ENERGY SYSTEM INTERACTION IN TEAM-SPORT ATHLETES

An examination of VO_2peak, O_2 kinetics, and their advocacy for a new general preparation model

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A CALL FOR CHANGE

- How we think about and talk about energy metabolism is wrong
  - Too often we think of team-sport athletes as "anaerobic" athletes
  - Could not be further from the truth!
    - The On/Off Chart
    - System runs out of...
    - Lactic/Alactic or Aerobic/ Anaerobic
- Team-sport requires a blend of metabolic training to maximize performance
- Team-sport metabolism = Repeated Sprint Ability (RSA)
  - System is built around aerobic capacity

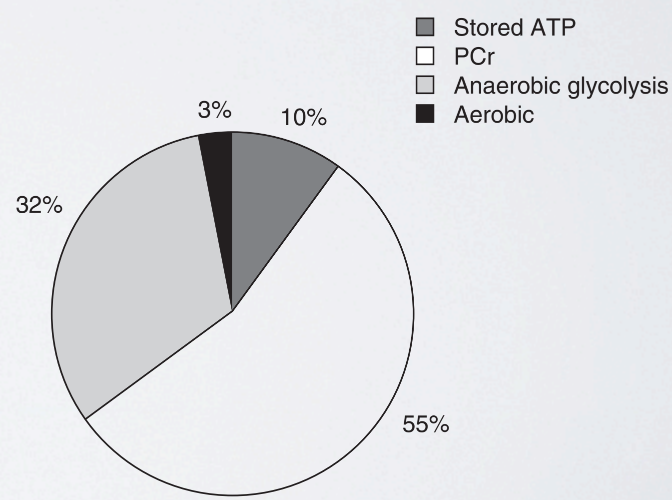
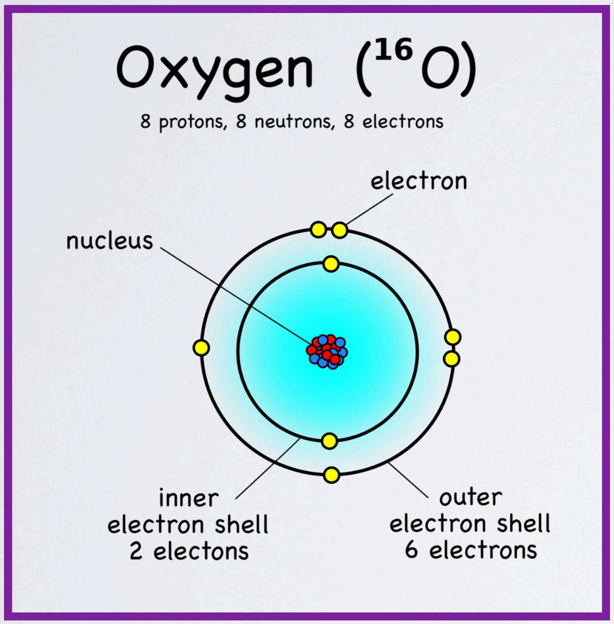


Fig. 2. Estimated energy system contribution of a 3-second sprint.[24,29,30,33,34] **ATP** = adenosine triphosphate; **PCr** = phosphocreatine.

REPEATED SPRINT ABILITY

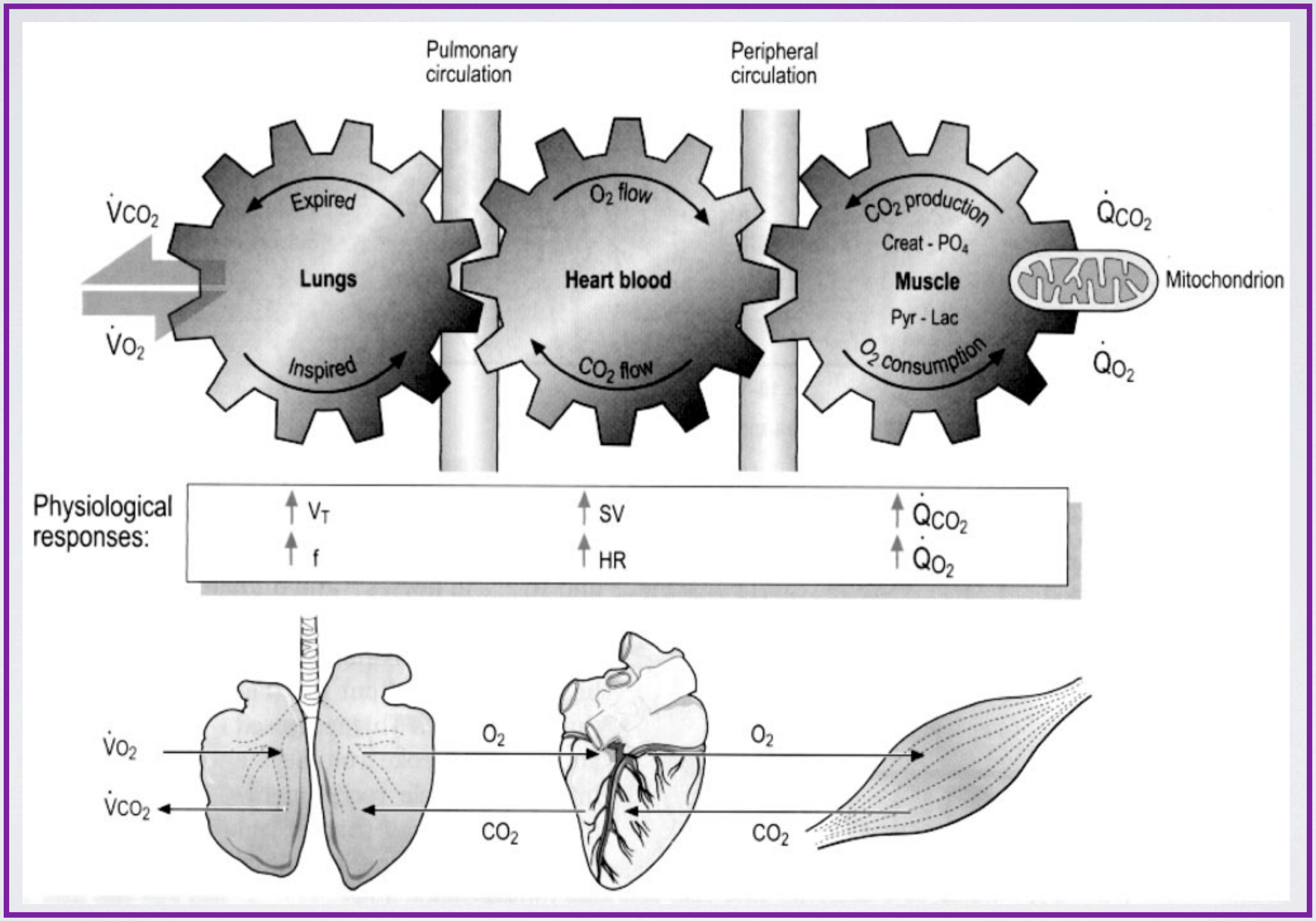


Aerobic Metabolism Effect on RSA:

- Increase aerobic energy contribution during maximal sprint bouts
  - Total blood flow to muscle
    - Heart
    - Lungs
  - Oxygen uptake (VO_2) kinetics
    - O_2 extraction from arterial blood
- Increase fast phase of PCr resynthesis
- Enhance the clearance rate of metabolite (H^+; P_i); Speed recovery between work bouts
  - Slow Phase PCr
  - Glycogenolysis

McMahon & Jenkins, 2002; Spencer & Katz, 1991; Dupont et al., 2005; Gastin, 2010; Bishop & Edge, 2006; Tomlin & Wenger, 2006; Westerblad et al., 2006

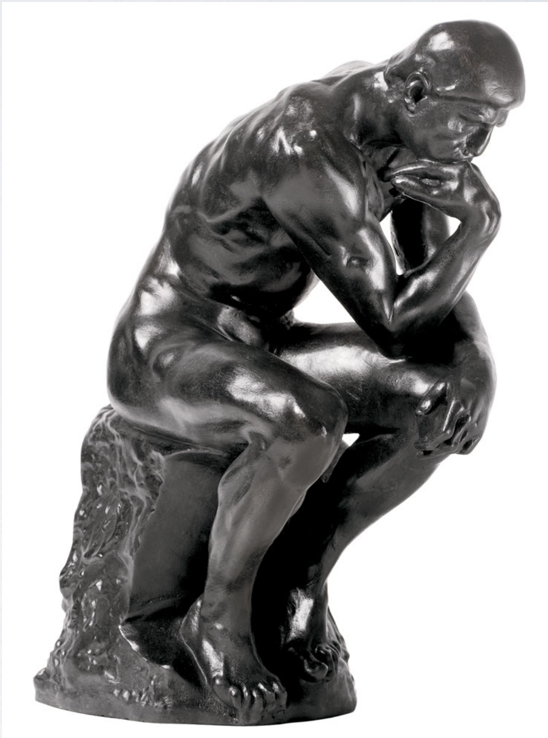
REPEATED SPRINT ABILITY



Jones et al. (2005)

CONTROVERSY AROUND VO_2PEAK / RSA RELATIONSHIP

- Despite all this evidence - all these connections inferring a tightly regulate, dynamic, integrated system - controversy remained
- VO_2peak has been shown to correlate with RSA, ranging from $r = -0.50$ to -0.83
  - *McMahon & Jenkins, 2002; Spencer & Katz, 1991; Dupont et al., 2005; Gastin, 2010; Bishop & Edge, 2006; Tomlin & Wenger, 2006; Westerblad et al., 2006*
- Researchers have found non-significant correlations ($-0.35 < r < -0.46$)
  - *Aziz, Chia & Teh, 2000; Bishop & Spencer, 2004; Wadley & LeRossignol, 1998; Carey et al., 2007*



Is there, or isn't there?

CONTROVERSY AROUND VO_2PEAK / RSA RELATIONSHIP

Deficiencies of Current Research:

- Repeated Sprint Ability: Short duration sprints (<10 seconds), interspersed with short (<60 seconds) passive or active recovery periods
- Wide range of testing parameters, all claiming to evaluate RSA performance
    - 2x30sec bike sprint with 4min recovery
    - 6x4sec sprint with 2min recovery (football)
    - 5x5sec sprint with 30sec recovery (rugby)
    - 12x20m sprint with 20sec recovery (soccer)
- Studies try to write one prescription; lack defining sport-specific work-to-rest ratio

Girard, Mendez-Villanueva, & Bishop, 2011; Glaister, 2008

CONTROVERSY AROUND RELATIONSHIP

Deficiencies of Current Research (con't):

- Testing-modalities are significantly different:
  - Example: Hockey Players
    - *Bike:* 43.6 ± 0.7 mL/kg *vs On-Ice:* 46.9 ± 1.0 mL/kg*
    - *Treadmill Run:* 66.9 ± 4.9 mL/kg
      Continuous Skating Treadmill: 62.86 ± 7.8 mL/kg
      Discontinuous Skating Treadmill: 60.8 ± 6.3 mL/kg*
- Current testing protocols only employ straight ahead running
- Small Sample Size (n < 15)

Durocher et al., 2010; Koepp & Janot, 2008: Reilly, 1997

U OF M STUDY

Study eliminated shortfalls of the current research in three ways:

1) Recruited a more complete sample of the population

2) Account for task-specificity by obtaining players' VO_2peak on a skating treadmill using a graded exercise test

3) Evaluate RSA using an on-ice test, developed to mimic the motor patterns typically performed by hockey players during competition using ecologically significant parameters

Hypothesis:
Players with a higher aerobic capacity (VO_2peak) will exhibit less fatigue during an on-ice repeated shift test than those with lower levels.

