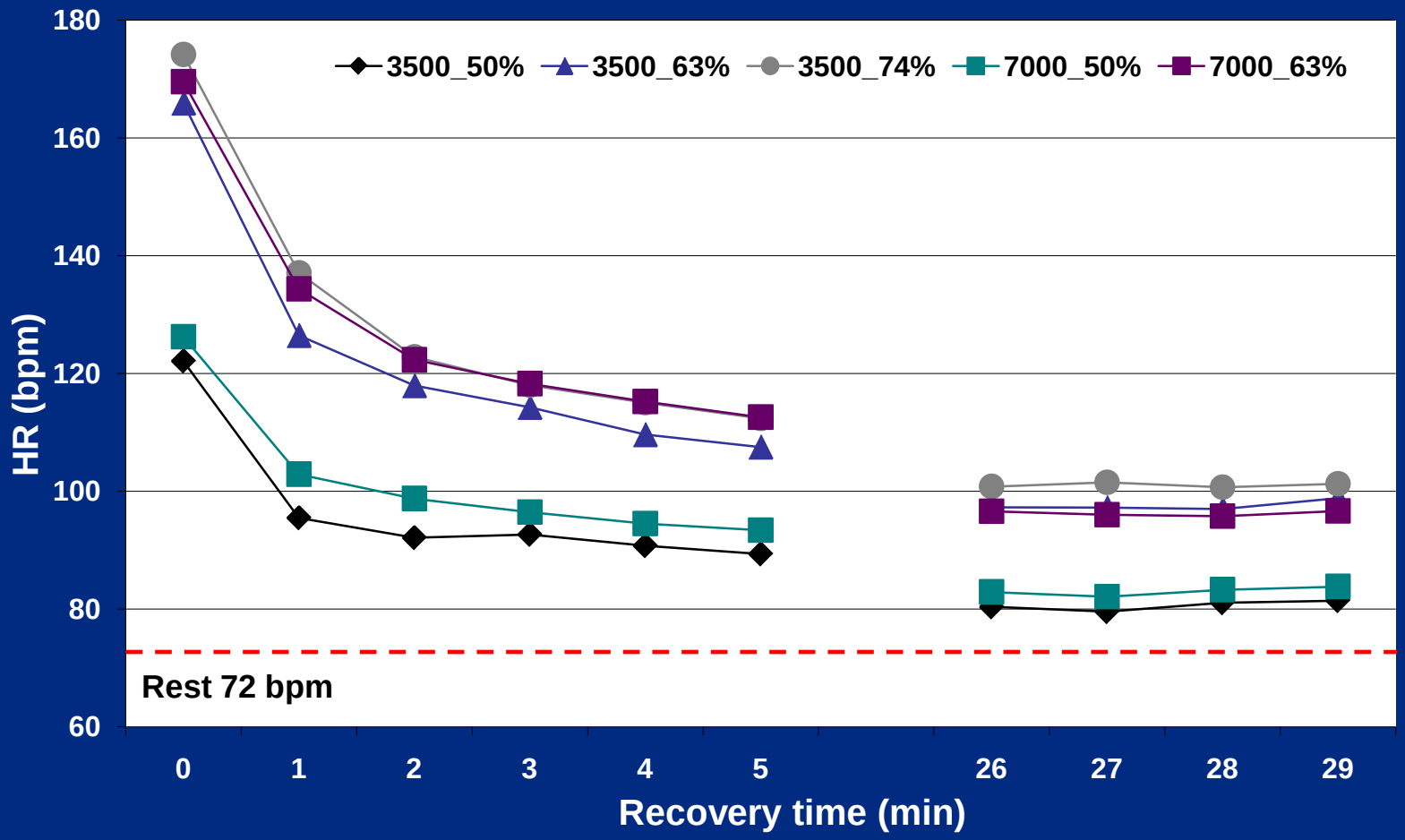


Nummela unpublished

Effect of intensity and duration on heart rate

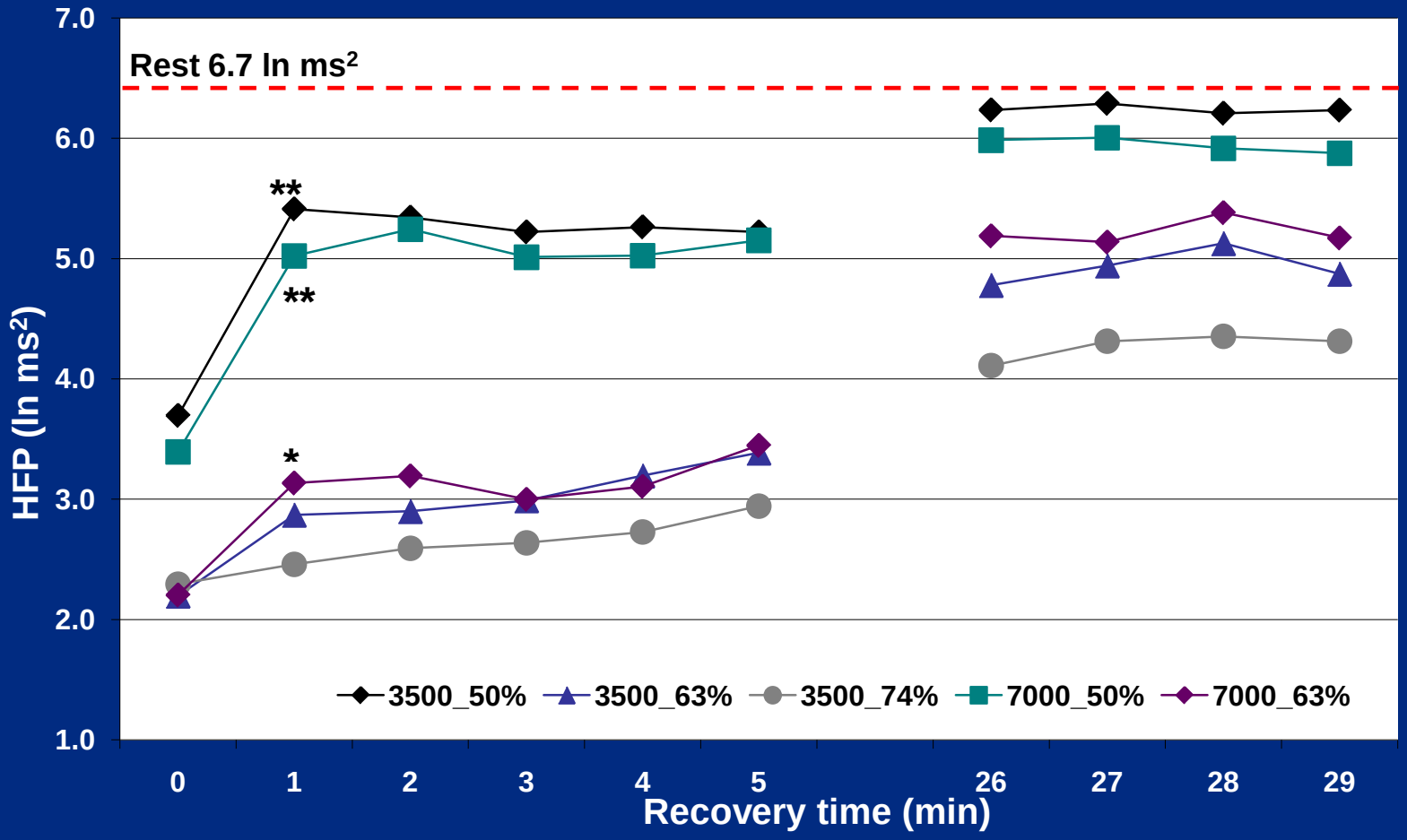


Effect of intensity and duration of exercise on HR recovery in untrained subjects



