The Physiological Basis of Lance Armstrong's Tour de France Performances

Jay T. Kearney, PhD, FACSM
VP Carmichael Training Systems

Lance Armstrong – July 22, 2005

Presentation Overview

- The purpose of this presentation is to:
  1) Highlight the complex nature of extreme endurance performance
  2) Provide some examples of how a change in a single predictor of performance may not be associated with a change in overall performance
  3) Review some of the data that are available on Lance Armstrong
  4) Demonstrate that based on these data Armstrong's performances can be justified.

CL 119

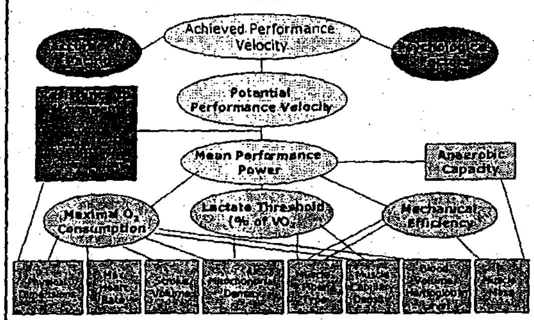
EXHIBIT
2
Kearney
1/6/06

Optimal Performance Is Complex and Multifaceted

- Attempts have been made to challenge the performances of Armstrong based on the calculation of an array of isolated variables
- A performance as complex as the Tour de France can not be dissected based on the analysis of single determinants of performance
- The basis of this tutorial review of factors relevant to performance is a model by Seiler, however, multiple other similar models could be employed.

Endurance Performance Model

-Seiler



What Contributes to Optimal Performance?

- * Genetic endowment
- Physiological factors
- Psychological factors
- Training adaptability
- Technology factors
- Team dynamics
- Luck

I will attempt to walk through a review of these determinants of optimal performance.

Achieved Performance Velocity

- Accuracy of Pacing
  - *Exceptional team dynamics and coordination*
  - Limited number of "bad days"
  - Multiple strategies over the year in de Tour
- Potential Performance Velocity
- Psychological Factors
  - Arguably there is no one in de Tour who is more competitive and focused on success!

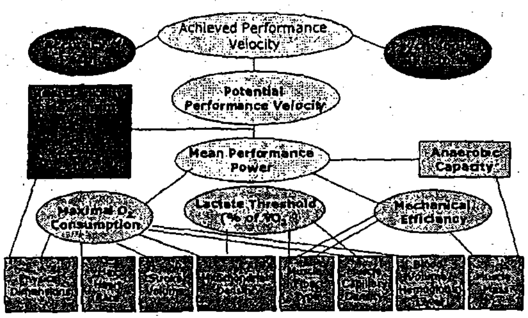
Quote

"It is not the will to win that matters – everyone has that. It is the will to prepare to win that makes the difference."

Paul Bear Bryant

Lance Armstrong demonstrated a single-minded commitment to excellence in the Tour de France

Endurance Performance Model
-Seller



Potential Performance Velocity

- Resistance to Movement*
  - Gravity
  - Mechanical resistance
  - Rolling resistance
  - Aerodynamic drag
  - Technical mastery
  - Flexibility
  - (* Discussion of the F-One team is included later)
- Mean Performance Power

Performance Modeling – Heil, 2004

W_D = 0.5 x air density x frontal surface area x coefficient of drag x velocity^3

Where:

- air density is in (kg/m^3)
- FSA = 0.00916 x $m_b^{+0.762}$ + 0.066
- CD = 4.45 x $m_b^{-0.45}$

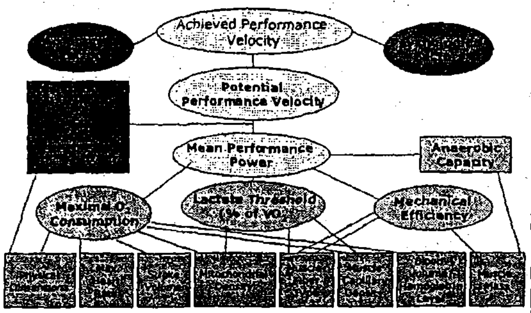
Based on Armstrong's reported power, "...both ... models predict Armstrong's potential to break both the UCI Hour Record and the Best Hour Performance at sea level and altitude velodromes."