U OF M STUDY

Methods:

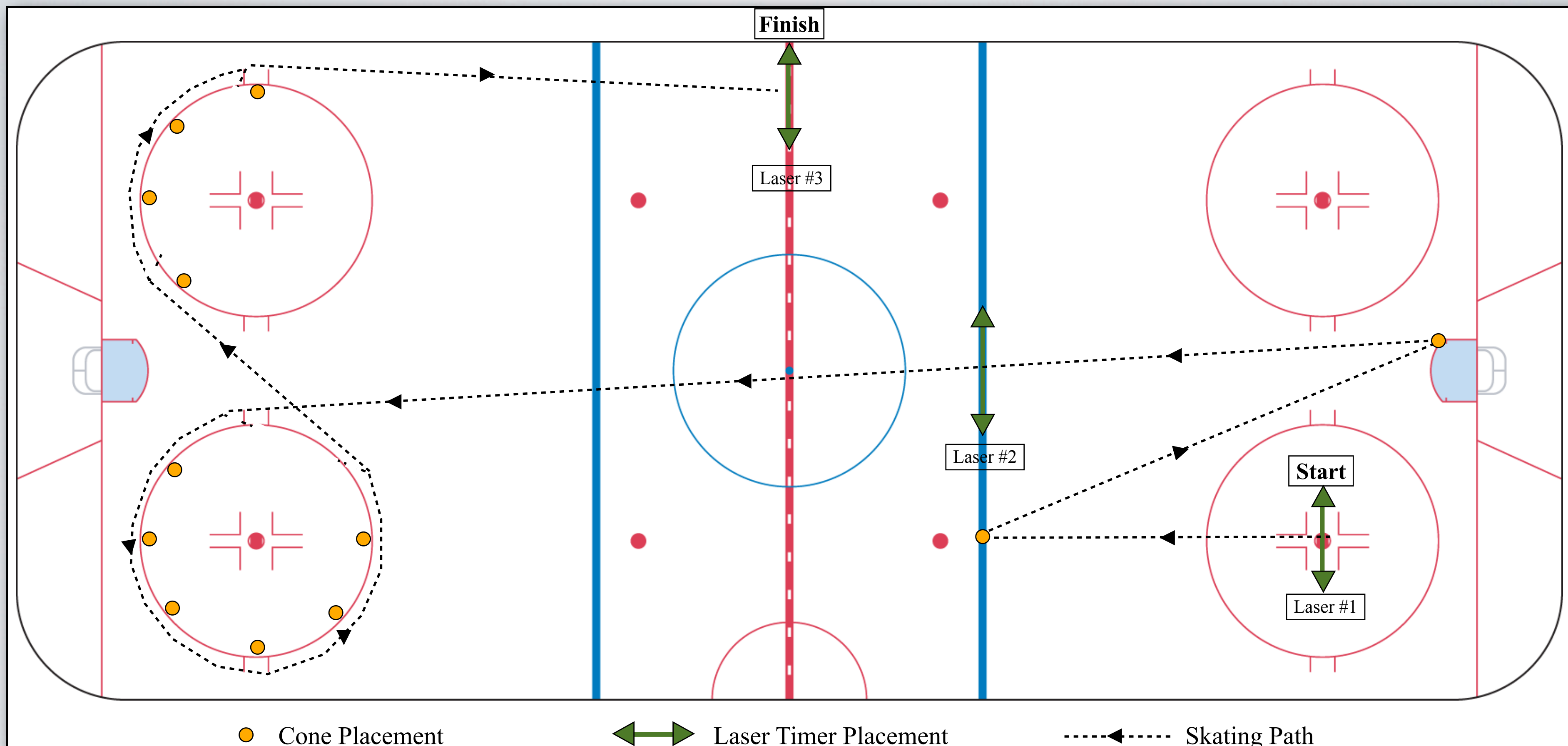
- 46 male college aged (18-24 years) hockey players
- Each participant completed:
  - Hydrostatic Weighing
  - Graded exercise test on a skate treadmill (VO_2peak)
  - The Peterson on-ice repeated shift test

Measures:

- Body Composition
- Aerobic Capacity (VO_2peak)
- Fatigue (% decrement score)

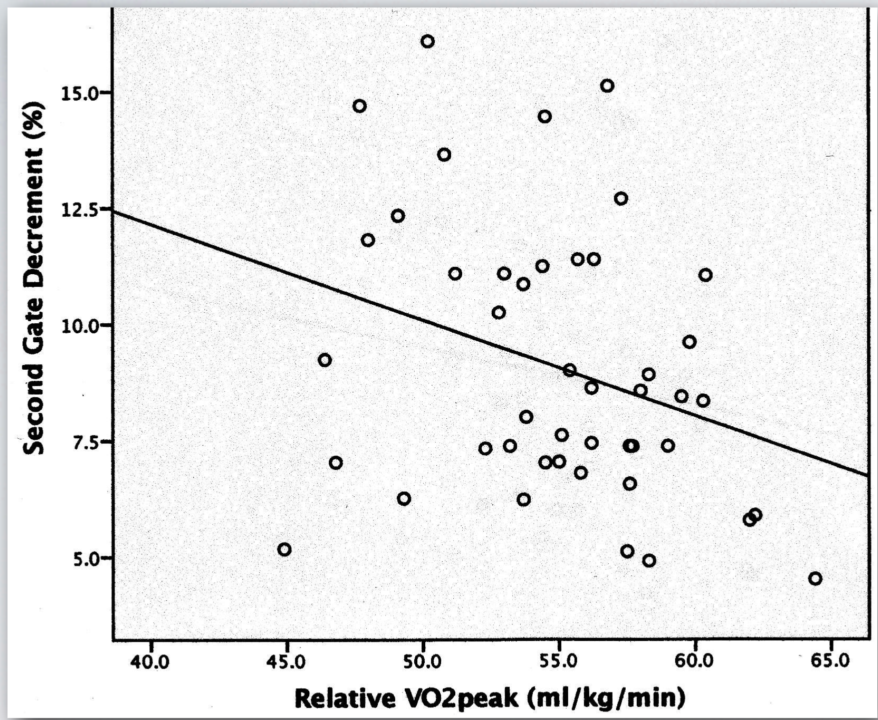
% dec = (100 x (Total sprint time ÷ Ideal Sprint Time)) - 100
*Total Sprint Time = Sum of sprint times from all trials
**Ideal Sprint Time = Fastest sprint time multiplied by number of trials.

PETERSON ON-ICE REPEATED SHIFT TEST



8 maximal sprints (approx. 23 seconds); 90 seconds rest between bouts

U OF M STUDY RESULTS



R_2 Linear = 0.097

- VO_2peak significantly correlated to Second Gate Decrement (%)
  - Aerobic contribution during shift
- VO_2peak not significantly correlated to First Gate or Total Course Decrement (%)
  - PCr pathway robust against fatigue
    - Recovery > 21 seconds
    - First Gate approx. 10 -11 seconds maximal output

	First Gate Decrement (%)	Second Gate Decrement (%)	Total Course Decrement (%)
Relative VO_2peak (ml/kg/min)	-.114 p = 0.458	-.311 **p = 0.038**	-.170 p = 0.263
Absolute VO_2peak (ml/min)	-.080 p = 0.600	-.354 **p = 0.017**	-.193 p = 0.204
Final Stage Completed	-.344 **p = 0.021**	-.461 **p = 0.001**	-.408 **p = 0.005**

Is that it?

↑VO_2peak = ↓Fatigue = ↑Performance

Of course not!

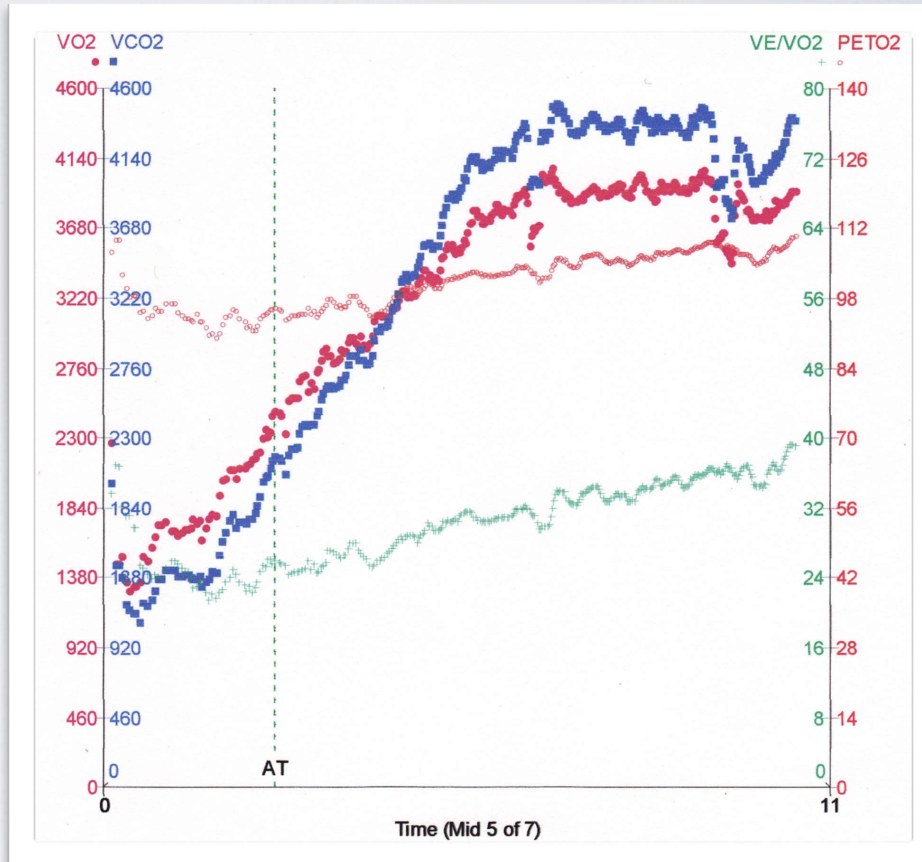
UNDERSTANDING METABOLIC RESPONSE TO EXERCISE

Gas Exchange Threshold (GET) Method:

- Allows for a better "dynamic" understanding
- Uses intersection point to estimate ventilatory threshold

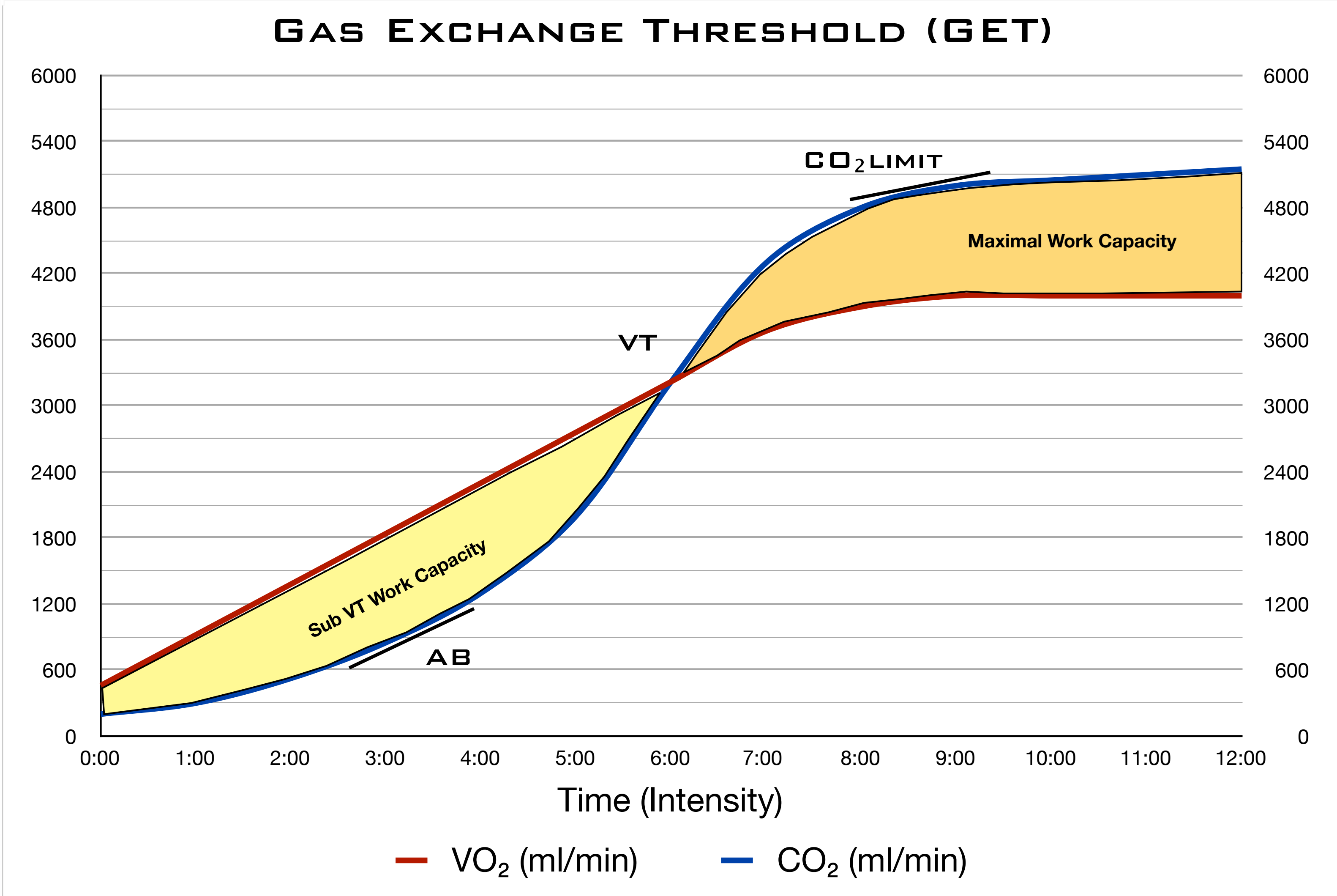
Positives:

