POWER TRAINING, POWERFUL RESULTS

Pedaling Symmetry and Power Meters that measure Bi-lateral Power

By Hunter Allen

Power meters that have TRUE Left and Right

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- Garmin Vector pedals
- PowerTap Pedals
- Bepro Pedals
- Infocrank by Vervecycling
- Pioneer cranks
- Rotor Power cranks
- 4iii mounted on both cranks
- Stages mounted on both cranks
- Watteam mounted on cranks
- Shimano Cranks

Power meters that have Pseudo left and right

- Quarq
- Power2max

Current measuring challenges

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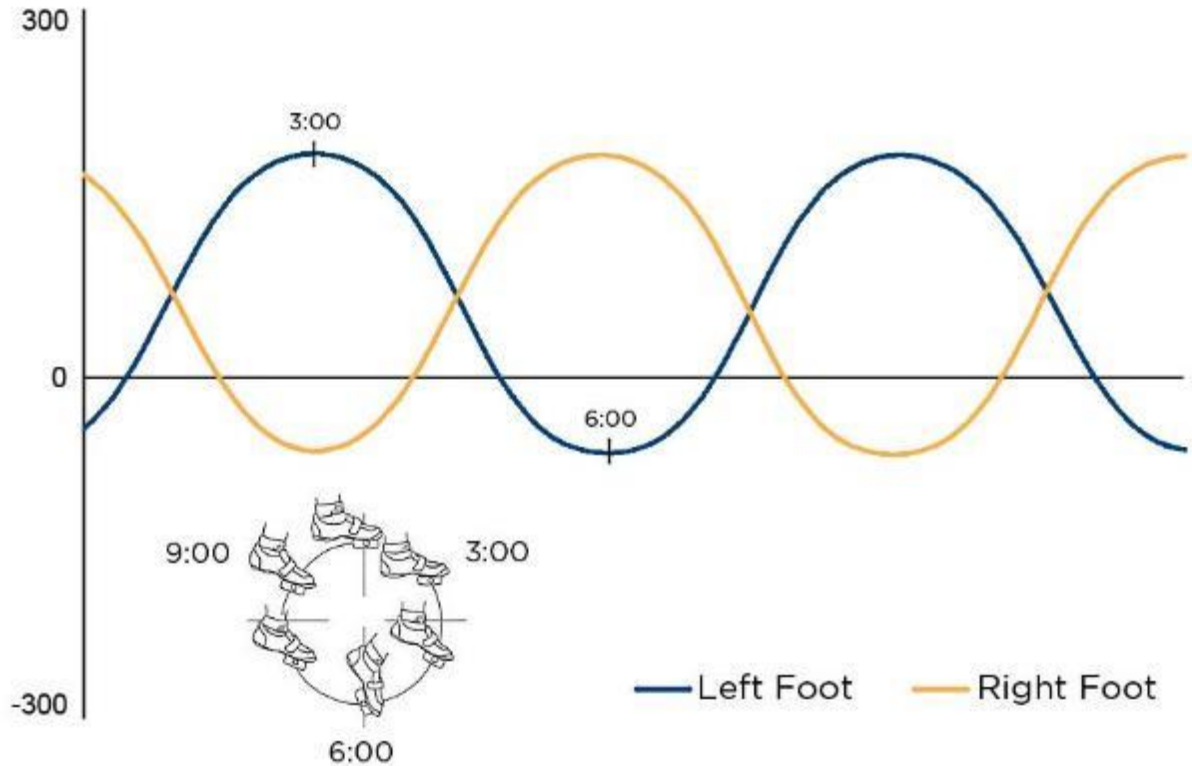
- Current Power meters only have ability to measure one complete side at a time.
  - All data points from Left leg are averaged and this is "Left Leg" power.
- This gives the user a false sense of individual leg contribution.
- Current Power Balance measures the Left and Right legs and then calculates the percentage each contribute to the total and calls this "Balance". For example if LEFT leg power is 150Watts and RIGHT leg power is 120Watts, the total is 270Watts with 55% coming from LEFT leg and 45% coming from the RIGHT leg.

How balance is actually produced.

- The actual way we pedal is in a "Phase". The legs do not act independently. The LEFT Positive is opposed by the right Negative forces. And Vice Versa.



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Pedaling Smoothness

- What is this? How is it calculated?
- *Pavg/Pmax=Pedal Smoothness. A LOWER number means the rider has a larger Pmax in relation to the Pavg. For example: Pavg=200W, PMax=1500, so PS=13%. Big PEAKS of power in relation to a small average. An opposite would be: Pavg=350W, Pmax= 700W, so PS=50%.*
- Is it important? Does it tell us anything? *Helps to tell how much of a "Stomper" or a "Smoother" the rider is. Might be possible to use as a teaching tool to teach an athlete to become more even in their pedaling stroke.*
- Can we change it? Does it matter? Change is possible with awareness of the issue. The hardest part about this kind of change is to prevent the rider from doing too much work to smooth the pedaling motion and overcorrecting.

11.3.1 Calculating Pedal Smoothness

P_{avg} is the mean power averaged across 1 crank cycle and P_{max} is the peak power applied during that cycle, as shown in Figure 11-2. These values can be used to calculate pedal smoothness, as defined as in Equation 10. The shape of the power curve and the resulting value of pedal smoothness will vary depending on the style of riding, and on whether the power is measured per crank arm (i.e. in left-right systems) or for the whole system.

