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Validity and Reproducibility of the Ergomo®Pro Power Meter Compared With the SRM and Powertap Power Meters

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Purpose: The Ergomo®Pro (EP) is a power meter that measures power output (PO) during outdoor and indoor cycling via 2 optoelectronic sensors located in the bottom bracket axis. The aim of this study was to determine the validity and the reproducibility of the EP compared with the SRM crank set and Powertap hub (PT). ***Method:*** The validity of the EP was tested in the laboratory during 8 submaximal incremental tests (PO: 100 to 400 W), eight 30-min submaximal constant-power tests (PO = 180 W), and 8 sprint tests (PO > 750 W) and in the field during 8 training sessions (time: 181 ± 73 min; PO: ~140 to 150 W). The reproducibility was assessed by calculating the coefficient of PO variation (CV) during the submaximal incremental and constant tests. ***Results:*** The EP provided a significantly higher PO than the SRM and PT during the submaximal incremental test: The mean PO differences were +6.3% ± 2.5% and +11.1% ± 2.1%, respectively. The difference was greater during field training sessions (+12.0% ± 5.7% and +16.5% ± 5.9%) but lower during sprint tests (+1.6% ± 2.5% and +3.2% ± 2.7%). The reproducibility of the EP is lower than those of the SRM and PT (CV = 4.1% ± 1.8%, 1.9% ± 0.4%, and 2.1% ± 0.8%, respectively). ***Conclusions:*** The EP power meter appears less valid and reliable than the SRM and PT systems.

Key Words: cycling, mobile power meter, comparison, field, laboratory

Many sport scientists and coaches now use power output (PO) instead of heart rate to specify training intensity in cycling. PO can be estimated by using mathematical models or measured directly on the cyclist's bicycle thanks to mobile power meters.[1,2] Such devices (eg, SRM, Powertap [PT], Ergomo®Pro [EP], Polar S710) enable the measurement of PO, pedaling cadence, and velocity during field (training and competition) and laboratory conditions.

The first goal of a power meter is to provide a valid and reproducible PO. All mobile power meters, except the EP, have been studied before for their validity and reproducibility. The SRM crank set (Schoberer Rad Messtechnik, Welldorf,

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Germany) is viewed as the best device for measuring a cyclist's PO because of its measures' high validity and reproducibility.[3,4] Through its negligible error in PO, the SRM has been used as a reference system to validate other mobile ergometers such as the Polar S710 and the PT[5,6] and stationary ergometers such as the Kincycle ergometer and the Axiom Powertrain ergometer.[7,8] The PT is also viewed as a valid and reliable power meter when compared with the SRM[6] or a dynamic calibration rig.[3]

The EP (SG Sensortechnik GmbH & Co, KG, Mörfeldn-Walldorf, Germany) power-monitoring system consists of an EP sensor (an instrumented bottom bracket axis), an EP computer (that displays and saves data), a speed sensor to measure the cyclist's velocity on the front wheel, and a sensor plug. This device uses 2 optoelectronic sensors located at the bottom bracket axis (Figure 1). The advantage of this technology is that, unlike the SRM and PT sensors (strain gauges), the EP sensors are not sensitive to temperature. The shifted phase position between the 2 sensors is assumed to be proportional to the force applied to the pedal (and thus the torsion of the bottom bracket). The EP stores 72 data points per crank cycle. The manufacturers of the EP claim an accuracy of ±1%. The EP sensor only measures the PO developed by the left lower limb because of the location of the 2 sensors on the left side of the bottom bracket axis. Thus, the PO displayed on the EP computer is calculated by multiplying by 2 the PO measured by the sensors. This method seems doubtful because some cyclists show an asymmetry in pedaling technique between their 2 lower limbs, notably in the force applied to the pedals.[9,10]