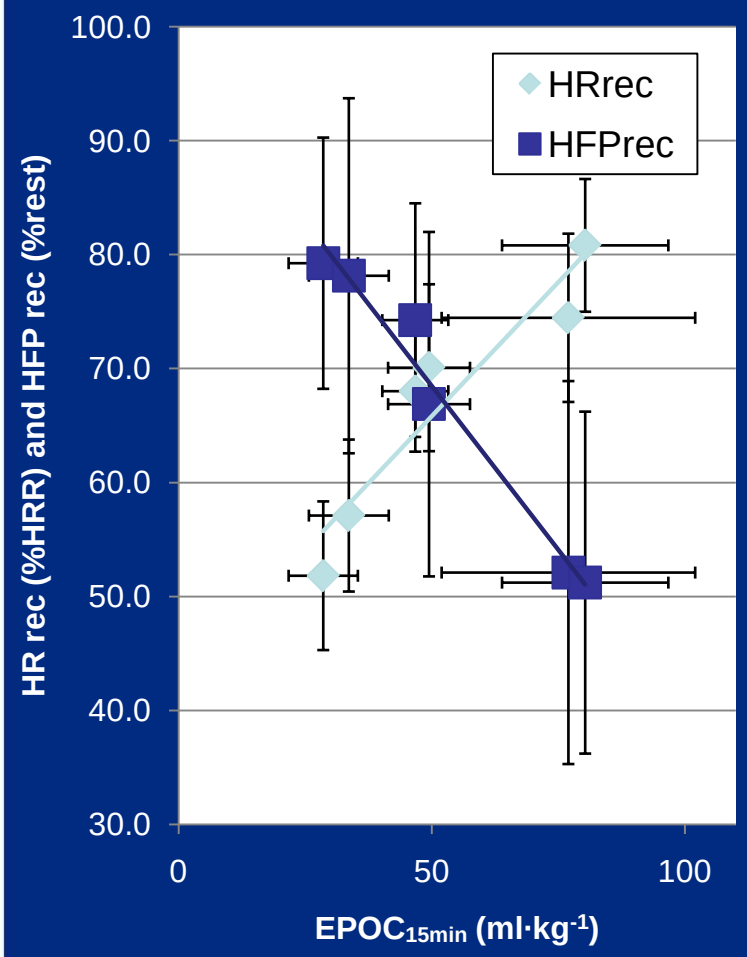
Kaikkonen et al. EJAP 2007

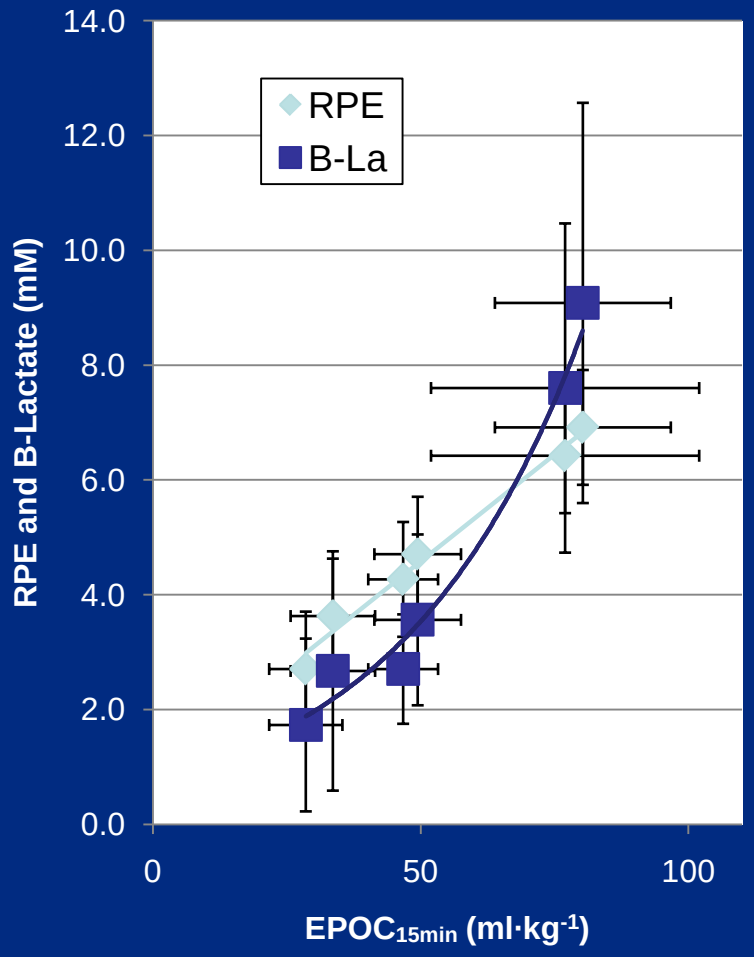
Effect of intensity and duration of exercise on HFP recovery in untrained subjects



