# Interval Training for Athletic Performance and the Role of Nutrition

8ο Συνέδριο Βιοχημείας & Φυσιολογίας της Άσκησης

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## Overall Message

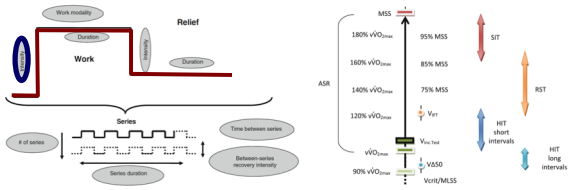
**Interval training is an infinitely variable form of exercise that elicits physiological adaptations linked to improved health and performance in a time-efficient manner.**

## Physiological Determinants of Performance

Bangsbo et al. Scand J Med Sci Sports 25 (Suppl. 4): 88-99, 2015.

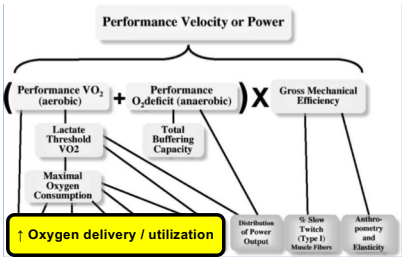
## Characterizing Interval Training

**Alternating periods of more intense effort and recovery in a single session**




Buchheit & Laursen, Sports Med 43:313–338, 2013.

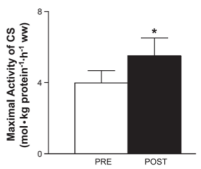
## Physiological Determinants of Performance




Joyner & Coyle. J Physiol 586: 35-44, 2008.

## Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans

**6 sessions of 4-7 x 30-s 'all out' cycle sprints with 4-min recovery over 2 wk**

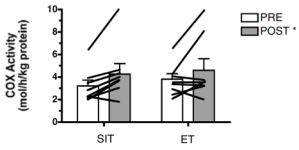



**"short sprint interval training (~15 min of intense exercise) doubled endurance capacity during intense aerobic cycling in recreationally active individuals."**

Burgomaster et al. J Appl Physiol 98: 1985-1990, 2005.

## Short-term sprint interval *versus* traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance

**6 sessions of 4-7 x 30-s 'all out' sprints or 90-120 min continuous moderate ex over 2 wk**




"intense interval training is a time-efficient strategy to induce rapid performance adaptations comparable to traditional endurance training (despite) a training volume for the SIT group was only ~10% that of the ET group."

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Gibala et al. J Physiol 575: 901-911, 2006.

## Optimizing Performance in Highly-Trained Individuals?

Roger Bannister breaking the world mile record and the four-minute barrier at Iffley Road Track in Oxford on 6 May 1954. Photograph: Getty Images

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www.theguardian.com/sport/2014/may/05/roger-bannister-sixty-years-four-minute-mile

## Adaptations to swimming training: influence of training volume

**Collegiate male swimmers maintained or doubled volume for 6 wk during a 25-wk period**

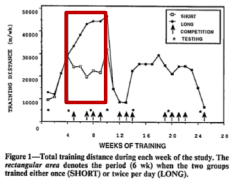


Figure 1—Total training distance during each week of the study. The *rectangular area* denotes the period (6 wk) when the two groups trained either once (SHORT) or twice per day (LONG).

"the additional training method imposed on the LONG group did not produce a greater improvement in performance…

"It is difficult to understand how training at speeds that are markedly slower than competitive pace for 3-4 h•d$^{-1}$ will prepare the swimmer for the supramaximal efforts of competition."

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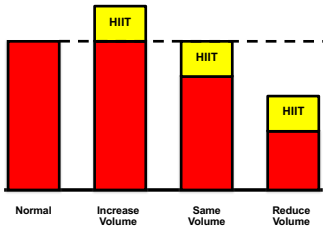
Costill et al. Med Sci Sports Exerc. 23: 371-377, 1991.

## Incorporating HIIT with "Regular" Training: Potential Strategies

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Lindsay et al. Med Sci Sports Exerc. 28: 1427-1434, 1996.

## Improved athletic performance in highly trained cyclists after interval training

**6 HIIT sessions over 4 wk (6-8 x 5 min @ 80% PPO)**


"a 4-wk program of HIT increased the PPO and fatigue resistance of competitive cyclists and improved their 40-km time-trial performance."


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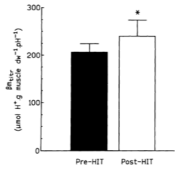
Lindsay et al. Med Sci Sports Exerc. 28: 1427-1434, 1996.