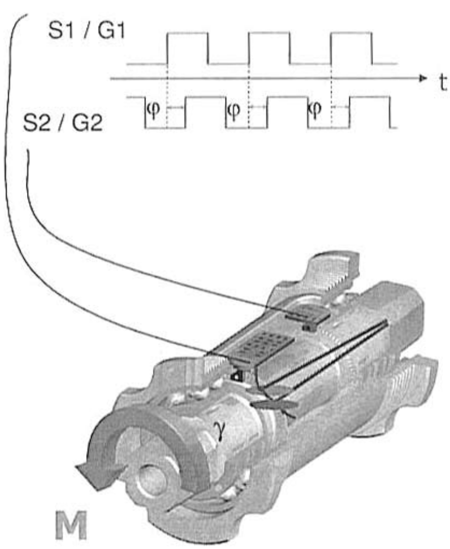

Figure 1 — The optoelectronic sensor of the Ergomo®Pro power meter.

Compared with the SRM and PT, EP has some advantages. First, it can be used on every kind of bike (road, off-road, track, and BMX). Second, when compared with standard equipment (Shimano), the additional mass of replacing the "10 Speed Dura Ace" component with the EP power meter (0.074 kg) is lower than the additional mass of the PT (0.152 kg) and the SRM (0.280 kg). Third, the EP measures altitude. This additional function allows the determination of the change in altitude during a training session or the calculation of the mean grade of a mountain pass. Moreover, the EP computer displays the road grade in real time with a slight delay.

To the best of our knowledge, the validity and the reproducibility of the EP have never been studied. Therefore, the aim of this study was to assess the validity and reproducibility of the EP by comparing it with the SRM and PT power meters.

Methods

Subjects

A regional-level male competitive cyclist (age 27 years, height 1.80 m, body mass 65 kg, maximal aerobic power 360 W) volunteered as the subject for this study. Before testing and after having received full explanation concerning the nature and the purpose of the study, the subject gave written informed consent. Before participating, he underwent several habituation sessions to familiarize himself with the testing procedure and material.

Design

The validity and reproducibility of the EP compared with the SRM and PT power meters were studied for indoor and outdoor conditions. The testing procedure has been described in a previous study.[6] By means of 4 different test protocols, PO_{EP} was compared with PO_{SRM} and PO_{PT} across different levels of PO, pedaling cadences, and pedaling posture to establish validity. Those 4 test protocols were repeated on 8 days to establish reproducibility.

Methodology

Indoor Tests. Three tests were performed in the laboratory: a submaximal incremental test, a submaximal constant-power test, and a sprint test. The subject performed these 3 different tests on the same day and repeated them on 8 different days during a 5-week period (thus, in all, 8 × 3 tests = 24 tests). The submaximal tests were completed on a large motorized treadmill (S 1830, HEF Techmachine, Andrézieux-Bouthéon, France) 1.8 m wide and 3.8 m long, and the sprint tests were performed on a Cateye ergometer (CS-1000, Cateye, Osaka, Japan).

Submaximal Incremental Test. The submaximal incremental test consists of cycling on a treadmill with different slopes (2%, 4%, and 6%). For each slope, 2 treadmill velocities were used (15 and 25 km/h) with 3 different gear ratios (39/15, 39/19, and 39/23). Nevertheless, the subject used a 39/21 gear ratio when he pedaled against the 6% slope at 25 km/h because of difficulties of maintaining high pedaling cadence at high PO (>350 W). The combinations of these velocities and gear ratios resulted in 6 different pedaling cadences (47, 60, 75, 80, 100, and 123 rpm) and POs (100, 165, 175, 230, 280, and 395 W) and thus allowed a study of the effect of the pedaling cadence on the PO_{EP}. All the trials were performed in the seated position. To test the effect of pedaling posture on the PO_{EP}, however, 1 additional trial was completed in the standing position with a 6% slope, a velocity of 15 km/h, and a 39/19 gear ratio. Each trial lasted 1 minute, and the subject performed the 19 different trials ([3 slopes × 2 velocities × 3 gear ratios] + 1 standing position) in a random order.