Kaikkonen et al. EJAP 2007

Training load variables in six different exercises



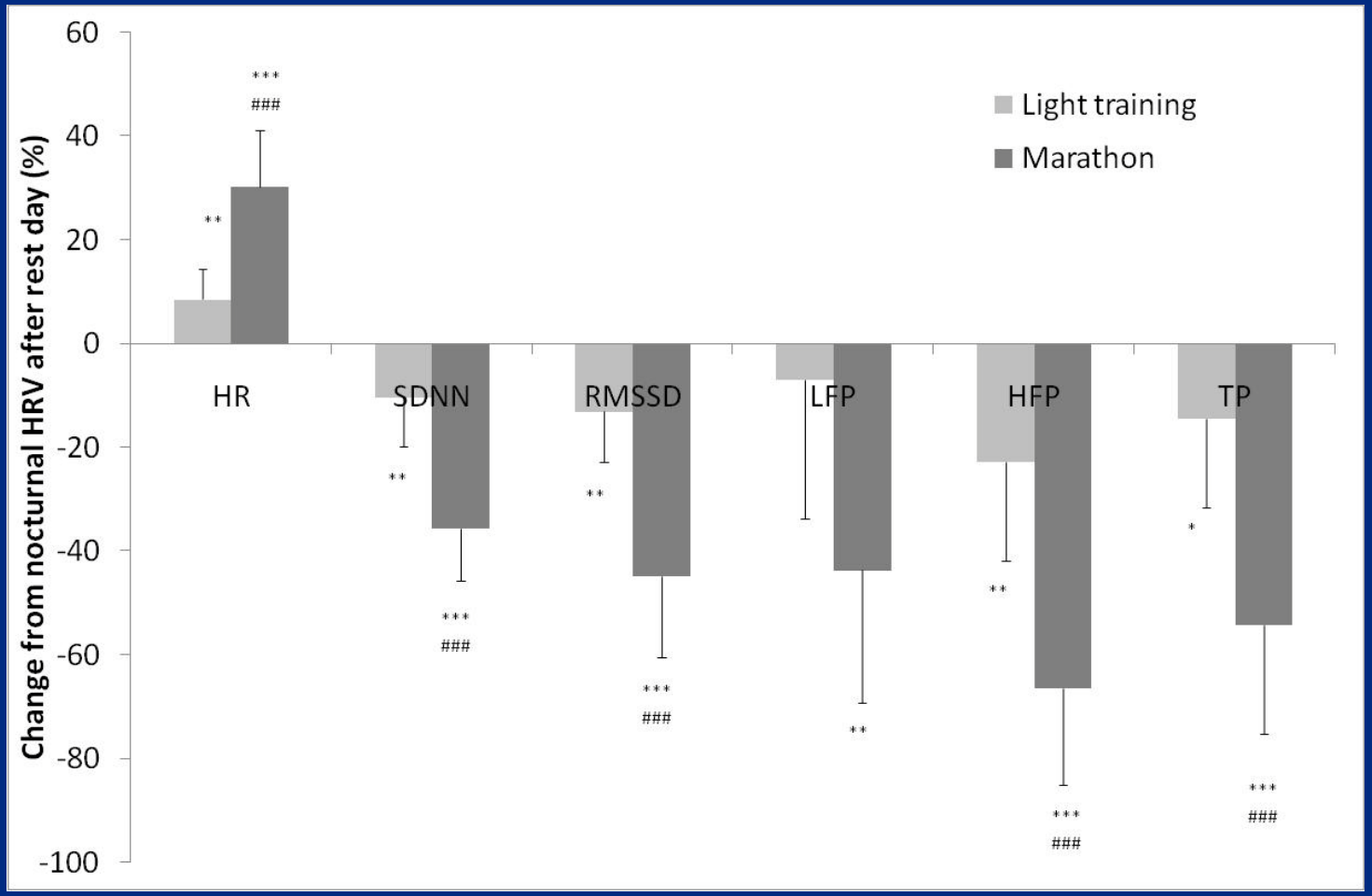


Exercises: 3km 60% - 14km 60% - 12x250m 85% - 6x500m 85% - 3km 85% - 12x250m 105%

How fatigue increases during training periods?

- Exercise tests
- The Profile of Mood States (POMS)
- Heart rate
  - Evaluation of autonomic nervous system: Orthostatic Test
  - Nocturnal heart rate variability
  - HR recovery after a standard submaximal exercise
- Haematological, biochemical and immunological measures

Effect of training load on nocturnal HRV



Hynynen et al. 2009

Nocturnal HRV and training load

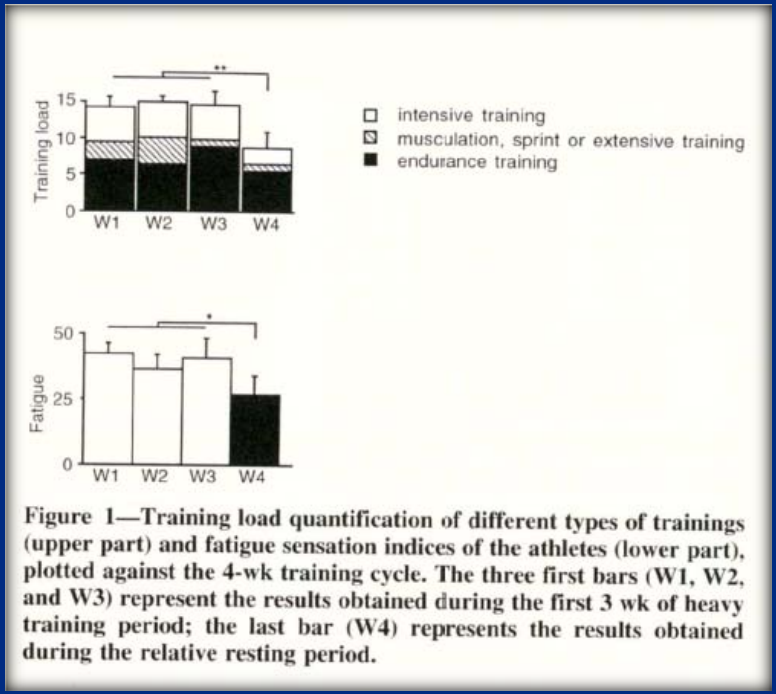