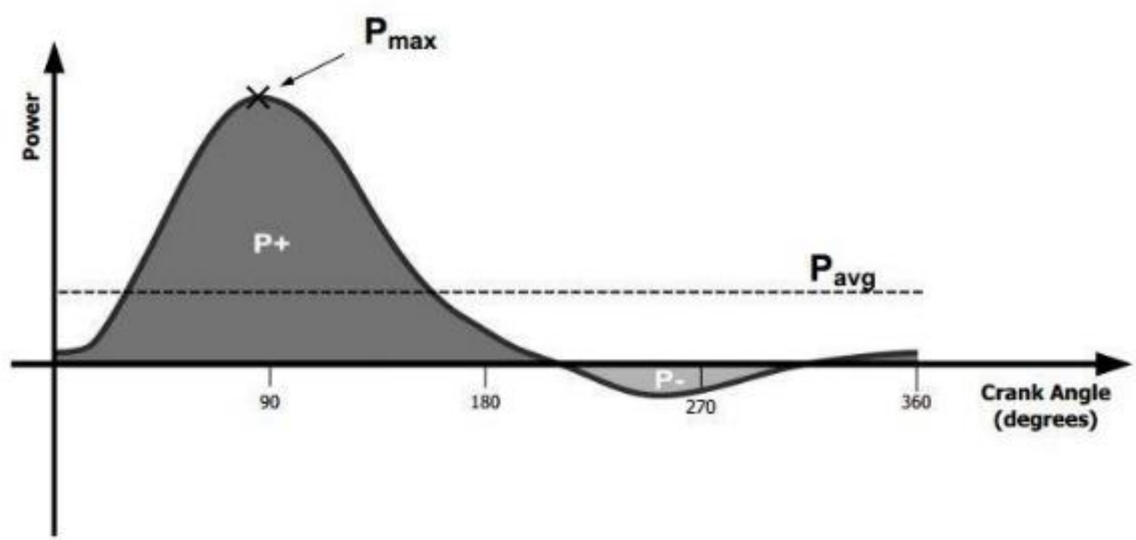
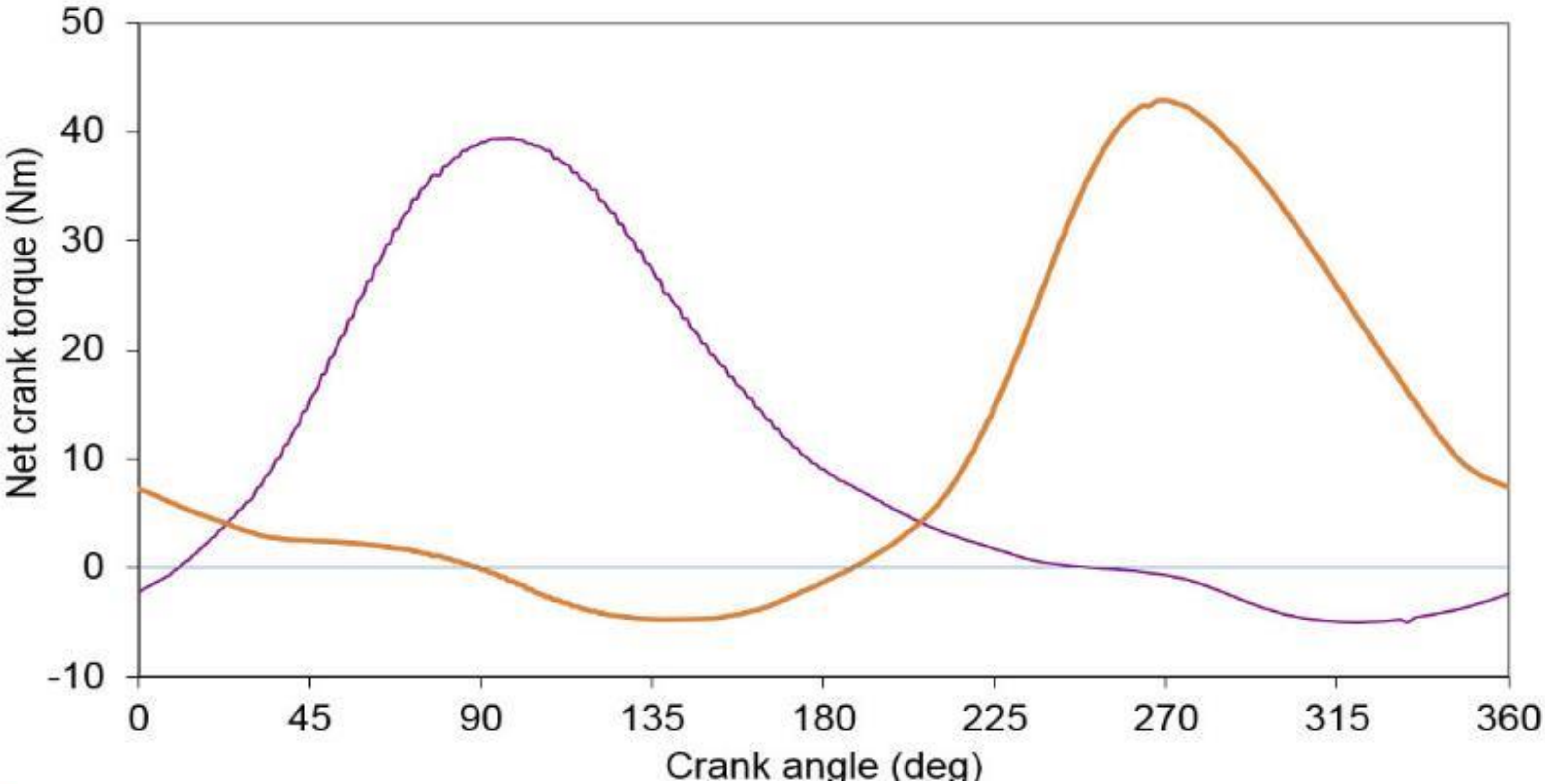


Figure 11-2. Values used to calculate Pedal Smoothness

$$Pedal\ Smoothness = \frac{P_{avg}}{P_{max}}$$

Real world “balance” 50-50

127W left(blue), 128W right(yellow)



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New pedaling metrics

- **Gross power released (GPR)** – The gross (i.e., muscular + inertial + gravitational) power released by one leg (L or R), primarily during the down stroke.
- **Gross power absorbed (GPA)** – The gross power absorbed by one leg (L or R), primarily during the upstroke.
- **Kurtotic index (KI)** – A measure of the peakedness of the pattern of force/torque/power application during the power-producing phase. (how skewed?)

GPR, GPA, and KI during a trainer ride

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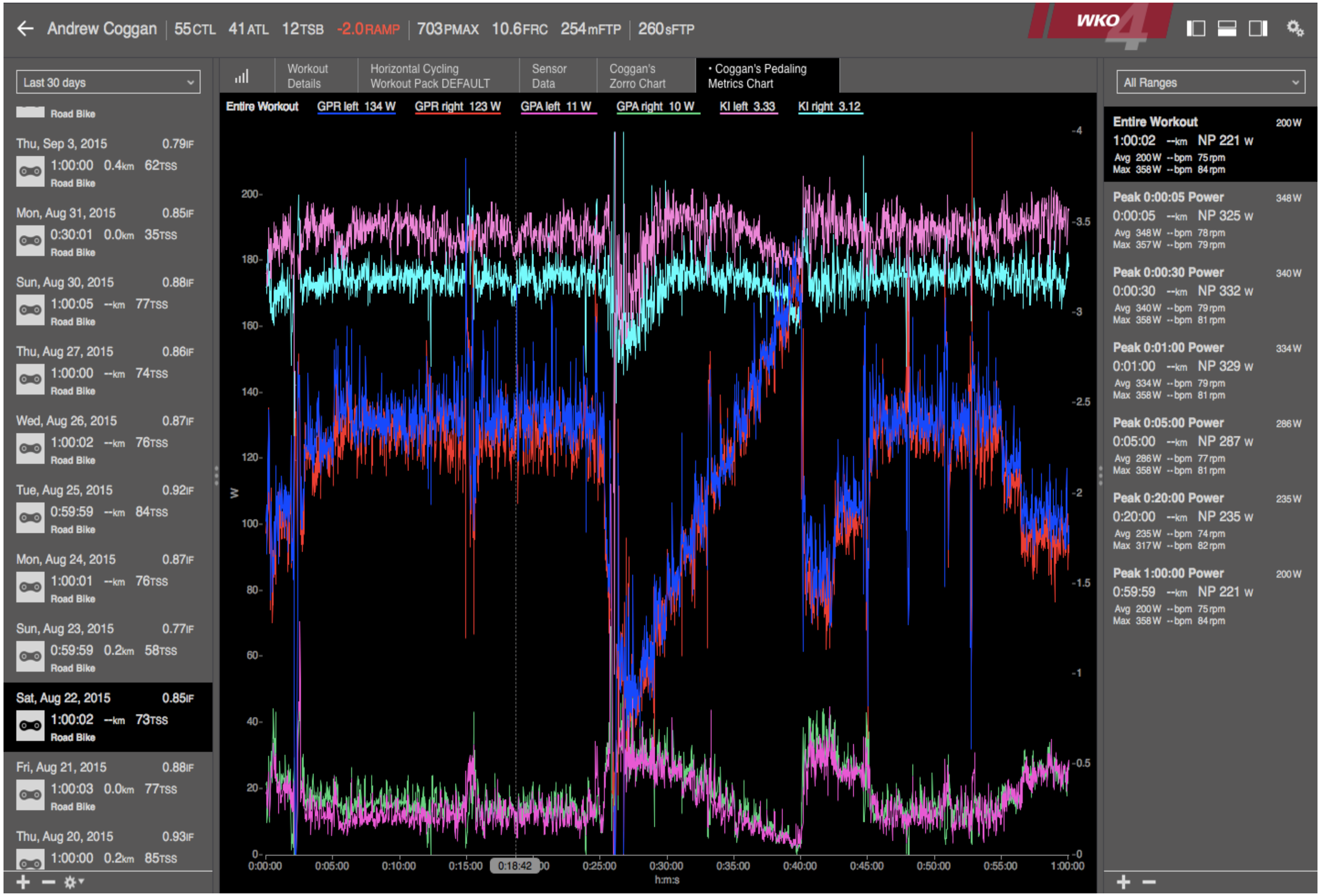