Submaximal Constant-Power Test. In order to study the EP validity across time, a 30-minute constant-power test was performed in seated position against a 2% slope at 25 km/h and with a 39/16 gear ratio to achieve a moderate intensity (PO = 170 W) and a pedaling cadence of 85 rpm.

Sprint Test. The sprint test consisted of three 8-second sprints (all-out exercise) in the seated position to determine maximal PO (PO_{max}). To test the validity of PO_{max} measured by the EP, 3 different gear ratios were used (53/15, 53/17, and 53/21), which led to 3 different maximal pedaling cadences (104 ± 5, 114 ± 5, and 134 ± 10 rpm, respectively). Sprints were separated by 5-minute active-recovery periods at low intensity (<150 W). The PO_{max} was defined as the maximal PO value obtained in each sprint. For these sprints the racing bicycle was mounted on a Cateye ergometer, which provides a wind and magnetic resistance to simulate field conditions. The front wheel of the bicycle was removed, and the bicycle fork was attached to the ergometer by a quick-release skewer. The rear wheel of the bicycle was fixed by the rear-wheel quick-release skewer in the ergometer stand. These 2 fixation points restrained the lateral motion of the bike and the rear wheel. During each sprint the magnetic resistance was set at a simulated grade of 4% (displayed on the small Cateye monitor).

Field Test. The field tests consisted of 8 actual road-cycling training sessions on hilly ground that included various field conditions (flat, uphill, and downhill sections) and different pedaling cadences and cycling postures. Time, distance, and PO_{SRM} (mean ± SD) of the 8 field-training sessions were 181 ± 73 minutes, 77 ± 31 km, and 140 ± 13 W, respectively.

Material

All testing sessions were performed by the same subject with the same road-racing bicycle (mass = 9 kg), which was equipped with clipless pedals. The mass of the system (subject + bicycle) contributes to the power required to ride on a treadmill at a given speed and gradient. A slight change in subject mass would have changed the PO required to ride on the treadmill, so every test day, the subject's body mass was measured to avoid its influence on the PO during the submaximal incremental and constant-power tests that were performed on the inclined treadmill. Changes in body mass were corrected by adding or removing water from 2 bottles in the bottle cages of the racing bicycle. The bicycle tire pressure was inflated to 700 kPa, and the chain was well lubricated. The chain had been used for 6 months (~3000 km) before the testing session. The bicycle was fitted with an SRM crank set (first SRM scientific model with 20 strain gauges) and an EP bottom bracket. The rear wheel was equipped with a Powertap hub (professional model). The recalibration of the SRM (ie, the resetting of the "frequency vs torque" slope) had been performed by the SRM manufacturer 3 months before the first tests of this study.

Before each test, calibration (ie, "zero offset" procedure) of the SRM, the PT, and the EP were performed according to the manufacturer's recommendations. The zero-offset procedure of the SRM and PT have been described in previous studies.[3,6,11] For the EP system, this zero-offset procedure is as follows: While standing beside the bicycle, one takes the rear wheel off the ground by pulling up the bike with one hand and uses the other hand to steadily accelerate the right crank until a pedaling cadence between 50 and 70 rpm is obtained. To obtain this steady acceleration, the chain has to be put on the smallest sprocket on the rear wheel, and the largest chain wheel, on the front wheel (ie, gear ratio of 53/12). Once the pedaling cadence is between 50 and 70 rpm, and when the rotation of the crank is smooth, the zero offset of the EP can be set. After this calibration procedure the validity of the zero offset can be controlled, because the PO indicated by the EP computer must be between 0 and 5 W when rotating the right crank by hand and between 5 and 15 W when rotating the left crank by hand (Ergomo, personal communication).