Figure 1—Training load quantification of different types of trainings (upper part) and fatigue sensation indices of the athletes (lower part), plotted against the 4-wk training cycle. The three first bars (W1, W2, and W3) represent the results obtained during the first 3 wk of heavy training period; the last bar (W4) represents the results obtained during the relative resting period.

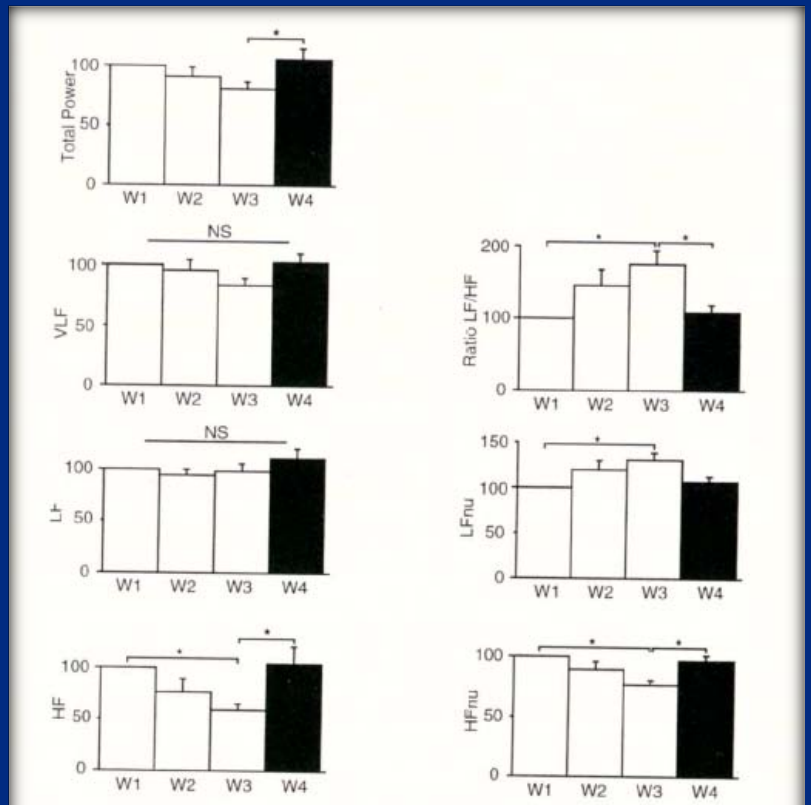


Figure 2—Relative indices of Fourier analysis of heart rate variability on the night periods during the 4-wk training cycle. The three first white bars (W1, W2, and W3) represent the results obtained during the first 3 wk of heavy training period; the black bar (W4) represents the results obtained during the relative resting period. Week 1 has been taken as the 100% reference value for each subject and each variable.