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GPR/GPA Mean Max curve

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Net Power released

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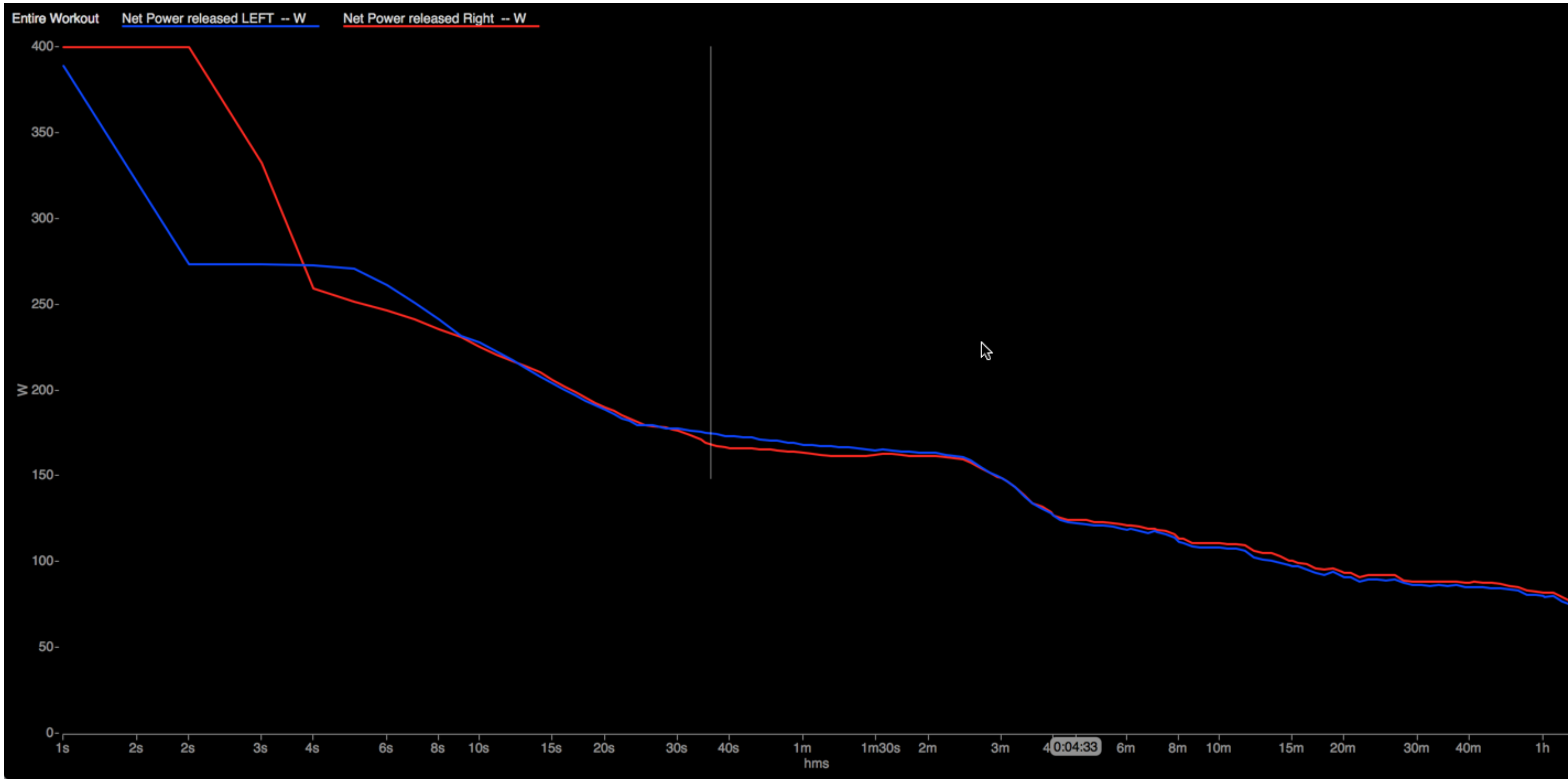
- Left Leg GPR-Right leg GPA=Net Power Released for Left Leg Phase.
- Right Leg GPR-Left Leg GPA=Net Power Released for Right Leg Phase.

NET Power Released Mean Max curve



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Should negative forces be minimized?

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- Power/Torque/Force is the sum of muscular, gravitational and inertial components.
  - Need to know mass of limbs and position in space to isolate negative forces.
- Higher cadences, muscular component is rarely negative.
- Negative power/force/torque means the cyclist si not pulling their foot up rapidly enough to get it completely out of the way of the rising pedal.

Three studies have shown that:

- Elite cyclists actually pull up slightly less than non-elite cyclists. *(Coyle et al,. Med Sci Sports Exerc 1991;23:93-107),2)*
- Metabolic efficiency is negatively correlated with minimum power/torque/force generated during the pedal cycle, i.e., across cyclists those who pulled up more were less efficient. *(Edwards et al., J Sports Sci 2009; 15:319-325)*
- Deliberately modifying the pattern of force application during pedaling to emphasize pulling up reduces metabolic efficiency. *(Koroff et al., Med Sci Sports Exerc 2007; 39:991-995)*

Uses for Left/Right measurement

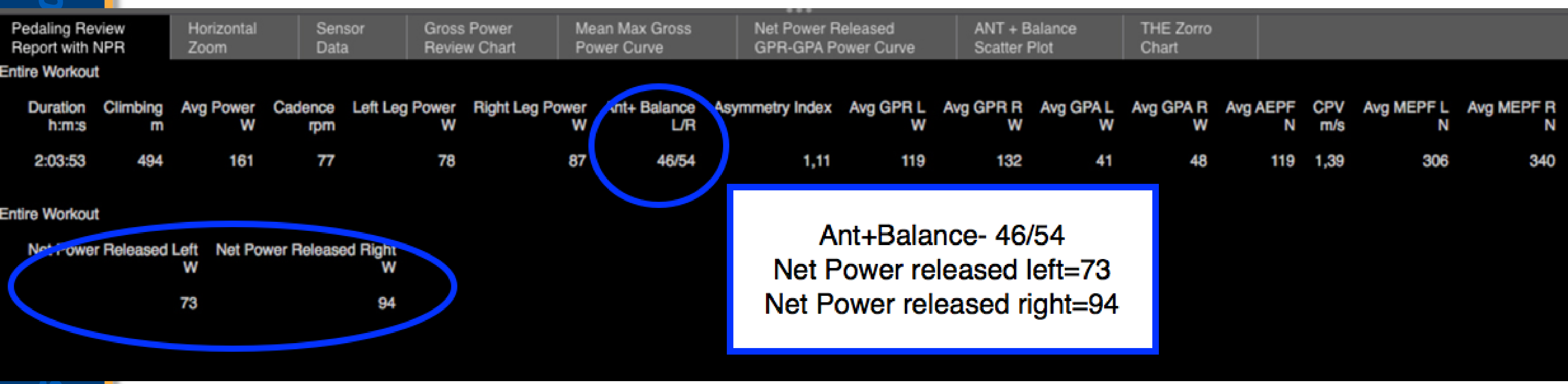
- Incorrect or inefficient body positioning on the bicycle.
- Diagnose imbalances in muscular in-balances. – For example, the hamstring on left leg could be weaker than the hamstring on the right.
- How power is released and absorbed in Standing vs. seated?
- Bike fit – Poor bike fit can be diagnosed and corrected. Javier Sola case study.
- Rehabilitation for injury- Clearly demonstrates when one leg is different than the other.