Statistical Analysis

PO, pedaling cadence, and cycling speed were stored every 1 second during the laboratory tests (every 1.26 seconds for PT) and every 5 seconds during the field tests. The PO_{EP}, PO_{SRM}, and PO_{PT} and the pedaling cadence of the submaximal incremental tests were averaged for 1 minute of each pedaling trial, during the whole duration of the submaximal constant-power test, and during the field-training session to obtain the mean PO and pedaling cadence for each power meter. Moreover, the PO data from the submaximal constant-power test were averaged every 5 minutes to analyze the PO drift.

Spearman's correlation coefficient (r) was used to determine the degree of association between the PO_{EP} and PO_{SRM} during the 8 submaximal incremental tests. The data from the submaximal incremental tests were checked for heteroscedasticity by calculating the heteroskedasticity correlation between the absolute differences between PO_{EP} and PO_{SRM} and the mean PO of 2 devices as described by Atkinson and Nevill.[12] This analysis showed that there was no heteroskedasticity of the data (Figure 2). Thus, the data were logarithmically transformed according the recommendations of Nevill.[13] The 95% levels of agreement of the PO differences between the EP and the SRM were defined using the method of Bland and Altman.[14] The PO differences were drawn in relation to the mean values, and 95% of the differences were expected to lie between the 2 limits of agreement, which were mean difference ± 2 SDs of the difference, expressed as bias ± random error according to Atkinson and Nevill.[12] The 95% confidence interval for the bias was also calculated.

The data from the indoor and outdoor tests were not normally distributed. Thus, the analysis of differences between the mean PO_{EP}, the mean PO_{SRM}, and the mean PO_{PT} of each step of the submaximal incremental test; the 30-minute

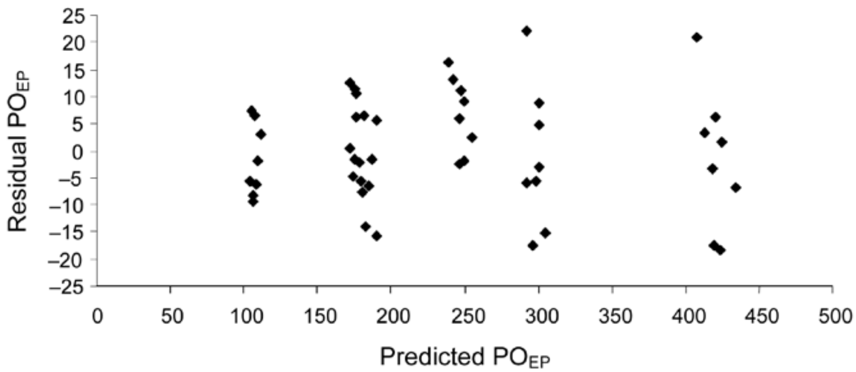

Figure 2 — Plot of values of predicted power output measured on the Ergomo®Pro power meter (PO_{EP}) against their residuals during the submaximal incremental test.

submaximal constant-power test; the sprint tests; and the field tests were assessed with a nonparametric Kruskal–Wallis test. Pedaling cadence on PO_{EP} during the submaximal incremental test and time effects on PO_{EP} during the submaximal constant-power test were evaluated with a nonparametric 1-way repeated-measures Friedman test. A pairwise multiple-comparison procedure using the Tukey test was conducted to determine the significant difference between the 3 power meters. The effect of change in cycling posture on PO_{EP} was analyzed with a nonparametric pairwise Wilcoxon test.

To assess the reproducibility of each power meter, the mean coefficient of variation (CV) of the submaximal incremental test was calculated according to the mean PO_{EP}, PO_{SRM}, and PO_{PT} determined from the 8 testing sessions performed in laboratory. The CV was calculated as the standard-deviation-to-mean ratio multiplied by 100. All significant differences were set at $P < .05$. Data are presented as mean ± SD.

