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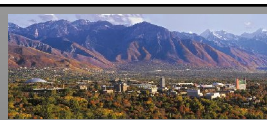


Myth and Science in Cycling: Crank Length and Pedaling Technique

James C. Martin, PhD

NeuroMuscular Function Lab

The University of Utah

Myth and Science in Cycling

- Crank length
  - Maximal power
  - Metabolic cost or efficiency
  - Fatigue during maximal sprinting
- Pedaling Technique
  - Metabolic cost/efficiency
  - Power

Crank Length: Premises

1. There is an optimal crank length for each cyclist
2. The optimal crank length will substantially improve performance
3. Non optimal crank length will substantially compromise performance

Cycling Crank Length

- Google: optimal ”crank length” = 2270 hits
- Books, magazines, web sites etc.
- Scientific evidence?

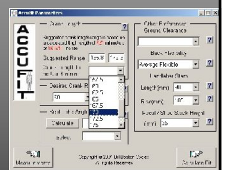
Inbar et al., 1983 (Wingate test power)

Yoshihuku and Herzog 1996 (model)

Martin et al., 2000, 2001, 2002 (maximum power)

McDaniel et al., 2002 (metabolic cost)

Thomas and Martin, work in progress (fatigue)



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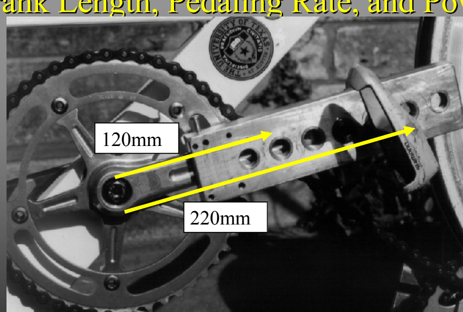
Crank Length, Pedaling Rate, and Power

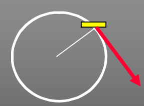


Martin et al. Biomechanics 2000

Martin et al. Euro JAP 2001, 2002

Purposes

- Determine the effects of crank length on
  - Maximum cycling power
  - Optimal pedaling rate
  - Optimal pedaling speed
    - » Crank length x pedaling rate

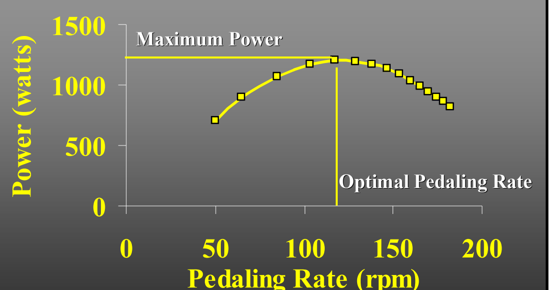


- Determine the optimal crank length for maximum power

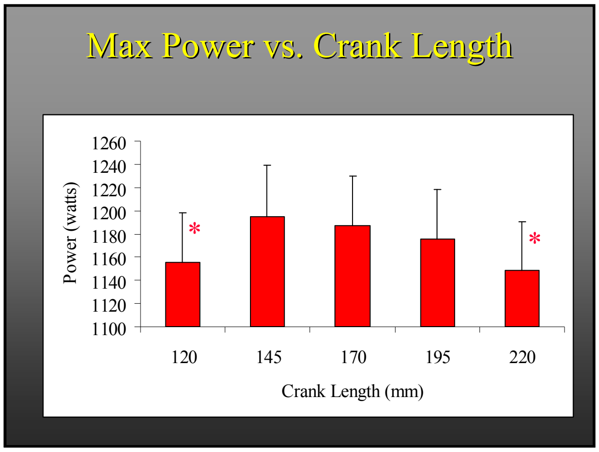
Methods

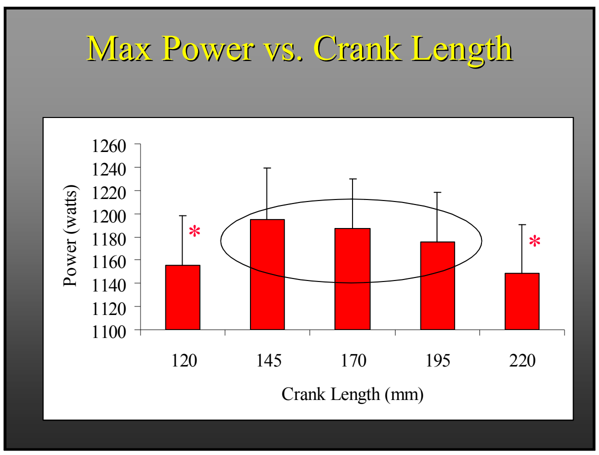
- 16 trained cyclists performed maximal cycling with 120, 145, 170, 195, and 220mm cranks
- TALL and short cyclists
  - Measured Thigh, Tibia, and Total leg length
- Two practice sessions on each length
- Maximal power-velocity relationships