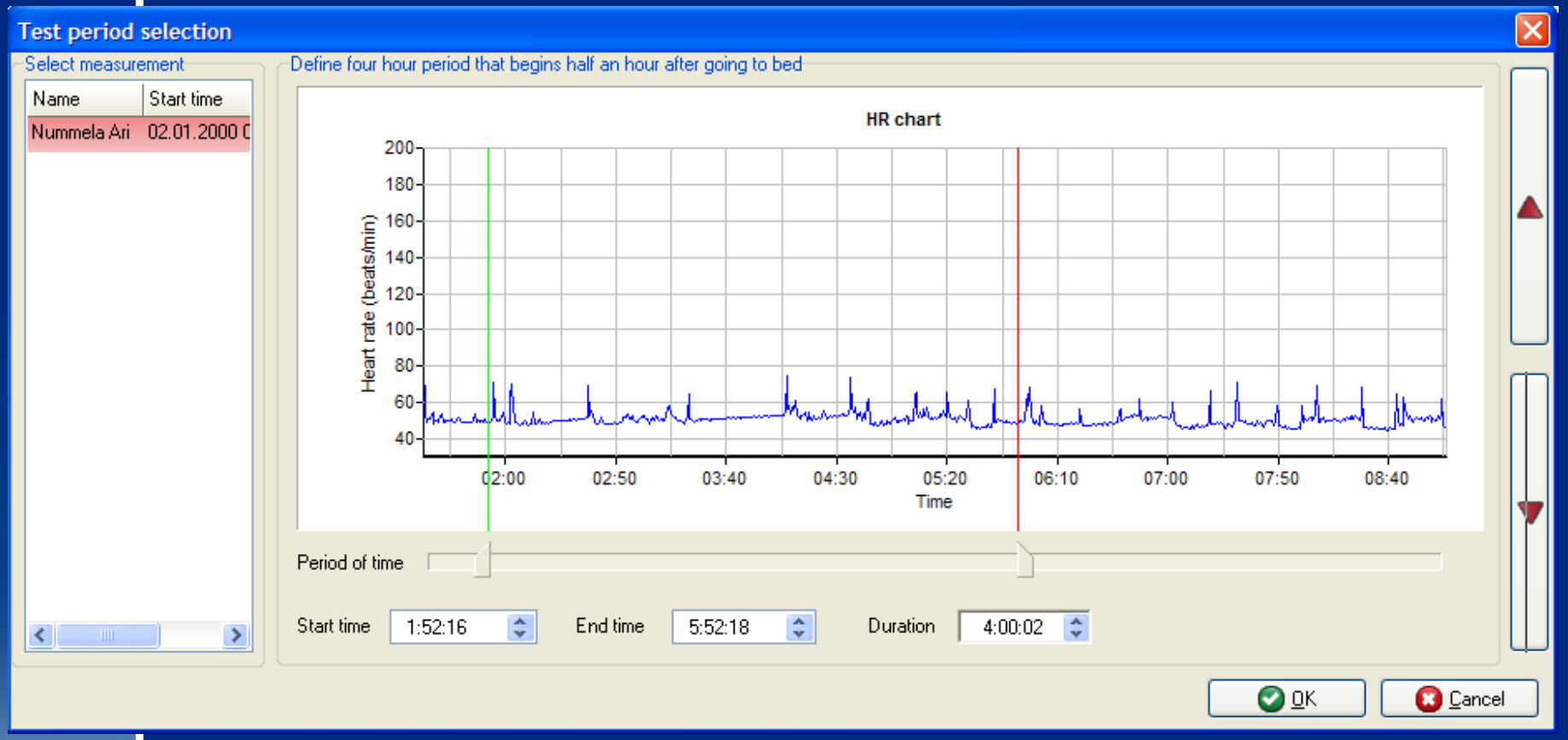
- 7 male middle distance runners
- 3 weeks of intensive training and one week of light training
- 6 – 10 training sessions / week

→ Increased nocturnal HR

→ Decreased nocturnal HRV

Pichot et al. MSSE 32: 1729-36, 2000

Nocturnal HRV analysis



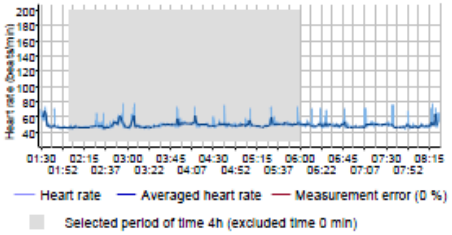
First 30 min of the collections are excluded and the following 4-hour section is analyzed

