The Scientific Preparation and Monitoring of the Elite Athlete

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We have seen amazing advances in science in the sport

Denying the scientific approach in the XXI century is denying progress

However, when it comes to training & coaching many coaches and athletes don’t rely on science

Marginal gains are thought to be the scientific approach...But they are just that: Marginal gains...That 1%...

The Major gains (The ABC’s) however are not achieved many times because the scientific approach is not applied by coaches and athletes
Today's Main Topics

- Physiology
- Training
- Monitoring
- Overtraining
- Nutrition
Determinants of Performance

- Physiology
- Genetics
- Training
- Nutrition
- Monitoring
- Health
- Injuries
- Psychology
- Lifestyle
HOW MANY ELEMENTS DO WE CONTROL???
Physiology
Training
Nutrition
Recovery

MAJOR GAINS
MARGINAL GAINS
MAJOR GAINS

Vs

MARGINAL GAINS

.........That 1%
THE MAJOR GAINS
What Training Really Elicits
Muscle Metabolism is Absolutely Key in Endurance Performance

Endurance Training is mainly about improving at the Metabolic Level

What are the Principles of Training?

- Specificity
- Individuality
- Overload
- Progression
- Adaptation
- Recovery
Training Individualization
Why is it so important?

Each Body is DIFFERENT!. We have DIFFERENT Metabolism and Physiology and therefore different parameters and training zones!!
The Only way to Individualize training scientifically is to know who we are working with

We MUST measure the physiology and metabolism of who are we working with
Peter Drucker

- The man who invented Management
- Father of Business Analytics
- Father of Modern Business Corporation

What Gets Measured, Gets Managed” –Peter Drucker
Physiological Testing

- The foundation of any scientific-based training program - Coaching 101

- It is crucial to establish the physiological and metabolical parameters of each athlete in order to prescribe the most accurate and scientific-based training program.
- Evaluation of the “engine” of an athlete.
- Evaluation of the weak and strong points.
- Evaluation of quantity and quality of training
Traditional View

Exercise Physiology LAB
Exercise Physiology/Human PERFORMANCE Lab

- VO2max
- Lactate Threshold LT
### Patient Information

**Name:**

**Age:** 25 yrs

**Height:** 72.5 in (184 cm)

**Test Protocol**

**Test degree:** Maximal

**Exertion device:** Treadmill

**Test Environment**

- **Intr. temp.:** 22.0 deg C
- **Intr. humidity:** 32.0%
- **Exp. flow temp.:** 20.94 %
- **Intr. CO2:** 4.92 %
- **Base Press.:** 73.0 mm Hg
- **Base Temp.:** 37.0 deg C
- **BTPS to STPD:** 1:2.505

### Base Values for Sampling

**Base CO2:** 6.65 mmHg

**Measured CO2:** 20.96%, **CO2:** 0.02%

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Lactate Response to Running Intensity

Blood Lactate (mM)

Percent of VO2max

lactate threshold
WORTHLESS!!
Professional 32 y.o. male cyclist

**Improvement in Performance but not necessarily in VO2max**

No Improvement in VO2max

**Very important Improvement in Lactate Clearance Capacity**
The events happening at the cellular level ultimately make the difference. A mediocre athlete can have the highest VO2max but not the best cellular adaptations to exercise.
Physiological Testing - Coaching 101

Main Parameters

• Lactate Metabolism
• Fat metabolism
• Carbohydrate Metabolism
• VO2max
• Metabolic Efficiency

- Only with the evaluation of these parameters it is possible to establish an appropriate and individual training program for an athlete

- Otherwise, without testing.....We are guessing!
Physiological/Metabolic Testing

In the Laboratory:
In the Field:

Ryder Hesjedal
2012 Tour of Italy (Giro) Winner

Tom Danielson
1st Stage 4 of US Pro Cycling Challenge 2012

Rory Sutherland
Winner of Queen Stage of US Pro Cycling Challenge 2012
In the Field:

CU Football

Colorado Rapids
Physiological/Metabolic Testing
Physiological/Metabolic Testing
Physiological/Metabolic Testing
Cellular and Metabolic Mechanisms Behind Performance
Mitochondrion is the Absolute King in Metabolism
Mitochondrion is the Absolute King in Metabolism
**Mitochondria and Performance**