Pedaling Asymmetry Test

- Each day you will complete three five-minute intervals at your VO2Max power (roughly 113-115% of your FTP). The first interval will be standing the entire time, the second will be seated the entire time, and the third interval will be alternating standing and seated: stand when you want to and sit when you want to.
- **Pedaling Asymmetry Hill Climbing Test**
  - Day 1: Complete the test with no emphasis on either leg. Just climb naturally.
  - Day 2: Emphasize the leg that releases less power to see if you can balance out the GPR/GPA.
  - Day 3: Emphasize the left leg only for all efforts.
  - Day 4: Emphasize the right leg only for all efforts.

Case Study: bike fit

- In the following images, we can see this cyclist is working with an imbalance of 46/54 percent. There is a net power of 73 watts from the left leg and 94 watts from the right.



Entire Workout

Duration h:m:s	Climbing m	Avg Power W	Cadence rpm	Left Leg Power W	Right Leg Power W	Ant+ Balance L/R	Asymmetry Index	Avg GPR L W	Avg GPR R W	Avg GPA L W	Avg GPA R W	Avg AEPF N	CPV m/s	Avg MEPF L N	Avg MEPF R N
2:03:53	494	161	77	78	87	46/54	1,11	119	132	41	48	119	1,39	306	340

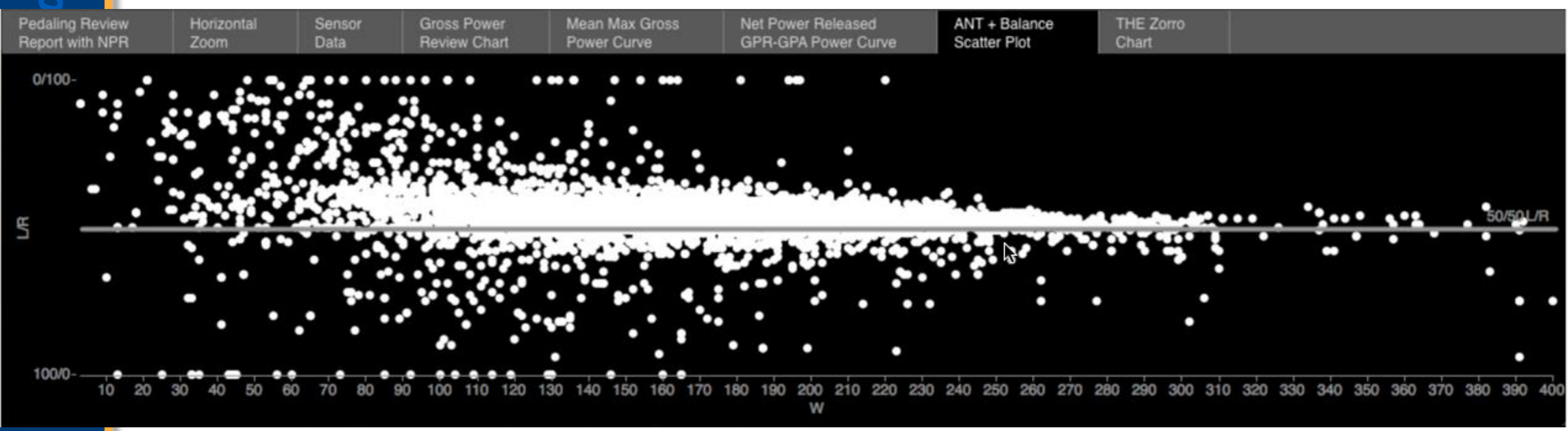
Entire Workout

Net Power Released Left W	Net Power Released Right W
73	94

Case Study by Javier Sola

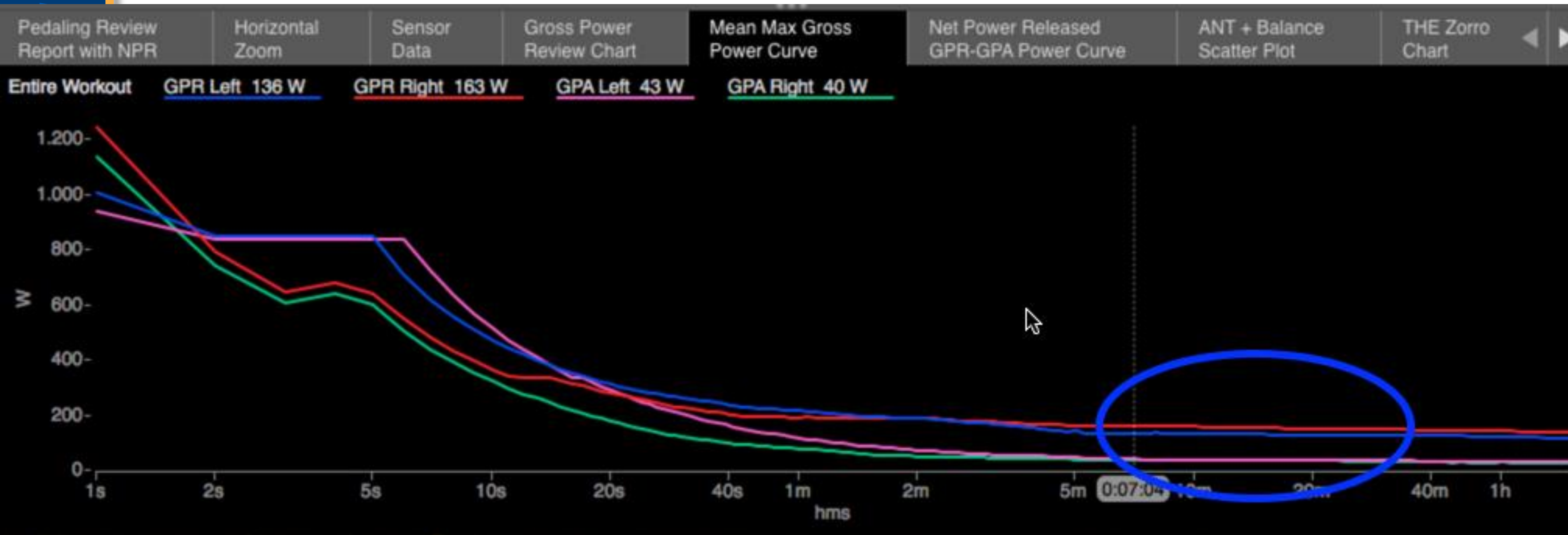
Scatter plot of Ant+ balance

- The scatter plot shows the pedaling balance at different watts and in most cases the right leg is above the left.



GPR/GPA

- Gross Power Released (GPR) for the right leg is higher than GPR for the left. We also can see that Gross Power Absorbed (GPA) for the left is sometimes higher than GPA for the right. All of this is a consequence of the asymmetry. This cyclist experienced pain in the pyramidalis and left hamstring muscles because they were so tight.



Changes to fit made

- Corrected saddle height and setback
- Adjusted cleat position
- Used insoles to provide stability to the feet
- Switched to a new saddle that stabilizes the pelvis
- Prescribed some exercises to strengthen the psoas muscles

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After?

- The power balance improved from 46/54 to 48/52, and the net power completely changed to the opposite side!

