Coaching with WKO4

Education #1  |  Power Duration Model and Metrics
Questions

• User Control Panel
  – Open with orange arrow

• Find the questions title and open

• Type your questions

• Ask as we go
My psychiatrist told me I was crazy, and I said I wanted a second opinion. He said, “Okay, you're ugly too.”

Rodney Dangerfield
Session 1: Objectives

**Background**
Review and understand the Power-Duration Curve Model and its uses

**Metrics**
Build an understanding of the key metrics derived from the power duration curve model

**Case Study**
Give overview and example of use
Power-Duration Curve Model
To build the only analytics engine specifically built for the endurance community, we need a "model"
...so, let's start with understanding human performance modeling
Human Performance Modeling

data-driven development and application of predictive, reliable, and executable quantitative models of human performance
Example: Critical Power Model
The Modern Athlete

Science
Information
Technology

Robust Human Performance Model
Power-Duration Model

a superior approach
A new beginning…

COGGAN: POWER-DURATION CURVE
So why did you build a power-duration model?
Why a PDC Model?

The perceived answer has been:

**INCORRECT**

TO DO A BETTER JOB AT PREDICTING POWER AT VARIOUS DURATIONS
A better system of modeling

Using the *exercising athlete* to better understand their physiology…

…and using *their specific physiology* to better understand how to *specifically train them*. 
...by building a robust model that gave us specific insight into the athlete’s physiology, we can better understand the dose-and-response relationship.
Metabolic Pathways

- **Anaerobic**
  - ATP-CP System
    - ATP/Creatine Phosphate
  - Glycolysis System
    - Carbohydrates

- **Aerobic**
  - Oxidative System
    - Fats, CHO, Proteins

Resynthesize ATP

Insight Accelerated
Prediction vs. Physiology

The end goal was to more closely estimate the performing athlete historical and current physiology…why?

- Models based on prediction tend to overpredict
- Individualization of the training process
- To gain insight into the underlying physiology
- To improve both understanding and tracking of the dose-response mechanism in endurance training
…so what is the basis of this model?
Mathematical Basis

A few points about the mathematical basis of the PDC model

- Proprietary and black box; why?
- Based on all data over the course of select days (90 days)
- Needs a small range of maximal data: short, medium, and long
- Subject to GIGO (garbage in, garbage out)
...but is it **accurate**?
Distribution of normalized residuals: WKO4 model

Mean absolute error = 3.2 ± 2.8%

Slide contribution: Dr. Andrew Coggan
Comparison of root mean squared errors

\[ \hat{\theta} = \sqrt{\text{variance}} + \text{bias} \]

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<thead>
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<th>Model</th>
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<td>CP\textsubscript{1-10}</td>
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<tr>
<td>CP\textsubscript{3-30}</td>
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<tr>
<td>CP 3-parameter</td>
<td>1.1±0.4%</td>
</tr>
<tr>
<td>AIS</td>
<td>4.6±0.9%</td>
</tr>
<tr>
<td>Ward-Smith</td>
<td>2.5±0.6%</td>
</tr>
<tr>
<td>Pinot and Grappe</td>
<td>1.1±0.6%</td>
</tr>
<tr>
<td>WKO4 model</td>
<td>0.3±0.1%</td>
</tr>
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</table>
Limitations of other models: residuals

CP$_{1-10}$

CP$_{3-30}$

CP 3-parameter

AIS

Ward-Smith

Pinot and Grappe

Slide contribution: Dr. Andrew Coggan
Power-Duration Metrics
A simple starting point

Response to training is a complex phenomenon.

We need to look deeper than just critical power or FTP.
Power-Duration Metrics

- Phenotype
  - Pmax
  - mFiber Type
  - FRC
  - TTE
  - mVO2max
  - Stamina
  - mFTP
Power-Duration Metrics

- Phenotype
  - Pmax
  - FRC
  - Corrected Power
  - Enhanced Power Profile
  - mFTP
  - mFiber Type
  - mVO2max
  - Stamina
  - TTE
Phenotyping

The objective (i.e., statistically-based) classification of an athlete into one of four (for now) phenotypes (e.g., “sprinter”), based on the overall shape of their power-duration relationship.

