Technical Report:

Accuracy Testing of
4iiii PRECISION PRO Dura-Ace 9100

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Executive Summary

The Locomotion Lab at the University of Colorado, Boulder is a world-class facility renowned for independent analysis of biomechanical performance systems. Rodger Kram, Ph.D., and his team at the Locomotion Lab have developed an objective testing protocol to confidently determine the accuracy of bicycle power meters. Following a previous study in September 2018, *4iiii* Innovations Inc. requested a follow up study to independently test the accuracy of the PRECISION Powermeter technology at the Locomotion Lab.

Tests included multiple PRECISION PRO Powermeters installed on Shimano Dura-Ace R9100 cranksets being compared to power calculated by a bike treadmill for outputs ranging from 150-350W. Results showed an average error in power reading of 1.06% for PRECISION PRO Powermeters demonstrating a marked improvement from the observed 1.56% error in the previous tests in September 2018. These third-party test results demonstrate the accuracy of PRECISION PRO Powermeters on the Shimano Dura-Ace 9100 crankset.

The sports technology industry is driven by advancements such as higher accuracy and reliability, however, these are seldom verified by independent testing. By encouraging studies such as these, verification of power meter performance can help consumers make more informed product decisions and strengthen the validity of the sports technology market.

Introduction

The purpose of this testing was to evaluate the accuracy and precision of crank-based bicycle powermeters manufactured by *4iiii* Innovations of Alberta, Canada. The powermeters were mounted on three different Shimano Dura-Ace R9100 cranksets.

For all measurements, the subjects rode on an inclined, motorized treadmill. Knowing the angle of the incline, the treadmill velocity, the mass of the rider and bicycle, directly measured rolling resistance and assuming 2.4% drive-train power losses, the actual mechanical power output required was calculated. The output of each of the powermeters was compared to the calculated reference power across a range of mechanical power outputs (~150, 200, 250, 300 and 350 Watts) to determine powermeter accuracy.

Methods

Theoretical Power Determination

Test riders were weighed before and after testing and the total weight of the bike and rider noted. The bike's rolling resistance (C_{RR}) was determined using a simple force balance as demonstrated in Figure 1.

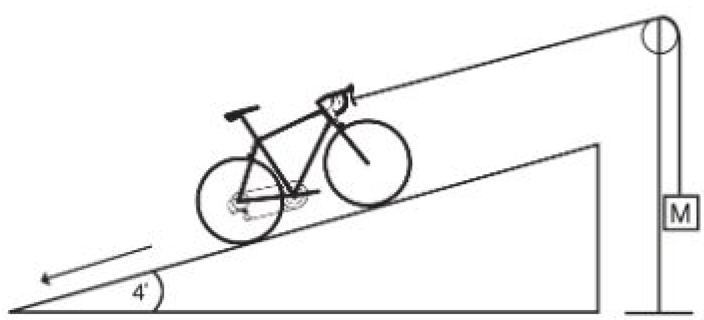

Figure 1: Schematic diagram of force balance used to determine C_{RR}

Briefly, the amount of mass required to keep a freewheeling rider stationary in this setup allowed for the determination of the force, F_N, of the rider + bicycle normal to the treadmill when the treadmill was set to a 4.1° incline and 3.13 m/sec velocity. This result was used in Equation 1 to determine C_{RR}:

$$C_{RR} = Force_{Pull} / F_N \tag{1}$$

The mechanical power ($Power_{Mech}$) and rolling resistance power ($Power_{RR}$) were calculated using Equations 2 and 3:

$$Power_{Mech} = (\text{Total Rider + Equipment Mass}) * g * V_{treadmill} \sin(4.1°) \tag{2}$$

$$\text{Power}_{RR} = (\text{Total Rider} + \text{Equipment Mass}) * g * \cos(4.1^{o}) * C_{RR} * V_{treadmill}$$
(3)

With the total theoretical power being calculated using Equation 4:

$$\text{Power} = \text{Power}_{Mech} + \text{Power}_{RR}$$
(4)

Powermeter Test Protocol

A test rider rode for 2min at each 150, 200, 250, 300 and 350W on the treadmill set to a 4.1° incline. It should be noted that there was a certain response time of changing the treadmill speed and slight variation in physiological output of the rider. Therefore recorded power was taken during the 2nd minute of each power step. The rider remained in the same gear ratio for the duration of the protocol.

During testing, 10 second average power was used and a data point was sampled every 10 seconds for 1 minute. These 6 values were then averaged to calculate the data points at each power output and are referred to as “Powermeter Power”. The theoretical power output calculated using the treadmill data are referred to as “Calculated Power”.

Table 1: Variables used to calculate theoretical power

Variable	Value
Treadmill Incline	4.13°
Bike Weight	8.55kg (depending on crank mass)
C_{RR}	0.0036
Tire Pressure	100psi
Drivetrain Losses	2.4%

Results

Three PRECISION PRO Powermeters were put through the testing protocol, Table 2. These cranks were "off-the-shelf", being shipped directly from the *4iiii* factory to increase objectivity of the study.

Table 2: Cranks used for testing protocol

Crank Number	Crank Model	Crank Material	Powermeter
1	Shimano Dura-Ace FC-9100	Alloy	PRECISION PRO
2	Shimano Dura-Ace FC-9100	Alloy	PRECISION PRO
3	Shimano Dura-Ace FC-9100	Alloy	PRECISION PRO

The collected data for each crank can be found in Tables 3-5.

Table 3: Results of testing for Crank 1

Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
150.0	154.2	4.2	2.76%
200.0	201.8	1.8	0.88%
250.0	253.5	3.5	1.40%
300.1	299.6	-0.5	0.16%
350.1	352.6	2.5	0.73%

Table 4: Results of testing for Crank 2

Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
150.0	148.9	-1.1	0.78%
200.1	201.3	1.3	0.61%
250.1	249.5	-0.6	0.22%
300.1	300.5	0.4	0.15%
350.1	347.1	-3.0	0.85%

Table 5: Results of testing for Crank 3

Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
150.2	152.3	2.1	1.40%
199.8	204.0	4.2	2.09%
249.5	252.8	3.3	1.33%
299.7	303.9	4.2	1.40%
349.4	353.1	3.7	1.08%

The collected data is summarized in Table 6.

Table 6: Compiled results for PRECISION PRO Powermeters

Crank	Absolute % Error
1	1.18%
2	0.52%
3	1.46%
Average	**1.06%**

Conclusions

This follow up study testing the PRECISION PRO Powermeter on Shimano Dura-Ace R9100 cranksets demonstrated *4iiii* Innovations drive to continue to improve product quality, redefining the Gold Standard. With improved technology and engineering, *4iiii* has improved the average accuracy of off-the-shelf cranks from 1.56% (published in a white paper report in September 2018) to 1.06% in spring of 2019. *4iiii* is committed to meeting this standard across the whole line of PRECISION PRO Powermeters.

Limitations

Within this study, calculated power required knowledge of both drivetrain losses as well as rolling resistance, C_{RR}. The margin of error on C_{RR} calculation is relatively small with respect to the order of magnitude of power calculations. Currently, the Locomotion Lab is developing a method of accurately measuring drivetrain losses but for now, the value used was an estimate. Previous research has identified drivetrain losses to be on the order of 2-3% giving confidence in the 2.4% estimate. However, C_{RR} and drivetrain loss errors affect the results of this study and the Locomotion Lab will continue to refine their methodology.

Disclosures

This testing was commissioned by *4iiii* Innovations. Cranks were provided to the University off-the-shelf from general inventory from the *4iiii* Alberta Factory. No *4iiii* employee was involved in the testing protocol or collection of data.