## Skeletal muscle buffering capacity and endurance performance after high-intensity interval training by well-trained cyclists

**6 HIIT sessions over 4 wk (6-8 x 5 min @ 80% PPO)**

| | $\dot{W}_{peak}$ (W) | $t_{T40}$ (min) | $t_{TF30}$ (s) |
|---|---|---|---|
| Pre-HIT | 417.5 (48.8) | 57.1 (4.4) | 59.3 (9.0) |
| Post-HIT | 432.3 (46.3) | 55.9 (4.2) | 72.5 (10.8) |
| | $P < 0.05$ | $P < 0.05$ | $P < 0.05$ |

| | CS | 3-HAD | PFK | HK |
|---|---|---|---|---|
| Pre-HIT | 162 (23) | 86 (7) | 304 (39) | 14.9 (4.2) |
| Post-HIT | 166 (23) | 88 (8) | 344 (64) | 16.6 (2.5) |
| | ns | ns | ns | ns |

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Weston et al. Eur J Appl Physiol. 75: 7-12, 1997.

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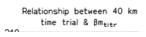
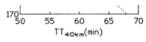



**"Oxidative muscle enzyme activities were not altered by the HIT regime (but) Bm was sensitive to sustained submaximal HIT in already well-trained cyclists and emerged as a significant predictor of high-intensity endurance performance."**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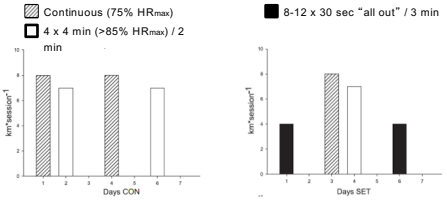
Reduced volume and increased training intensity elevate muscle $Na^+$-$K^+$ pump $\alpha_2$-subunit expression as well as short- and long-term work capacity in humans

**Trained runners added SIT and reduced volume by ~25% for ~2 months**

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Bangsbo et al. J Appl Physiol. 107: 1773-1780, 2009.

Reduced volume and increased training intensity elevate muscle $Na^+$-$K^+$ pump $\alpha_2$-subunit expression as well as short- and long-term work capacity in humans

**Trained runners added SIT and reduced volume by ~25% for ~2 months**


**"In already trained subjects, further muscle adaptations can occur and performance can be improved by adding speed endurance training (combined) with a reduction in training volume."**


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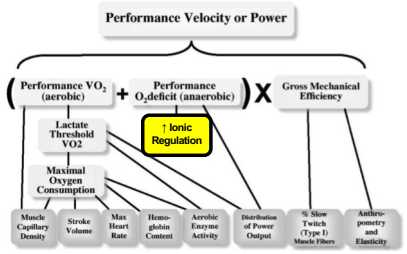
## Physiological Determinants of Performance

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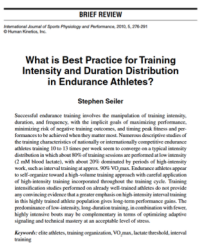
Joyner & Coyle. J Physiol 586: 35-44, 2008.

## Optimizing Performance: What Is the Right Mix?



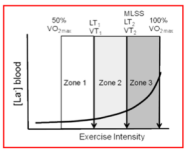
BRIEF REVIEW

What is Best Practice for Training Intensity and Duration Distribution in Endurance Athletes?

Stephen Seiler

Successful endurance training involves the manipulation of training intensity, duration, and frequency, with the implicit goals of maximizing performance, minimizing risk of negative training outcomes, and timing peak fitness and performances to be achieved when they matter most. Numerous descriptive studies of the training characteristics of nationally or internationally competitive endurance athletes training 10 to 13 times per week seem to converge on a typical intensity distribution in which about 80% of training sessions are performed at low intensity (2 mM blood lactate), with about 20% dominated by periods of high-intensity work, such as interval training at approx. 90% $VO_2$max. Endurance athletes appear to self-organize toward a high-volume training approach with careful application of high-intensity training incorporated throughout the training cycle. Training intensification studies performed on already well-trained athletes do not provide any convincing evidence that a greater emphasis on high-intensity interval training in this highly trained athlete population gives long-term performance gains. The predominance of low-intensity, long-duration training, in combination with fewer, highly intensive bouts may be complementary in terms of optimizing adaptive signaling and technical mastery at an acceptable level of stress.

*Keywords:* elite athletes, training organization, $VO_2$max, lactate threshold, interval training




**"HIT is a critical component in the training of all successful endurance athletes (and) an ~80-to-20 ratio of LIT to HIT gives excellent long-term results."**

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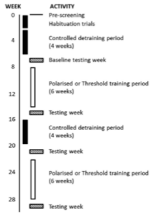
Seiler et al. Int J Sports Physiol Perform 5: 276-291, 2010.