**Lactate Metabolism**

Power Output decreases up to 50%

Debold et al, 2008
Differences in Lactate Metabolism

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<th>AC</th>
<th>PC</th>
<th>WPC</th>
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<td>$W_{\text{peak}}$</td>
<td>317 ± 23$^{1,2}$</td>
<td>338 ± 26$^{3,4}$</td>
<td>370 ± 32$^{1,3}$</td>
<td>401 ± 29$^{2,4}$</td>
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<td>$W_{\text{peak}} \cdot \text{kg}^{-1}$</td>
<td>4.91 ± 0.28$^{5,6}$</td>
<td>5.09 ± 0.21$^7$</td>
<td>5.27 ± 0.39$^{5,8}$</td>
<td>6.10 ± 0.31$^{6,7,8}$</td>
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<td>3.5 W·kg$^{-1}$</td>
<td>1.8 ± 0.2$^{d,e,f,g}$</td>
<td>1.3 ± 0.2$^d$</td>
<td>1.3 ± 0.1$^{e,h}$</td>
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<td>3.0 ± 0.9$i,j,k$</td>
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<td>4.5 W·kg$^{-1}$</td>
<td>6.6 ± 2.0$n,h,o$</td>
<td>4.6 ± 1.3$n,p,q$</td>
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<td>1.88 ± 0.4$n,q,r$</td>
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<td>5.0 W·kg$^{-1}$</td>
<td>10.1 ± 2.1$s,l$</td>
<td>8.7 ± 2.0$u,v$</td>
<td>5.8 ± 1.5$s,u,w$</td>
<td>3.1 ± 0.9$s,v,w$</td>
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<td>5.5 W·kg$^{-1}$</td>
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<td>9.35 ± 3.26</td>
<td>7.86 ± 2.16</td>
<td>5.64 ± 1.29</td>
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<td>6.0 W·kg$^{-1}$</td>
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<td>8.63 ± 0.50</td>
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<td>6.5 W·kg$^{-1}$</td>
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<td>11.4 ± 1.21</td>
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</table>

- WPC Criteria:
  - Tour de France, Italy and Spain winners or podium finishers.
  - World Champions.
  - UCI Pro Tour stage races or “classics” winners.

Mainly recruited: Easy - Long "Tempo riding"

Mainly recruited: Mild - Intense Exercise. Competition

Mainly recruited: Sprinting, Intense Exercise

FFA (free fatty acids)
Type I muscle cells
SLOW TWITCH

Type IIa muscle cells
FAST TWITCH

Type IIb muscle cells
FAST TWITCH

Effects of pH and Pi on Contraction Velocity in Rat Type II muscle fibers

Nelson et al, 2014

Muscle Lactate Clearance

Glucose

Glucose + ATP + PC

Lactate

Debold et al, 2008

Nelson et al, 2014

FFA (free fatty acids)
Type I muscle cells
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Type IIa muscle cells
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Type IIb muscle cells
FAST TWITCH

Nelson et al, 2014

Muscle Lactate Clearance

Glucose

Glucose + ATP + PC

Lactate

Debold et al, 2008

Nelson et al, 2014
Mitochondria and Performance
Substrate Utilization
Substrate Utilization

- FATmax
- Crossover Point

Recreational Athlete

World Class Athlete

San Millán’s Lab Data
The Metabolic Map

**Type I Fiber (Red)**
- Slow Twitch
- Oxidative System (Aerobic)
- Mainly recruited: Easy - Long “Tempo Exercise”

**Type Ila Fiber (White/Red)**
- Fast Twitch
- Glycolytic System (Aerobic)
- Mainly recruited: Mild - Intense Exercise, Competition

**Type Iib Fiber (White)**
- Super Fast Twitch
- PC & Glycolytic System (Anaerobic)
- Mainly recruited: Maximal Exercise, Sprinting, Weight Lifting

- **Fat is main fuel used**
  - This happens in the mitochondria. That’s why these fibers have the highest mitochondrial content

- **Glucose is main fuel used**

**Muscle Fiber Recruitment**
- **Type I Fibers (Slow Twitch)**
- **Type Ila Fibers (Fast Twitch)**
- **Type Iib Fibers (Super-Fast Twitch)**

As exercise intensity increases, muscles need to contract faster and stronger so faster muscle fibers need to be recruited. Fuel needs also change. Fat provides energy at low-moderate intensities (Z1-22) but it is not fast enough to provide energy at higher intensities, so Glucose is then the preferred fuel.
The Metabolic Training Concept

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<td>Z1</td>
<td>Easy- Recovery/Fat/Type I</td>
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<td>“Endurance”/Fat/Type I</td>
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<tr>
<td>Z6</td>
<td>&quot;Anaerobic&quot;/CHO-ATP-PC/Type IIb</td>
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</table>

