Pedaling effectiveness
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About us

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Usefull & useless forces

Osorio Valencia 2007

- Tangential / radial
- Muscular / Inertial
Definitions

- **Mechanical Efficiency**: Carrying out a movement with less work from the mechanical point of view. Ratio work input vs work output.

- **Gross efficiency**: is the percentage ratio of external work achieved compared to total energy expenditure.

- **Metabolic Efficiency**: level of caloric waste of the body.

- **Delta**: Measures mechanical efficiency with changing workloads. Compare the work output between different workloads with the difference in energy expenditure over time in each load.
Muscular non / muscular forces.

Kautz 93
WKO4 & Power effectiveness

Classic metrics

- Torque effectiveness
- Smoothness
WKO4 & Power effectiveness
WKO4 & Power effectiveness

- Pedaling metrics
  - GPR: power that you are releasing on each pedal stroke to propel the bicycle forward
  - GPA: the power that is being produced but is not going to moving the bicycle forward and is being absorbed. Oposite vector to GPR.
  - Kurtotic index: how “punchy or smooth” your pedaling stroke each and the higher the number the more “punchy” your stroke.
Pro rider.
Amateur rider
Kurtotic Index: pro vs amateur.
Mechanical vs metabolic efficiency.

Korf 2007

- The improvement of the Mechanical ef. by altering the technique worsens the metabolic efficiency.
Mechanical vs metabolic efficiency

Leirdal 2011

- Mec eff. no relationship with gross efficiency
- No relationship with saddle setback
- No relationship with % climb
- Affected by cadence
Mec efficiency & intensity

Busko 2005

- Allouts 300 / … / 750 watts
- Improves with intensity

<table>
<thead>
<tr>
<th>Variables</th>
<th>2.5% BW</th>
<th>5.0% BW</th>
<th>7.5% BW</th>
<th>10.0% BW</th>
<th>12.5% BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_m$ [rpm]</td>
<td>151.5±8.9</td>
<td>142.0±7.2</td>
<td>113.8±5.5</td>
<td>98.2±7.9</td>
<td>78.0±9.2</td>
</tr>
<tr>
<td>$v_a$ [rpm]</td>
<td>192.5±11.2</td>
<td>171.1±9.2</td>
<td>141.9±5.7</td>
<td>119.0±9.9</td>
<td>97.2±10.3</td>
</tr>
<tr>
<td>$W_m$ [kJ]</td>
<td>20.0±1.7</td>
<td>20.2±1.6</td>
<td>20.1±1.7</td>
<td>20.2±1.7</td>
<td>20.1±1.7</td>
</tr>
<tr>
<td>$P_a$ [W]</td>
<td>383.3±34.7</td>
<td>681.9±67.1</td>
<td>844.0±77.2</td>
<td>948.4±109.1</td>
<td>958.0±142.8</td>
</tr>
<tr>
<td>$P_a$/BM [W/kg]</td>
<td>4.72±0.28</td>
<td>8.39±0.45</td>
<td>10.39±0.43</td>
<td>11.67±0.97</td>
<td>11.93±1.26</td>
</tr>
<tr>
<td>$P_e$ [W]</td>
<td>293.5±28.5</td>
<td>547.9±46.7</td>
<td>670.9±56.8</td>
<td>761.0±87.5</td>
<td>753.8±96.3</td>
</tr>
<tr>
<td>$E$ [kJ]</td>
<td>344.9±58.3</td>
<td>288.0±51.0</td>
<td>273.1±66.1</td>
<td>260.0±47.2</td>
<td>254.2±45.3</td>
</tr>
<tr>
<td>$E_{cost}$ [kJ]</td>
<td>168.4±32.7</td>
<td>129.7±29.5</td>
<td>115.2±26.8</td>
<td>112.6±27.8</td>
<td>106.7±14.2</td>
</tr>
<tr>
<td>GE [%]</td>
<td>5.9±1.0</td>
<td>7.2±1.2</td>
<td>7.8±2.1</td>
<td>8.0±1.4</td>
<td>8.1±1.1</td>
</tr>
<tr>
<td>NE [%]</td>
<td>12.1±2.6</td>
<td>16.0±2.8</td>
<td>16.3±3.2</td>
<td>16.9±3.2</td>
<td>17.6±1.6</td>
</tr>
<tr>
<td>HI [%]</td>
<td>24.7±3.3</td>
<td>21.1±4.1</td>
<td>21.1±4.4</td>
<td>19.2±5.8</td>
<td>18.2±2.8</td>
</tr>
<tr>
<td>$f$ [s]</td>
<td>68.5±4.1</td>
<td>36.9±2.0</td>
<td>30.0±0.0</td>
<td>26.6±1.9</td>
<td>27.0±3.4</td>
</tr>
<tr>
<td>HR$_d$ [beat/min]</td>
<td>106.5±7.2</td>
<td>105.0±11.4</td>
<td>97.8±9.9</td>
<td>100.5±9.3</td>
<td>94.2±8.9</td>
</tr>
<tr>
<td>HR$_{max}$ [beat/min]</td>
<td>177.0±9.0</td>
<td>174.2±8.1</td>
<td>168.8±12.6</td>
<td>169.2±10.9</td>
<td>166.5±9.7</td>
</tr>
</tbody>
</table>
Mec efficiency, met eff. & cadence