Results

Validity

Submaximal Incremental Test. There was a strong correlation ($PO_{EP} = 1.0638 \times PO_{SRM}$, $r = .99$, $P < .001$) between PO_{EP} and PO_{SRM} measured during the submaximal incremental test (100 to 400 W). Figure 2 shows a plot of the predicted PO_{EP} against their residuals. The ratio limits of agreement of the PO differences between the EP and the SRM was 1.062 ×÷ 1.093 (95% confidence interval = 1.048 to 1.077). Figure 3 shows the Bland–Altman plot. The mean bias between PO_{EP} and PO_{SRM} was 14.5 ± 7.7 W, which represents a difference of 6.3% ± 2.5%.

Table 1 shows the mean PO obtained during each pedaling condition of the submaximal incremental test. Over all the pedaling conditions, EP overestimated the PO by 22.9 ± 8.0 W when compared with the PT, which represents a difference of 11.1% ± 2.1%. Kruskal–Wallis analysis showed that there is a significant

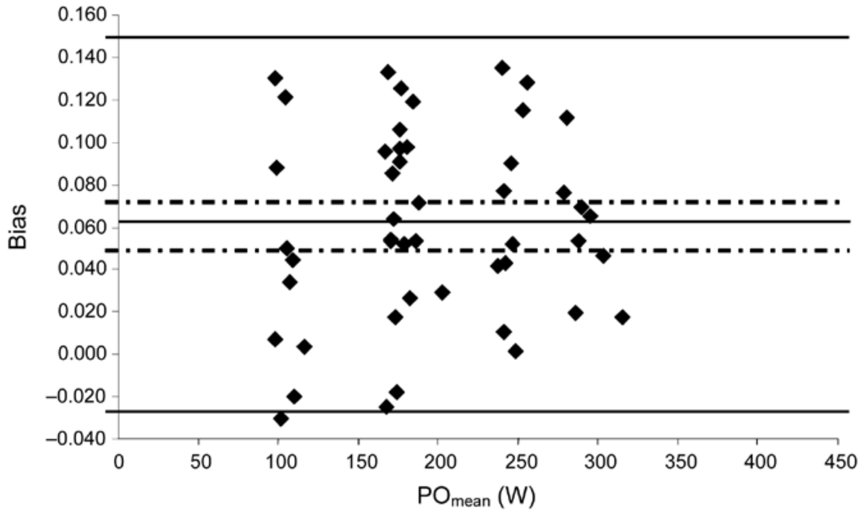

Figure 3 — Bias (center line), limits of agreement (continuous line), and 95% confidence interval (dashed line) obtained with Bland–Altman analysis for the comparison between the power outputs (PO) measured on the Ergomo®Pro (EP) and SRM power meters during the 8 submaximal incremental tests. $PO_{mean} = (PO_{EP} + PO_{SRM})/2$.

effect of the power-monitoring system on the PO for all steps of the submaximal incremental test ($P < .001$). A post hoc Tukey test revealed that the PO_{EP} was significantly greater than the PO_{PT} for all PO levels (100 to 400 W). The PO_{EP} was also higher than the PO_{SRM}, but the difference was only significant for high PO levels (200 to 400 W). In contrast, the PO_{SRM} was higher than the PO_{PT} when the PO was below 200 W.

Sprint Tests. There were no significant differences in PO_{max} between the 3 power meters for any of the gear ratios (Figure 4). The EP PO_{max} measured during the 3 sprints (53/15, 53/17, and 53/21 gear ratios) was on average 2.6% higher than the SRM PO_{max} (range: –2.3% to 5.4%) and 7.0% higher than the PT PO_{max} (range: 2.8% to 10.4%).

Submaximal Constant-Power Test. Kruskal–Wallis analysis showed a significant difference of mean PO between the 3 power meters during the submaximal constant-power test ($P < .001$). Post hoc analysis (Tukey test), however, revealed that only the difference between the EP and PT was significant (180 ± 10 vs 161 ± 7 W, respectively, $P < .05$). The mean PO_{SRM} during the submaximal constant-power test was 171 ± 4 W.