- **Type I Fiber (Red)**
  - Slow Twitch Oxidative System (Aerobic)
  - Mainly recruited: Easy - Long "Tempo Exercise"

- **Type IIa Fiber (White/Red)**
  - Fast Twitch Glycolytic System (Aerobic)
  - Mainly recruited: Mild-Intense Exercise - Competition

- **Type IIb Fiber (White)**
  - Super Fast Twitch PC & Glycolytic System (Anaerobic)
  - Mainly recruited: Maximal Exercise, Sprinting, Weight Lifting

**Fat is main fuel used**

This happens in the mitochondria. That’s why these fibers have the highest mitochondrial content.

**Glucose is main fuel used**

This is why these fibers have the highest mitochondrial content.
Training Monitoring and Quantification
Monitoring of Overtraining
Monitoring of Overtraining
Preventing Overtraining is KEY

It is important to measure and monitor different important parameters throughout the season

We need to apply a scientific approach
General Workout/Recovery Cycle

- Training Stimulus
- Supercompensation
- Involution

Fatigue
Recovery

Zatsiorsky & Kraemer, 2006
Supercompensation Models

- Supercompensation positive
- Supercompensation positive
- Supercompensation negative
- Supercompensation positive accumulated
- Supercompensation null

Zatsiorsky & Kraemer, 2005
Physiological Monitoring throughout the season

Blood lactate levels vs power output
Hematological Monitoring of Overtraining

- Essential to prevent Overtraining before it happens
- Diagnose Overtraining in time
- One of the most important tools for an elite athlete and Coach
- Essential to have a scientific and clinical approach
- The answer is in the blood
Monitoring of Overtraining

- There are many parameters in the blood indicators of many different physiological conditions
  - Hematological
  - Biochemical
  - Hormonal
  - Serological

- About 200 Billion RBC’s are destroyed daily. So 200 Billion have to be replaced daily
Hematological Monitoring Throughout the Season
Bolood Profiling

- DETECTION, INTERVENTION AND CORRECTION
- Optimum Performance Frame
Hematological Monitoring Throughout the Season
Bolood Profiling

Hgb Evolution during the season

- 15g/dl Hgb x 1.34 mL O2 = 20.1g/dl O2
- 14.0g/dl Hgb x 1.34 mL O2 = 18.76 g/dl O2
  -6.8%

Hgb Evolution during the season
Hematological Monitoring Throughout the Season
Blood Profiling

Hgb Evolution during the season

- Optimum Performance Frame
- NO Detection, Intervention, correction = OVERTRAINING!!
Hematological Monitoring Throughout the Season
Bolood Profiling

- 15g/dl Hgb x 1.34 mL O2 = 20.1g/dl O2
- 12.8g/dl Hgb x 1.34 mL O2 = 17.15 g/dl O2
  -15% !
Hematological Monitoring Throughout the Season
Bolood Profiling

Muscle Damage
- Healthy muscle
- Muscle Injury

- Z-Lines

**Sarcomere**

---

Figure 4.11: An electron micrograph showing the normal arrangement of the actin and myosin filaments and Z-disk configuration in the muscle of a rat (a) before and (b) after a marathon race. A muscle sample taken immediately after a marathon race shows Z-disk streaming caused by the eccentric actions of running. Reproduced from Trigges and et al. (1986).
Hematological Monitoring Throughout the Season
Bolood Profiling

-Microrupture
Hematological Monitoring Throughout the Season
Blood Profiling

Muscle Damage

Muscle Enzymes
Hematological Monitoring Throughout the Season
Bolood Profiling

Average Muscle Damage Index for Starters on a Football Team During the Season

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Normal Levels

Decrease in Injury rate: 3x!
Hematological Monitoring Throughout the Season
Bolood Profiling

Muscle Damage Index

- No Damage
- Mild Damage
- Moderate Damage/slight Risk of Injury
- Important Damage/Moderate Risk of Injury
- Very High Damage/ High Risk of Injury
Marginal Gains. How important are they?
Aren’t Major Gains what we should be focusing on First?
Where is the Future?

The Biosensors
Scientific Training maximizes and utilizes all possible resources.

The Goal is to utilize 100% of genetic potential.

No Scientific Training = minimization and under-utilization of potential.

Overtraining is a great unknown affecting many Athletes and it should be assessed properly by a professional.

A true Scientific Training Necessary to make it to the next level.
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Assistant Professor, University of Colorado School of Medicine
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