- Gives a real time view of energy system integration
- Allows for interpretation efficiency at differing work loads
- Enables a coach to identify weak links in energy system chain

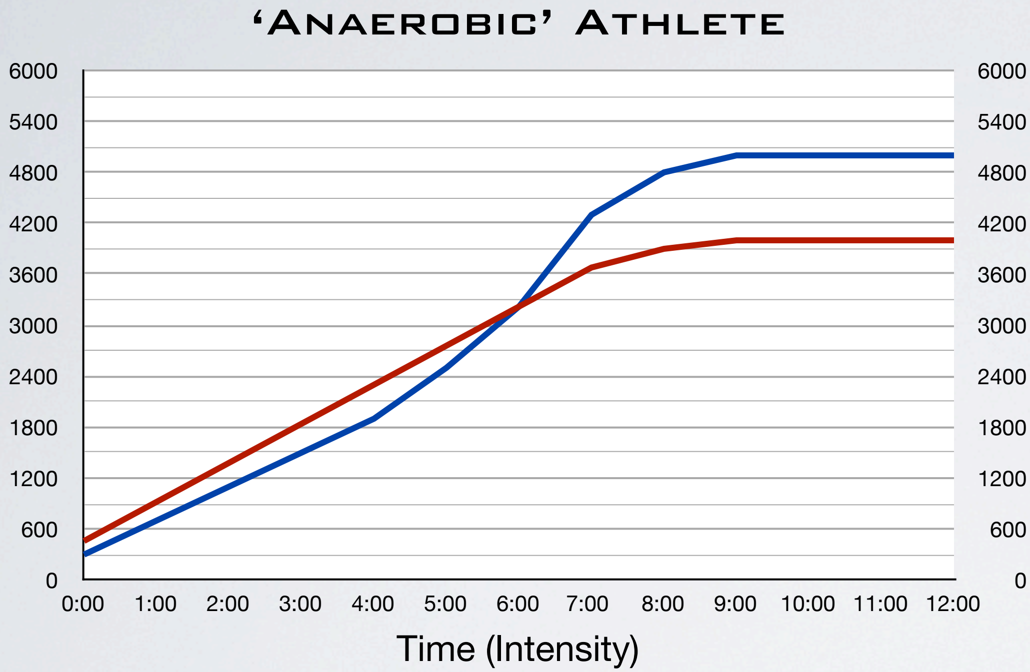


Wasserman, Stringer, Casaburi, Koike, & Cooper, 1994

METABOLIC RESPONSE TO EXERCISE



METABOLIC RESPONSE TO EXERCISE



This athlete has a...

- Low sub ventilatory work capacity
- Average contractile efficiency
- Average stroke volume

This athlete will...

- Perform well at high intensity, short duration activity (non-repetitive)
- Slow to fatigue at outputs above ventilatory threshold
- Have high anaerobic power output
- Take long periods of time (>5min) to recover from maximal exertion bouts

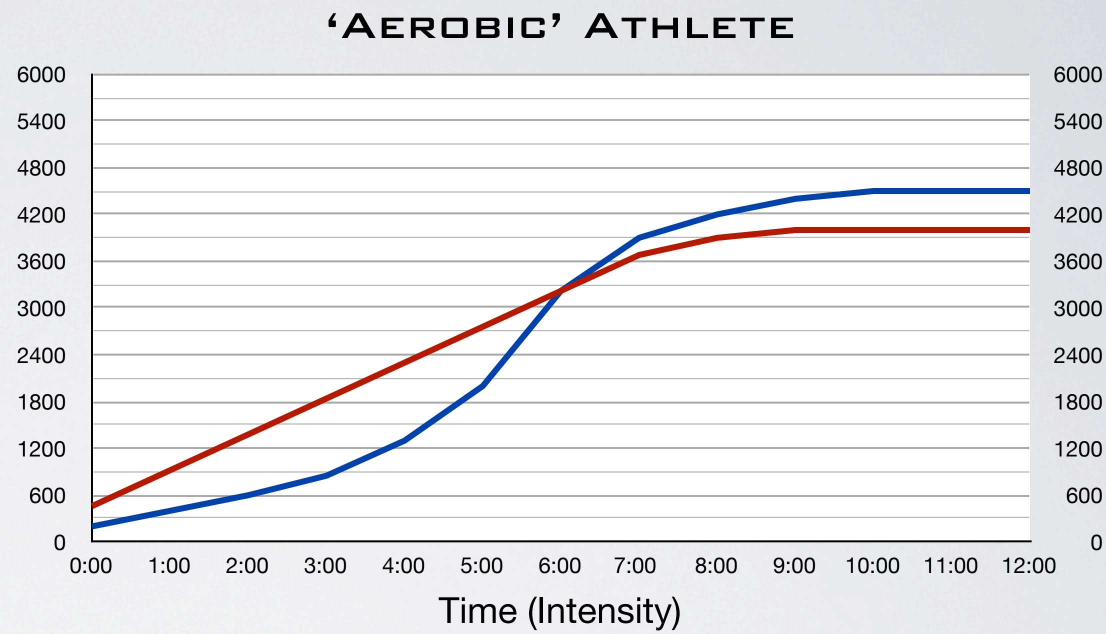
METABOLIC RESPONSE TO EXERCISE

This athlete has...

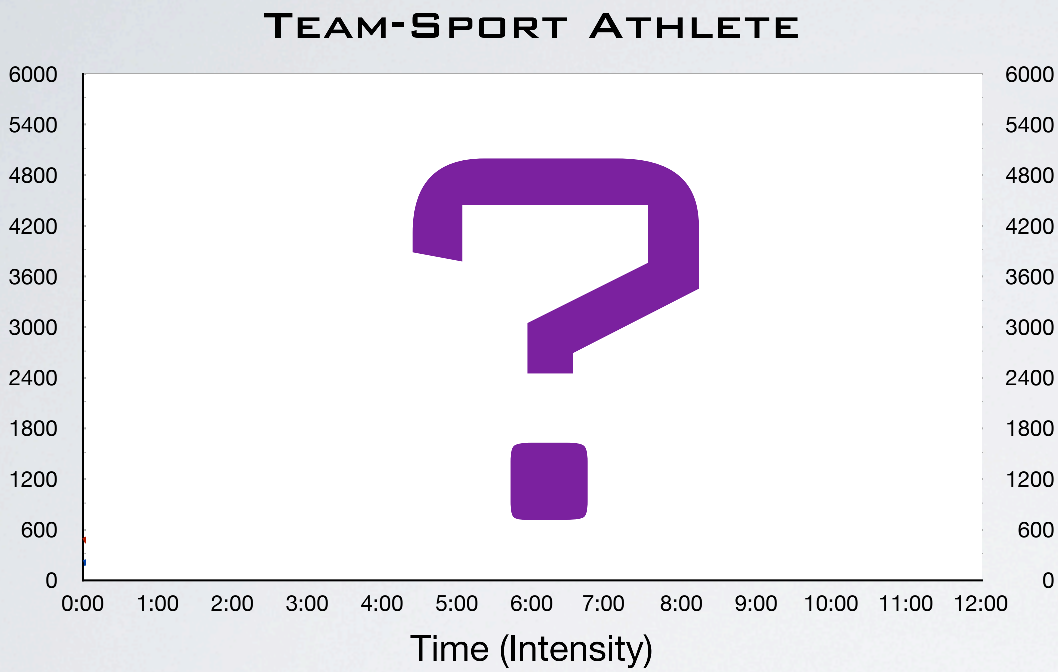
- High sub ventilatory work capacity
- Good contractile efficiency of the heart
- Large stroke volume
- Poor resistance to fatigue

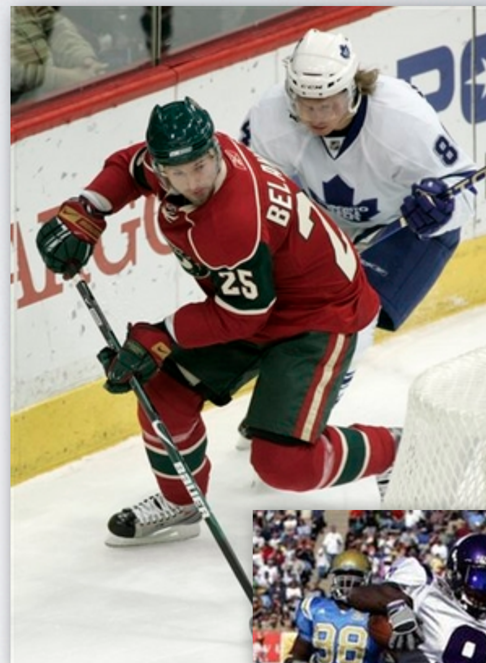
This athlete will...

- Perform well at long distance, low intensity activity
- Fatigue quickly at outputs above ventilatory threshold
- Have low anaerobic power output
- Recover quickly after maximal exertion (O_2 off-kinetics)



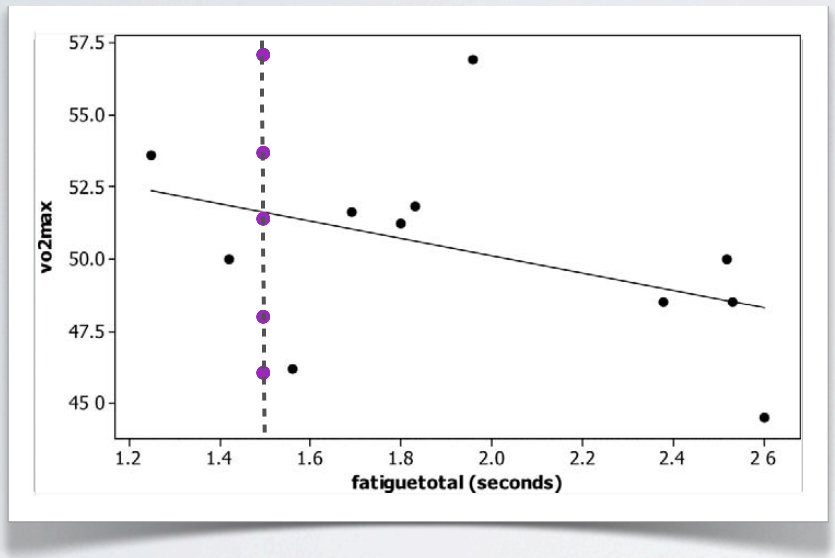
METABOLIC RESPONSE TO EXERCISE





- No one I am aware of has ever looked at a “typical” GET profile for team-sport athletes
- How do the metabolic pathways of these athletes work to meet energy demand?

