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Original Investigation

Title:
Validity of the Velocomp PowerPod compared to the Verve Cycling InfoCrank power meter

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Abstract

Purpose: Determine the validity of the Velocomp PowerPod power meter in comparison with the Verve Cycling InfoCrank power meter. ***Methods:*** This research involved two separate studies. In *Study 1* twelve recreational male road cyclists completed seven maximal cycling efforts of a known duration (2 times 5 s, and 15, 30, 60, 240, and 600 s). In *Study 2* four elite male road cyclists completed 13 outdoor cycling sessions. In both studies power output of cyclists was continuously measured using both the PowerPod and InfoCrank power meter. Maximal mean power output was calculated for durations of 1, 5, 15, 30, 60, 240, and 600 s, plus the average power output in *Study 2*. ***Results:*** Power output determined by the PowerPod was almost perfectly correlated with the InfoCrank ($r > 0.996$; $p < 0.001$) in both studies. Using a rolling resistance previously reported, power output was similar between power meters in *Study 1* ($p = 0.989$), but not in *Study 2* ($p = 0.045$). Rolling resistance estimated by the PowerPod was higher than what has been previously reported, this might have occurred because of errors in the subjective device setup. This overestimation of rolling resistance increased power output readings. ***Conclusion:*** Accuracy of rolling resistance seems to be very important in determining power output using the PowerPod. When using a rolling resistance based on previous literature the PowerPod showed high validity when compared with the InfoCrank in a controlled field test (*Study 1*) but less so in a dynamic environment (*Study 2*).

Keywords cycling, power profile, training, performance, power output

Introduction

Cycling power meters typically rely on a measurement of crank arm, chain, pedal, or rear hub torque and angular velocity to calculate power output.[1] There are several models of power meters available on the market, with many validated against the SRM power meter[1-6] or a mathematical model of treadmill cycling.[7] The high accuracy of power output data recorded by SRM devices has been previously reported (< 1%[8] and 2.3 ± 4.9% error[9]). Both the SRM and the Verve Cycling InfoCrank power meter have shown similar mean deviation (trueness) to a mathematical model of treadmill cycling and coefficient of variation (precision) (i.e. Trueness = -0.5 ± 2.4 and -1.7 ± 1.1%; Precision = 0.8 ± 0.4 and 0.6 ± 0.4%, respectively).[7]

The Velocomp PowerPod power meter is among the cheapest on the market. An advantage of this power meter is that no changes to the bicycle have to be made (e.g. changing crank arms, rear hub, etc.) and it can be easily mounted on to the handle bars of the bicycle. The novel aspect of this power meter is that when paired with a speed sensor it continuously calculates the opposing forces caused by road gradient, air resistance, acceleration, and friction. These forces are calculated using 9 different measurements: three accelerometers to measure displacements in the x, y, and z direction, frontal air pressure using a small port at the front of the device, environmental air pressure, altitude, air temperature, inclination, and wheel speed (using an ANT+ or Bluetooth speed sensor). Based upon these calculated opposing forces and Newton's first law the Velocomp PowerPod power meter calculates cycling power output. This differs to most of the currently available power meters in which power output is calculated with the use of strain gauges. To date the validity of power output calculated by the Velocomp PowerPod power meter is unknown. Therefore, the aim of this study was to determine the validity of the Velocomp PowerPod power meter during field cycling tests and training in comparison with the Verve Cycling InfoCrank power meter.

Methods

Participants

This study was separated into two studies. These include a first study in a controlled field test during which a wide range of power outputs was tested and a second study during typical training rides when velocity and power output were dynamic. In *Study 1*, twelve recreational male road cyclists (age, 35.0 ± 7.6 y; height, 178.2 ± 5.5 cm; body mass, 78.9 ± 8.7 kg) completed a power profile test created and validated by Quod and colleagues.[10] At the time of the study the participants were riding 5.1 ± 1.0 times and for 10.3 ± 3.9 hours per week and were classified as performance level 3 or higher, as per de Pauw and colleagues.[11] In *Study 2*, four elite male road cyclists (age, 19.1 ± 1.2 y; height, 176.2 ± 1.0 cm; body mass, 70.3 ± 2.8 kg), racing for a continental cycling team, completed a combined total of thirteen training sessions (duration: 202.03 ± 69.60 min; distance: 95.12 ± 32.35 km) over a period of five weeks during the competitive season. At the time of the study the participants were riding 6-7 times and 18-20 hours per week, covering over 500 km per week. They had more than 5 years of cycling experience and were classified as performance level 5, as per de Pauw and colleagues.[10] In both these studies, the bicycles were equipped with both a Verve Cycling InfoCrank and a Velocomp PowerPod power meter. The Verve Cycling InfoCrank power meter has previously shown shown similar trueness (-1.7 ± 1.1%) and precision (0.6 ± 0.4%) to a mathematical model of treadmill cycling.[7] Prior to data collection, all participants provided written informed consent in accordance with the Edith Cowan University Human Research Ethics Committee and the principles outlined in the Declaration of Helsinki.