Mean Performance Power

: Is the average power (watts) that a rider is able to generate over the course of a stage (15 min to 5+ hours) and is the resultant of sum of aerobic and anaerobic sources x the efficacy of the man:machine interface.

- Maximum Oxygen Consumption
- Lactate Threshold
  - Expressed in % of VO2 or absolute ml/kg
  - In "prologues" the term maximum lactate steady state is more appropriate
- Mechanical Efficiency

Endurance Performance Model
-Seiler



Maximum Oxygen Consumption

: Is the maximum volume of oxygen consumed during an exercise bout of progressive intensity to failure.

- Physical dimensions
- Max heart rate
- Stroke volume
- Mitochondrial density
  - Size and complexity are also important
  - Development of aerobic enzymes within
- Muscle capillary density
- Blood volume
- Hemoglobin level
  - Muscle levels of myoglobin

The Details of the Equation

VO2 = Cardiac output X a – v Oxygen difference

Cardiac output = max Heart Rate X Stroke Volume
(unknown for LA)

a (arterial saturation) oxygen = 18 to 20 ml O2/100 ml blood
(unknown for LA)

v (venous saturation) oxygen = 2 to 15 ml O2/100 ml blood
(unknown for LA)

6.1 L/min = (195 X 200?) x (19 ml O2/100 – 3 ml O2/100)

6.1 L/min (83 ml/kg @ 73 kg) = 39 L/min (cardiac output) x 16 ml O2 delivery/100 ml blood (a – v O2 difference)

VO2 and Lance Armstrong

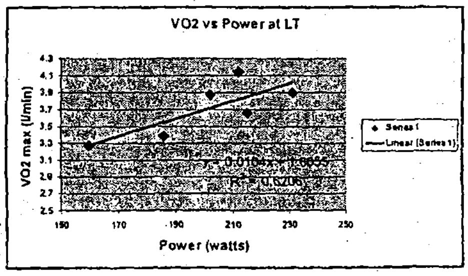
- Does Lance have the engine?
- Based on laboratory data acquired just prior to racing season or shortly after – YES!
- Coyle – September '93 – 6.10 L/min
- USOC – End of Feb '91 – 6.2 L/min
- USOC – September "93 – 6.08 L/min
- At body weights of 76,74,72,and 70 kg these are:
  - 80.9 ml/kg
  - 83.1 ml/kg
  - 85.4 ml/kg
  - 87.8 ml/kg
- Indurain was 6.4 L/min (79 ml/kg) Padilla, et al., 2000.

Lactate Threshold

: Is the highest workload (watts or VO2) with less than 1.0mM increase in blood lactate

- Mitochondrial density
  - (size, complexity of structure, and enzyme concentration)
- Muscle fiber type
- Muscle capillary density
- Fuel sources
- Capacity of other muscle tissue to metabolize lactate
- Relevance of Max Lactate Steady State

VO2 and Power at Lactate Threshold are not matched 1:1



Mechanical Efficiency (Economy)

: Is the percentage of total energy expended (cost or input) that is expressed as external work (output).

- Muscle mass
- Muscle fiber type
- Neuromuscular recruitment
- Contractile economy
- Force profile
- Pedaling mechanics

Calculation of Mechanical Efficiency

- % Efficiency = Energy used / Work done
- Work done is measured in Watts
- Energy used is measured in oxygen (kcals)
- At 100% efficiency 1 kcal/min = 70 Watts
- 1 L oxygen = ~ 5 kcals, therefore 5L O_2/min = ~ 25 kcals/min
- At 100% efficiency this would be ~ 1,750 W
- At 23% efficiency this represents ~ 405 W

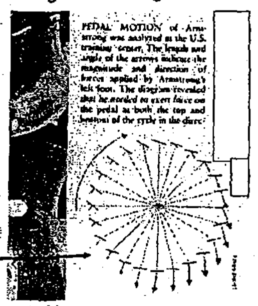
Mechanical Efficiency Data on Armstrong

- Coyle, J. Appl. Physiol., 2005 concluded that Armstrong has progressively increased his ME by 18% through a combination of:
  - Reduction in % body fat and total body mass
  - Improved efficiency of ATP turnover in muscle
  - Increased # or reliance on Type I fibers
  - Altered myosin and myosin ATPase activity
- Data from the USOC confirm a progressive increase in efficiency of 20%
- Armstrong's increase in self-selected cadence while racing should also contribute to gains.