Field Test. The mean PO_{EP} (157 ± 12 W) overestimated the mean PO_{SRM} (140 ± 13 W) and the mean PO_{PT} (135 ± 8 W) by 12.0% ± 5.7% and 16.5% ± 5.9%, respectively. The post hoc analysis (Tukey test), however, revealed that only the difference between the EP and PT was significant ($P < .05$).

Table 1 Means (± SD) and Coefficients of Variation (CV) of PO_{EP}, PO_{SRM}, and PO_{PT} Obtained During the Cycling Conditions of the Submaximal Incremental Test Performed on a Motorized Treadmill*

	Grade (%)	Velocity (km/h)	Pedaling cadence (rpm)	Mean PO_{EP} (W)	Mean PO_{SRM} (W)	Mean PO_{PT} (W)	CV PO_{EP} (%)	CV PO_{SRM} (%)	CV PO_{PT} (%)
Seated	2	15	47 ± 1	106 ± 7‡	100 ± 2§	94 ± 4	6.3	1.9	2.5
			60 ± 2	105 ± 7‡	101 ± 2§	96 ± 1	6.2	2.3	1.3
			73 ± 1	105 ± 10‡	102 ± 3§	96 ± 2	9.3	2.8	1.9
	2	25	80 ± 1	178 ± 6‡	172 ± 4§	161 ± 4	3.6	2.0	2.4
			102 ± 2	183 ± 11‡	173 ± 5§	162 ± 6	6.1	2.7	3.4
			121 ± 4	178 ± 11‡	175 ± 4§	162 ± 5	6.2	2.5	3.0
	4	15	47 ± 1	181 ± 6‡	164 ± 2§	157 ± 5	3.4	1.1	3.0
			60 ± 1	179 ± 8‡	164 ± 2§	159 ± 4	4.2	1.4	2.7
			72 ± 1	177 ± 9‡	166 ± 3§	158 ± 5	5.2	1.6	3.4
	4	25	81 ± 1	293 ± 15†‡	278 ± 3	268 ± 6	5.0	1.2	2.1
			101 ± 2	295 ± 14†‡	280 ± 4	268 ± 9	4.7	1.3	3.2
			122 ± 1	302 ± 11†‡	282 ± 6	269 ± 11	3.7	2.0	3.9
	6	15	48 ± 1	257 ± 5†‡	231 ± 4	225 ± 3	1.8	1.8	1.5
			61 ± 1	254 ± 8†‡	232 ± 5	227 ± 3	3.2	2.1	1.1
			72 ± 1	250 ± 8†‡	233 ± 5	226 ± 4	3.1	2.3	1.8
	6	25	80 ± 1	419 ± 13†‡	393 ± 7	383 ± 9	3.1	1.7	2.2
			102 ± 2	418 ± 12†‡	396 ± 8	387 ± 6	2.8	2.0	1.5
			114 ± 4	418 ± 9†‡	397 ± 8	387 ± 10	2.2	1.9	2.5
Standing	6	15	48 ± 1	249 ± 6‖	232 ± 4	226 ± 5	2.5	1.9	2.2
			60 ± 2	246 ± 10‖	232 ± 4	225 ± 4	4.2	1.9	1.9
			72 ± 2	244 ± 7‖	233 ± 5	226 ± 6	2.8	2.0	2.6
Mean							4.1 ± 1.8	1.9 ± 0.4	2.1 ± 0.8
Confidence interval							1.7–6.5	1.4–2.4	1.0–3.2

*PO indicates power output; EP, Ergo®Pro; and PT, Powertap. All $P < .05$.

†Significant difference between EP and SRM. ‡Significant difference between EP and PT.

§Significant difference between SRM and PT.

‖Significant difference between standing and seated conditions.