Study 1 - Power profile test

Participants completed the power profile test individually on a road bicycle, with the seat height and saddle setback adjusted to replicate the participants own bicycle. The bicycle was equipped with a Verve Cycling InfoCrank power meter (Verve Cycling, Perth, Australia) and a Velocomp PowerPod power meter (Velocomp LLC, Jupiter, USA). The Verve Cycling InfoCrank power meter contained four strain gauges per crank arm.[7] Before data collection, the Velocomp PowerPod power meter was setup in the Isaac software (Velocomp LLC, Jupiter, USA) including the participant's body mass, height, and the sum of body mass and bicycle mass; riding position (i.e. drops); tire size (i.e. 700x23c), type (i.e. clincher), grade (i.e. utility), and pressure (i.e. 7 bars); device mount location (i.e. front mount); road type (i.e. rough asphalt); and calibration ride type (i.e. best accuracy). After the setup, the Velocomp PowerPod power meter was paired to an SRM speed sensor (Schoberer Rad Messtechnik, Jülich, Germany) followed by an 'out-and-back calibration ride' of approximately 10 minutes as per manufacturer's manual. Briefly, during the 'out-and-back calibration ride' power output was displayed on a Garmin Edge 820 (Garmin, Schaffhausen, Switzerland). Power increased from 0 to 50 W (as in 0 to 50%). When power output was at 50 W participants stopped for 5 s. Turned around and rode the same course but in the opposite direction during which power output increased from 51 to 100 W (as in 51 to 100%). The 'out-and-back calibration ride' started and finished at the same location for every participant and was performed on the same open road (outdoor) as the power profile test. The calibration ride was followed by two 5 s sprints at approximately 70 and 80% of self-reported maximal effort to select gear for the first effort of the power profile test.

Three minutes following this procedure, participants began the power profile test[10] on an open road (outdoor; elevation gain = 46 ± 8 m (Garmin Edge 820)). Briefly, all participants completed seven maximal efforts, including two times 5 s followed by 15, 30, 60, 240, and 600 s.[10] All efforts were performed from a rolling start and at a self-selected gear. During recovery periods between each effort participants rode at a freely chosen low-intensity and were allowed to drink water ad libitum.

Throughout the power profile test, power output data of the Verve Cycling InfoCrank power meter was recorded by the Garmin Edge 820 head unit at 1 Hz. Data of the Velocomp PowerPod power meter was stored on the device itself at 1 Hz. Given the time delay required to calculate power output for the Velocomp PowerPod power meter, data was synchronized by starting each duration (i.e. 5, 15, 30, 60, 240, and 600 s) at the peak power output reached during that effort. Synchronizing the data showed a delay in power output data of 2.45 ± 1.85 s of the Velocomp PowerPod power meter data compared with the Verve Cycling InfoCrank power meter data. Maximal mean power outputs for durations of 1, 5, 15, 30, 60, 240, and 600 s were calculated for the complete power profile test. Data was analyzed using the rolling resistance estimated by the Velocomp PowerPod power meter, as well as using a rolling resistance observed in previous research (0.006),[12] since rolling resistance estimated by the Velocomp PowerPod was higher than suggested in literature for rough road (0.011 ± 0.0 vs. 0.006,[12] respectively).