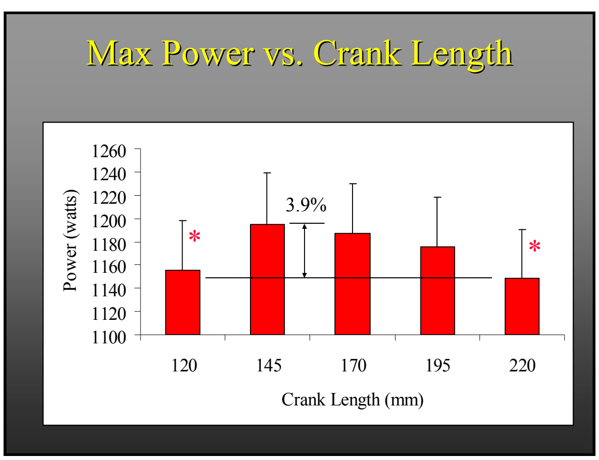
Inertial Load Cycle Ergometry



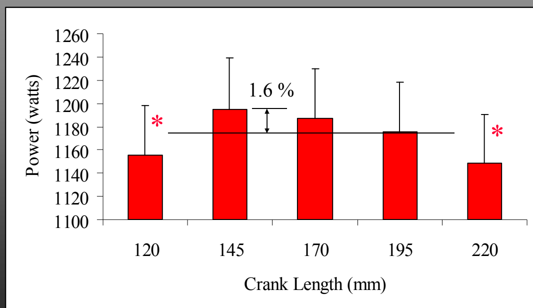
Martin et al. Med Sci Sports Exerc. 1997


Max Power vs. Crank Length
1260
1240
1220
1200
1180
1160
1140
1120
1100
Power (watts)
*
*
120
145
170
195
220
Crank Length (mm)


Max Power vs. Crank Length
1260
1240
1220
1200
1180
1160
1140
1120
1100
Power (watts)
*
*
120
145
170
195
220
Crank Length (mm)


Max Power vs. Crank Length
1260
1240
1220
1200
1180
1160
1140
1120
1100
Power (watts)
3.9%
*
*
120
145
170
195
220
Crank Length (mm)

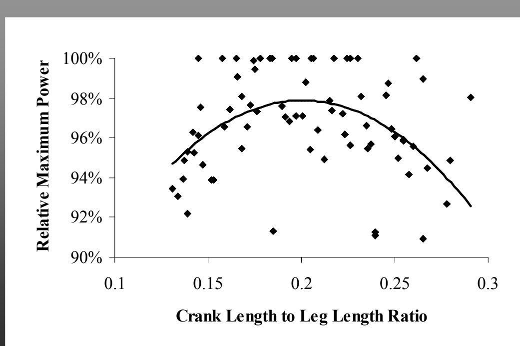
Max Power vs. Crank Length



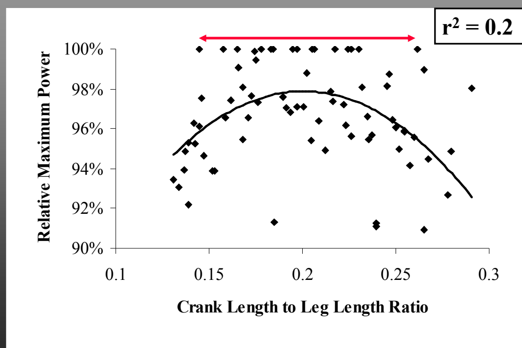
What about Individual Differences?

