Internal Mechanical Power During Cycling Using Non-Circular Versus Circular Chainrings

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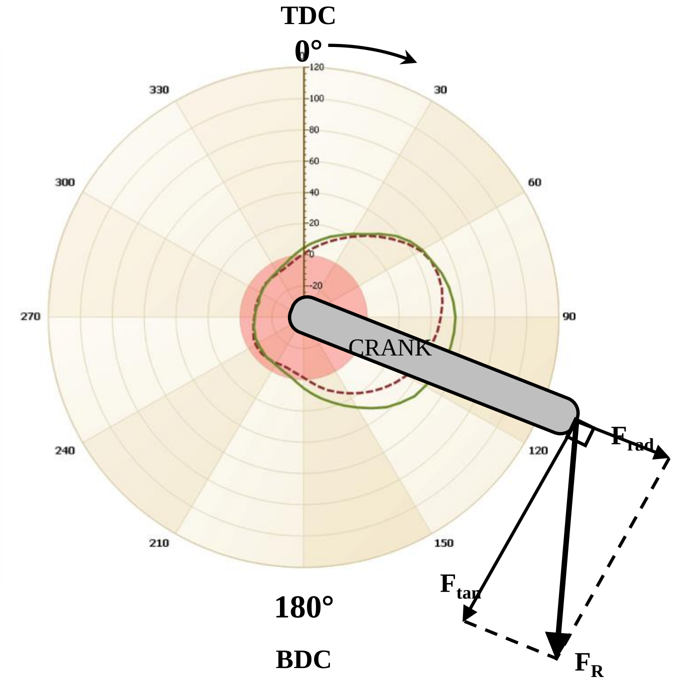
Background:

Non-circular chainrings are typically characterised by:

- A decreased radius when the crank is around TDC & BDC
- An increased radius when the crank is around 90°

Q-Rings

- Conflicting findings on effects on physiological, kinematic, EMG and performance variables for maximal and submaximal cycling (Malfait et al. 2010; Martinez et al. 2006; Mateo-March et al. 2010, 2012, 2014; O'Hara et al. 2012; Peiffer & Abbiss 2010; Strutzenberger et al. 2014)



Internal Mechanical Power

The rate of energy required to move the limb segments against gravitational and inertial forces

- Physiological Approach
  - Assumes Total P_{mech} = EP + IP

$IP_{met} = \text{x-intercept}_{\text{EP-MP linear regression}} \cdot DE$

- Biomechanical Approach
  - There may be a transfer of energy between EP and IP, i.e., IP ≠ EP + IP

$IP_{mech} = |P_{mj,hip} + P_{mj,knee} + P_{mj,ankle}| + P_{fj,hip} - P_{pedal}$

IP is dependent on:

- Gravity
- The translational and rotational displacements of the limb segments
- The linear and angular velocities of the segments
- The mass of the segments
- The distribution of mass along the segments

IP & Rotor Q-Rings

- Physiological differences – inconsistent findings in the literature; a change in VO_2 or metabolic power could indicate a change to IP for the same EP and cadence

- Changes to hip muscle joint power reported by Strutzenberger et al. (2014) may indicate a change to IP:

$$IP_{mech} = \left| P_{mj,hip} + P_{mj,knee} + P_{mj,ankle} \right| + P_{fj,hip} - P_{pedal}$$

Methods

- 3 chainring conditions: circular, Rotor Q-Ring pos #1, Rotor Q-Ring pos #5
- 10 elite male road cyclists
  age 18.8 ± 2.0 years, mass 70.8 ± 7.9 kg, stature 1.80 ± 0.05 m, training 20 ± 3 h/wk & 558 ± 133 km/wk
- 5-min bouts @ 100, 200 & 300 W
- 80 rev · min^{-1}

Methods

Physiological Analysis

Gross VO_2 converted to total metabolic power (MP; W) using RER and energy equivalents

IP_{met} = x-intercept$_{\text{EP-MP linear regression}}$

(adapted from Francescato et al. 1995)

Biomechanical Analysis

Three-segment, rigid-link system with fixed joint centres

Data was collected for 10 crank revolutions

Video recorded at 120 fps; left and right tangential and radial forces sampled at 100 Hz