Pedaling Review Report with NPR | Horizontal Zoom | Sensor Data | Gross Power Review Chart | Mean Max Gross Power Curve | Net Power Released GPR-GPA Power Curve | ANT + Balance Scatter Plot | THE Zorro Chart

Entire Workout

Duration h:m:s	Climbing m	Avg Power W	Cadence rpm	Left Leg Power W	Right Leg Power W	Ant+ Balance L/R	Asymmetry Index	Avg GPR L W	Avg GPR R W	Avg GPA L W	Avg GPA R W	Avg
0:02:05	1	165	83	80	86	48/52	1,12	107	106	27	20	

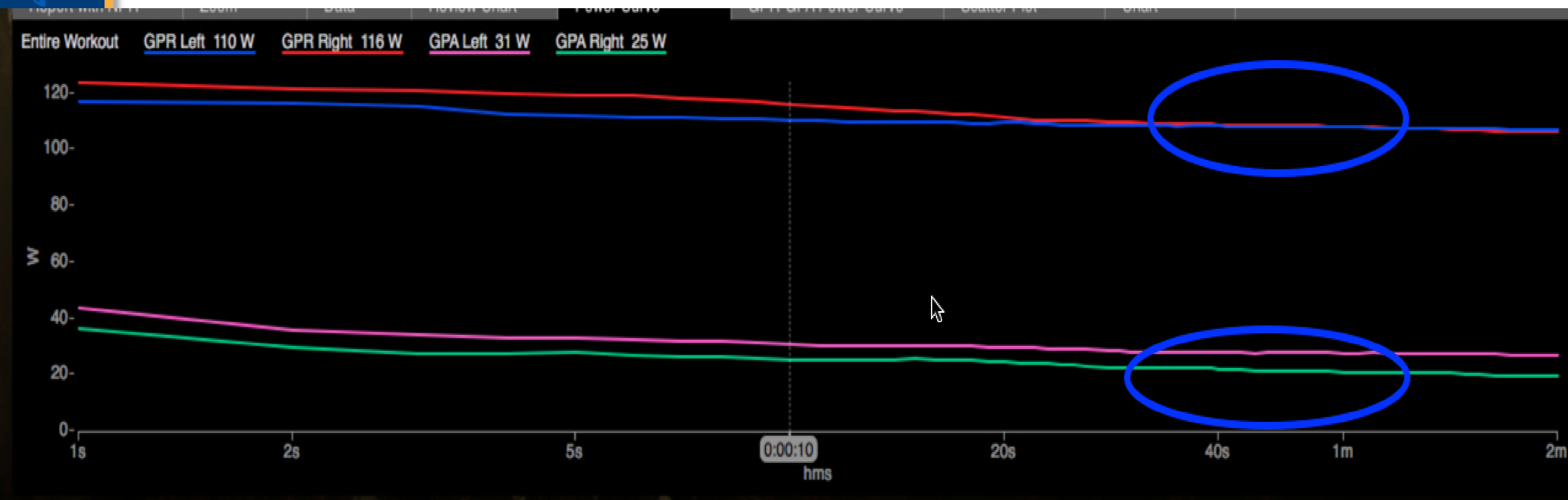
Entire Workout

Net Power Released Left W	Net Power Released Right W
87	79

Ant+ Balance= 48/52
Net Power Released Left= 87
Net Power Released Right=79

Almost there

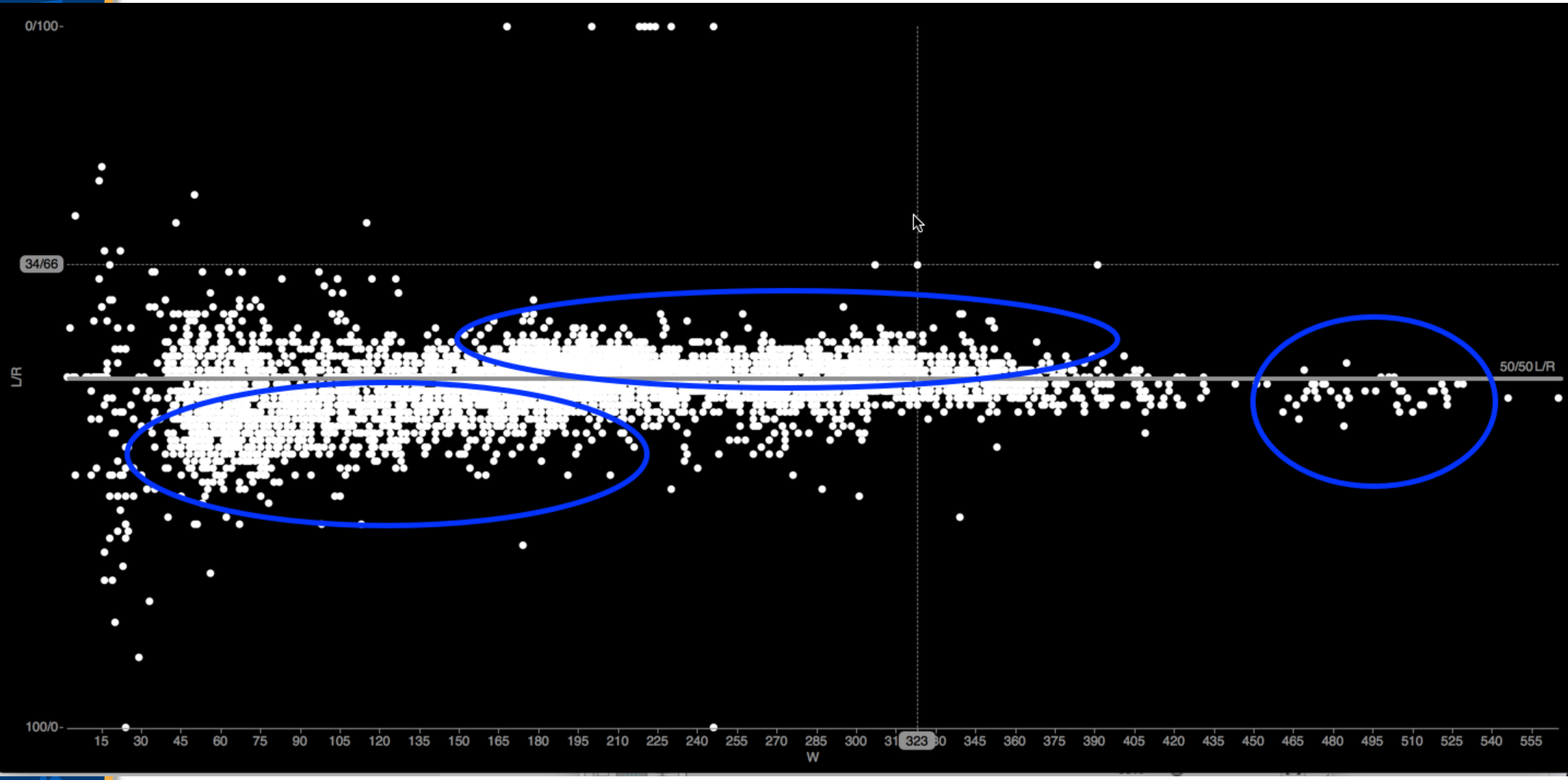
- GPR left and right were now almost symmetrical. There was still more GPA on the left than the right, which can be explained by the motor pattern; the cyclist tends to pull up more with the left leg because of his previous asymmetry. Our next task is to improve his pedaling technique to pull more equally with both legs.