METABOLIC RESPONSE TO REPEATED MAXIMAL BOUTS

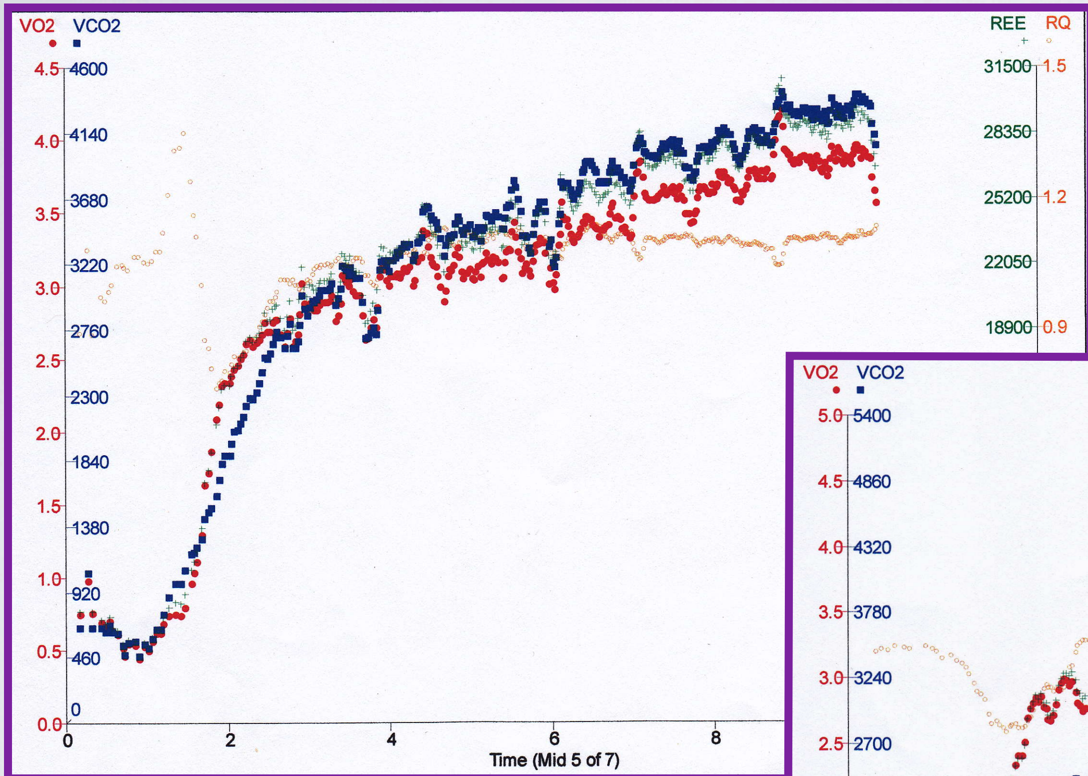


"Scientific research consists of seeing what everyone else has seen, but thinking what no one else has thought."

- Albert Szent-Gyorgyi

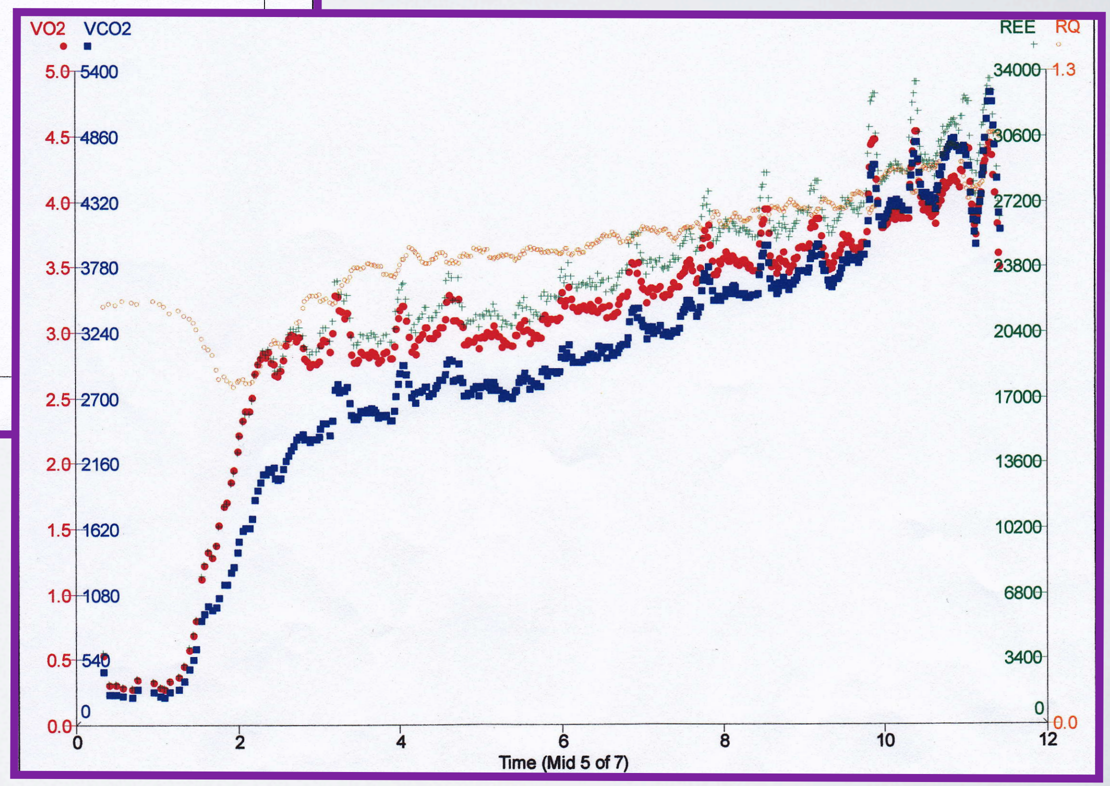
- Players with different VO_2peak's had same fatigue score
  - Outliers?
  - Skating Efficiency?
- 5 guys with same fatigue index
  - Fatigue: 6%
  - VO_2peak range: 46.8 to 64.4
- Had the idea to look at GET graph's
  - Would not see this on V-Slope graph
- Found discrepancies in metabolic output at different intensity levels
  - Sub VT Work Capacity
  - Maximal Work Capacity

METABOLIC RESPONSE (GET)



- Aerobic Base = 1:57
- **Ventilatory Threshold = 8:36**
- VO$_2$peak (min) = 8:50
- Total Time (Efficiency) = 10:03
- **VO$_2$peak = 54.9 ml/kg/min**
- Fatigue Index = 6%

- Aerobic Base = 2:53
- **Ventilatory Threshold = 11:05**
- VO$_2$peak (min) = 11:23
- Total Time (Efficiency) = 11:36
- **VO$_2$peak = 46.7 ml/kg/min**
- Fatigue Index = 6%

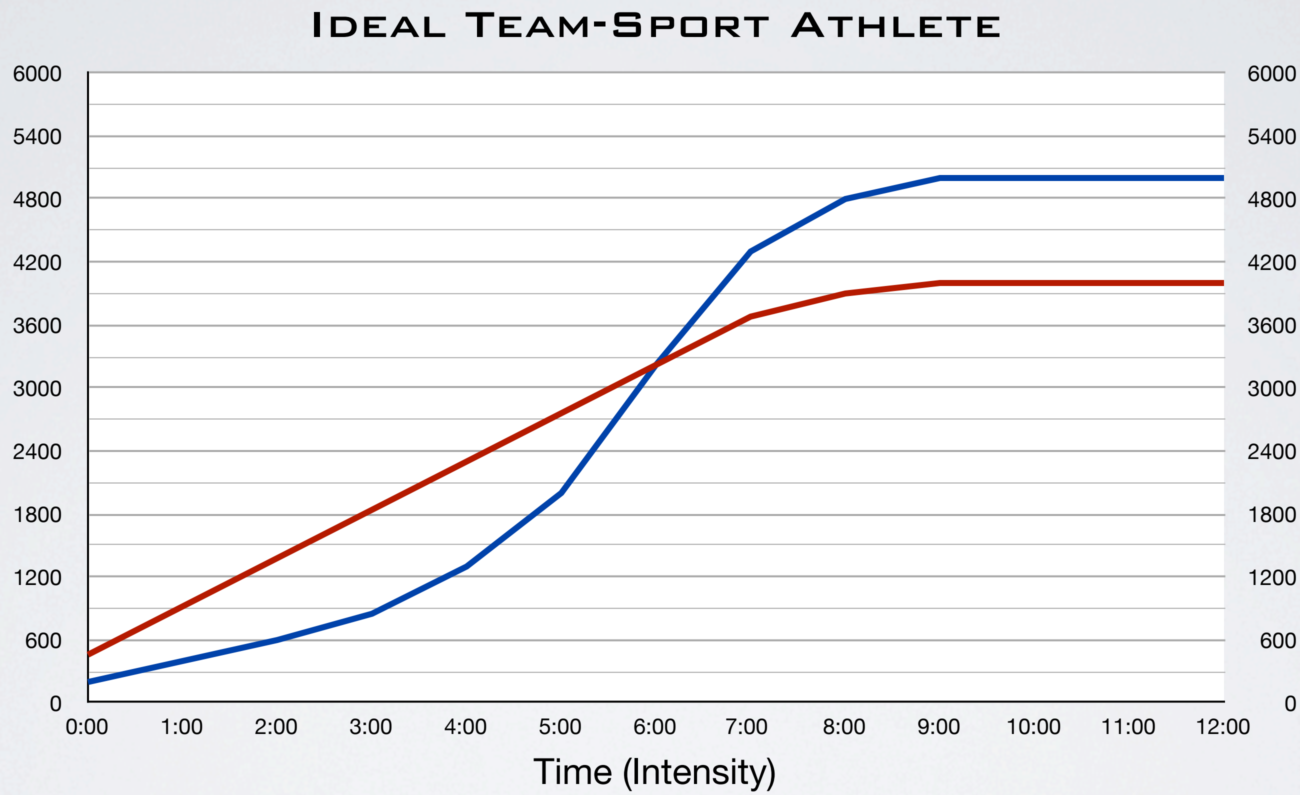


WHAT DOES THIS MEAN?

- No standard GET for team-sport athletes
- Implies that every aspect of metabolic profile contributes to RSA
- Athlete's metabolic system can adapt in multiple ways to meet energy demand
- Identifying weak link in athletes metabolic chain could lead to improved performance (RSA)

- Different stimulus required to target each component (pathway) of metabolism
  - Not targeting specific pathway!
  - Training efficiency at different levels of work output - **integration**

What would happen if an athlete had it all? A good base, a high VT, and a large maximal work capacity?



How would you train to achieve that?

CURRENT GENERAL PREPARATION PHASE (GPP) MODEL

What Coaches Agreed On:

- Goal:
  - Develop Oxidative Capacity
- High Volume

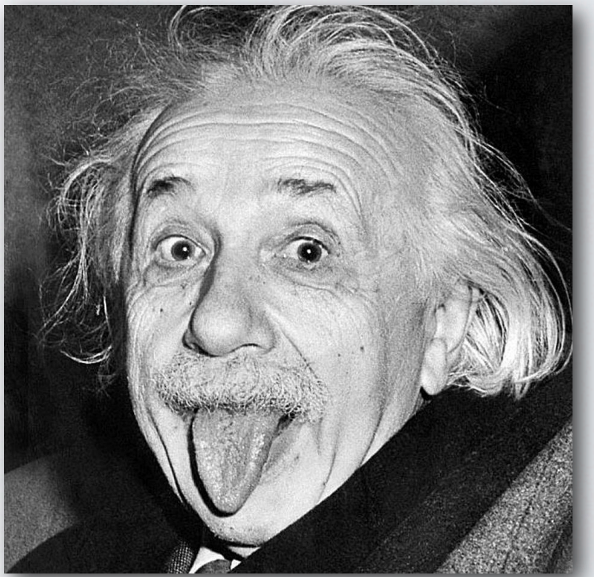
What Coaches Disagreed On:

- Block duration
  - 2 to 6 weeks
- Intensity:
  - Heart rate at work and rest
- Duration:
  - 30 to 90 minutes
- Loading:
  - 30-60% 1-RM
- Method of application:
  - Cardio
  - Complexes
  - Circuits
  - Bodybuilding

What if there was a better way?

- Pair the application of volume with a scientific method that maximizes adaptation in a short amount of time

"Insanity: doing the same thing over and over again and expecting different results."