Leg length
Thigh length
Tibia length

Leg/Crank Length vs. Power



Leg/Crank Length vs. Power

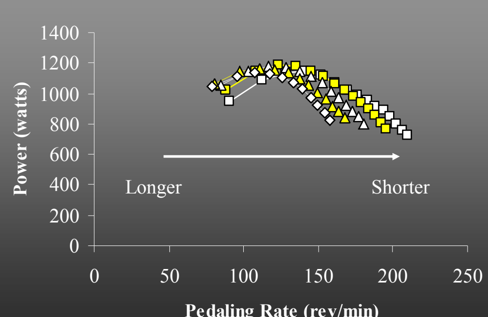


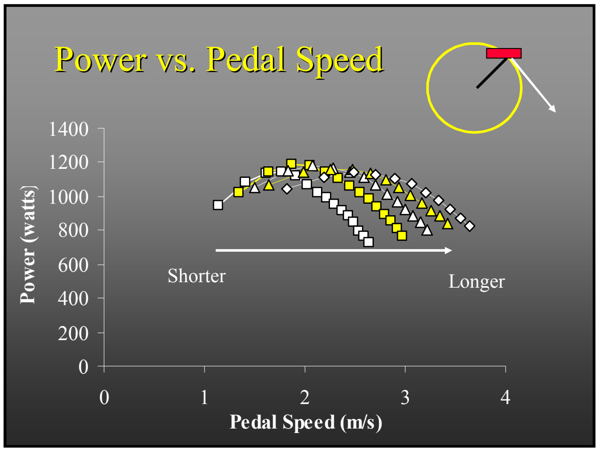
One Size Fits All?

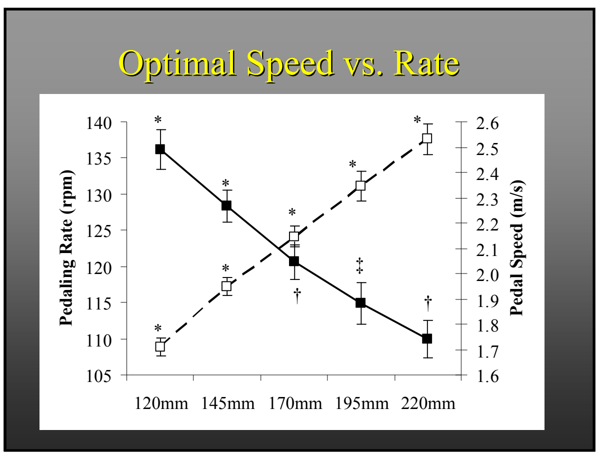
170 mm cranks would compromise the power of the shortest and tallest riders by AT MOST 0.5%

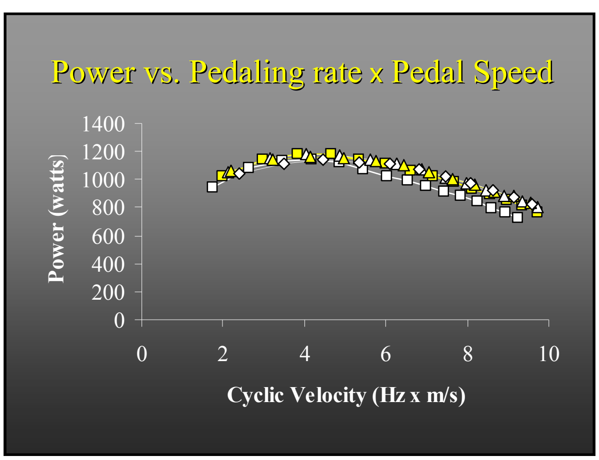
For example 6 watts out of 1200

Basic Science: Power vs. Pedaling Rate




Power vs. Pedal Speed
Power (watts)
1400
1200
1000
800
600
400
200
0
Shorter
Longer
0
1
2
3
4
Pedal Speed (m/s)


Optimal Speed vs. Rate
Pedaling Rate (rpm)
140
135
130
125
120
115
110
105
Pedal Speed (m/s)
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
120mm
145mm
170mm
195mm
220mm


Power vs. Pedaling rate x Pedal Speed
Power (watts)
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
Cyclic Velocity (Hz x m/s)

Pedal Speed x Pedaling Rate

Velocity Specific Force

Scaled by Excitation
(time for full activation)