Six weeks of a polarized training-intensity distribution leads to greater physiological and performance adaptations than a threshold model in trained cyclists




| | Units | POL | THR |
|---|---|---|---|
| Total training time | min/wk | 381 (±85) | 458 (±120)* |
| Training load | intensity zone × duration | 517 (±90) | 633 (±110)* |
| Zone 1 | % of training time | 80 (±4) | 57 (±10)* |
| Zone 2 | % of training time | 0 (±0) | 43 (±10)* |
| Zone 3 | % of training time | 20 (±4) | 0 (±0)* |

*Difference between POL and THR ($P < 0.05$).

**Polarized (POL):**
**6 x 4-min, Zone 3 intensity, 2-min rest**
**PO ≈ 330 W, HR ≈ 172 bpm, RPE ≈ 7-8**

**Threshold (THR):**
**60 min continuous, Zone 2 intensity**
**PO ≈ 275 W, HR ≈ 158 bpm, RPE ≈ 5-6**

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Neal et al. J Appl Physiol. 114: 461-471, 2013.

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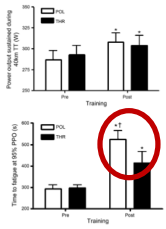


"A polarized training model is recommended for trained cyclists wishing to maximally improve performance."

"There is, however, much still to be understood regarding the impact (of) different training-intensity distributions in endurance athletes."

Neal et al. J Appl Physiol. 114: 461-471, 2013.

## Adaptations to aerobic interval training: interactive effects of exercise intensity and total work duration

Trained cyclists (~52 ml/kg/min) performed 7 wk of continuous low-moderate training or incorporated 1 of 3 interval protocols matched for *maximal overall effort* (n=9)

| INT Group | %HRpeak | Blood La | RPE |
|---|---|---|---|
| 4 x 16-min | 88 ± 2 | 5 ± 2 | 15 ± 1 |
| 4 x 8-min | 90 ± 2 | 10 ± 3 | 16 ± 1 |
| 4 x 4 min | 94 ± 2 | 13 ± 2 | 19 ± 1 |

Seiler et al. Scand J Med Sci Sports 23: 74-83, 2013.

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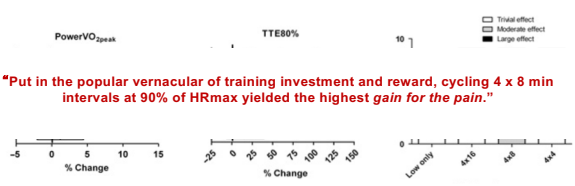
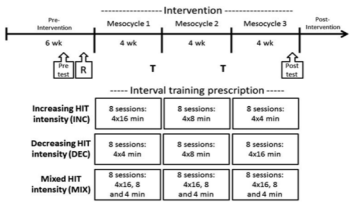



"Put in the popular vernacular of training investment and reward, cycling 4 x 8 min intervals at 90% of HRmax yielded the highest *gain for the pain*."

Seiler et al. Scand J Med Sci Sports 23: 74-83, 2013.

## The Effect of Different High-Intensity Periodization Models on Endurance Adaptations

Trained cyclists (~60 ml/kg/min) assigned to 1 of 3 matched-load INT protocols (n=20 each)




Sylta et al. Med Sci Sports Exerc 48: 2165-2174, 2016.

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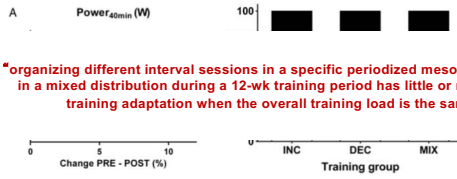



"organizing different interval sessions in a specific periodized mesocycle order or in a mixed distribution during a 12-wk training period has little or no effect on training adaptation when the overall training load is the same."

Sylta et al. Med Sci Sports Exerc 48: 2165-2174, 2016.

Scand J Med Sci Sports 2010: 20 (Suppl. 2): ii–iv
doi: 10.1111/j.1600-0838.2010.01183.x

SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

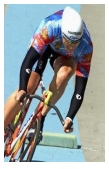
## Editorial

### Performance in Top Sports Involving Intense Exercise

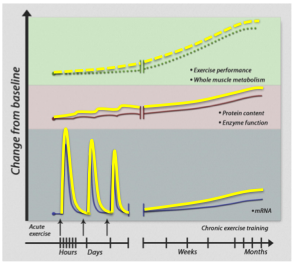
"Evidence-based recommendations are limited because most of the scientific studies have been performed on sub-elite athletes."

### Consensus statements

"When long-duration low-intensity training is periodically supplemented with or partly replaced by high-intensity interval training, physiological and performance adaptations are enhanced in highly trained athletes."



## Nutrition Manipulation of Exercise Adaptation: Theoretical Basis

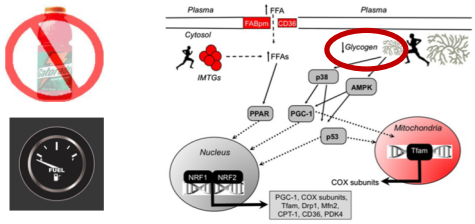



Egan & Zierath, Cell Metab 17: 162-184, 2013.