Busko 2004

- 40 / 60 / 80 /100

- Both aggravate when we separate in excess of the self selected one.

<table>
<thead>
<tr>
<th>Variable</th>
<th>40 rpm</th>
<th>60 rpm</th>
<th>80 rpm</th>
<th>100 rpm</th>
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<tbody>
<tr>
<td>$W_a$ (kJ)</td>
<td>44.1±1.14</td>
<td>43.7±1.4</td>
<td>43.8±0.68</td>
<td>43.6±0.7</td>
</tr>
<tr>
<td>$E_i$ (kJ)</td>
<td>297.8±36.2a</td>
<td>299.3±43.0a</td>
<td>291.4±39.7a</td>
<td>358.1±44.2</td>
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<tr>
<td>$E_{total}$ (kJ)</td>
<td>203.2±28.2</td>
<td>194.0±15.7</td>
<td>191.3±16.2a</td>
<td>233.1±34.2</td>
</tr>
<tr>
<td>GE (%)</td>
<td>15.0±2.2a</td>
<td>14.9±2.6a</td>
<td>15.3±2.1a</td>
<td>12.3±1.5</td>
</tr>
<tr>
<td>NE (%)</td>
<td>21.8±2.8a</td>
<td>22.6±2.1a</td>
<td>23.1±2.1a</td>
<td>19.0±2.7</td>
</tr>
<tr>
<td>HR (beats·min⁻¹)</td>
<td>163.6±14.9</td>
<td>161.5±16.8</td>
<td>165.3±13.5</td>
<td>171.7±11.4</td>
</tr>
<tr>
<td>ΔHR (beats·min⁻¹)</td>
<td>83.2±12.9a</td>
<td>84.8±15.2</td>
<td>87.3±13.7</td>
<td>95.2±15.9</td>
</tr>
</tbody>
</table>

- averages differ significantly from mean 100 rpm; a - P<0.05
Metabolic efficiency and pedaling technique/ankling

Cannon 2007

- Ankling (plantarflexion in descending phase) increases metabolic expenditure and increases EMG demand of hamstrings and Gastrocnemius.
Ankling

<table>
<thead>
<tr>
<th>Entire Workout</th>
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</thead>
<tbody>
<tr>
<td>Ant+ Balance</td>
<td>Asymmetry Index</td>
<td>Avg GPR L</td>
<td>Avg GPR R</td>
<td>Avg GPA L</td>
<td>Avg GPA R</td>
<td></td>
</tr>
<tr>
<td>L/R</td>
<td></td>
<td>W</td>
<td>W</td>
<td>W</td>
<td>W</td>
<td></td>
</tr>
<tr>
<td>50/50</td>
<td>0.77</td>
<td>110</td>
<td>125</td>
<td>12</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>
Intensity & Gross metabolic efficiency

Jobson 2012

• Increase with HIIT
• Not changes by changing pedaling technique in short term.