Inverse dynamics analysis

$$\int_{t_i}^{t_f}\left(\left|P_{mj_{hip}} + P_{mj_{knee}} + P_{mj_{ankle}}\right| + P_{fj_{hip}}\right)dt = \int_{t_i}^{t_f} P_{pedal}\,dt + TME$$

$$IP_{mech} = \left|P_{mj,hip} + P_{mj,knee} + P_{mj,ankle}\right| + P_{fj,hip} - P_{pedal}$$

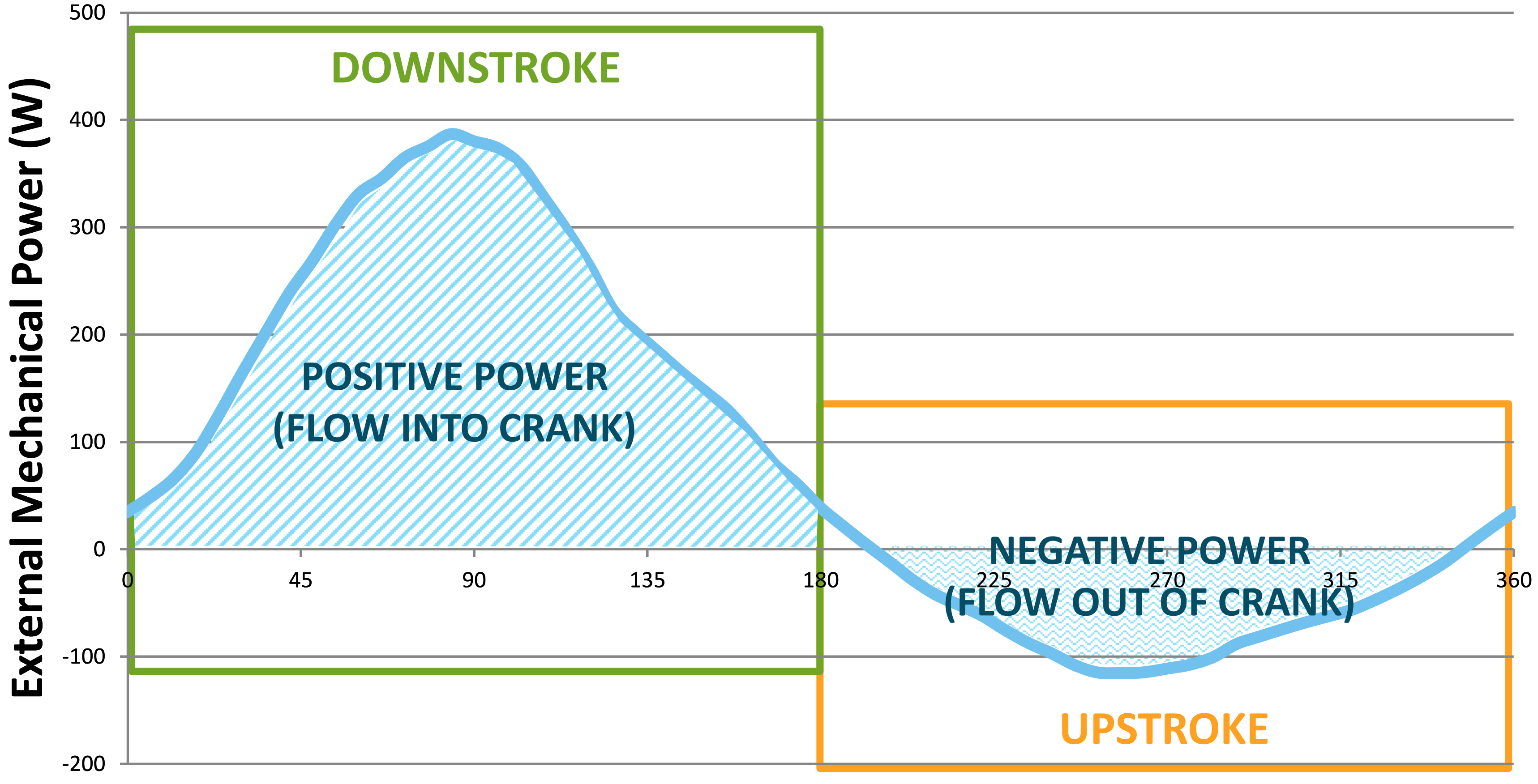
(Broker & Gregor 1994)