GPP RE-INVENTED

- What we know, what I have found, advocates for a multi-stage GPP approach
- Introducing the P.C.S.P. Method
  - Stands for Push - Climb - Stretch - Pull
  - Develops entire metabolic system, enabling maximal work output and enhanced recovery during repeated sprint bouts
  - Optimizes energy pathway integration in team-sport athletes

GPP RE-INVENTED

Block I

Goal:

- General Work Capacity
  - Improve sub VT work capacity
  - Increase Ventilatory Threshold
  - Raise CO_2 Limit and improves anaerobic work capacity
  - Increase VO_2peak

Physiological Focus:

- Central and peripheral cardiovascular structure
  - Heart
  - Lungs
  - Capillaries

Duration:

- 1 to 3 Weeks

Block II

Goal:

- VO_2 Kinetics
  - Increase rate of O_2 response from rest to maximal effort
  - Improve coordination/integration of metabolic response

Physiological Focus:

- Peripheral and localized muscular structures
  - Increase mitochondrial density
  - Rate of O_2 extraction
  - Increase levels of rate limiting enzymes
    - Ex. Creatine Kinase

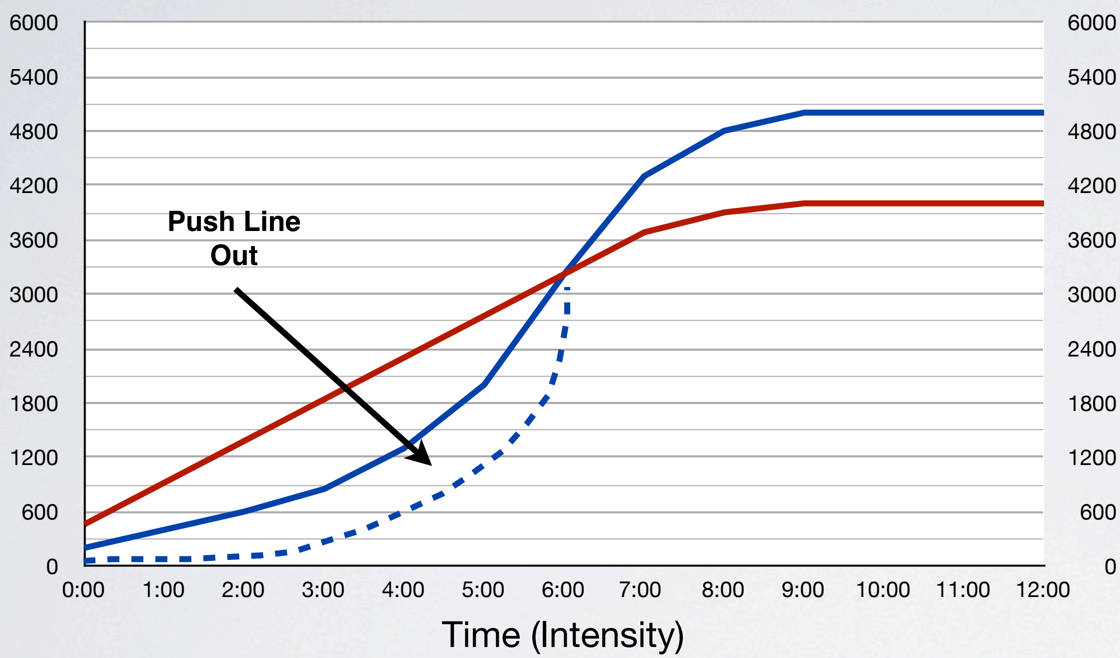
Duration:

- 2 to 3 weeks

P.C.S.P. METHOD:

BLOCK I

METABOLIC PUSH



- Less CO_2 (ml/min) exhaled than at previous equivalent rates of O_2 consumption
- More efficient utilizing O_2 for energy production
- Places less stress on glycolytic pathway during high intensity, repeated exercise

Training Parameters

- Intensity:
  - Aerobic base pace
  - 65 to 70% heart rate max

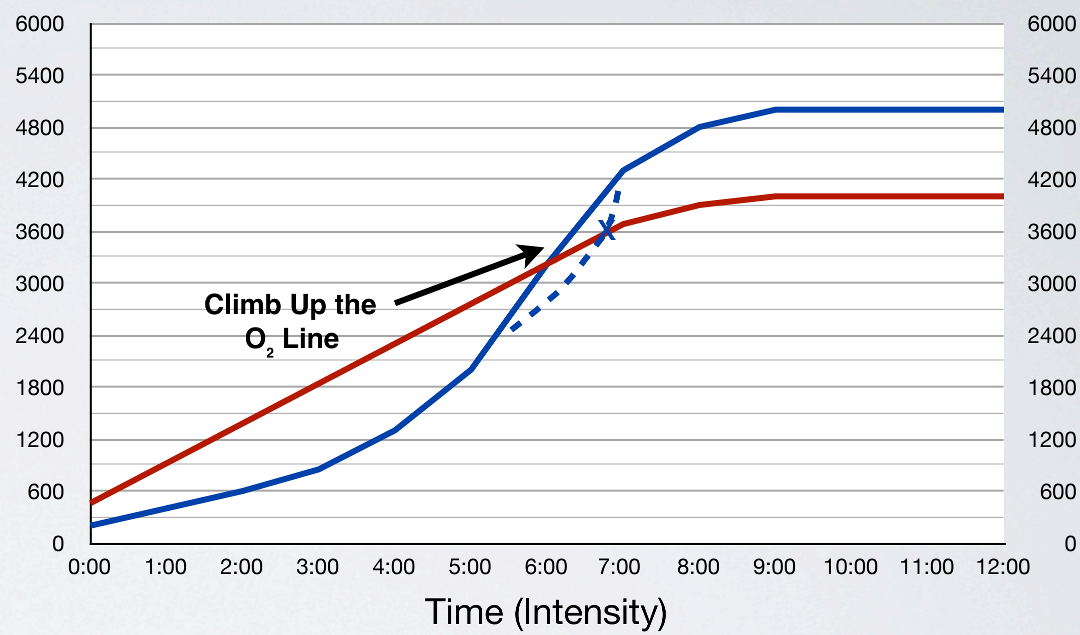
    (covers 85% of athletes)
- Duration:
  - Continuous
    - 20 to 45 minutes
- Mode (Weight Training):
  - Circuit Training
    - Unilateral movements
    - Pace dictated by HR
    - Alternate compound/ isolation
- Mode (Conditioning):*
  - Rowing
  - Running
  - Biking

* For some larger athletes this may be walking on a treadmill (i.e. Football Lineman)

METABOLIC CLIMB

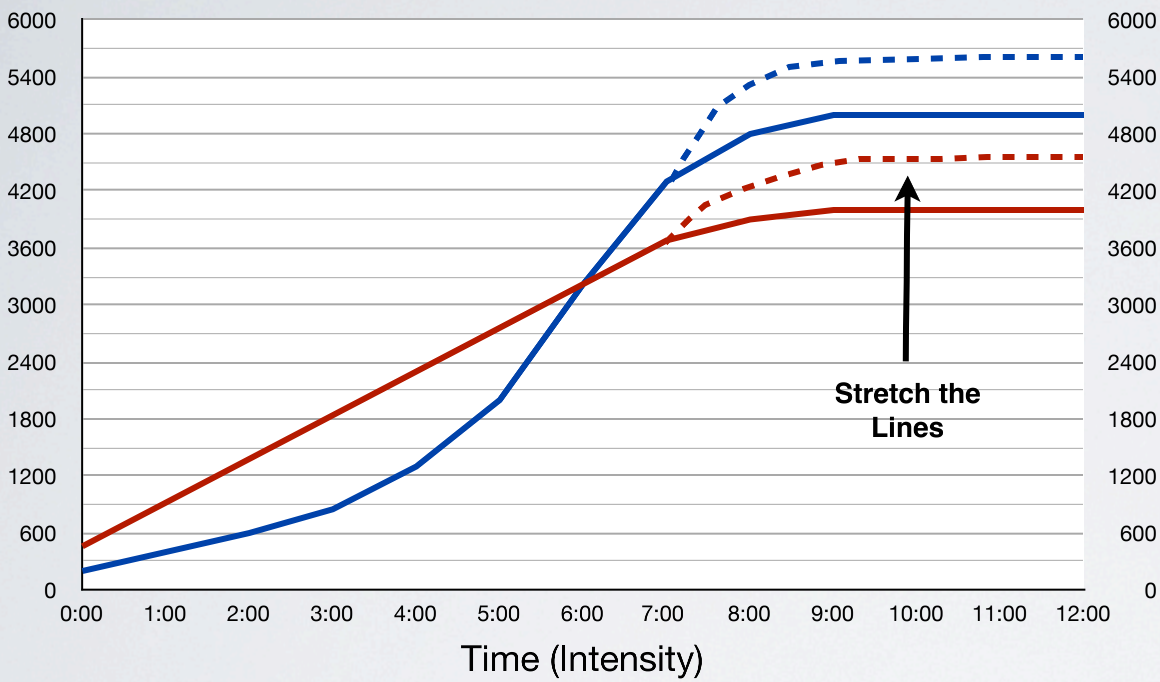
Training Parameters

- Intensity:
  - Ventilatory Threshold
  - 80 to 85% heart rate max
- Duration:
  - Long Intervals
    - 6 to 8 minutes @VT/2-3 minutes at AB (65% HR)
    - Repeat 2-4 times
- Mode (Weight Training):
  - Isometric Circuit Training
    - 65-70% 1-RM
    - 30-second sets
- Mode (Conditioning):
  - Rowing
  - Running
  - Biking



- Able to perform work at higher intensities without fatigue (assuming glycogen stores sufficient)
- Reduces negative effect of active recovery
- Onset of fatigue during high intensity, repeated exercise is delayed; faster recovery between bouts

METABOLIC STRETCH



- Improving the aerobic capacity (VO_2peak)
- Less metabolite accumulated during high-intensity exercise
- Improves efficiency of system, clearing metabolite during maximal exercise; reduced fatigue

Training Parameters

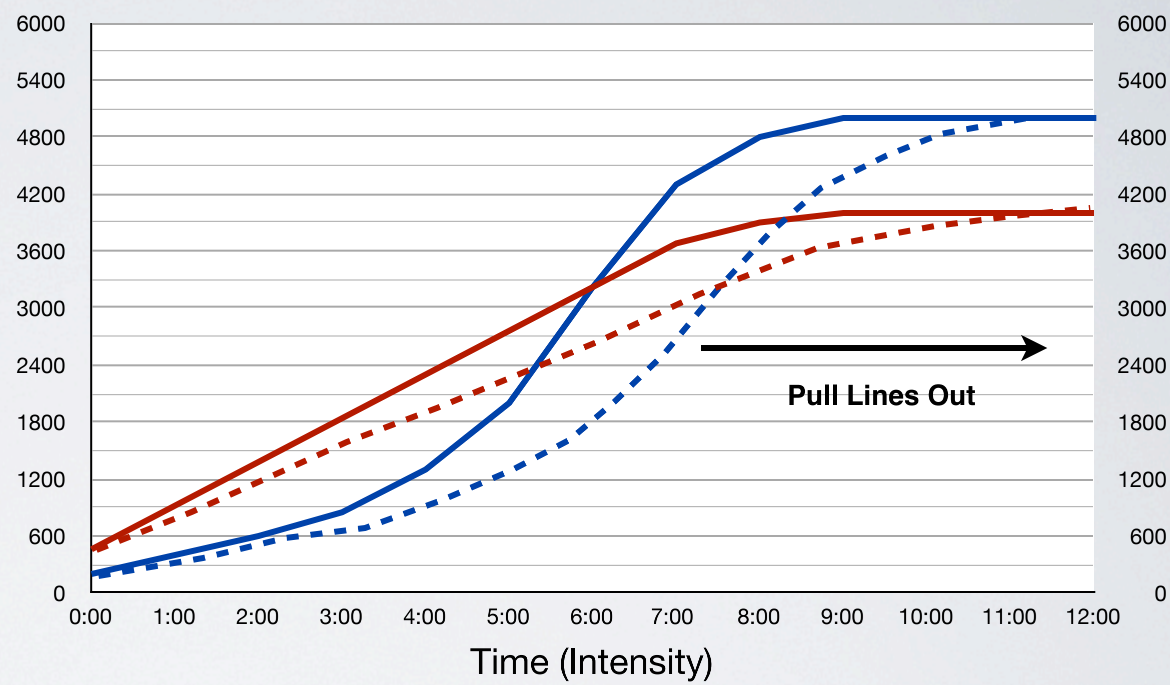
- Intensity:
  - VO_2peak
  - 95 to 100% heart rate max
- Duration:
  - Short Intervals
    - 2 to 4 minutes @VO_2peak/ 1-3 minutes at AB (65% HR)
    - Repeat 3-4 times
- Mode (Weight Training):
  - Escalating Density Training (EDT)
    - Compound Movements
    - Active metabolic recovery
- Mode (Conditioning):
  - Game Speed conditioning*
  - Plate Circuits*
  - Running