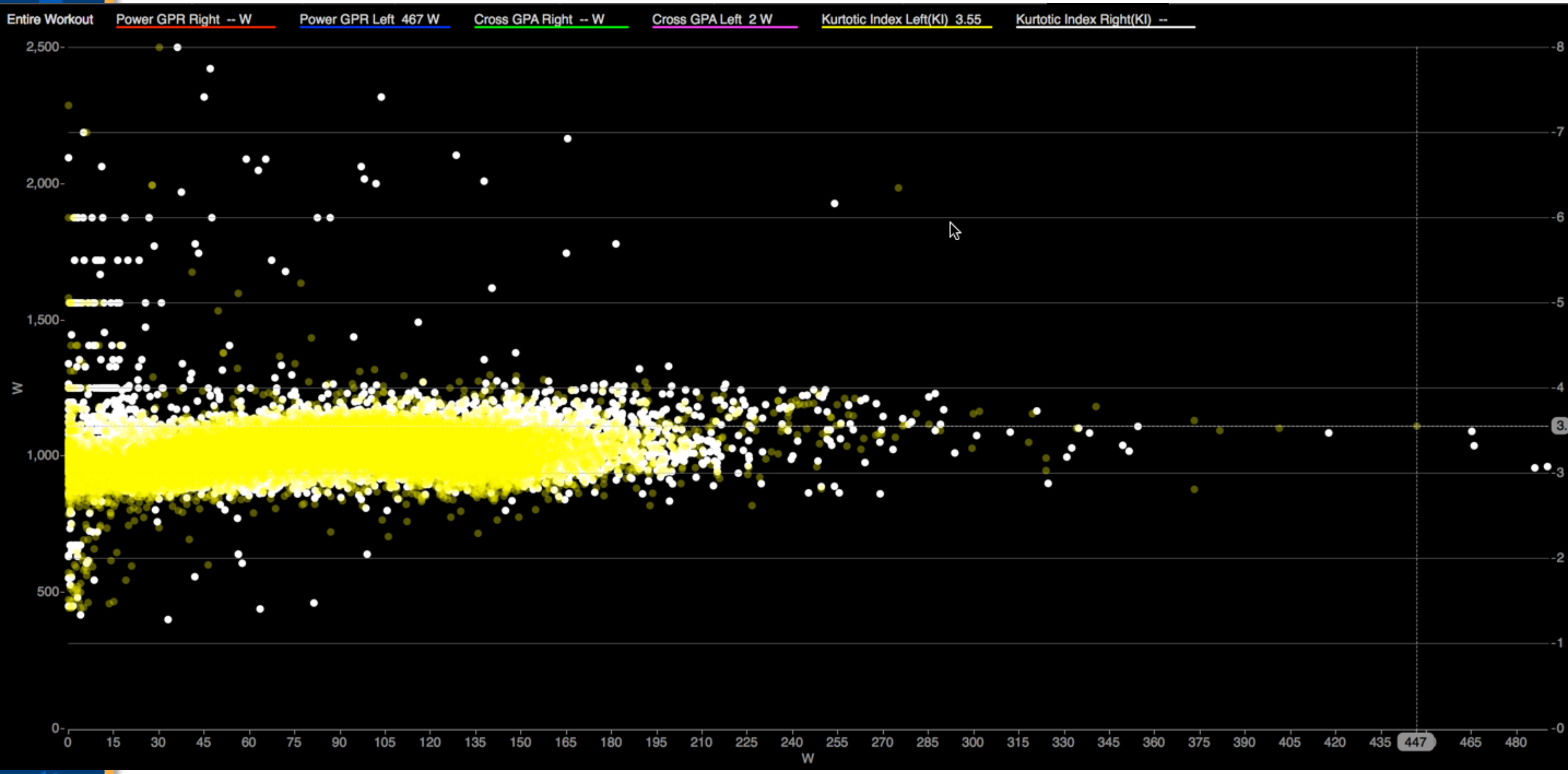
Interesting ideas that need further exploration

- Holding one leg in reserve.
  - It appears that some riders "hold" or "rest" one leg during lower intensities. This leg releases less power during lower intensities, but then when in higher intensities, it releases more.
  - Case Study
- Propulsive leg vs. Non-Propulsive leg.
  - Most of us appear to have a leg that "smoothes" the power throughout the stroke and one leg that is more "peaky", with more distinct pulses.
  - Case Study
- Each person has a "sub-optimal" power and cadence "location".
  - Case study

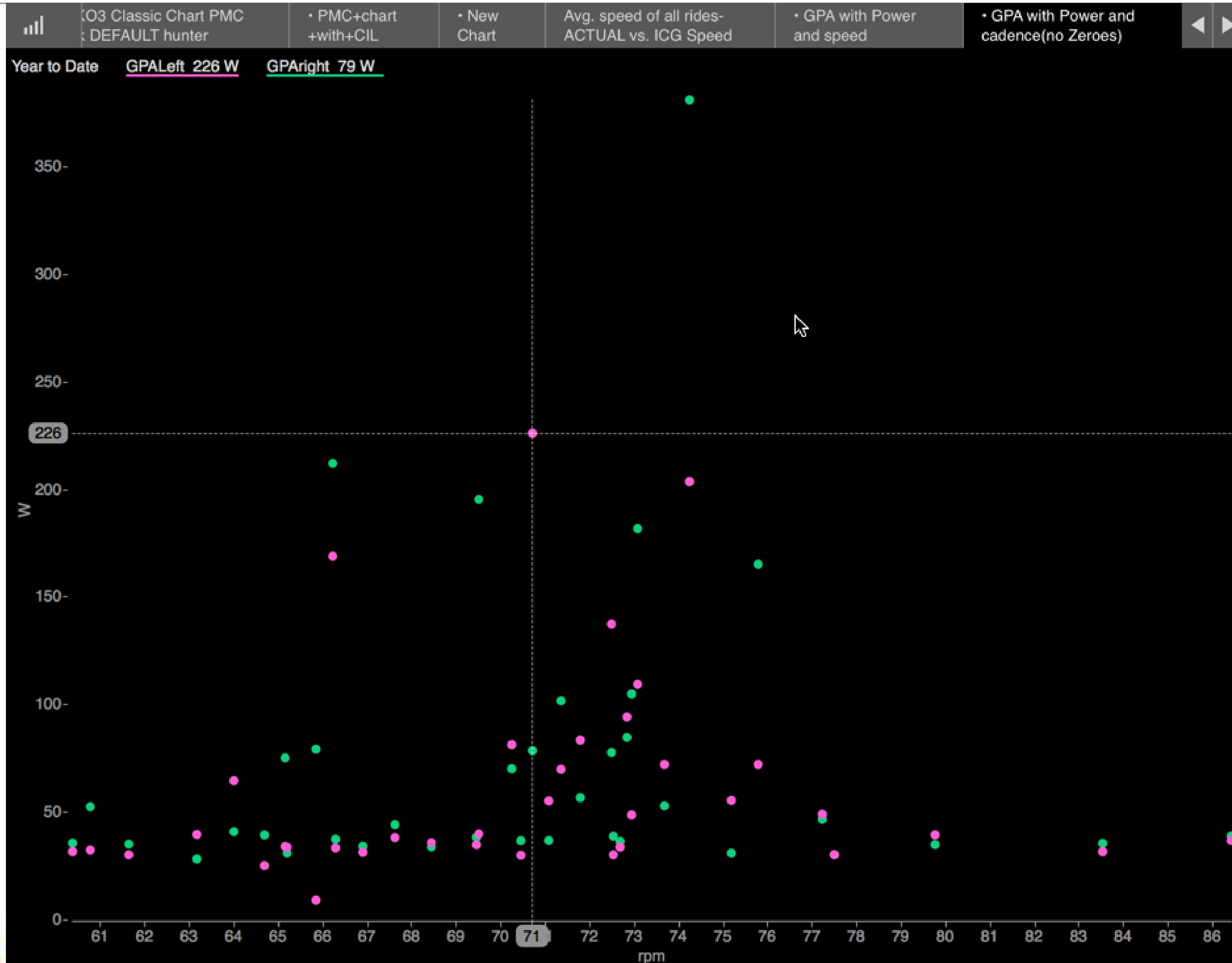
Do some riders "rest" one leg



Smooth vs. Stomp

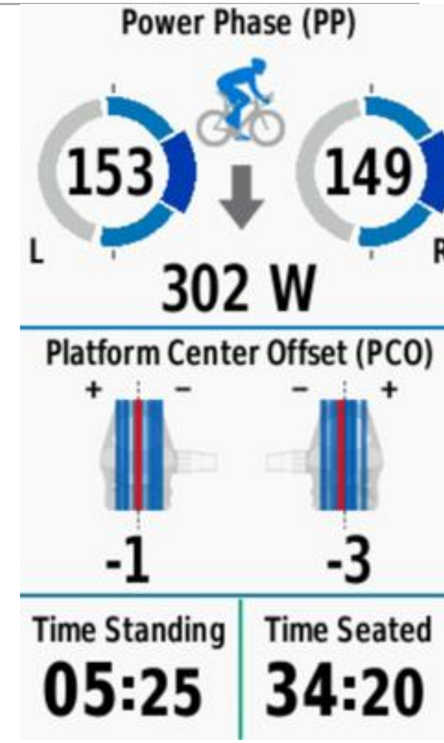


GPA with Power and Cadence



Other Unique Pedaling Metrics

- Garmin Vector Pedals
  - Cycling Dynamics
    - Standing vs. Seated
    - Power Phase- Where cyclist starts and stops producing driving force
    - Platform Center Offset- precise axial location of applied force