Physiological Results

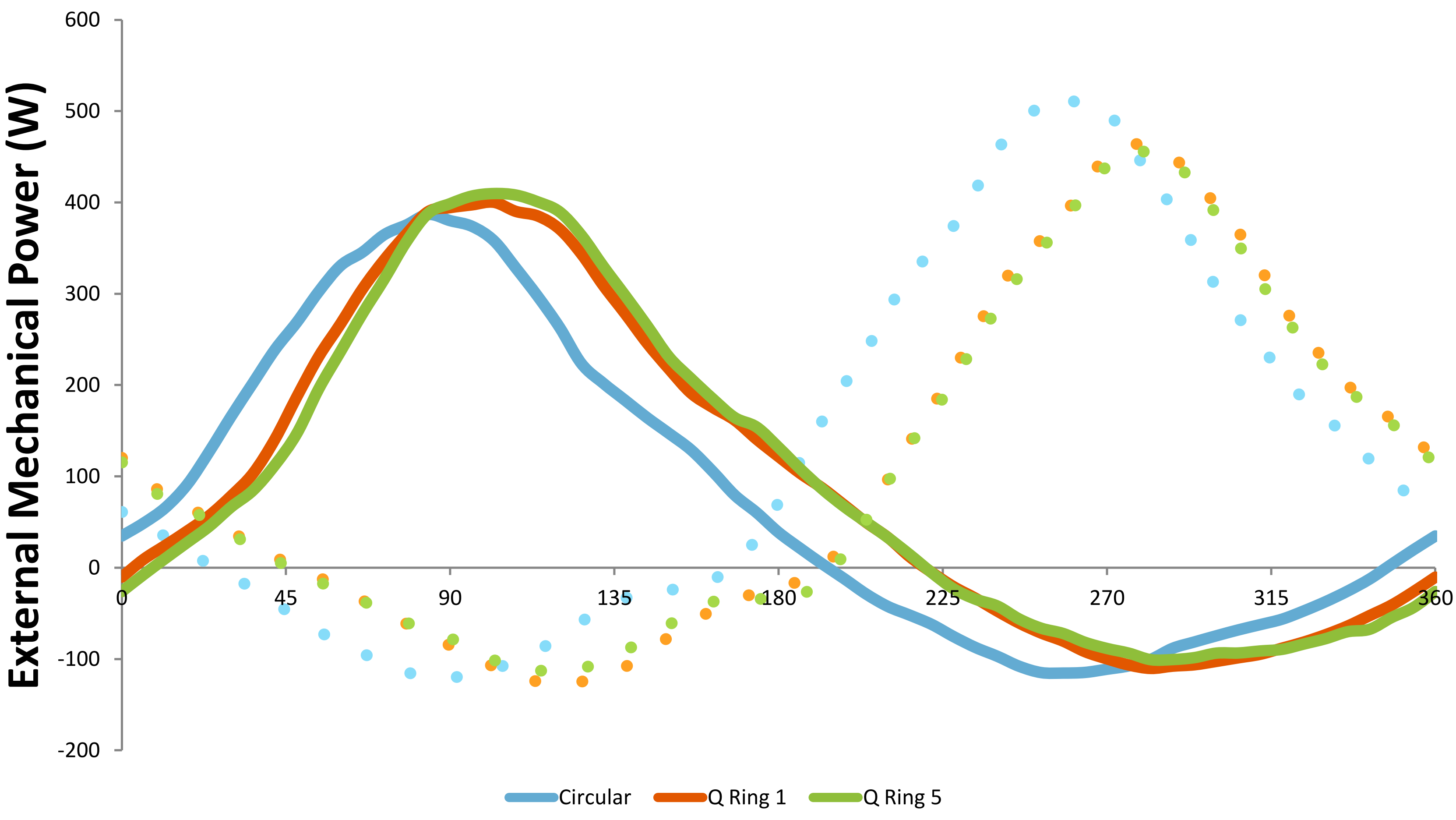
Total Metabolic Power (W)	100 W	200 W	300 W
Circular Chainring	551 ± 19	947 ± 34	1403 ± 72
Q-Ring Position 1	558 ± 33	962 ± 60	1423 ± 59
Q-Ring Position 5	559 ± 29	955 ± 42	1427 ± 61