Study 2 - Training sessions

The participants' personal bicycles were equipped with a Verve Cycling InfoCrank and a Velocomp PowerPod power meter. Before their first training session, the Velocomp PowerPod power meter was setup in Isaac software as described in *Study 1* and the participants performed the 'out-and-back calibration ride'. Riding position, tire size, and road type were setup differently compared to *Study 1* (i.e. hoods, 700x25c, and good asphalt, respectively). These settings were kept consistent for all following training sessions. Power output data was analyzed as per *Study 1,* with the addition of the average power output per training session. Furthermore, since the rolling resistance estimated by the Velocomp PowerPod power meter was higher than suggested in literature for smooth road (0.005 ± 0.0 vs. 0.004,[12] respectively) the same analysis was performed using a rolling resistance of 0.004 as suggested previously for smooth road.[12]

Statistical analysis

Two-tailed Pearson's correlations were used to determine the strength of the linear relationship between the two power meters, whereby the strength was classified as 0.0 to 0.09 (trivial), 0.10 to 0.29 (small), 0.30 to 0.49 (moderate), 0.50 to 0.69 (large), 0.70 to 0.89 (very large), 0.90 to 0.99 (near perfect), and 1.0 (perfect).[13] Dependent variables for *Study 1* (i.e. power output per duration: 1, 5, 15, 30, 60, 240, and 600 s) and *Study 2* (i.e. power output per duration: 1, 5, 15, 30, 60, 240, 600 s, and average) were compared between the Verve Cycling InfoCrank and the Velocomp PowerPod power meters using a two-way analysis of variance (ANOVA). Furthermore, partial eta squared was calculated. When a main effect of device (i.e. Verve Cycling InfoCrank vs. Velocomp PowerPod power meter) was found an additional ANOVA was performed as a post-hoc test. Bland-Altman plots and 95% limits of agreement (95% LoA)[14,15] were applied to assess the agreement among the two power meters. The level of significance was set at $p \leq 0.05$ for all tests. All statistical analyses were completed using SPSS (IMB SPSS Inc. Statistics, Chicago, USA).

Results

Study 1 - Power profile test

The Pearson correlation showed a significant near perfect correlation between the two devices ($r = 0.998$; $p < 0.001$). Furthermore, a significant main effect of device on power output was observed ($F(1,22) = 18.982$; $p < 0.001$; Partial $\eta 2 = 0.463$; Figure 1A). Post-hoc comparisons revealed that power output was significantly greater for the Velocomp PowerPod power meter, compared with the Verve Cycling InfoCrank power meter for each duration (26.68-38.57%). The bias was -197.52 ± 137.51 W (95% LoA = 269.52 W; Figure 2A).

When using a rolling resistance of 0.006 a significant perfect correlation between the two devices ($r = 1.000$; $p < 0.001$) was observed. Furthermore, no significant main effect of device on power output was observed ($F(1,22) = 0.00$; $p = 0.989$; Partial $\eta 2 = 0.000$; Figure 1B) (-0.57-0.24%). The bias was 0.50 ± 10.59 W (95% LoA = 20.76 W; Figure 2B).

Study 2 - Training sessions

The Pearson correlation showed a significant near perfect correlation between the two devices ($r = 0.996$; $p < 0.001$). Furthermore, a significant main effect of device on power output was observed ($F(1,24) = 6.819$; $p = 0.015$; Partial $\eta 2 = 0.221$; Figure 1C). Post-hoc comparisons revealed that power output was significantly greater for the Velocomp PowerPod power meter compared with the Verve Cycling InfoCrank power meter for maximal mean power outputs at 1, 5, 30, 240s, and for the average power output (15.23-47.68%). The bias was -200.20 ± 250.21 W (95% LoA = 490.41 W; Figure 2C).

When using a rolling resistance of 0.004 a significant near perfect correlation between the two devices ($r = 0.995$; $p < 0.001$) was observed. Furthermore, a significant main effect of device on power output was observed ($F(1,24) = 4.496$; $p = 0.045$; Partial $\eta 2 = 0.158$; Figure 1D). Post-hoc comparisons revealed that power output was significantly higher for the Velocomp PowerPod power meter, compared with the Verve Cycling InfoCrank power meter for the maximal mean power output at 1 s but not for the other durations. The bias was -139.03 ± 241.57 W (95% LoA = 473.48 W; Figure 2D).

Discussion

The aim of this study was to assess the validity of the Velocomp PowerPod power meter. Both the power profile test data and the training data showed nearly perfect to perfect correlations between the two power meters before and after adjusting rolling resistance (before: $r = 0.998$ and 0.996; after: $r = 1.000$ and 0.995, respectively). Using a rolling resistance previously reported in literature,[12] power output was similar between the Verve Cycling InfoCrank and Velocomp PowerPod power meter in *Study 1* ($p = 0.989$), but not in *Study 2* ($p = 0.045$). Rolling resistance estimated by the Velocomp PowerPod was higher than what has been previously reported in literature,[12] affecting power output readings.