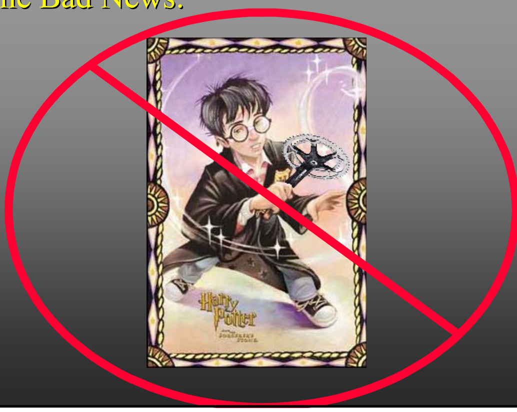
Summary

- Effect of crank length is small and significant only at extreme lengths
- 170mm cranks will compromise power of the tallest and shortest riders by at most 0.5%
- Pedal speed and pedaling rate interactively limit power

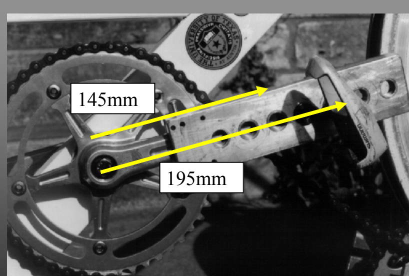
The Good News:

Cyclists can ride the crank length they prefer without concern of decreasing maximal power

The Bad News:



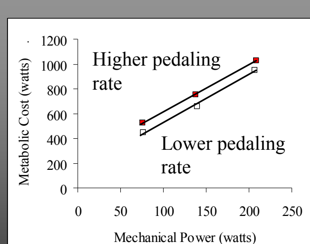
Crank Length, Pedaling Rate, and Metabolic cost



McDaniel, Durstine, Hand, and Martin JAP 2002

Background

- Metabolic cost increases with pedaling rate
- Higher metabolic cost means lower efficiency
- Pedaling rate proportional to pedal speed for any specific length



Purposes

Determine the effects of

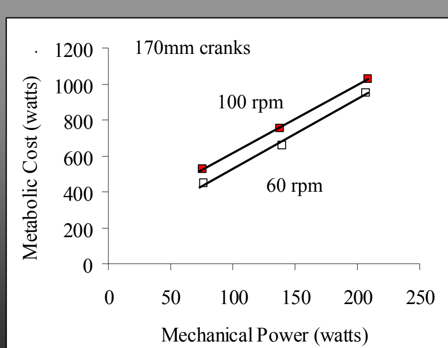
- Pedaling rate
- Pedal speed
- Crank length

on metabolic cost

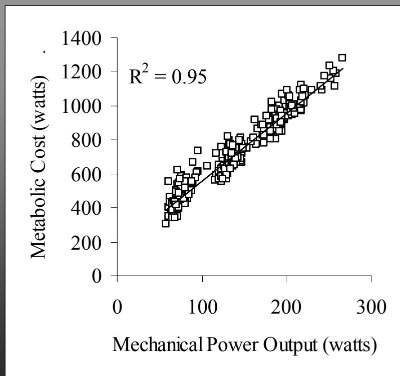
Methods

- 9 trained cyclists performed submaximal cycling
  - 145, 170, and 195mm cranks
  - 30, 60, 90% of lactate threshold
  - 40, 60, 80, and 100 rpm
  - Combination of 3 lengths and 4 rates = 12 pedal speeds
- Metabolic cost determined with by measuring $\dot{V}O_2$ and $\dot{V}CO_2$
- Power and pedaling rate recorded with SRM