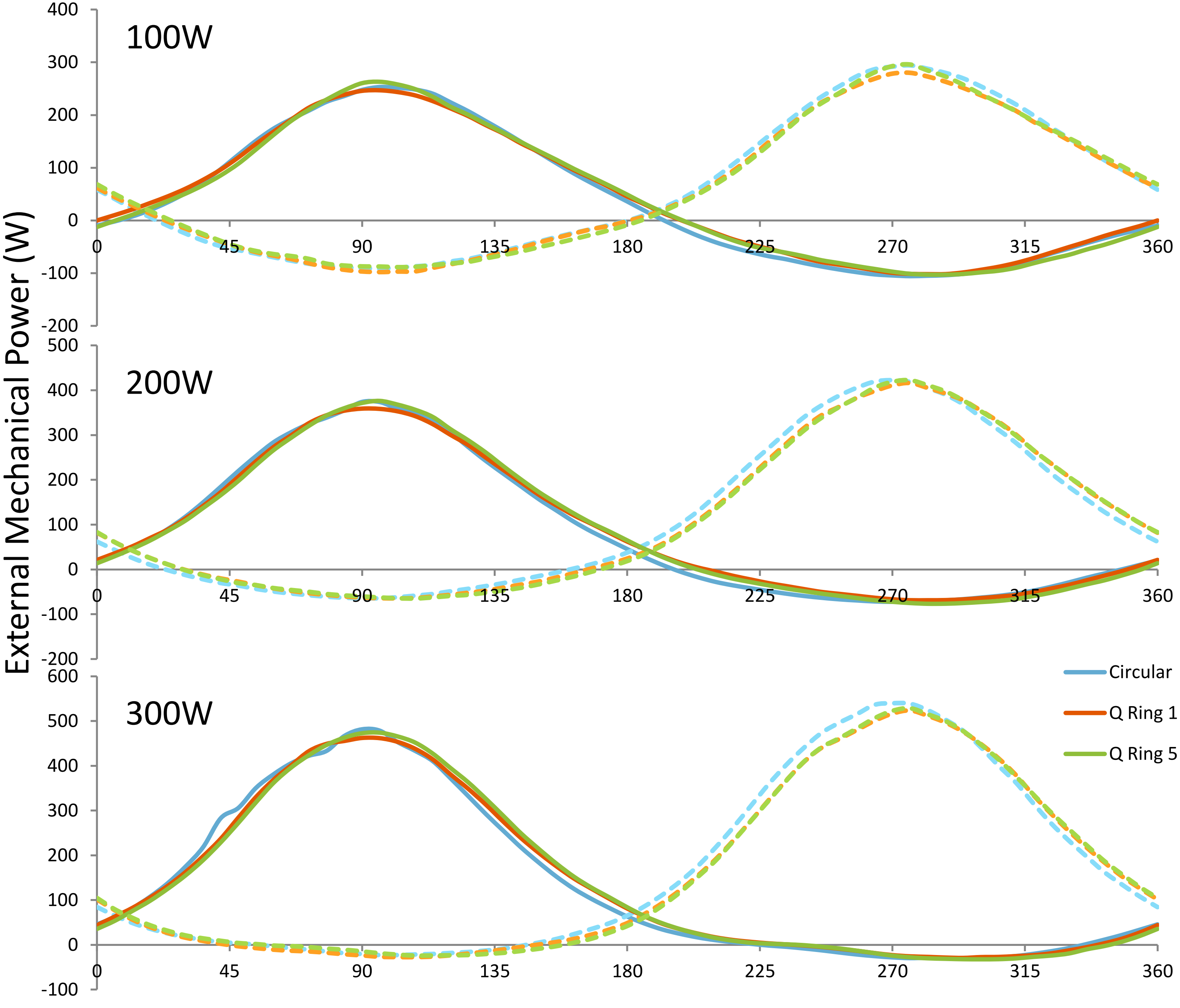
IP_{met} (W)	
Circular Chainring	105 ± 44
Q-Ring Position 1	94 ± 34
Q-Ring Position 5	114 ± 35

Preliminary Mechanical Results



Preliminary Mechanical Results





Preliminary Mechanical Results

Conclusions & Discussion

- No change to the total metabolic cost or IP_{met}, using the two "end-point" settings of Rotor Q-Rings compared to circular chainrings, although conclusive comments cannot be made about IP until the biomechanical analysis is completed.
- Future investigations can look at the mechanical destinations of energy during performance trials with non-circular chainrings and also the effects of training/habituation.

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