## Nutrition Manipulation of Exercise Adaptation: Theoretical Basis

- Intervention augments power output during exercise and enhances the training stimulus
- Intervention alters substrate utilization during exercise and enhances metabolic stress
- Is the surplus or lack of substrate the 'trigger'?


## Nutrition Manipulation of Exercise Adaptation: Reduced Carbohydrate Availability




Hawley & Morton, Clin Exper Pharm Physiol 41: 608-613, 2014.

## Exercise with low glycogen increases PGC-1α gene expression in human skeletal muscle

**Trained cyclists performed acute intermittent exercise with normal or low glycogen (n=10)**


**"exercise with low glycogen levels amplifies the expression of the major genetic marker for mitochondrial biogenesis in highly trained cyclists (and) may be beneficial for improving muscle oxidative capacity."**

exercise exercise exercise

Psilander et al. Eur J Appl Physiol. 113: 951-963, 2013.

## Skeletal muscle adaptation and performance responses to once a day versus twice every second day endurance training regimens

**Trained cyclists performed single sessions daily or two sessions every other day for 3 wk**

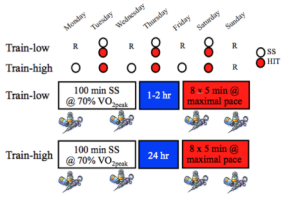




Photo courtesy Dr. M. Hargreaves

Yeo et al. J Appl Physiol 105: 1462–1470, 2008.

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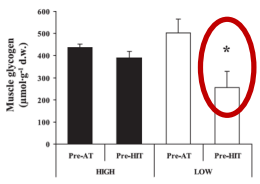



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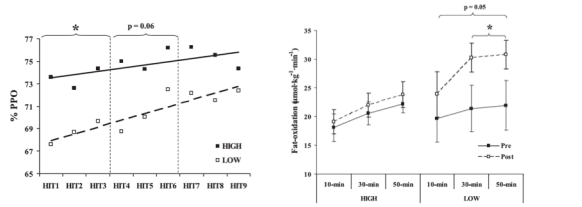


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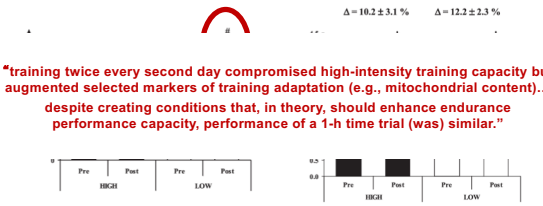
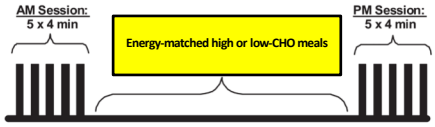



**"training twice every second day compromised high-intensity training capacity but augmented selected markers of training adaptation (e.g., mitochondrial content)… despite creating conditions that, in theory, should enhance endurance performance capacity, performance of a 1-h time trial (was) similar."**

Yeo et al. J Appl Physiol 105: 1462–1470, 2008.

Manipulating Carbohydrate Availability Between Twice-Daily Sessions of High-Intensity Interval Training Over 2 Weeks Improves Time-Trial Performance

**Active but not highly trained subjects performed 6 twice-daily HIIT sessions over 2 wk**




Cochran et al. IJSNEM 25: 463-470, 2015.

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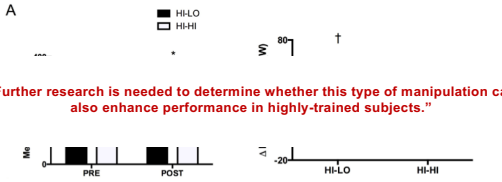


**"Further research is needed to determine whether this type of manipulation can also enhance performance in highly-trained subjects."**

Cochran et al. IJSNEM 25: 463-470, 2015.

CURRENT OPINION

**Fuel for the Work Required: A Theoretical Framework for Carbohydrate Periodization and the Glycogen Threshold Hypothesis**

- **Should train-low sessions always be left to low intensity-type sessions or is it the deliberate completion of a high-intensity session (even at the expense of a potential reduction in absolute workload) that is really required to create the metabolic milieu that is conducive to signalling?**
- **What is the minimal CHO intake and glycogen concentration required to facilitate periods of 'train low' without compromising absolute training intensity during specific sessions?**

Impey et al. Sports Med. 48: 1031-1048, 2018.

## Take Home Point

**Interval training enhances performance in highly-trained individuals although the mechanisms are likely different compared to less-trained individuals; nutritional interventions (e.g, manipulating carbohydrate availability) can alter acute exercise responses and selected markers of training adaptation but the impact on performance is less clear and depends on numerous variables.**