Metabolic Cost vs. Mechanical Power



Metabolic Cost vs. Mechanical Power

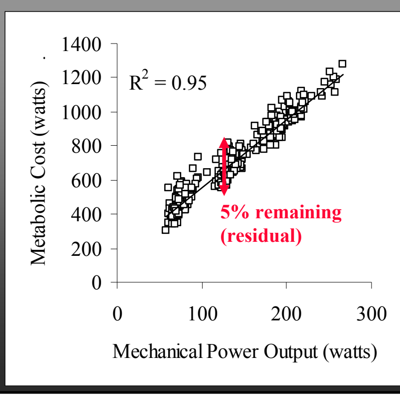


3 lengths

4 pedaling rates

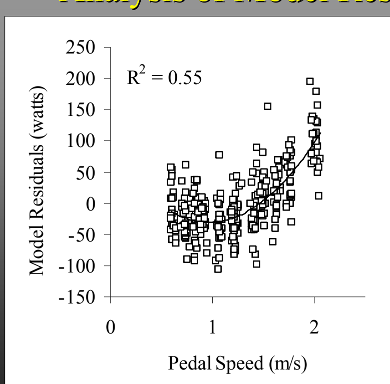
12 pedal speeds

Metabolic Cost vs. Mechanical Power



Only 5% of variability not due to power output

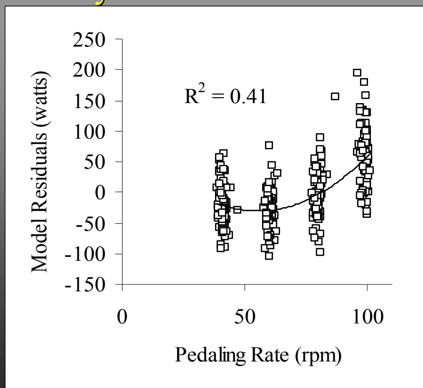
Analysis of Model Residuals



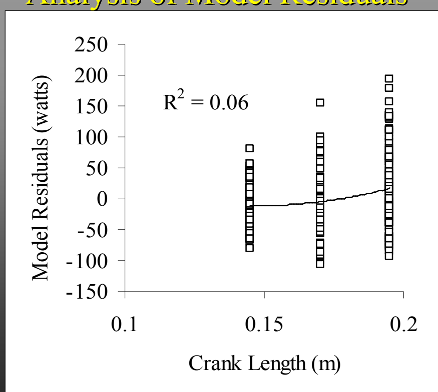
55% of the 5% not accounted for by power

2.7% of the total variation

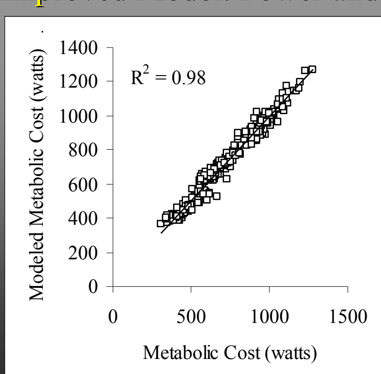
Analysis of Model Residuals



Analysis of Model Residuals



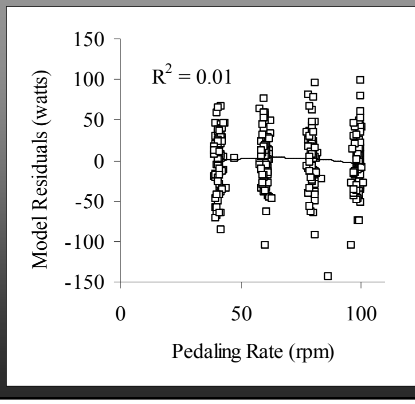
Improved Model: Power and Pedal Speed



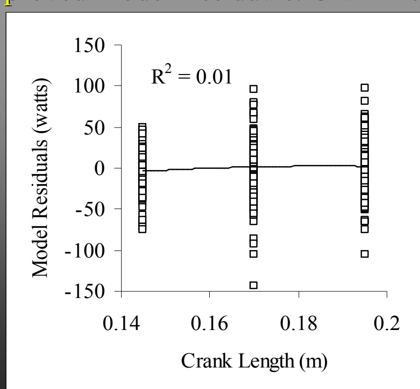
Power and pedal speed accounted for 98% of the variability in metabolic cost for all subjects

Individual predictions were even better: 99%

Improved Model Residuals: Pedaling Rate



Improved Model Residuals: Crank Length



Summary

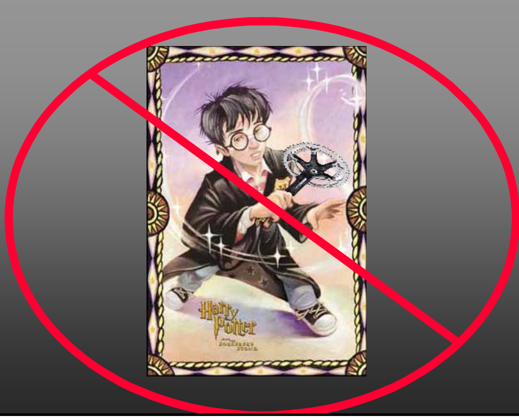
- Power Output and Pedal Speed account for 98% of the varaibility in metabolic cost in this group of 9 cyclists.
  - 99% of the variablity for each individual
- Of the remaining 2% variability, crank length and pedaling rate each accounted for 1% or 0.02% of total

Conclusion

Crank length and pedaling rate influence metabolic cost and efficiency only by influencng pedal speed