Recovery Report

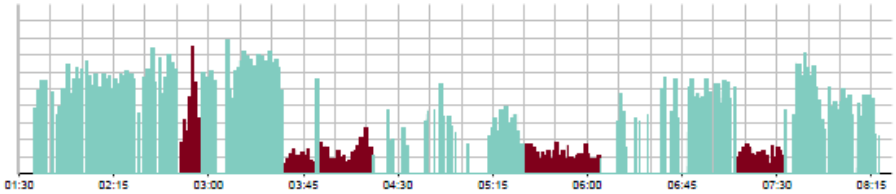
Person: Nummela Ari
Date: 22.9.2009

Background information		Measurement information	
Age	46	Measurement length	06:54:51
Height (cm)	176	Measurement time	1:29:19 - 8:24:10
Weight (kg)	74	Lowest heart rate	45
Resting heart rate	34	Highest heart rate	73
Maximum heart rate	185	Average heart rate	49

Notes



Stress and recovery chart



	Duration	Proportion
Stress	1h 21min	34 %
Recovery	1h 59min	50 %

Stress
Increased level of physiological activation that may be caused by intensive physical training or other life stressors.
Recovery
...ivation that may be caused by the absence of intensive physical training and absence of other

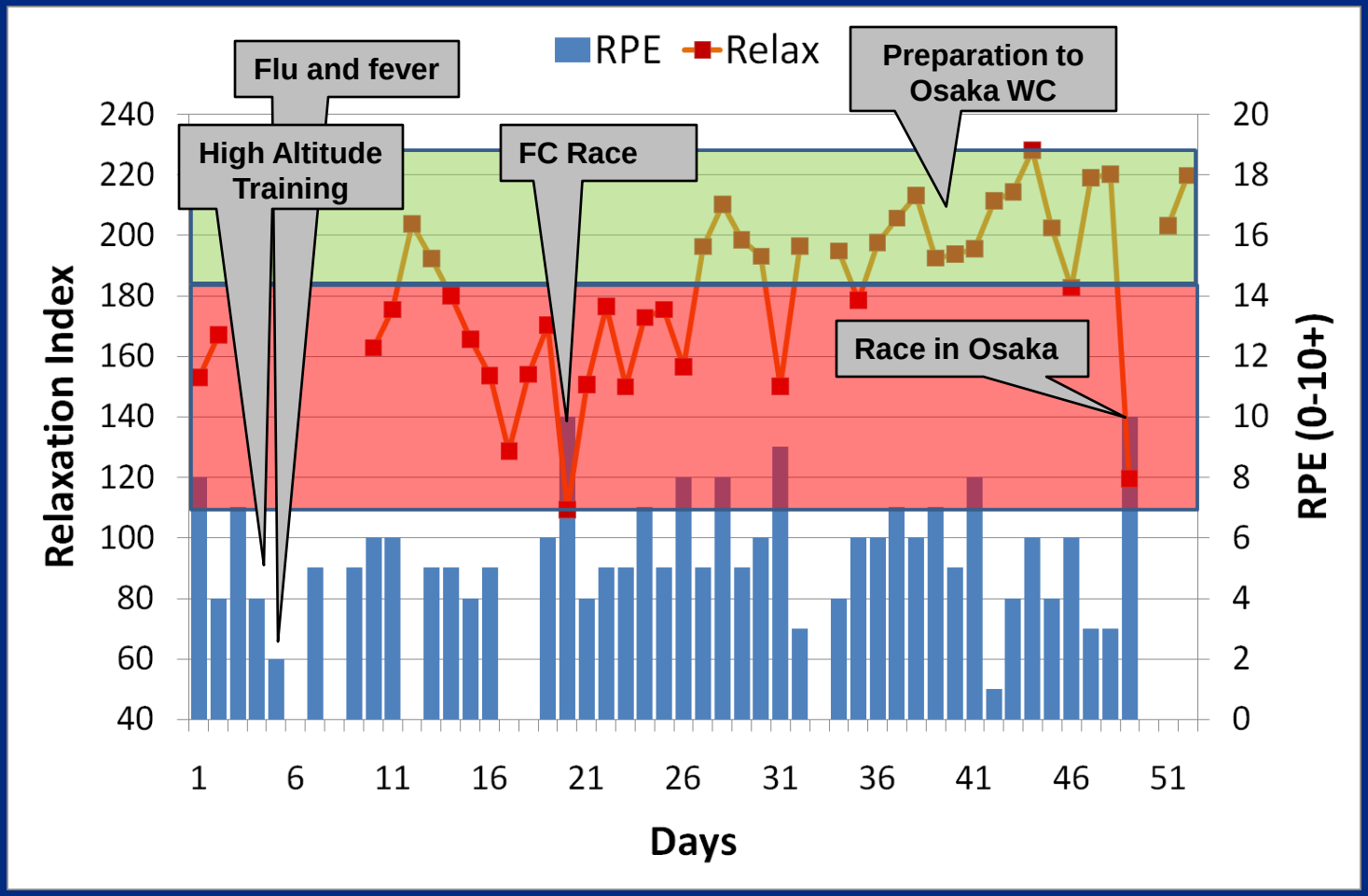
Recovery index: 99

Interpretation of results

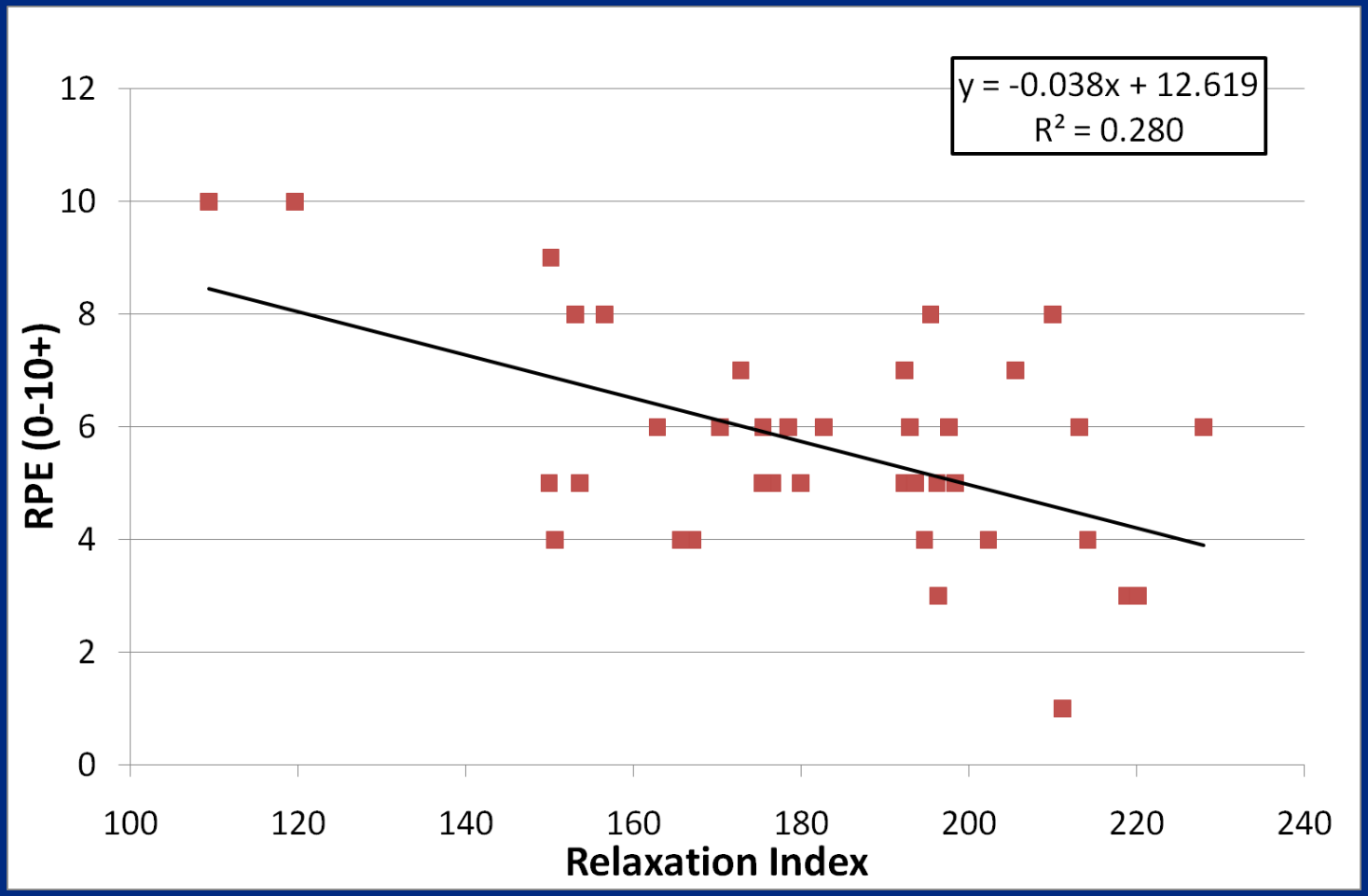
Recovery index is scaled individually based on person' s measurement history. It is recommended to measure the recovery status during both hard and easy training periods for detecting the individual range for the recovery index.

In the follow-up chart the index should vary according to the overall load of training: during hard training periods it should decrease and during recovery training periods it should increase close to the maximum before starting a new hard training period.

Nocturnal HRV example: endurance athlete



Nocturnal HRV example: endurance athlete



Endurance training guided individually by daily heart rate variability measurements
(Kiviniemi et al. 2007, EJAP)

- Three training groups:
  - Predefined training group (n = 8)
  - HRV-Guided training group (n = 9)
  - Control group (n = 9)
- Four week training period consisted of 40 min running sessions at either low- or high intensity level
- Predefined training group had two low and four high intensity training sessions / week
- HRV-Guided training group had individual training program based on changes in HFP

Endurance training guided individually by daily heart rate variability measurements

(Kiviniemi et al. 2007, EJAP)

	Predetermined training group	HRV-Guided training group
VO_{2max} (ml/kg/min)	54 → 55 ns	56 → 60**
vVO_{2max} (km/h)	15.1 → 15.7**	15.5 → 16.4***
VT (km/h)	11.8 → 12.1 ns	12.0 → 12.7*

It was concluded that cardiorespiratory fitness can be improved effectively by using HRV for daily training prescription.