High validity is important in the use of power meters to monitor training and competition performance. When the rolling resistance was adjusted according to previous research,[12] the difference in power measured with the Verve Cycling InfoCrank and Velocomp PowerPod in *Study 1* (-0.57-0.24%), but not during *Study 2* (8.94-33.14%), were comparable to differences previously observed between the SRM power meter and the PowerTap (-3.5% to -0.5%[9]); Gamin Vector (3.0% to 3.8%[3]), and Garmin Vector 2 (2.9% to 7.4%[2]). Without the adjusted rolling resistance, the difference in power measured with the Verve Cycling InfoCrank and Velocomp PowerPod were notably higher (*Study 1* 27-39% and *Study 2* 16-49%). These results indicate that a significant aspect of the difference in power output observed between devices in this study might be associated the Velocomp PowerPod power meter estimations of rolling resistance. Martin and colleagues[16] reported that rolling resistance accounted for 10 to 20% of total power output, and the proportion of rolling resistance power output to total power output decreased with increased speed. A change in rolling resistance from 0.0016 to 0.0066, could affect cycling velocity by up to 6%.[16] The amount of force a cyclist has to produce to overcome rolling resistance is related to the cumulative weight of the cyclist and the bicycle; tire type, grade and pressure; and road gradient and type.[16]

The Velocomp PowerPod power meter calculates rolling resistance based upon the selected/entered tire type, grade/quality and pressure, and road type.[17] Given that the classification of these variables are somewhat subjective (i.e. good asphalt vs rough asphalt) it is not possible to determine the magnitude of error caused within the present study and should be an area of future research. The error in the estimation of rolling resistance (based upon assumed road and tire quality) is likely to have little influence on the reliability of power output measurements when these variables are consistent (i.e. using the same tires or similar roads) and therefore the Velocomp PowerPod power meter should be useful in monitoring changes in workload. However, this needs to be established in future research. Additionally, caution should be taken when comparing power output data collected by different cyclists, on different road types or using different bicycles and tires. In the current study, no measurements of rolling resistance were made which might be subject for future research.

The significant difference in power output observed between the Velocomp PowerPod and Verve Cycling InfoCrank power meter in *Study 2* (Figure 1) may be due to the variability in road gradient and wind direction in *Study 2* compared to *Study 1*. Additionally, data in *Study 2* was collected during participants' regular training rides, including both individual and group rides. From the data files it was not possible to determine the effect of drafting behind other cyclists or passing traffic. Since the participants collected data during their regular training rides and the classification of the settings is subjective it was not possible to measure road quality and tire type for each individual training session and change the Velocomp PowerPod power meter settings if needed. Additionally, road type might change between good and rough asphalt within one training session in Study 2. Since it is not possible to change the settings during the training session this limitation might give errors in calculating power output. Another difference between Study 1 and Study 2 is the riding position. In Study 1 this was somewhat controlled, all efforts were performed with the hands in the drops. However, other variables like seated and standing, head high or low, or elbows tucked or not were not controlled. These small changes in riding position are likely to affect aerodynamic drag (CdA).[18-22] The Velocomp PowerPod uses a constant CdA value for its power output calculations which might result in errors since CdA has a dynamic nature and changes with riding position.[18-22] For example, changing from a seated position to a standing or forward standing position when riding 60 $km \cdot h^{-1}$ can cost or save you 25 or 190 W, respectively (with cyclist + bicycle weight: 80 kg; air density: 1.175; gradient: 0%; wind velocity parallel to the cyclist: 0 $m \cdot s^{-1}$; and rolling resistance: 0.004).[22] Hence, changing riding position has a major effect on CdA and therefore on power output. This could explain the higher variability in Study 2 compared to Study 1 since in Study 2 riding position was in no way controlled and might have varied even more than in Study 1 (i.e. hands in the drops, hoods, or on top of the handle bars). The effect of these variables (i.e. road gradient, wind direction, drafting, passing traffic, road type, and riding position) on the validity of the Velocomp PowerPod needs further investigation.