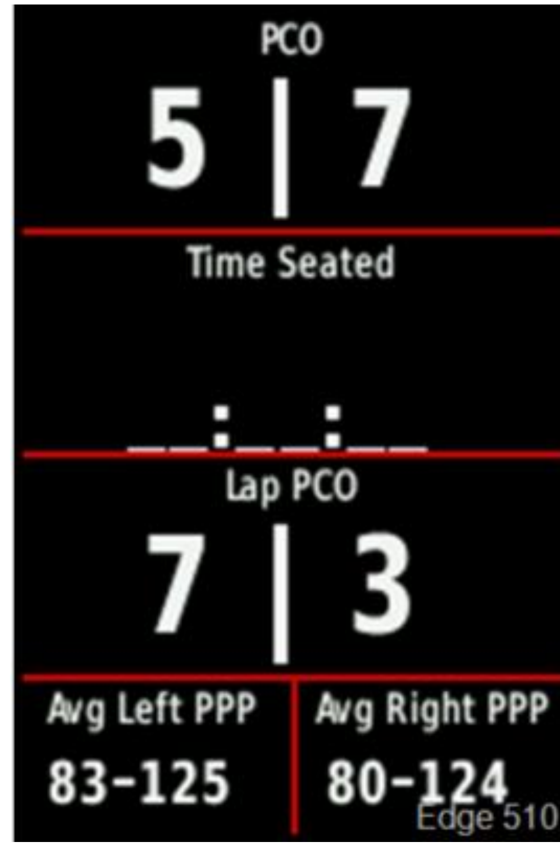
- Pioneer Cranks
  - Radial and Tangential forces

Power Phase

- Where the driving forces begin and end within the pedal stroke.
- Peak Fraction: the crank angle location and the distance in crank travel where this percentage of work is completed in the shortest crank rotation distance.
  - Shorter peak fraction = More distinct pulse in pedal stroke, greater "Ppeak" in the torque curve.
  - Longer peak fraction = smoother application of positive forces in pedal stroke.

Platform Center Offset explanation & Uses:

- Determines the precise axial location of the applied force throughout each pedal stroke.
  - Measured in mm from the CENTER of pedal platform.
  - Negative is closer to frame.
  - Positive is farther away from frame.
- Indicator of need for custom insoles.
  - A regular metric on one side or other indicates a need for a more centered application of power through the foot. A custom insole would allow a more even distribution of power across the foot.
- Indicator of need for bike fit or cleat adjustment.
  - Poor bike fit does not allow for the proper “stacking” of bones and joints above the pedal axle, resulting in poor economy in translation of muscular strength to axle.



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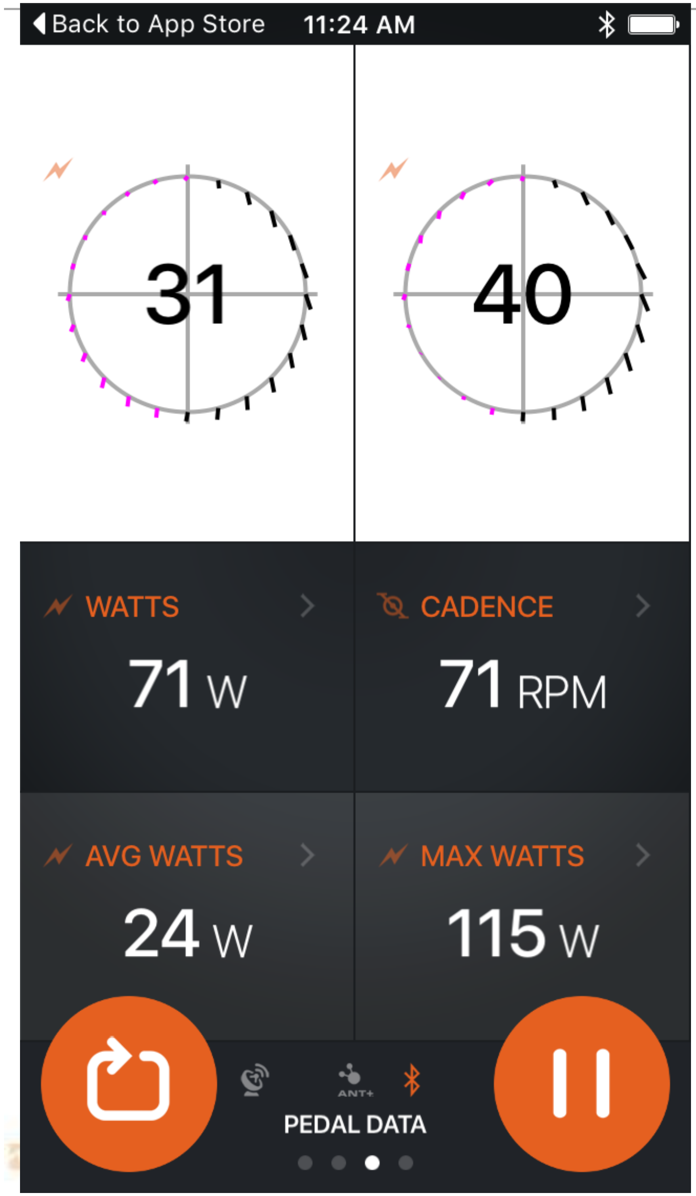
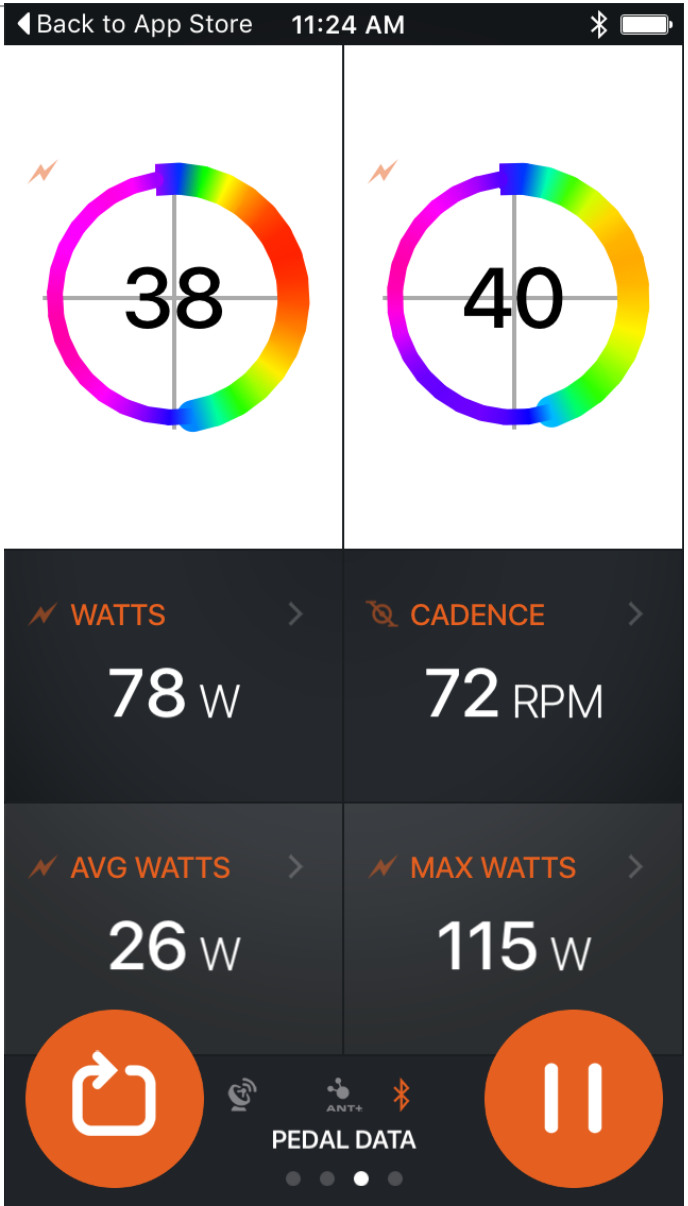
PowerTap ability and app



Tangential and Radial forces displayed on the left.