Mechanical Efficiency Data on Armstrong (2)

- Pedaling Mechanics
  - The efficacy with which a rider applies force to the pedal – or the % of the force applied that is used to produce torque
  - Early in his senior career, Armstrong was modest to poor – referred to as a "masher"!
  - Improvements in pedaling mechanics may have contributed significantly to his improved efficiency

Armstrong Pedaling Clock Diagram



Counterproductive application of force on the upstroke

(Kearney, Scientific American, July 1996)

Additional Observations - JTK

There are some additional factors that in my opinion may have contributed to the success of Armstrong and US Postal/Discovery

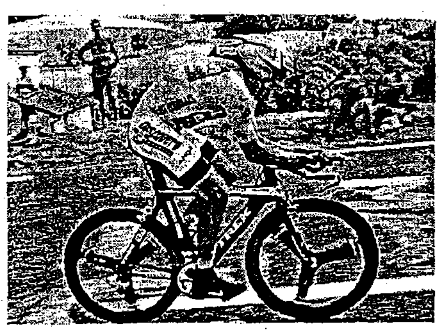
- Obsession with Technology
- Unusual Altitude Physiology
- Durability and Training Adaptability
- Luck!

Obsession with Technology

- US Postal/Discovery Teams have revolutionized the commitment to performance optimization of the bike-rider complex
- Development of the F-One team
  - Assembly of leading cycling technology experts – focused on performance
- Trek bikes – stage and rider customized
- Shamino components
- Head wheels
- Nike and customized aerodynamic clothing
- Gyro helmets
- ADM information management
- Wind tunnel testing
- Other teams have been forced to follow

Ulrich and Armstrong in Time Trial

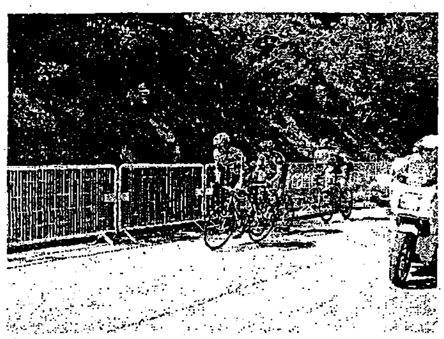
Armstrong on TT Bike - 2005



Unusual Altitude Physiology

- Some of Armstrong's most dominant or dramatic stages have been on hill top finishes or long climbs!
- The established principle of altitude physiology is that VO2max decreases as a function of altitude at rate of about 1%/1,000ft or 300m
- Data from the USOC lab (JTK testing) indicate that Armstrong does not appear to be affected at 1,862m or about 6,000ft
- Consequence: If Armstrong and a competitor start a 2,000m climb with exactly the same capacity and power output and rider B demonstrates a normal response, by the end of the climb Armstrong will have accumulated a 6% or about 25 watt advantage.

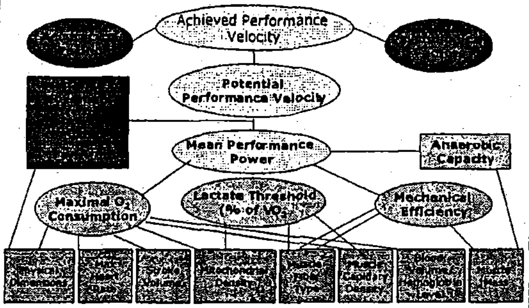
Armstrong Attacking on a Climb in Stage 15 - 2005



Durability and Training Adaptability

- Armstrong has traditionally become stronger in later stages/mountains!
- Factors that may influence this include:
  - Pacing and commitment to the "big" picture
  - Team dynamics
  - Ability to handle the volume/intensity load
    - Very high percentage Type 1 muscle fibers
    - Excellent attention to nutrition during and after stages
    - Commitment to recovery processes
  - Training adaptation data from ASU – Armstrong was able to improve LT (lactate threshold) by 75 watts based on 36 hours of training.

Endurance Performance Model
-Seiler



"Successful Olympic performance is a complex, multifaceted, fragile, and long-term process that requires extensive planning and painstaking implementation. It seldom happens by chance and can easily be disrupted by numerous distractions. Attention to detail counts, but must also be accompanied by flexibility to deal with numerous unexpected events."

"Positive and Negative Factors Influencing U.S. Olympic Athletes and Coaches: Atlanta Games"
by
Dan Gould and Diane Guinan