It appears from this study that the difference in power output between devices was greatest at higher power outputs (Figure 1 and 2). Similar findings were shown in studies comparing the Garmin Vector power meter with the SRM power meter.[2,3] Nimmerichter and colleagues[2] showed a higher typical error during sprint cycling when compared to submaximal trials and time trials in laboratory and field conditions (7.4% and 2.9%, respectively). Furthermore, Novak and colleagues[3] reported the greatest variance during 5 s efforts compared with longer durations up to 10 minutes. However, in contradiction with the current study the difference in their study was not significant.

Practical applications

The Velocomp PowerPod power meter is easy to mount to different bicycles; when using a rolling resistance previously reported, the Velocomp PowerPod power meter was able to show highly valid measurements in a controlled field test, but not as much in a more dynamic situation. When setting up the Veolocomp PowerPod power meter in the Isaac software, coaches and cyclists are assumed to have the knowledge about the effect of tire type, grade and pressure, and road type on rolling resistance and therefore on power output. Measuring these variables in real time rather thans relying on estimations may drastically improve the accuracy of devices such as the Velocomp PowerPod and could be an avenue of future research. Additionally, using the Velocomp PowerPod during dynamic high intensity training sessions/races might lead to an overall overestimation of training load, since the Velocomp PowerPod overestimates power output at higher intensities. Regardless, the Velocomp PowerPod power meter is an interesting advancement in the measurement of power output during cycling which may have many additional applications (i.e. estimating CdA).

Conclusion

Accuracy of rolling resistance seems to be very important in determining power output using the Velocomp PowerPod power meter. When using a rolling resistance based on previous literature the Velocomp PowerPod power meter showed high validity when compared with the Verve Cycling InfoCrank power meter in a controlled field test (*Study 1*) but less so in a dynamic environment (*Study 2*).