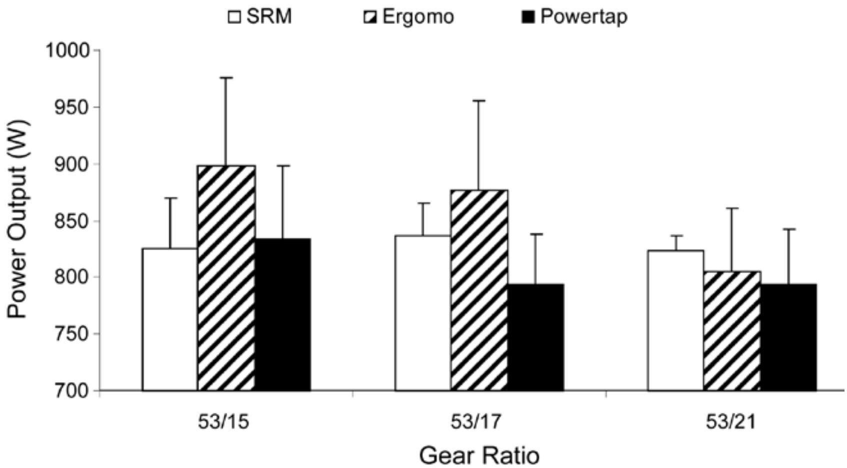

Figure 4 — Maximal power output obtained during the 8 sprint tests with the 3 power meters.

Effect of Change of Pedaling Cadence, Posture, and Time on PO_{EP}. The Friedman test showed that a change of pedaling cadence had no significant effect on PO_{EP}. The mean PO_{EP} measured at 15 km/h with a 6% slope was lower in the standing than in the seated position (246 ± 7 vs 254 ± 5 W, respectively, $P = .008$). There was no significant drift of PO_{EP} with time during the submaximal constant-power test.

Reproducibility

The mean CVs for the 8 submaximal incremental tests are shown in Table 1. For all 8 incremental tests, the mean CVs for all the cycling conditions (3 treadmill slopes, 2 velocities, and 2 pedaling postures) were 4.1% ± 1.8%, 1.9% ± 0.4%, and 2.1% ± 0.8% for PO_{EP}, PO_{SRM}, and PO_{PT}, respectively. For all 8 submaximal constant-power tests, the mean CVs were 5.4%, 2.4%, and 2.5% for PO_{EP}, $PO_{SRM,}$ and PO_{PT}, respectively.

Discussion

The most important finding of this study is that the EP registers a significantly greater PO at submaximal intensities than the SRM (for 200 to 400 W) and PT (for 100 to 400 W). Moreover, the CV of the PO_{EP} was nearly 2 times higher than those of the PO_{SRM} and the $PO_{PT.}$ Thus, the EP appears to have low validity when compared with the SRM and PT power meters and seems less reliable than the SRM or PT.

Our results indicate that the EP reads, in general, a higher PO than the SRM and PT during submaximal exercise in the laboratory and in the field. This PO difference is greater than the manufacturer's claimed accuracy (±1%). During the field-training sessions the PO differences with SRM and PT were higher than the

PO differences obtained in the laboratory test sessions. This could be explained by the fact that the field-training sessions included all the different experimental laboratory conditions (different PO levels and pedaling cadence, seated and standing position, acceleration and deceleration).