Figure 1. Relative changes in gross efficiency (GE) across the study period. Values are averaged across intensities to the highest common work rate and presented as means ± standard deviation. Group A completed: high intensity training between tests 1 and 2; unrestricted training between tests 2 and 3. Group B completed: no high intensity training between tests 1 and 2; unrestricted training between tests 2 and 3. * = significant increase above previous test (p < 0.05); † = significant difference between groups (p < 0.05). Source: Hopker et al. (2010).
Metabolic efficiency & feedback

Theurel 2012

• With feedback on mechanical efficiency to increase it, the metabolic efficiency is not altered, but the subject is fatigued before.
Metabolic efficiency & feedback

Chartogne 2016

- Same power and same metabolic efficiency
Metabolic efficiency and core

Weijmans 2014

• does not improve the gross metabolic efficiency but improves the perception of the effort of the subjects.
Torque & Gross metabolic efficiency

Camara 2012

- More medium torque, more efficiency.

**FIG. 5.** DATA ILLUSTRATING THE RELATIONSHIP BETWEEN THE TMEAN AND THE GE AT THE EXERCISE INTENSITY AT WHICH THE OBLA WAS PRODUCED (I3)

Legend: Linear regression is represented by a solid black line, ± 95% confidence interval is represented by dashed lines. There is a positive correlation between the two variables ($r = 0.63$, $p < 0.05$). The formula describing the relationship is $y = 0.569x + 11.781$; $R^2 = 0.396$. $T_{mean}$, mean of the propulsive and resistive torque; $GE$, gross efficiency; OBLA, onset of blood lactate accumulation; I3, power output at which the OBLA was produced.
Gross metabolic efficiency and cadence

Camara 2012

- Decreases metabolic efficiency when in OBLA cadence increases

**FIG. 6.** DATA ILLUSTRATING THE RELATIONSHIP BETWEEN THE CADENCE AND THE GE AT THE EXERCISE INTENSITY AT WHICH THE OBLA WAS PRODUCED (I3)

Legend: Linear regression is represented by a solid black line, ± 95% confidence interval is represented by dashed lines. There is a positive correlation between the two variables (r = −0.81, p < 0.05). The formula describing the relationship is $y = -0.298x + 47.932$; $R^2 = 0.661$. GE, gross efficiency; OBLA, onset of blood lactate accumulation; I3, power output at which the OBLA was produced.
Metabolic efficiency (Meta analysis)

Bini 2013

- When it increases, metabolic efficiency decreases
- It decreases when tilt decreases.
- The saddle setback changes do not affect
- It is not related to the experience of cycling or to fatigue.
Mechanical efficiency and pedaling technique

Takaishi 98

- The use of hip flexors alleviates the generation of torque of the knee extensors, being able to be a good technique training guide.
Max/min torque and metabolic efficiency

Jobson 2009

Figure 3. Mean torque data from 6 min at 250 W. These are the participants with the highest and lowest ranges of torque at this work rate.
Mechanical efficiency and sport level

Coyle 91

- Elite cyclists greater mechanical torque in the lowering of the pedal, perhaps by greater intensity of pedaling.
Mechanical efficiency and sport level

Garcia 2009

• Better in Pros than in amateurs
• Maybe from experience or expertise
Torque while pedaling

Bini 2013

- Decrease
  - Cadence
  - Back Tilt
- Increase:
  - More resistance/intensity
  - Feedback

Increasing makes decrease metabolic efficiency

- Innocuous:
  - Saddle position
  - Fatigue
  - Years of practise
Mechanical efficiency and torque

Bertucci 2008

- The elite cyclists give equal peaks of torque but they are more prolonged
Asymmetry

Smak 98
- No relationship with leg dominance neither intensity

Bini 2016
- Retraining for reducing asymmetry index.
Asymmetry index
Asymmetry

Bini 2015

• No relationship with performance
Mechanical efficiency and HIIT

Kautz 91

- High intensity improves mechanical efficiency at equal cadence
Mechanical efficiency and intensity

