Technical Report:
Accuracy Testing of 4iiii Innovations PRECISION Powermeter Technology

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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 biometric 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 power meters used on bicycles.

4iiii Innovations Inc. requested a study to independently test the accuracy of the PRECISION Powermeter technology at the Locomotion Lab.

Tests included multiple PRECISION PRO and Podiiiium Pro PRECISION Powermeters on alloy and carbon cranks being compared to power calculated by a bike treadmill for outputs ranging from 150-350W. Results showed an average error in power reading of 1.58% for PRECISION PRO Powermeters and 0.84% for Podiiiium Pro PRECISION Powermeters on carbon cranks.

These third-party test results prove the accuracy of PRECISION and Podiiiium PRECISION Powermeters.

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

Currently in the sports technology industry, there is little independent data to support product claims to device accuracy and reliability. Dr. Rodger Kram at the Locomotion Lab at the University of Colorado, Boulder has developed a quantitative and unbiased protocol to determine the accuracy of bike powermeters. Using a bicycle treadmill in a controlled environment allows accurate determination of theoretical power to compare to powermeters installed on the bike of test riders following a defined power profile.

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.

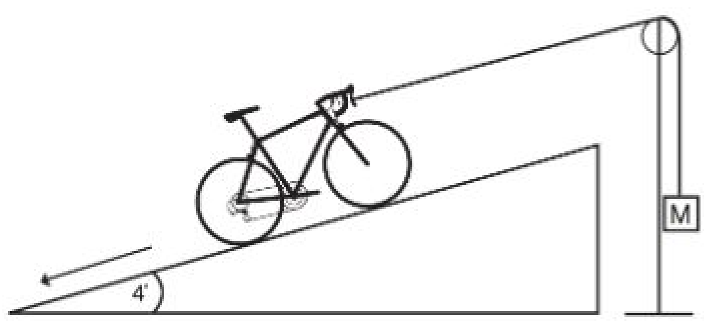

Figure 1: Schematic diagram of force balance used to determine C_{RR}

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}:

$$C_{RR} = Force_{Pull} / F_N \qquad (1)$$

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

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

$$Power_{RR} = (\text{Total Rider + Equipment Mass}) * g * \cos(4.1^{\circ}) * C_{RR} * V_{treadmill} \quad (3)$$

With the total theoretical power being calculated using Equation 4:

$$Power = Power_{Mech} + Power_{RR} \quad (4)$$

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	4.14°
Rider Weight	75.60kg
Bike Weight	8.55kg
C_{RR}	0.0041
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

Cadence (RPM)	Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
49	149.8	147.6	-2.17	-1.45%
65	200.4	193.1	-7.31	-3.65%
73	250.2	240.9	-9.25	-3.70%
80	300.1	295.1	-4.98	-1.66%
85	350.4	358.2	7.84	2.24%

Table 4: Results of testing for Crank 2

Cadence (RPM)	Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
49	150.0	149.2	-0.75	-0.50%
65	200.2	198.3	-1.93	-0.96%

73	250.2	246.9	-3.25	-1.30%
80	300.1	298.1	-1.98	-0.66%
85	350.2	350.0	-0.18	0.05%

Table 5: Results of testing for Crank 3

Cadence (RPM)	Calculated Power (W)	Powermeter Power (W)	Absolute Difference (W)	Absolute % Error
49	150.1	152.7	2.57	1.71%
65	200.2	201.3	1.07	0.53%
73	250.3	254.5	4.17	1.66%
80	300.3	304.7	4.44	1.48%
85	350.5	358.7	8.16	2.33%

The collected data is summarized in Table 6.

Table 6: Compiled results for PRECISION PRO Powermeters

Crank	Absolute % Error
1	2.50%
2	0.70%
3	1.54%
Average	**1.58%**

Based on this data, 4iiii is confident to claim an accuracy of 1.58% on PRECISION PRO Powermeters.

Conclusions

4iiii endeavoured to use third-party testing to determine an objective measure of the accuracy of PRECISION Powermeter technology. Dr. Roger Kram at the University of Colorado Boulder, previously developed a protocol to accurately measure power output using a bicycle treadmill. 4iiii sent multiple off-the-shelf cranks from their factory which had PRECISION PRO dual powermeters installed on them. Following the testing, an average absolute error of +/-1.58% was observed.

Within these tests, the top performing powermeter had a calculated error of +/-0.70% demonstrating the accuracy the technology is capable of. These measurements were observed on alloy cranks but similar results have also been seen from previous testing on this apparatus with Podiiiium Pro PRECISION Powermeters on carbon cranks, Table 7.

Table 7: Results for SRAM XX1 cranks with Podiiiium Pro PRECISION Powermeters installed (early 2018)

Crank	Absolute % Error
1	1.01%
2	0.61%
3	0.81%
4	0.93%
Average	**0.84%**

It is evident that the 4iiii PRECISION Powermeter Technology is capable of achieving within +/-1% error. 4iiii endeavours to ensure this level of accuracy on its entire product line which includes a variety of alloy and carbon crank options.

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 work has identified drivetrain losses to be on the order of 2-3% giving confidence in the 2.4% estimate. However, both of these errors compound the results of this study and the Locomotion Lab will continue to refine their protocols to decrease this error.

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.