* Available, free, on XLathlete.com

METABOLIC PULL

Training Parameters

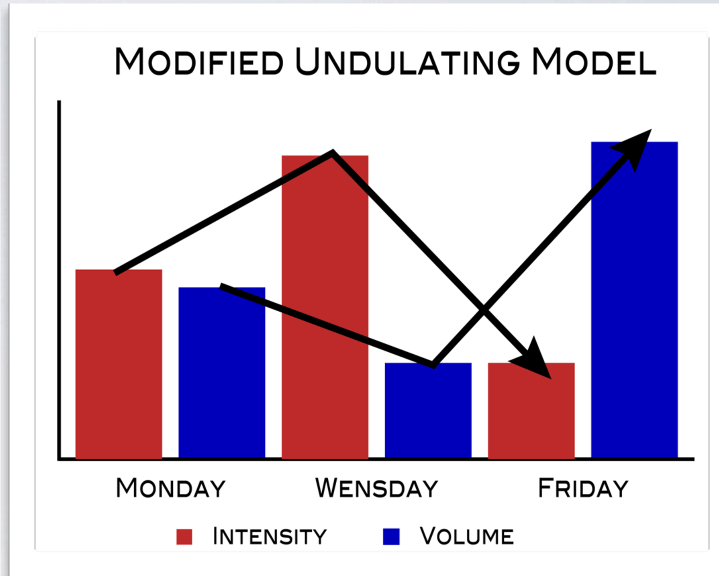
- Intensity:
  - Maximal Effort (Sprint)
- Duration:
  - 10 to 60 seconds
    - 100 to 400m sprints
    - Work : Rest Ratio = 1 : 4
    - 4 to 10 reps
- Mode (Weight Training):
  - Isometric Circuits
    - Maximal Effort
    - 10-second sets
  - Oscillatory Lifting Circuits
    - 65-70% 1-RM
    - 10 to 30-second sets
- Mode (Conditioning):
  - Sprinting



- Improves overall work capacity; significantly greater improvement at high work intensities (≥ VO_2peak)
- Delays onset of metabolite accumulation; Ventilatory Threshold
- Improved intensity tolerance

PCSP Block 1

- **Goal:** Improve general work capacity
- **Model:** Modified Undulated
- **Duration:** 1 to 3 weeks

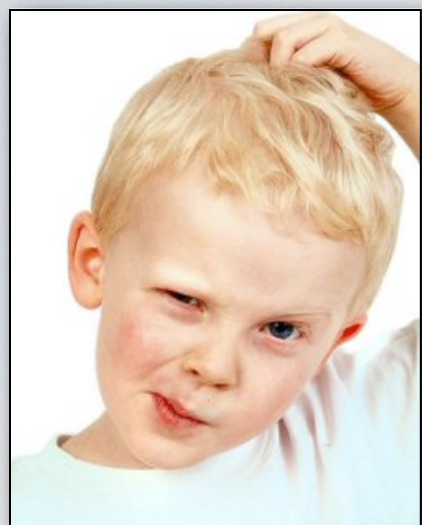


	Day 1	Day 2	Day 3
3-Day Model	Climb	Stretch	Push

	Day 1	Day 2	Day 3	Day 4
4-Day Model	Climb	Stretch	Stretch	Push

	Day 1	Day 2	Day 3	Day 4	Day 5
5-Day Model	Climb	Climb	Stretch	Stretch	Push

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
6-Day model	Climb	Climb	Stretch	Stretch	Push	Push



Is that it?

↑VO_2peak +↑ VT + ↑CO_2Limit = ↑Work Capacity + ↓Fatigue = ↑Performance

Nope, but getting close!

METABOLIC RESPONSE TO EXERCISE

VO_2peak ↑

Bishop and Spencer (2004)

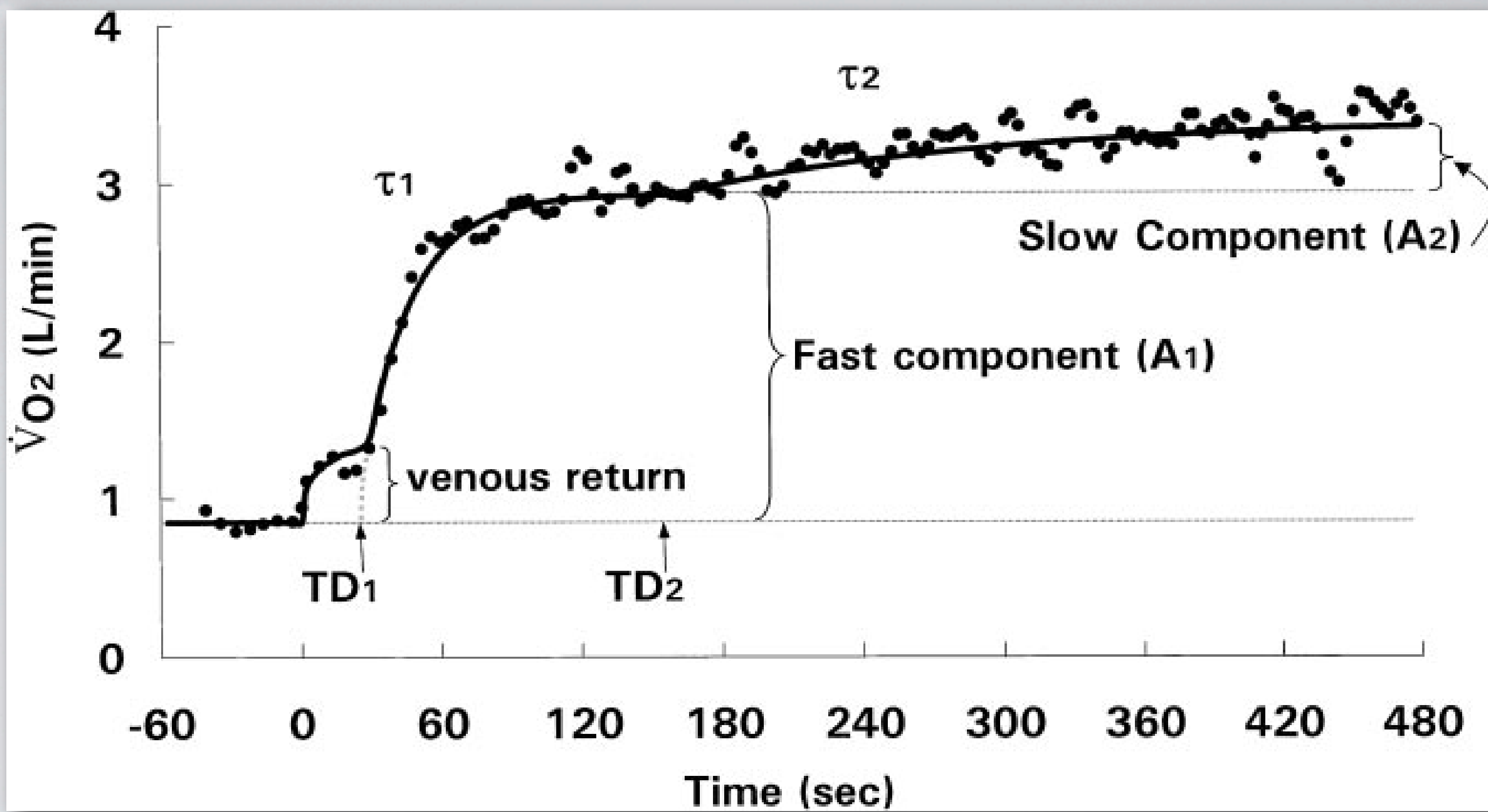
- Compared two groups (team-sport athletes versus endurance-trained athletes) who were homogenous with respect to VO_2peak
- Found that total work and power decrement in RSA test were higher for team-sport athletes

Glaister et al. (2007)

- Found 6 weeks of endurance training (70% of VO_2peak) resulted in a 5.3% increase in VO_2peak
- No significant effect on measures of fatigue during an RSA test (20 x 5 second sprints with 10 seconds passive recovery)
- **Suggests that factors in addition to VO_2peak are important to RSA performance**

↓ Fatigue

VO_2 KINETICS (EFFICIENCY)

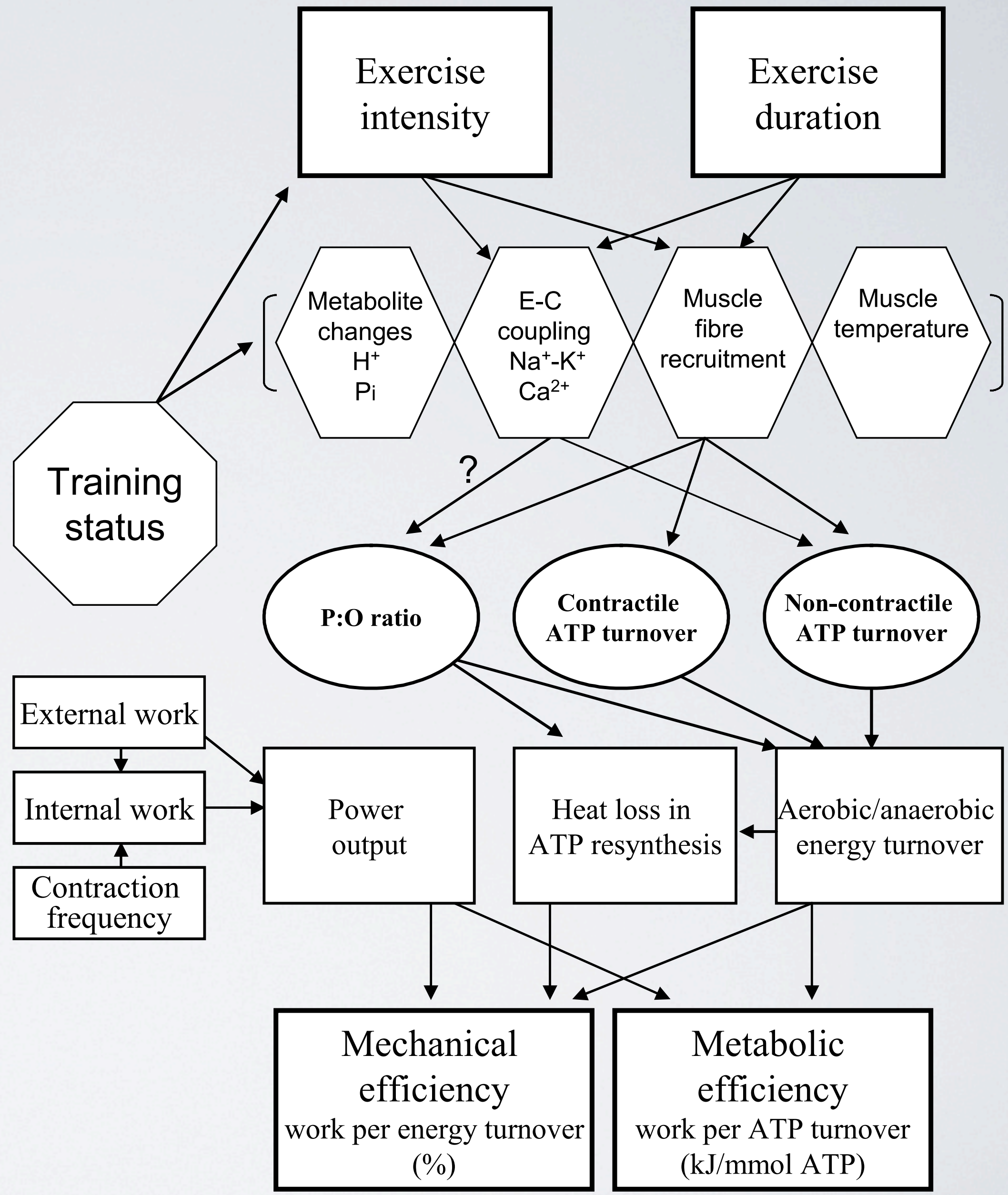


Bearden et al. (2005)

VO_2 KINETICS

Training Goals:

- Increase slope of the line for fast component
- Decrease amplitude of slow component; improve efficiency at high work rates



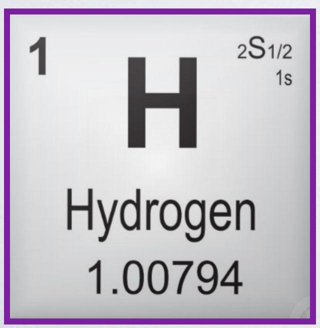
DO VO_2 KINETICS MATTER?

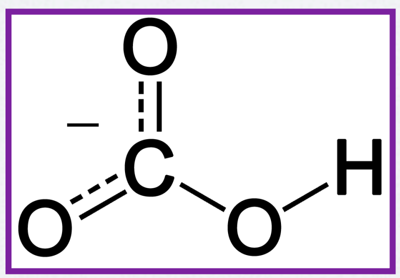
Rampinini et al. (2009)

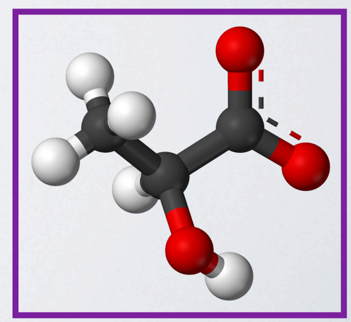
Table 2. Correlation coefficients between repeated-sprint ability test scores (RSA_{best}, RSA_{mean}, and RSA_{dec}) and physiological responses to high-intensity, intermittent test and cardiorespiratory measurements ($N = 23$).

