Quantitative analysis of power output in the field performance of wheel-sports athletes.

Ryuji Hiramatsu, Ph.D
UTokyo Sports Science Initiative, The University of Tokyo

Katsuyuki Kakinoki, Ph.D
Blue Wych LTD.
Outline:

1. Power analysis in Cycling

2. Application of Power analysis to Para-cycling

3. Application of Power analysis to Wheelchair racing
Powermeter: a tool for quantifying the power

- This tool can quantify the power/force output of a rider by measuring the torque coming from the legs with strain gauges in the crank and cadence of pedaling.

- Measured data is recorded in the data logger on handle.

1. Power analysis in Cycling

Comparison between Power and HR
1. Power analysis in Cycling

Utilizing the powermeter as “wearable sensor” on bicycle

① Quantification of “Goal”
Measuring temporal changing work
⇒ Grasping the performance process in the race
Grasping the related matters with the capacity of a rider in the race

① How much capacity is required in the target race?

![Graph showing work vs. distance with sections labeled: climbing section, high-speed flat section before climbing, up-down section in the first half of the race.](image-url)
1. Power analysis in Cycling

Utilizing the powermeter as “wearable sensor” on the bicycle

② Quantification of “Rider’s capacity”
Identifying the lactate threshold, the predictor of potential race performance, with the incremental load test

① Required capacity

② How much is the current capacity of a rider? (fundamental ability, technique, tactics …)
LT (Lactate Threshold): Exercise intensity at a sharp increasing of glucose utilization.

From LT, fast-twitch muscle fiber is mobilized.
1. Power analysis in Cycling

Utilizing the powermeter as “wearable sensor” on the bicycle

① Required capacity

② Current capacity of a rider

③ For closing this gap, how does a rider train?

③ Quantification of “Training”
Optimizing the training intensity and time
Recording the training history
1. Power analysis in Cycling

**Right-shift of Lactate curve = Improvement of the endurance capacity**
Carrying the Power-training combined with utilizing power meter and measuring LT

An example of training composition at a day
(The intensity of each training menu is shown on the lactate curve schematically)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Middle</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time and frequency</td>
<td>10 min x 2 times</td>
<td>2.5 min x 3 times</td>
</tr>
<tr>
<td>Course profile</td>
<td>flat</td>
<td>climbing</td>
</tr>
</tbody>
</table>
1. Power analysis in Cycling

**Indicator for evaluating sprint performance**

**200m Flying Time Trial**: The performance period is the shortest. The acceleration force is the major element.

Evaluating with power, torque, and cadence during flying.
1. Power analysis in Cycling

Torque and cadence of pedaling are in a linear relationship during acceleration.


During 200m (approx. 10 sec), and the rider endures exerting the sufficient torque in the peak cadence (142~152 rpm) to keep the speed.
1. Power analysis in Cycling

Extracting the moment of sprint performance with power analysis

Shifting torque-cadence line to the upper-right

Increasing the peak cadence

Track bike: fixed gear
1. Power analysis in Cycling

Torque distribution

Professional rider

Amateur rider

Extracting the technique of pedaling with power analysis
Power training is effective for the paracycling riders to improve the performance.

2. Application of Power analysis to Para-cycling

During this period, this rider improved the performance of 3000m Individual Pursuit. (shortened approx. 5% of the time)

10% increase of Power

Process of the intensities of the training menus

Middle
High

2013 autumn ~ 2014 winter

2014 autumn ~ 2015 winter
Application of power analysis to developing the prostheses for double below-knee amputated rider

Requirements
- All equipments must meet UCI equipment regulations.
- No energy storage or assistance mechanism is integrated into a prosthesis.

Both legs below knees are amputated. ⇒ Is the limitation loose or severe?

What is the optimized form/alignment of the prosthesis?
Adjustment of the alignment of the prostheses for maximizing the rider’s potential through the power and motion analysis

Fabricating endoskeletal prostheses for measurements

Power and motion analysis
Rider’s subjective evaluation

Confirmation of the optimized design

Fabricating exoskeletal prostheses for competitions

Compare the parameters regarding the power (torque distribution, LR ratio, efficiency etc.)
2. Application of Power analysis to Para-cycling

**Slight modification of the length can affect the pedaling movement**

Before change of the length  After change of the length
2. Application of Power analysis to Para-cycling

The modification of the length of the prosthesis can affect the movement of the hip joint.

- The vertical motion of the pelvis was reduced after the change.
  - Range of the vertical motion of each side of the pelvis.
  - Improved the stability.

Comparison of range before and after change:
- Left:
  - Before: 1
  - After: 0.8
- Right:
  - Before: 0.6
  - After: 0.4
The alignment of cycling prosthesis may have a severe limitation

Even if the length and angle are modified slightly, pedaling performance can be affected.

It is assumed that the limitation is defined by the rider’s physical characteristics and riding position.
3. Application of Power analysis to Wheelchair racing

Developing a wheel to measure the power output during running in the field

Attachment of SRM power meter to wheelchair racer wheel

![Wheelchair racer with SRM power meter attached](image)

<table>
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<th>Power (Total)</th>
<th>Power (Left)</th>
<th>Power (Right)</th>
</tr>
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<tbody>
<tr>
<td>(W)</td>
<td></td>
<td></td>
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</table>
3. Application of Power analysis to Wheelchair racing

\[
\text{Power} = \text{Torque loading on a handrim} \times \text{cadence of a handrim} \\
(W) \quad (N \cdot m) \quad (\text{rad/s})
\]

(1) Force along the tangent line of a handrim  
(2) Cadence of a handrim  
(3) Pitch of an arm
3. Application of Power analysis to Wheelchair racing

In either vehicle, the loading point from the limbs (handrim or pedal) is connected to rear wheel to generate forward movement.

Otherwise, a leg is fixed to a pedal, but an arm is not fixed to a handrim.
3. Application of Power analysis to Wheelchair racing

An example of the training data

< Course profile >
Tokyo, rural region
Distance: 3160m
Average slope: 1.9%

Negative correlation between the average power and the climbing time.
3. Application of Power analysis to Wheelchair racing

The progress of wheelchair runner’s performance by carrying out power training (case rep.)

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Approx. 5% increase of Av. Power during 2 months training
Concluding Remarks:

➢ Power analysis can extract various elements of cycle sport performance, and can evaluate the rider’s abilities and characteristics quantitatively.

➢ Power analysis can provide the effective training for improving the rider’s endurance capacity with the physiological parameters like lactate threshold, and can monitor the progress of the athlete.

➢ Power training method can be adapted to the cycling athlete with the impairment, furthermore, be applied to developing the optimizing equipment which is specific for the impairment.

➢ Many elements of wheelchair running performance are common with that of cycling performance, otherwise, there are also the different elements between these sports. Defining and extracting these elements are effective to provide more optimized training, and the power analysis may be a strong approach to investigate.
Our Team and Collaborators

The University of Tokyo
Ryuji Hiramatsu

Fuji Construction Co., Ltd.
Masaki Fujita

The University of Tokyo
Hideo Hatta
Naoya Takei
Kimitaka Nakazawa

Blue Wych LTD.
Katsuyuki Kankinoki

Amanda Sports
Yozo Chiba

Japan Sport Council
Taisuke Kinugasa
Junichi Kawai
Sho Hatanaka
Yuzaburo Kojima