The Good News:

- Cyclists can ride the cranks they prefer without concern of decreasing efficiency
- Crank lengths can be chosen to meet other criteria:
  - Aerodynamic position (shorter)
  - Ground clearance (shorter)
  - Rehabilitation or flexibility (longer)



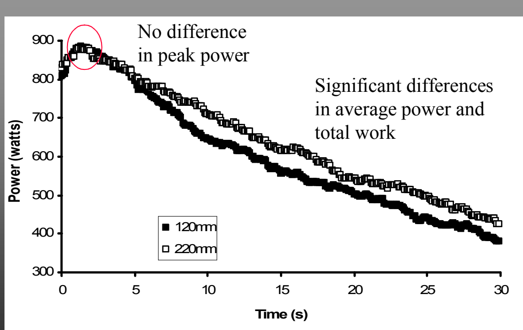
Crank Length and Fatigue

- Our previous work examined metabolic cost during cycling below lactate threshold and maximum rested power for < 4 sec
- Aleksander Thomas' Masters Thesis
- Practical question: Effects of crank length on fatigue during a maximal 30 sec sprint
- Basic science: Fatigue mechanism
  - Excitation vs. Force production

Methods

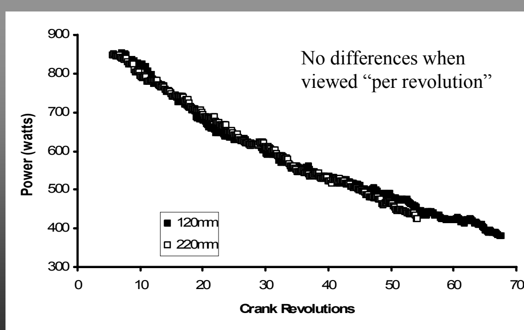
- Ten cyclists (road, mtn, and triathlon)
- Maximal 30 s trials
- 120 and 220 mm cranks
- Pedaling rate for maximum power
  - 135 rpm for the 120mm
  - 109 rpm for the 220mm
- Power recorded with SRM

Results



But….

But…

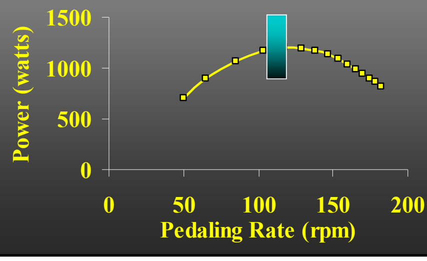


Summary

- Rate of fatigue was greater when cycling with shorter cranks than longer cranks
- Fatigue per revolution was identical for the two crank lengths
  - Crank length per se does not influence fatigue
- Data suggest that a relatively fixed increment of fatgue occurs with each maximal contraction

Performance Application

- Pedaling rates at or slightly below optimal pedaling rate should maximize total work by maximizing power and minimizing fatiuge



Crank Length Summary

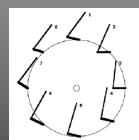
- Very small effect on maximum power
- No effect on metabolic cost (efficiency)
  - 145-195mm cranks
- No effect on fatigue

Pedaling Technique: Premises

1. Elite cyclists have highly developed pedaling technique that makes them more efficient
2. Efficient pedaling requires pedaling ”circles” or producing even torque throughout the cycle
3. Devloping the technique to produce maximal power, especially at high pedlaing rates, takes years of training

Pedaling Technique

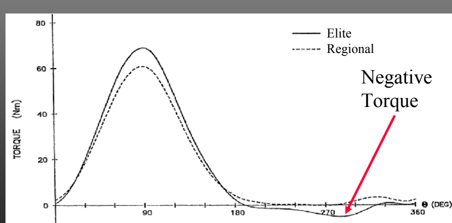
- Google "Pedaling Technique" 6,230 hits
  - Pedal circles, pull up, pull across the bottom, etc...