	$HIT_{[H^+]}$ ($mmol \cdot L^{-1}$)	$HIT_{[HC0_3^-]}$ ($mmol \cdot L^{-1}$)	$HIT_{[La^-]}$ ($mmol \cdot L^{-1}$)	$\dot{V}O_{2\ max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	τ_1 (s)
Correlation coefficients					
RSA_{best} (s)	0.01 (–0.34 to 0.36)	0.12 (–0.24 to 0.45)	0.03 (–0.33 to 0.38)	0.09 (–0.27 to 0.43)	0.14 (–0.22 to 0.47)
RSA_{mean} (s)	0.61* (0.33 to 0.79)	–0.71* (0.48 to 0.85)	0.66* (0.40 to 0.82)	–0.45* (–0.12 to –0.69)	0.62* (0.34 to 0.80)
RSA_{dec} (%)	0.73* (0.51 to 0.86)	–0.75* (–0.54 to –0.87)	0.77* (0.57 to 0.88)	–0.65* (–0.39 to –0.82)	0.62* (0.34 to 0.80)
Semipartial correlations					
RSA_{dec} (%)	0.77* (0.57 to 0.88)	–0.83* (–0.68 to –0.91)	0.81* (0.64 to 0.90)	–0.66* (–0.40 to –0.82)	0.70* (0.46 to 0.84)

Results suggest that faster VO_2 kinetics and the ability to buffer H^+ during high-intensity intermittent activity are important characteristics for team-sport athletes.







Rampinini et al. (2009)

DO VO_2 KINETICS MATTER?

Table 1. Differences between professional and amateur soccer players in performance measures from the repeated-sprint ability test, physiological responses during high-intensity, intermittent test, and cardiorespiratory measurements.

	Professional (*N* = 12)	Amateur (*N* = 11)	*p* value	*d* value
RSA				
RSA_{best} (s)	6.86±0.13	6.97±0.15	0.075	0.74 (moderate)
RSA_{mean} (s)	7.17±0.09	7.41±0.19	0.001	1.30 (large)
RSA_{dec} (%)	4.5±1.9	6.0±1.9	0.064	0.77 (moderate)
HIT				
$HIT_{[H^+]}$ ($mmol \cdot L^{-1}$)	46.5±5.3	52.2±3.4	0.007	1.06 (large)
$HIT_{[HCO3-]}$ ($mmol \cdot L^{-1}$)	20.1±2.1	17.7±1.7	0.006	1.09 (large)
$HIT_{[La-]}$ ($mmol \cdot L^{-1}$)	5.7±1.5	8.2±2.2	0.004	1.13 (large)
HIT_{HRmean} (% of max)	87.4±3.8	87.6±4.5	0.887	0.06 (trivial)
HIT_{RPE} (CR10)	4.4±0.7	6.4±1.0	<0.001	1.48 (large)
Cardiorespiratory measurements				
$\dot{V}O_{2\ max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	58.5 ±4.0	56.3 ±4.5	0.227	0.51 (moderate)
Amplitude ($mL \cdot min^{-1}$)	2519 ±211	2511 ±329	0.949	0.03 (trivial)
τ (s)	27.2 ±3.5	32.3 ±6.0	0.019	0.95 (large)

Professional and amateur players have same VO_2peak ($p = 0.227$)

Professional players had:

1) Significantly faster O_2 Kinetics (t_1) ($p = 0.019$)

2) Significantly faster average sprint times (RSAmean) ($p = 0.001$)

3) Reduced level of fatigue (RSAdec)

"Professional players had a lower La^-, lower H^+, and higher HCO_3^- response to HITT, suggesting a lower anaerobic contribution (higher aerobic contribution) and (or) a better buffering capacity compared to amateur players."

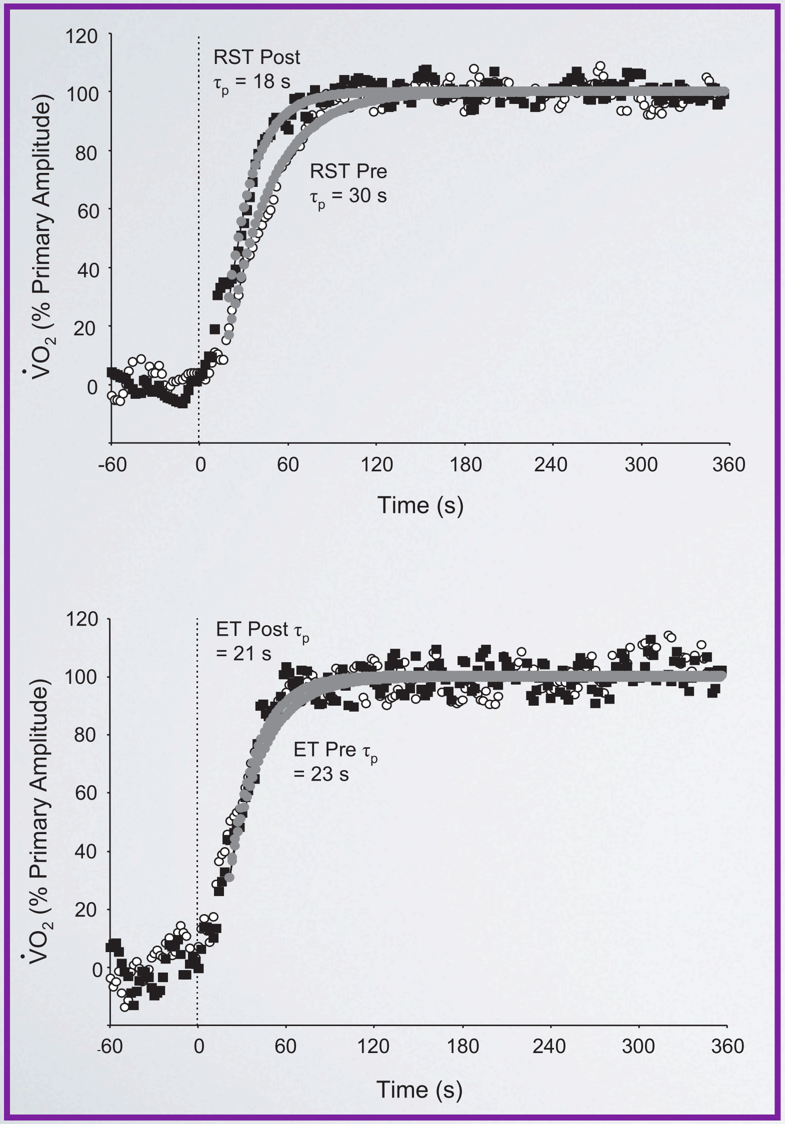
Rampinini et al. (2009)

ARE VO_2 KINETICS TRAINABLE?

Bailey et al. (2009)

- **Purpose:** Examine the effects of different training modalities on VO_2 kinetics and muscle deoxygenation
    - Measured as deoxyhemoglobin concentration (HHb) via NIRS
- **Goal:** Find the "optimal" training strategy to elicit improvements in VO2 kinetics
- **Population:** 24 subjects broken into three groups:
    - Repeated Sprint Training (RST) - six sessions of 4 to 7 30-second bike sprints (Wingate)
    - Endurance Training (ET)- work matched cycling at 70% VO_2peak
    - Control (C)

ARE VO_2 KINETICS TRAINABLE?



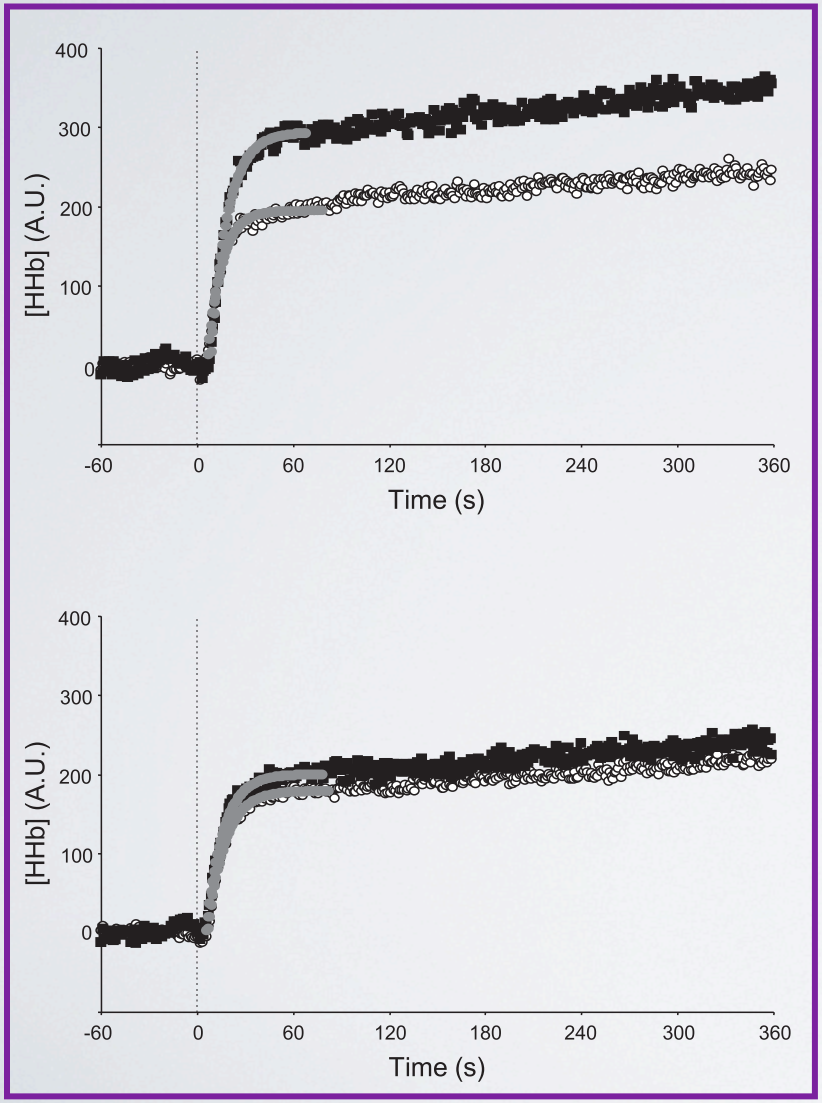
Results for RST Group:

- VO_2 kinetics were accelerated for both moderate (Pre: 28 ± 8, Post: 21 ± 8 s; $p < 0.05$) and severe exercise (Pre: 29 ± 5, Post: 23 ± 5 s; $p < 0.05$)
- Exercise tolerance was improved by 53% (Pre: 700 ± 234, Post: 1,074 ± 431 s; $p < 0.05$) during step exercise test

VO_2 response to a step increment from an unloaded baseline to sever-intensity work rate; RSA (top) and ET (bottom). Pre responses are shown as open circles, and the Post responses are shown as solid squares.

Bailey et al. (2009)

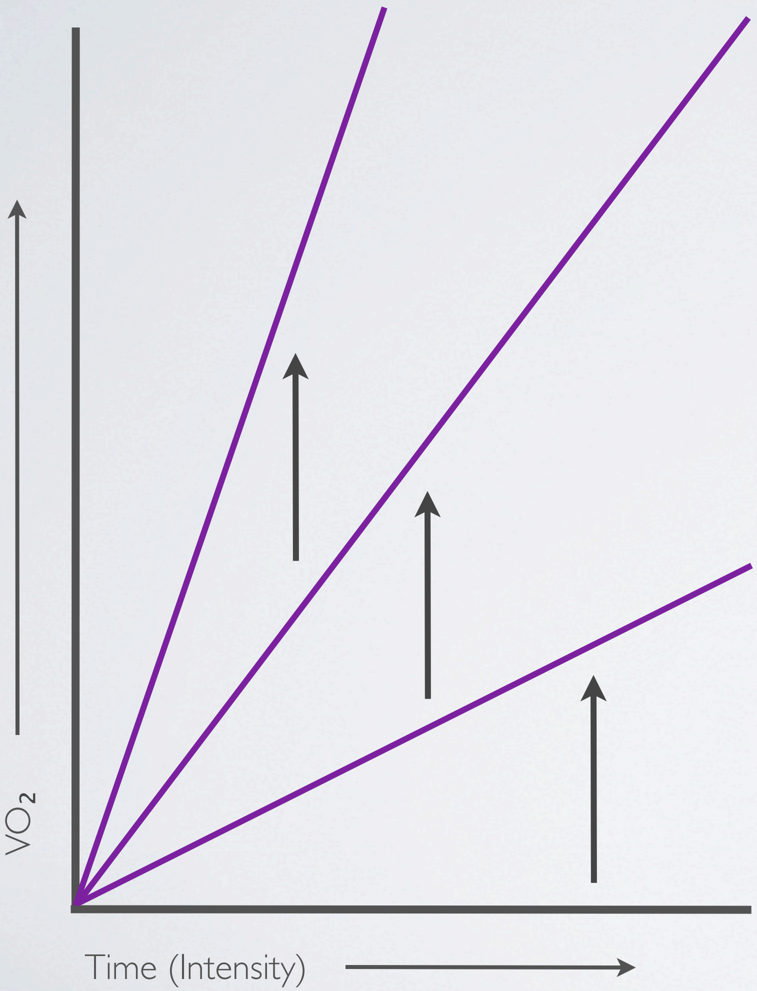
ARE VO_2 KINETICS TRAINABLE?