HR recovery as a guide to monitor fatigue and predict changes in performance parameters

Lamberts et al. SJMSS, 2009

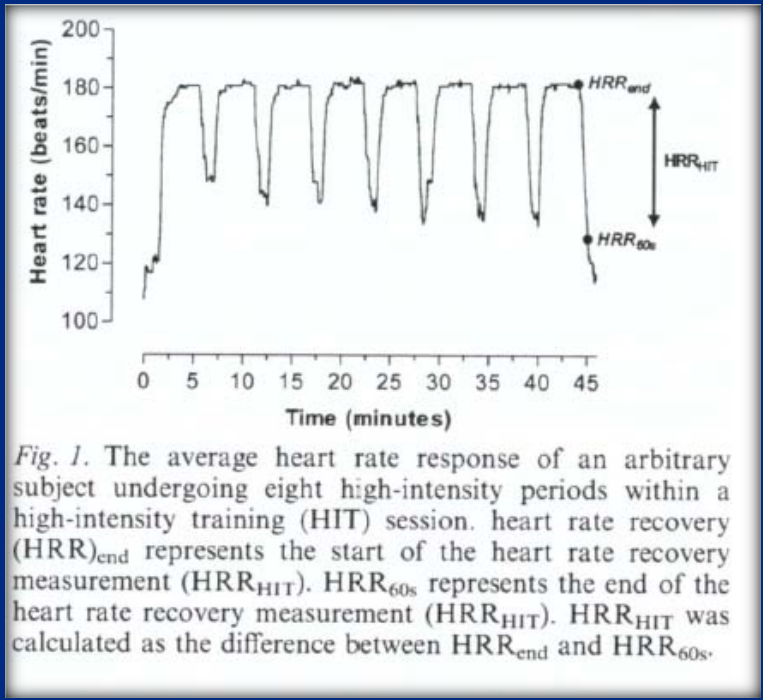


Fig. 1. The average heart rate response of an arbitrary subject undergoing eight high-intensity periods within a high-intensity training (HIT) session. heart rate recovery $(HRR)_{end}$ represents the start of the heart rate recovery measurement (HRR_{HIT}). HRR_{60s} represents the end of the heart rate recovery measurement (HRR_{HIT}). HRR_{HIT} was calculated as the difference between HRR_{end} and HRR_{60s}.

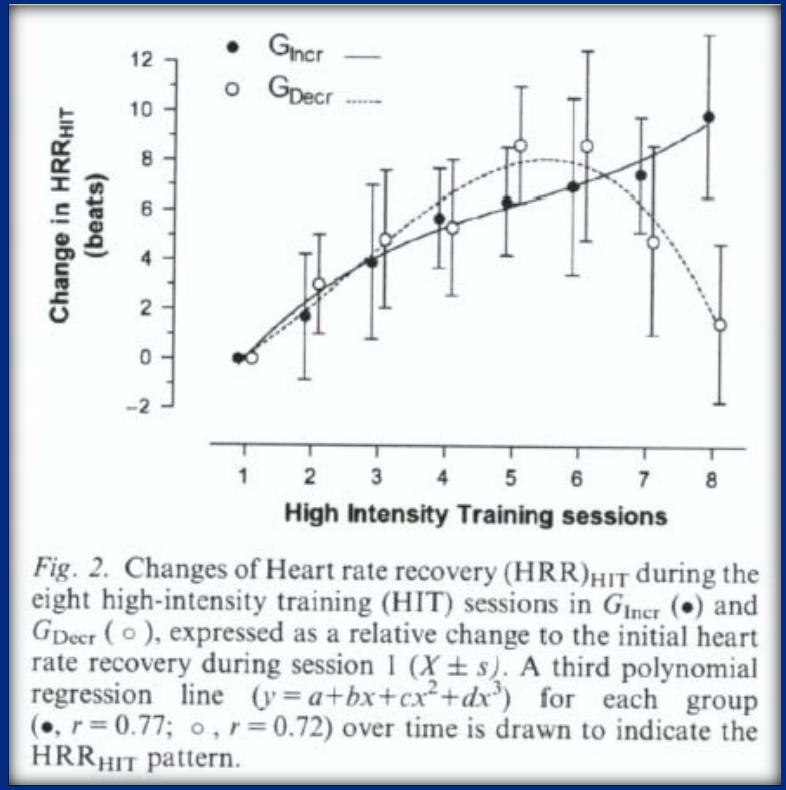


Fig. 2. Changes of Heart rate recovery $(HRR)_{HIT}$ during the eight high-intensity training (HIT) sessions in G_{Incr} (•) and G_{Decr} (○), expressed as a relative change to the initial heart rate recovery during session 1 ($X \pm s$). A third polynomial regression line ($y = a+bx+cx^2+dx^3$) for each group (•, $r = 0.77$; ○, $r = 0.72$) over time is drawn to indicate the HRR_{HIT} pattern.

- 14 well-trained cyclists completed a 4-week HIT period
- 8 HIT sessions included 8 x 4 min at 80% of peak power output with 90 s recovery
- G_{Incr} improved PPO 16 W and 40 km TT 111 s
- G_{Decr} no changes in PPO and 40 km TT was increased 53 s

Conclusions: Suggested measures for monitoring endurance training

- Training Load
  - Intensity of training
  - Duration of training
  - Training frequency
  - RPE
  - HR recovery
  - HRV recovery
  - Blood lactate in short-term exercises and interval training
- Stress & Training Effect
  - Perceived recovery
  - Nocturnal HR and HRV variables
  - HR and HRV recovery
  - Performance tests

Future directions

- Currently no single accurate quantitative methods to prescribe the training load and training effect
- A model for training load and training effect should be developed
- The search continues to find easily measurable physiological markers of training load and training effect
- More emphasis should be directed towards the measurement markers that reflect an individual differences in training response and adaptation
- Studying the individual fitness and fatigue curves may allow to the quantification of individual response and adaptation to training

Thank you for listening!