On the right, displays the resultant forces in colors to display where the range throughout the circle in which you create more or less power.

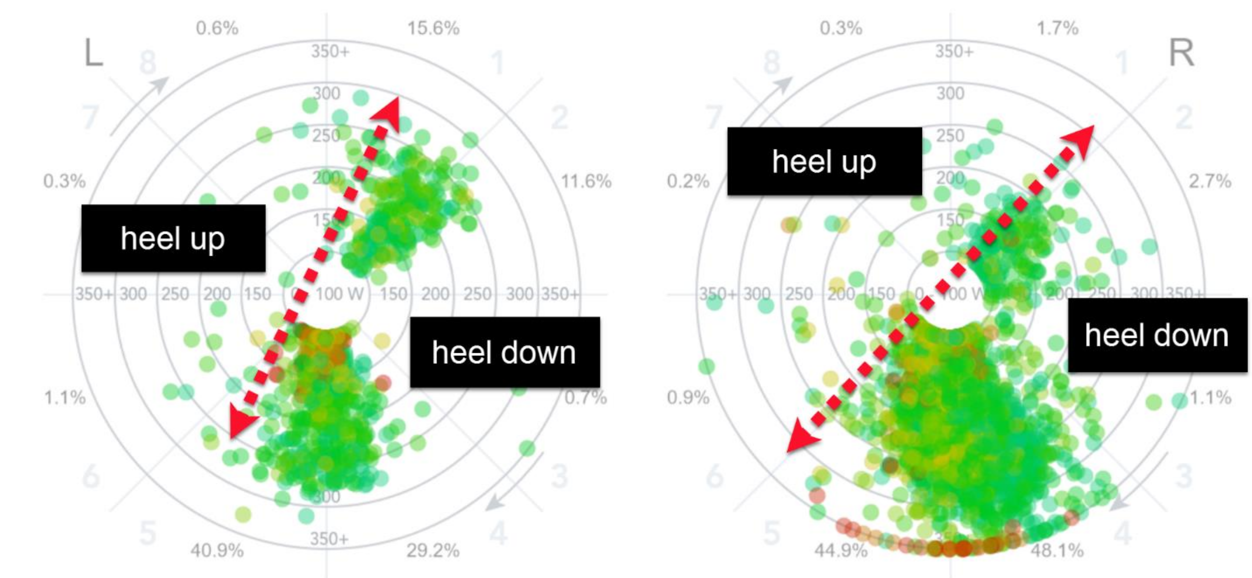


Leomo Type-R Motion Analysis

- 5 sensors, (2) feet, upper leg, pelvis and torso.
- Capture decelerations in the pedal stroke which are dead spots or areas of non-propulsion.

Leomo Motion Analysis

- The Leomo Type-R adds meaningful motion data to the left and right power output.
- Pedal Stroke Intelligence Plot



Leomo Motion Analysis

- Power/Cadence/Dead Spot Map

PCD Map

L

	0W ~100W	101W ~150W	151W ~200W	201W ~250W	251W ~300W	301W ~350W	351W ~400W	401W ~450W	451W ~500W	501W~
121rpm~	0%	-	25%	17%	0%	0%	0%	-	0%	-
111~120rpm	0%	0%	18%	0%	7%	0%	-	-	-	-
101~110rpm	14%	22%	13%	8%	4%	0%	0%	-	-	-
91~100rpm	14%	18%	17%	4%	1%	0%	0%	0%	0%	0%
81~90rpm	21%	26%	14%	6%	3%	4%	3%	0%	0%	8%
71~80rpm	39%	27%	18%	7%	6%	4%	23%	36%	25%	-
61~70rpm	40%	20%	13%	10%	11%	21%	48%	44%	-	0%
1~60rpm	2%	22%	17%	15%	14%	7%	17%	0%	-	100%

R

	0W ~100W	101W ~150W	151W ~200W	201W ~250W	251W ~300W	301W ~350W	351W ~400W	401W ~450W	451W ~500W	501W~
121rpm~	0%	-	0%	0%	0%	0%	0%	-	0%	-
111~120rpm	0%	0%	0%	7%	0%	0%	-	-	-	-
101~110rpm	0%	0%	6%	1%	2%	0%	0%	-	-	-
91~100rpm	7%	15%	6%	5%	1%	3%	14%	100%	33%	0%
81~90rpm	22%	16%	6%	4%	6%	5%	3%	0%	50%	8%
71~80rpm	22%	12%	5%	8%	11%	8%	29%	64%	0%	-
61~70rpm	27%	14%	10%	17%	21%	26%	48%	78%	-	100%
1~60rpm	2%	26%	20%	23%	26%	52%	50%	0%	-	0%

PCD Map

L

	0W ~100W	101W ~150W	151W ~200W	201W ~250W	251W ~300W	301W ~350W	351W ~400W	401W ~450W	451W ~500W	501W~
121rpm~	0%	-	25%	17%	0%	0%	0%	-	0%	-
111~120rpm	0%	0%	18%	0%	7%	0%	-	-	-	-
101~110rpm	14%	22%	13%	8%	4%	0%	0%	-	-	-
91~100rpm	14%	18%	17%	4%	1%	0%	0%	0%	0%	0%
81~90rpm	21%	26%	14%	6%	3%	4%	3%	0%	0%	8%
71~80rpm	39%	27%	18%	7%	6%	4%	23%	36%	25%	-
61~70rpm	40%	20%	13%	10%	11%	21%	48%	44%	-	0%
1~60rpm	2%	22%	17%	15%	14%	7%	17%	0%	-	100%

R

	0W ~100W	101W ~150W	151W ~200W	201W ~250W	251W ~300W	301W ~350W	351W ~400W	401W ~450W	451W ~500W	501W~
121rpm~	0%	-	0%	0%	0%	0%	0%	-	0%	-
111~120rpm	0%	0%	0%	7%	0%	0%	-	-	-	-
101~110rpm	0%	0%	6%	1%	2%	0%	0%	-	-	-
91~100rpm	7%	15%	6%	5%	1%	3%	14%	100%	33%	0%
81~90rpm	22%	16%	6%	4%	6%	5%	3%	0%	50%	8%
71~80rpm	22%	12%	5%	8%	11%	8%	29%	64%	0%	-
61~70rpm	27%	14%	10%	17%	21%	26%	48%	78%	-	100%
1~60rpm	2%	26%	20%	23%	26%	52%	50%	0%	-	0%

In conclusion

- Bi-Lateral Power meters add value.
  - Clear understanding of data allows for changes.
  - Testing protocols needed.
  - Capture of “Normal” and hard riding data needed.
  - GPR/GPA and KI help to better understand how the rider releases power.