**Phenotype**
the set of observable characteristics of an individual resulting from the interaction of its genotype with the environment
Phenotypes

![Graph showing power output over time for different phenotypes: Sprinter, All-rounder, Pursuer, TTer. The graph illustrates how each phenotype maintains its power output over time, with Sprinters starting high and All-rounders starting lower but maintaining a steady rate.]
Power-Duration Metrics

- Pmax
- FRC
- mVO2max
- mFTP
- Stamina
- TTE
- mFiber Type

Phenotype
Pmax

The maximal power that can be generated for a very short period of time. Units are W or W/kg. The maximum power over at least a full pedal revolution with both legs.
Metabolic Pathways

Anaerobic
- ATP-CP System
  - ATP/Creatine Phosphate
- Glycolysis System
  - Carbohydrates

Aerobic
- Oxidative System
  - Fats, CHO, Proteins

Resynthesize ATP
Pmax Advantage vs. Max Power

• Full revolution avoids power spikes; mode-driven metric, uses multiple points on model
• Most units record the data at the end of the record rate; Pmax ensures some balance, re-ensuring at least one full revolution
• Model – no infinite time/infinite power issue
• Better than max 5 second as not affected by fatigue
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<th>Women</th>
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<td>Average</td>
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<td>272</td>
<td>Standard Deviation</td>
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<td>Low</td>
<td>939</td>
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<td>Medium</td>
</tr>
<tr>
<td>High</td>
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<td>High</td>
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</table>
Functional Reserve Capacity (FRC)

The total amount of work that can be done during continuous exercise above FTP before fatigue occurs. Units are kJ or J/kg.
Metabolic Pathways

**Anaerobic**
- ATP-CP System
  - ATP/Creatine Phosphate
- Glycolysis System
  - Carbohydrates

**Aerobic**
- with O2
  - Oxidative System
    - Fats, CHO, Proteins

**Metabolic Pathways**
- Resynthesize ATP
Compared to AWC

**Anaerobic Work Capacity (AWC)** is a measure of the total work that can be performed utilizing only stored energy sources within the muscle, including Adenosine Triphosphate (ATP), phosphocreatine, glycogen, and the oxygen bound to myoglobin.

Based on Critical Power as basis

**Functional Reserve Capacity (FRC)** is the total amount of work that can be done during continuous exercise above FTP before fatigue occurs. Units are kJ or J/kg.

Based on Functional Threshold Power as basis
## FRC Standards

<table>
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<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
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<tbody>
<tr>
<td>Range</td>
<td>9.0-35.1 kj</td>
<td></td>
<td>Range</td>
<td>6.2-24.2 kj</td>
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<tr>
<td>Average</td>
<td>18.2 kj</td>
<td></td>
<td>Average</td>
<td>13.2 kj</td>
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<td>Standard Deviation</td>
<td>4.7 kj</td>
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<td>Standard Deviation</td>
<td>4.0 kj</td>
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<td>High</td>
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<td>High</td>
<td>17.2 kj</td>
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<tr>
<td>Medium</td>
<td>13.5-22.9 kj</td>
<td></td>
<td>Medium</td>
<td>9.2-17.2 kj</td>
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<tr>
<td>Low</td>
<td>&lt;13.5 kj</td>
<td></td>
<td>Low</td>
<td>&lt;9.2 kj</td>
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</table>
How does FRC “Convert” to Watts?

A Kilojoule is simply a thousand joules, and a joule is equal to \textit{watts x seconds} \,(J= W \times s). So when you do 400 watts for 5 seconds, you’ve \textit{used 2,000 joules, or roughly 2 KJs!}
Effect of Time over FTP

Rest MUST occur under FTP

Full

Pmax determines maximal usage / drain

When the “battery” is empty, rest must occur
modeled VO2max (VO2max)

the maximum amount of oxygen the body can use during a specified period of usually intense exercise
Why Vo2max?

VO₂max – why is it important?