- Scientific evidence?
  - Coyle et al., 1991 Physiological and biomechanical factors associated with elite cycling performance
  - Korff et al., 2007 Pedaling technique and efficiency
  - Martin et al., 2001 Learning to produce max power

Coyle et al., 1991

- Regional level cyclists and Elite cyclists (7-11 team and US National team)
- Elite cyclists pushed down harder and pulled up less
- Elite were significantly more efficient and had greater % slow twitch fiber

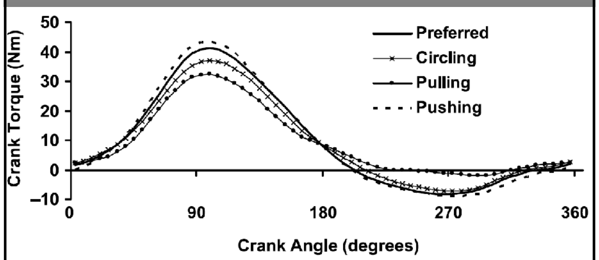


Pedaling Technique and Efficiency
Korff et al., 2007

- The Coyle results were complicated by muscle fiber type
- What if the same cyclist pedaled with different techniques?
- Methods
  - Eight cyclists were instructed to pedal with four techniques
    - Preferred
    - Circling
    - Pulling Up
    - Pushing
  - Pedal Forces and metabolic cost were measured
    - Index of effectiveness and eveness or torque distribution
    - Efficiency

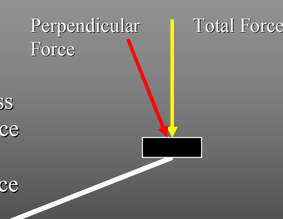
Pedaling Technique and Efficiency Korff et al

- Cyclists followed the directions and significantly changed their pedaling technique



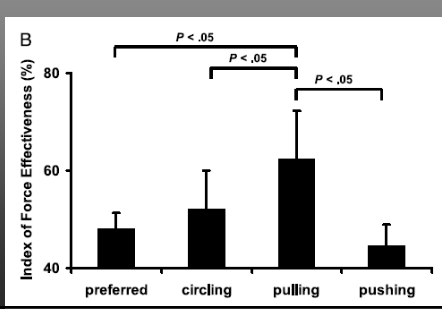
Pedaling Technique and Efficiency Korff et al

- Index of effectiveness is the ratio of the force perpendicular to the crank to the total force
- Averaged over the entire cycle



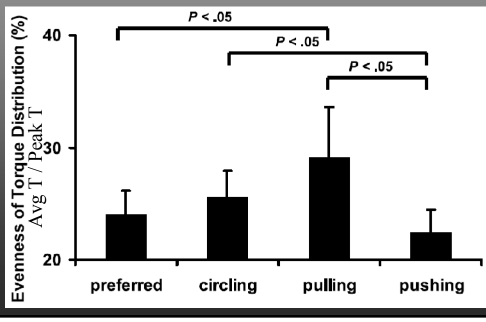
Pedaling Technique and Efficiency Korff et al

- More force was perpendicular to the crank with pulling
- Pulling was more “effective”



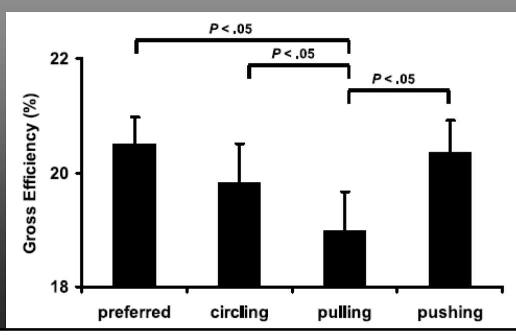
Pedaling Technique and Efficiency Korff et al

- Torque was distributed more evenly throughout the cycle with "pulling"



Pedaling Technique and Efficiency Korff et al

Pulling up was significantly LESS efficient!



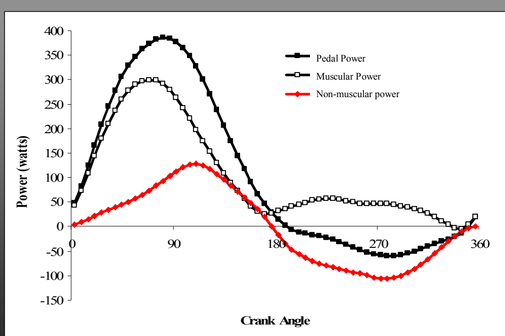
Pedaling Technique and Efficiency Korff et al

- Pulling up is significantly less efficient than pedaling with your own intuitive preferred technique
- Data suggest that muscles that flex the leg are intrinsically less efficient