Results for RST Group (con't):

- HHb kinetics were speeded, and the amplitude of the HHb response was increased during both moderate and sever exercise ($p < 0.05$)
  - Suggest improvement in muscle fractional O_2 extraction
- O_2 deficit was significantly reduced at moderate intensities (Pre: 0.45 ± 0.10, Post: 0.36 ± 0.10 liter; $p < 0.05$)
- Non of these parameters were significantly altered in ET or C groups

LET'S REVIEW



- Other factors, in addition to VO_2peak, play significant role is repeated sprint ability
- VO_2 kinetics - the ability of the aerobic pathway to respond to large changes in workload
- Athletes with faster O_2 kinetics outperform their peers with similar VO_2peak's in RSA tests
  - Show less fatigue (% Dec)
  - Increased metabolic Power: ↑W / T
- Faster O_2 kinetics likely mitigate fatigue via:
  - Increased energy contribution from aerobic pathway during exercise
    - Attenuate depletion of PCr and glycogen stores
  - Reduced rate of substrate accumulation
    - H^+ and P_i

LET'S REVIEW

- VO_2 kinetics are believed to be improved by an increase in muscle fractional O_2 extraction
    - Not directly linked to Sub VT Capacity, VT, or VO_2peak
    - Specific training required to target and improve VO_2 kinetics
- Both of these, VO_2 and HHb kinetics, appear to be improved with specified high intensity, repeated interval training

P.C.S.P. METHOD:

BLOCK II

PCSP Block II

- **Goal:** Improve response time of system (O_2 Kinetics)
- **Model:** Modified Undulated
- **Duration:** 2 to 3 weeks

- **Reduce sprint duration by 50%**
  - Block I, Stretch: 4min on/3min off
  - Block II, Stretch: 2min on/1.5min off

	Day 1	Day 2	Day 3
3-Day Model	Stretch	Pull	Climb

	Day 1	Day 2	Day 3	Day 4
4-Day Model	Stretch	Pull	Pull	Climb

	Day 1	Day 2	Day 3	Day 4	Day 5
5-Day Model	Stretch	Stretch	Pull	Pull	Climb

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
6-Day model	Stretch	Stretch	Pull	Pull	Climb	Climb

P.C.S.P. Parameters

<table>
<tr><th></th><th>Block</th><th>Push</th><th colspan="2">Climb</th><th colspan="2">Stretch</th><th colspan="2">Pull</th></tr>
<tr><td rowspan="2">Intensity</td><td>M.L.P.*</td><td>Aerobic Base (AB)</td><td colspan="2">Ventilatory Threshold (VT)</td><td colspan="2">VO_2max (Vmax)</td><td colspan="2" rowspan="2">80-100% Maximal Effort</td></tr>
<tr><td>C.F.T.**</td><td>65-70% Heart Rate Max</td><td colspan="2">80-85% Heart Rate Max</td><td colspan="2">95-100% Heart Rate max</td></tr>
<tr><td rowspan="2">Duration</td><td>1</td><td>20-40 minutes</td><td colspan="2">6-8 min @ VT / 2-3 min @ AB</td><td colspan="2">2-4 min @ Vmax / 1-3 min @ AB</td><td colspan="2">Not Applicable</td></tr>
<tr><td>2</td><td>Not Applicable</td><td colspan="2">3-4 min @ VT / 1-1:30 min @ AB</td><td colspan="2">1-2 min @ Vmax / :30-1 min @ AB</td><td colspan="2">10-60 seconds</td></tr>
<tr><td rowspan="2">Reps</td><td>1</td><td rowspan="2">Not Applicable</td><td colspan="2">2 to 3</td><td colspan="2">3 to 4</td><td colspan="2">Not Applicable</td></tr>
<tr><td>2</td><td colspan="2">3 to 5</td><td colspan="2">6 to 10</td><td colspan="2">8 to 12</td></tr>
<tr><td rowspan="3">Work:Rest Ratio</td><td rowspan="3">1 & 2</td><td rowspan="3">Continuous</td><td>Tier 1</td><td>2 : 1</td><td>Tier 1</td><td>1 : 1.5</td><td>Tier 1</td><td>1 : 4</td></tr>
<tr><td>Tier 2</td><td>3 : 1</td><td>Tier 2</td><td>1 : 1</td><td>Tier 2</td><td>1 : 3</td></tr>
<tr><td>Tier 3</td><td>4 : 1</td><td>Tier 3</td><td>1 : .75</td><td>Tier 3</td><td>1 : 2</td></tr>
<tr><td>Volume</td><td>1 & 2</td><td>Very High</td><td colspan="2">High</td><td colspan="2">Moderate</td><td colspan="2">Low</td></tr>
<tr><td>Mode</td><td>1 & 2</td><td>Rowing
Biking
Jogging
Trashball
Basketball
Ultimate Frisbee
Soccer</td><td colspan="2">Rowing
Running
Biking
1% Inc Treadmill Run</td><td colspan="2">Rowing
Running
Biking
1% Inc Treadmill Run
Metabolic Run Lvl 1-5</td><td colspan="2">Sprint 100m
Sprint 200m
Sprint 400m
Bike Sprint</td></tr>
<tr><td>Mode of Recovery</td><td>1 & 2</td><td>Not Applicable</td><td colspan="2">Active</td><td colspan="2">Active</td><td colspan="2">Passive</td></tr>
</table>

*Metabolic Lab Profile **Cooper Field Test

RESULTS FROM P.C.S.P. METHOD

Elite Level High School Hockey

- **Sample Size:** 11
- **Pre-test:** Start of off-season workouts
- **Avg. Pre-test Sprint Reps:** 5
- **Post-test:** 6 weeks
- **Avg. Post-test Sprint Reps:** 12 (↑140%)

Profile	Pre-Test	Post-Test	Change	% Difference
Body Fat %	16.19	**13.2***	-3.0	**18.5**
Vo_2peak (ml/kg/min)	47.1	**50.6***	+3.5	**7.4**
HR_{max}	200	197	-3.0	9.9
HR_{ab}	156	**136***	-20.0	**12.8**
HR_{vt}	140	**158***	+18.0	**12.9**

*Significantly different change from pre-test

Professional Hockey Players

- **Sample Size:** 6
- **Pre-test:** Start of off-season workouts
- **Avg. Pre-test Sprint Reps:** 7
- **Post-test:** 5 weeks
- **Avg. Post-test Sprint Reps:** 13 (↑85%)

Profile	Pre-Test	Post-Test	Change	% Difference
Body Fat %	12.0	**9.3***	2.7	14.2
VO_2peak (ml/kg/min)	52.5	**54.9***	+2.4	**4.6**
VO_2vt (ml/kg/min)	30.7	**34.2***	+3.5	**11.4**
HR_{max}	198	198	0.0	0.0
HR_{vt}	138	**157***	+19.0	**13.8**
Wingate (W) - Peak Power	1097	1137	+40.0	3.6
Wingate (W) - Average Power	698	**794***	+96.0	**13.8**
Wingate Fatigue Index (%)	56.2	**51.5***	-4.7	**8.4**

*Significantly different change from pre-test

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Do you have any questions?

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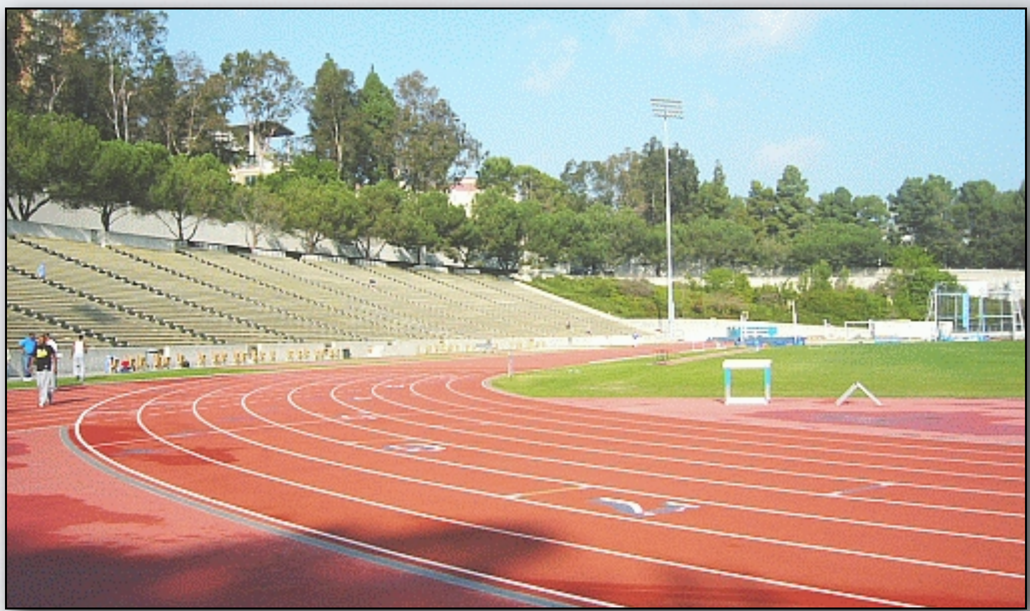
COOPER FIELD TEST



What you need:

- 400 meter track
- Stopwatch
- HR monitor
- Whistle

Goal:

- Run as far as possible in 12-minutes

Test Procedures:

- 10 minute warm-up
- On "GO" command, start the stopwatch and the athlete commences the test
- Keeps the athlete informed of the remaining time at the end of each lap (400m)
- The assistant blows the whistle when the 12 minutes has elapsed
- Record the distance the athlete covered to the nearest 10 meters

Cooper, 1968

COOPER FIELD TEST

Calculating VO_2peak:

- (Distance covered in meters - 504.9) ÷ 44.73
- Cooper reported a correlation of 0.90 between direct VO_2max and field test

Calculating Heart Rate:

- Highest heart rate achieved during test is athletes HRmax
    - HRmax x .65 = AB
    - HRmax x .80 = VT
    - HRmax x .95 = VO2peak

COOPER FIELD TEST

Normative Data for Male Athletes					
Age	Excellent	Above Average	Average	Below Average	Poor
13-14	>2700m	2400-2700m	2200-2399m	2100-2199m	<2100m
15-16	>2800m	2500-2800m	2300-2499m	2200-2299m	<2200m
17-19	>3000m	2700-3000m	2500-2699m	2300-2499m	<2300m
20-29	>2800m	2400-2800m	2200-2399m	1600-2199m	<1600m
30-39	>2700m	2300-2700m	1900-2299m	1500-1999m	<1500m
40-49	>2500m	2100-2500m	1700-2099m	1400-1699m	<1400m
>50	>2400m	2000-2400m	1600-1999m	1300-1599m	<1300m

Normative Data for Female Athletes					
Age	Excellent	Above Average	Average	Below Average	Poor
13-14	>2000m	1900-2000m	1600-1899m	1500-1599m	<1500m
15-16	>2100m	2000-2100m	1700-1999m	1600-1699m	<1600m
17-19	>2300m	2100-2300m	1800-2099m	1500-1799m	<1700m
20-29	>2700m	2200-2700m	1800-2199m	1700-1799m	<1500m
30-39	>2500m	2000-2500m	1700-1999m	1400-1699m	<1400m
40-49	>2300m	1900-2300m	1500-1899m	1200-1499m	<1200m
>50	>2200m	1700-2200m	1400-1699m	1100-1399m	<1100m