- VO₂max is the best overall measure of cardiovascular fitness and sets the upper limit to the production of energy (ATP) via aerobic metabolism (i.e., mitochondrial respiration). As such, having an adequately high VO₂max is a necessary but not a sufficient condition to be an elite endurance athlete.
Modeled Functional Threshold Power (mFTP)

mFTP is the model-derived highest power a rider can maintain in a quasi-steady-state without fatiguing.
Metabolic Pathways

**Anaerobic**
- ATP-CP System
  - ATP/Creatine Phosphate
- Glycolysis System
  - Carbohydrates
- without O2

**Aerobic**
- Oxidative System
  - Fats, CHO, Proteins
- with O2

Resynthesize ATP
## mFTP standards

<table>
<thead>
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<tbody>
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<td>173-316 W</td>
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<td>Average</td>
<td>319 W</td>
<td>247 W</td>
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<td>SD</td>
<td>54 W</td>
<td>32 W</td>
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<tr>
<td>Low</td>
<td>≤265 W</td>
<td>≤215 W</td>
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<tr>
<td>Med</td>
<td>266-372 W</td>
<td>216-279 W</td>
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<tr>
<td>High</td>
<td>≥373 W</td>
<td>≥280 W</td>
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Success

Functional Threshold Power (FTP) is the greatest (but not only) indicator of performance success.
Power-Duration Metrics

- $mFiber$ Type
- $TTE$
- Stamina
- $P_{\text{max}}$
- $FRC$
- $mVO_{2\text{max}}$
- $mFTP$
Time To Exhaustion (TTE)

the maximum duration for which a power equal to FTP can be maintained
TTE

• **Increase FTP.** Training to improve FTP is typically focused on lifting the Power-Duration Curve by increasing the amount of power one can put out in this quasi-steady state.

• **Extending TTE.** Training to extend the maximum duration at which a power equal to FTP can be maintained.
Stamina

A measure of resistance to fatigue during prolonged-duration, moderate-intensity (i.e., sub-FTP) exercise. Units are percent of maximum, i.e., 0-100%, although most individuals will fall in the 70-90% range.
Why do I want Stamina?

• Ability to reduce decline in power output over extended durations
• Ability to stay on the Power-Duration Curve for “over-extended” durations
• Beware: High costs
Use Case
We improve that which we measure!
Benefit Highlights

- Specific response
- Specific cost
- Align to performance demand
- Better understanding of athlete ability

360 View
Sprint Training

Quantify the change

<table>
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<tr>
<td>FRC</td>
<td>15.5 kjs</td>
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<td>VO2max</td>
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<tr>
<td>mFTP</td>
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<tr>
<td>TTE</td>
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Crit & 1 Day Training

- **Pmax**: Before 1,375, After 1,355
- **FRC**: Before 15.5 kjs, After 19.8 kjs
- **VO2max**: Before 65.1, After 66.8
- **mFTP**: Before 255, After 248
- **TTE**: Before 50:30:00, After 41:25:00

Quantify the change
MTB Training

Quantify the change

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pmax</td>
<td>1,375</td>
<td>1,324</td>
</tr>
<tr>
<td>FRC</td>
<td>15.5 kjs</td>
<td>19.3 kjs</td>
</tr>
<tr>
<td>VO2max</td>
<td>65.1</td>
<td>67.1</td>
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<tr>
<td>mFTP</td>
<td>255</td>
<td>257</td>
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<tr>
<td>TTE</td>
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TT Training

Quantify the change

<table>
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<th>TT</th>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>Pmax</td>
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<td>1,100</td>
</tr>
<tr>
<td>FRC</td>
<td>15.5 kjs</td>
<td>16.5</td>
</tr>
<tr>
<td>VO2max</td>
<td>65.1</td>
<td>67.1</td>
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<tr>
<td>mFTP</td>
<td>255</td>
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<tr>
<td>TTE</td>
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<td>40:00:00</td>
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Q&A

https://www.youtube.com/playlist?list=PLOhzd0zmrJznNH_fz5oO9UwwVm_KXsLQ3

Demystifying the WKO4 Power Duration Curve
Individualizing your Training with WKO4
Building Pmax and Functional Reserve Capacity in WKO4
Building Functional Threshold Power and Stamina