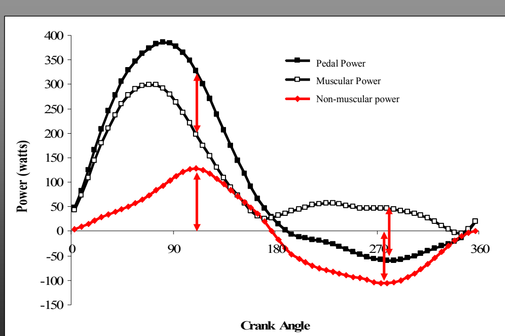
Pedaling Technique and Efficiency Korff et al

- How can it be more efficient to produce negative torque and power?
- Force and power measured at the pedal reflect the combined effects of:
  - Muscular effort
  - Gravity: weight of the limb
  - Changes in kinetic energy: accelerating/decelerating the limb

Pedal Power = Muscular + Non-muscular



Pedal Power = Muscular + Non-muscular



Take Home Messages

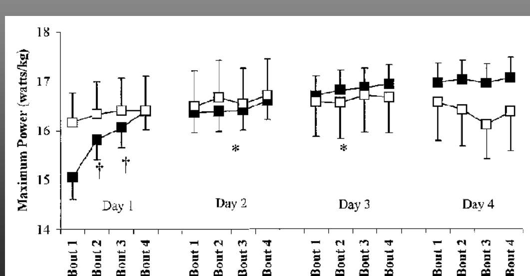
- Muscular power is almost always positive even in relative beginners
  - Exception at high pedaling rates (Neptune and Herzog 1999)
- The negative power observed at the pedal is mostly due to gravity
- That power is essentially balanced by the weight of the other leg

Time Course of Learning to Produce Maximum Power Martin et al., 2000 IJSM

- Thirteen trained racing cyclists (Cat 1-3)
- Thirty five active men who did not own bicycles
- Inertial load power tests 4 times per day for 4 or 8 days

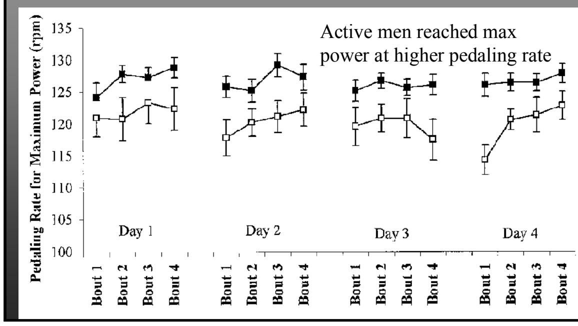
Learning to Produce Maximum Power

- Trained cyclists' power was stable from the first trial
- Active men increased power within day 1 and until day 3



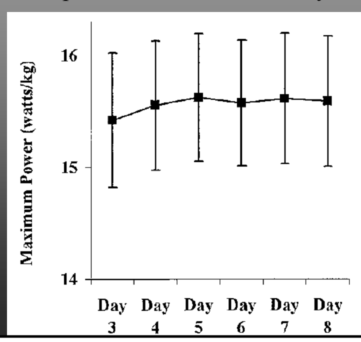
Learning to Produce Maximum Power

Trained and active subjects' optimal pedaling rate stable



Learning to Produce Maximum Power

Active men's power was stable from day 3 to day 8



Technique Summary

- Elite cyclists do not pull up more than regional level cyclists
- Pulling up is LESS efficient than preferred pedaling technique
- Pedal power and crank torque do not tell the whole story: muscular/non-muscular power
- Learning to produce maximum power requires only 3 days (36 sec total) practice

Just What Does Matter????

- Maximizing the power you can produce
- Minimizing the power you must produce

Maximizing the power you can produce

- Hard training to improve VO_2 max and Lactate Threshold for endurance
- Following a well-designed program
- Increased muscle mass and anaerobic capacity for sprint power
- Proper nutrition and hydration
- Recovery

Minimizing the power you must produce

- Reducing aerodynamic drag
  - Body position and equipment
  - Drafting
    - Cornering: Don't leave gaps
    - Climbing: Important even on steep climbs
    - Cross winds: Find whatever draft is available
- Reduced weight during climbing
- Maintaining equipment

Acknowledgments

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  Clay Anderson, Larry Durstine, Greg Hand
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- Gatorade Sports Science Institute

Thank you!

Serotta International Cycling Institute

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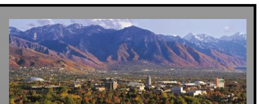

Questions?