Four hypotheses could explain the difference between PO_{EP} and PO_{SRM} and PO_{PT}. First, the algorithm that is used by the EP to calculate the PO might cause the PO overestimations. The time integration of data might be lower for EP than for SRM and PT and thus result in higher PO values. Second, a slight error in the measurement of φ (ie, the phase difference between the 2 optoelectronic sensors, which is proportional to the force applied to the left pedal) can lead to a high error in PO because φ is multiplied by a k-factor to obtain a PO value. The k-factor is proper to each EP axis (for the EP studied, $k = 194$). The minimal φ-value that can be detected by the EP sensors is 0.0025° and is equivalent to a 2.5-N force applied to the left pedal (Ergomo, personal communication). Third, the EP sensors measure only the PO developed by the left lower limb because of the measuring method of the 2 sensors. In fact, the right sensor located in the right side of the bottom bracket is taking account for the reference. The PO that is measured by the 2 sensors is multiplied by 2, and this calculated PO value is stored and displayed by the EP computer. Thus it might be possible that, compared with the SRM or PT, a higher PO could be obtained with the EP if the cyclist has an asymmetrical pedaling technique (ie, the left crank torque is higher than the right crank torque). By using the "torque analysis" option of the SRM, we observed during previous studies, in some cyclists, significant crank-torque differences between the left and right legs (unpublished observation). This means that, at least for some cyclists with these left–right torque differences, the PO_{EP} could be doubtful. This third hypothesis, however, could probably not have influenced our study results, because before this study we analyzed our subject's pedaling technique with the torque-analysis option of the SRM, and we did not observe a crank-torque difference between his 2 lower limbs (unpublished observation). Fourth, the difference between PO_{PT} and PO_{EP} seems to be greater than the difference between PO_{SRM} and PO_{EP}. This larger difference could be a result of the torque-measurement location. The PT measures torque at the hub, and the EP measures it at the bottom axis. Torque in the hub could be less than torque in the axis because of transmission losses in the chain-and-sprocket drive mechanism. This could lead to approximately 2% lower PO values for the PT. It is not clear, however, whether the PT tries to account for transmission losses and attempts to reflect power produced at the bottom bracket or whether the displayed power is the actual power produced at the rear hub.[3] The PO_{PT} underestimation in comparison with the SRM can be explained by mechanical loss in the chain-and-sprocket drive transmission. The PO_{EP} overestimation (compared with the SRM) cannot be explained by the same fact, however, because the EP measures the PO at the same part of the bicycle as the SRM does (bottom bracket vs crank set).

It is interesting to note that the bias between the EP and the SRM or PT can be decreased by changing the value of the k-factor, because this variable is directly proportional to the PO_{EP}. For example, during 5 road-cycling sessions the difference between the EP and the SRM was substantially lower (bias ~5%) after changing the k-factor from 194 to 181 (unpublished observation). Nevertheless, the reproducibility of the PO_{EP} remains unaffected by a new k-value.

The cause of the effect of cycling posture (standing vs seated) on PO_{EP} is unclear. One hypothesis is that cyclists lean alternately on the left and right sides of their bicycle when they are in standing posture during climbing. It is known that these lateral sways affect the biomechanics of pedaling.[15,16] The orientation of the force applied on the pedal is not only perpendicular to the surface riding but also inclined. It is possible that EP cannot take this change into account. The φ-phase difference between the 2 optoelectronic sensors can only be proportional to a 2-dimensional force applied to the pedal and not to a 3-dimensional force. This could explain why the PO_{EP} is lower in standing than in seated posture. As in the study of Bertucci et al,[6] PO_{SRM} and PO_{PT} were not influenced by cycling posture. This could confirm that the effect of cycling posture is related to the PO-measuring method of the EP.

The reproducibility of EP is substantially lower than those of the SRM and PT: The mean CVs of PO ranging from 100 to 400 W were 4.1%, 1.9%, and 2.1% for the EP, SRM, and PT power meters, respectively. The CV of a power meter's PO is influenced by the power-meter error and the biological variation of the subject. Recently, Paton and Hopkins[17] reported that the CV of PO was 1.5% for the PT and 1.6% for the SRM. The proportions of these CVs that were purely a result of power-meter error were about 0.9% for the PT and 1.1% for the SRM. This means that biological variation of the subject accounted for 0.6% and 0.5% for the PT and the SRM, respectively. Paton and Hopkins[17] recommended the use of ergometers that reduce PO variation in order to be able to detect small changes (<2%) in an athlete's performance caused by training or ergogenic aids. Therefore it seems that, unlike the SRM and PT, the EP cannot be used to detect small performance improvements because of its low reproducibility of PO measurement.

Conclusion

Our study shows that, when it is compared with the SRM and PT power meters, the EP appears less valid and reliable. Future studies should evaluate the validity and reproducibility of the EP by comparing it with a dynamic calibration rig in order to confirm our findings.

Acknowledgments

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