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Figures

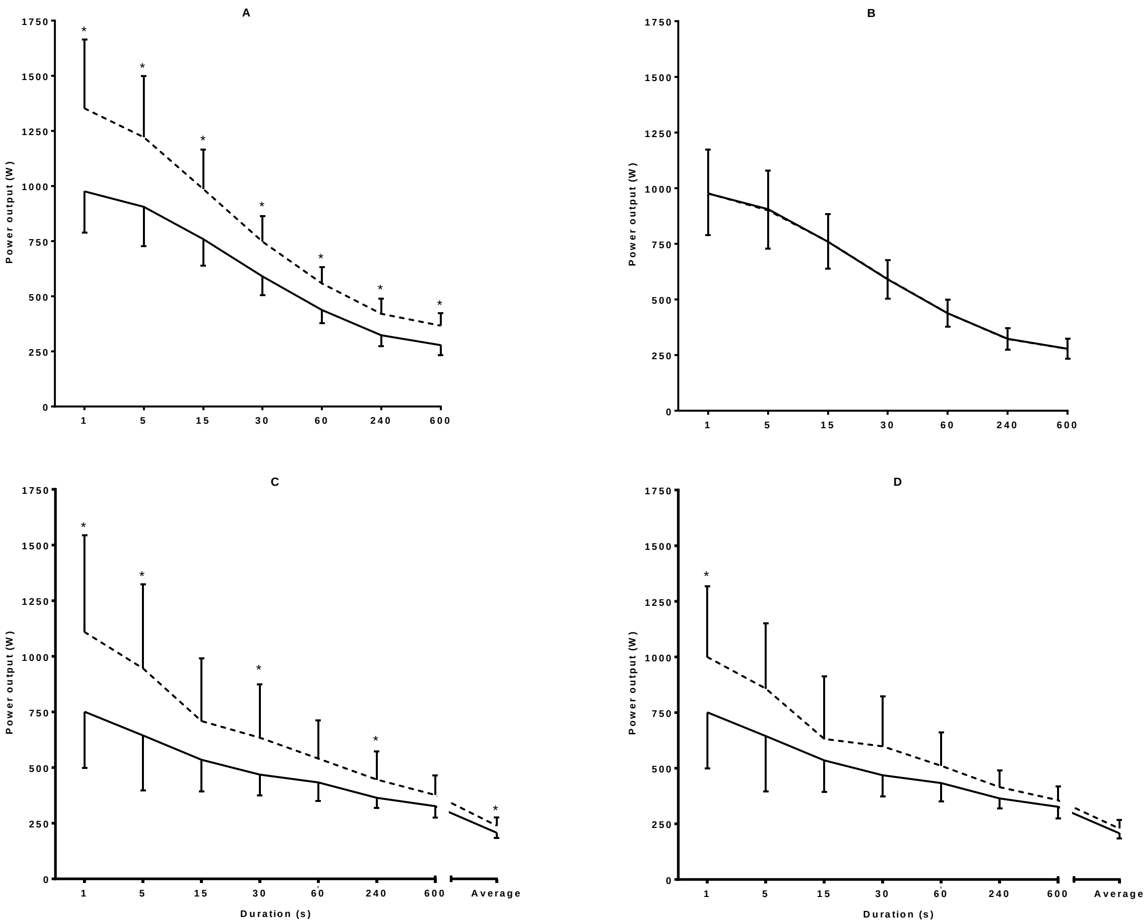

Figure 1 Maximal mean power output per duration for both the Verve Cycling InfoCrank (solid line) and the Velocomp PowerPod power meters (dashed line).
A: *Study 1* – Power profile test (n = 12); B: *Study 1* – Power profile test adjusted rolling resistance (n = 12); C: *Study 2* – Thirteen training sessions (n = 4); D: *Study 2* – Thirteen training sessions adjusted rolling resistance (n = 4); * = $p < 0.05$.

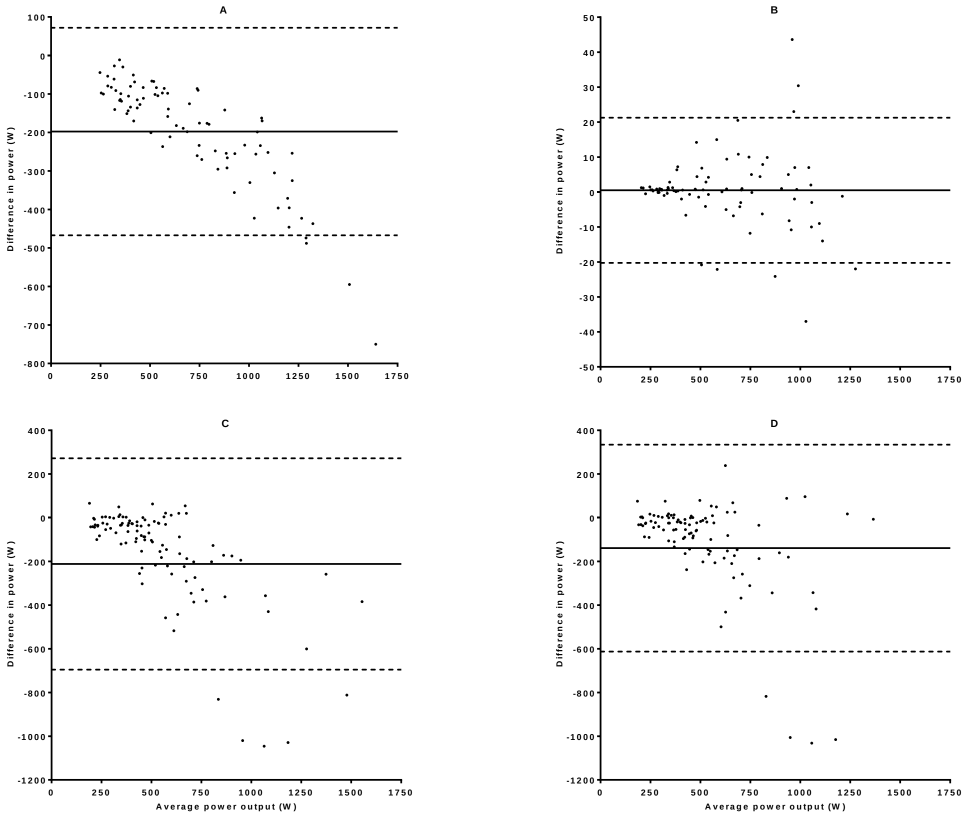

Figure 2 Bland-Altman plots of the difference in power output (W) between the Verve Cycling InfoCrank and the Velocomp PowerPod power meters for all data points.
A: *Study 1* – Power profile test (n = 12); B: *Study 1* – Power profile test adjusted rolling resistance (n = 12); C: *Study 2* – Thirteen training sessions (n = 4); D: *Study 2* – Thirteen training sessions adjusted rolling resistance (n = 4); Solid line = mean bias; Dashed line = the 95% LoA.