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Cadence</td>
<td>Left Leg Power</td>
<td>Right Leg Power</td>
<td>Ant+ Balance</td>
<td>Asymmetry Index</td>
<td>Avg GPR L</td>
<td>Avg GPR R</td>
</tr>
<tr>
<td>rpm 82</td>
<td>W 101</td>
<td>W 108</td>
<td>L/R 48/52</td>
<td>1.10</td>
<td>145</td>
<td>147</td>
</tr>
</tbody>
</table>
Mechanical efficiency and intensity
Mechanical efficiency and intensity
Mechanical Efficiency
Standing/ sitting

Bouillord 2014

- 20.5 to 21.5 increase in mechanical efficiency.
- The more intense and the more inclination.
Mechanical & metabolic efficiency – crank length

Ferrer Roca 2014

- Does not change metabolic efficiency
- Increases torque in different parts of the circle
- Decrease 1-2% mechanical efficiency
Mechanical efficiency and wedges of foot support control

Daehyeok Kim 2016

- The use of varo control wedges improves mechanical efficiency and vertical force.
Mechanical Efficiency and Bike fit

Bateman 2014
• Increases of 2.7% efficiency thanks to a bikefitting

Coyle 1995
• Increases of 1-2% in gross efficiency thanks to a bikefitting
Models of muscular activation

Hug 2009

- Dependent on power, cadence, body position and fitness.
- Can not be disconnected from mechanical analysis and vice versa
Mechanical Efficiency and Muscle Alternation

Sanderson 2010

• In prolonged efforts, the hip flexors become fatigued and should be replaced by greater torque in the knee extensors
Mechanical Efficiency and fatigue

Diefenthaler & Bini 2007
• Does not decrease with fatigue
Mechanical Efficiency, intensity, weight and cadence

Kitawaki 2014

- Intensity increases mechanical efficiency
- Weight and cadence are inversely related to mechanical efficiency.
Mechanical Efficiency & Insoles

Cole Meyers 2015

- Insoles improve muscular implications but do not improve performance.
Mechanical eff & variation
Speed Average pedaling

% Cadence oscillation

- Does not distinguish between subjects of different levels
- But distinguish between different cadences

Kitawaki 2014

Figure 6. Normalized angular velocity with respect to crank angle in all conditions, comparing measurements made by motion sensor and motion capture system.
To sum up evidence...

Optimizing metabolic efficiency

- Training at high intensity (HIT)
- Self selected cadence or slightly lower than usual 80-90.
- Keep the ankle without planting bending on the descent. Stif ankle.

Optimizing mechanical efficiency

- Sport level
- Position of the body on the bike in inclination and retreat of saddle (baricenter), and stabilization of the foot
- Feedback from our live pedaling.
- Simetrize the movement through re-education of the gesture.
- Optimize the ascending phase of pedaling
Pedaling technique-experiment

- Pioneer power meter.
- Cyclospeher analysis
- WKO4
- One cyclist, pedaling at the same cadence with the same resistance in the trainer, with different pedaling technique.
Pedaling technique

• Pulling
Pedaling technique

- Circling

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</tr>
<tr>
<td>49/51</td>
<td>0.95</td>
<td>130</td>
<td>138</td>
<td>11</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

**Pedaling Monitor**

- Cadence: 82 rpm
- Pedaling Power: 294 W
- Pedaling Efficiency: 64%

*PULL UP PULL UP DOWNSHIFT UP PULL UP*
Pedaling technique

• Pushing/ inertial
EVIDENCE BASED GUIDELINES

• Pushing could be a good pedaling technique for submaximal sustained efforts >60% FTP (+ met. eff.)
• Circling just in big/short efforts supramaximal efforts.
• Relationship with Korff (2007)
Without conclusive scientific evidence on the improvement of the gesture

- High cadence training
- Low intensity training
- Positioning of knee on the pedal axis
- Symmetry

- Core
- Position of the cleats
- Connecting crank Length
- Relationship between mechanical and metabolic efficiency.
Take home idea

• Enhance the mec. efficiency doesn’t mean always improvement in metabolic efficiency
New perspectives

• Garmin Cycling dynamics
Q&A

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