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A single field test evaluation for the assessment of the Record Power Profile in elite cyclists

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Abstract: The validity of a single field test to produce a Record Power Profile (RPP) has not been investigated thoroughly in comparison with a RPP obtained during a full cycling season. We hypothesized that the values obtained from a single field test would match closely the values obtained during the season to define a RPP, and that cyclists would reach the highest power outputs (PO) during training sessions rather than in competition. The PO of eight male elite cyclists (maximal aerobic power 6.8±0.4 W/kg) was recorded during 12 months. They completed a Peak Power Profile test (PPP) during the competitive season including all-out efforts of 5 s, 12 s, and 30 s followed by 5 and 20 min. They were required to self-select their itinerary, pace, warm-up strategy and recovery efforts. An overall significant positive correlation was found between maximal power outputs obtained during the successive durations during the PPP and i) during training sessions (R^2= 0.97) and ii) in competition (R^2= 0.91). Conversely, peak PO during the PPP were higher than in competition only for short efforts (≤ 30 s). Training sessions represented the most common situation to achieve a record PO (55%) followed by the PPP (27.5%). From a more general perspective, reaching ones peak PO over successive durations during one single field session is very demanding, so that it can be speculated that longer performance bouts may be altered. Practically, the 20 min peak power output may ideally be obtained from a field test on a separate day. This study reports the interest for a cyclist to perform a PPP to establish a RPP that would closely match potential values obtained during training (shorter efforts) or competition (longer efforts).

Keywords: Cycling, Performance, Training, Competition

1. Introduction

Nowadays, power meters can be considered as fundamental and powerful tools providing instant valuable information about the amount of mechanical power (or power output) production (Vogt et al., 2006; Weber et al., 2005). The immediate display of the (instant or averaged) power output reflects the effort of the cyclist at any moment (Grappe et al., 2012; Menaspà & Abbiss, 2017), and subsequently allows to determine training (and racing) load precisely, and use the monitoring of the power to elaborate adequate training contents (Atkinson et al., 2007; Capostagno et al., 2016; Sanders et al., 2018). The precise calibration of power meters is however paramount in order to ensure reliable data readings for testing and training purposes (Maier et al., 2014). Differences between power meters have hence already been reported, showing that trueness may vary considerably between different power meter brands, even with devices coming from the same manufacturer (Maier et al., 2017).

Beyond considerations on accuracy and precision, using a power meter on a daily basis to record efforts over different durations allows to define power output as a valid physiological proxy of cycling performance (Pinot & Grappe, 2015). With the analysis of the maximal power output that can be produced over a defined period of time, a Power Profile (PP) can be defined as the hyperbolic relationship between maximal PO sustained as a function of the effort duration (Allen & Coggan, 2010; Hill, 1993). The PP may indeed reflect the successive interplay of anaerobic (alactic and further glycolytic) and aerobic power production at different effort intensities (Billat, 2012). By using maximal cycling power output sustained over different durations, Pinot & Grappe (2011) defined the Record Power Profile (RPP). The RPP considers the maximal power outputs recorded along the season during training and competition. Recording different values for several effort durations (1s-4h) in different settings then allows to establish a RPP representing "a real signature" of the absolute or relative physical capacity in cyclists (Pinot & Grappe, 2015). Overall, the definition of a RPP enables coaches and scientists to evaluate and monitor performance to design adequate training plans accordingly (Pinot & Grappe, 2011). Currently, a valid RPP may only be obtained by collecting sufficient power output data over several months (or at least several specific training sessions) in order to draw the most accurate power to time hyperbolic curve (Grappe et al., 2012). For instance, a few proposals were made with laboratory tests to determine sustained power for successive durations (Allen & Coggan, 2010; Quod et al., 2010; Gonzalez-Tablas et al., 2016) with a recent study additionally supporting the usefulness of field data in evaluating maximal work capacity for different durations in professional cyclists (Leo et al., 2021). However, to the best of our knowledge, there is no recent study reporting if a single field test in elite cyclists is sufficient to define a valid RPP.

The aim of this study was to test the validity of a single field test consisting of successive bouts of maximal efforts lasting between 5 and 1200 s to establish a valid power profile in elite cyclists. We hypothesized that a specific field test with successive efforts of different durations in one single training session allows to reach sufficiently high values to obtain a reliable PP, and that the latter PP would match closely the power output values of the RPP calculated from power outputs obtained during an entire competitive season.

2. Materials and Methods

Subjects

For the purpose of the study, eight male elite cyclists (Age 23.8 ± 4 y, 66.6 ±5.8 kg, maximal aerobic power 6.8±0.4 $W \cdot kg^{-1}$) competing at an international level (UCI Elite International license) in track cycling, mountain-bike and road cycling were recruited. This study was conducted with the data collected in a study monitoring their training and hematological variables over 12 months (Astolfi et al., 2021) so that all subjects provided an informed written consent for the use of their data. The study was approved by the regional research ethics committee (CER-VD, Lausanne, Switzerland, #2018-01019) and conducted in respect of the Declaration of Helsinki. Maximal aerobic power (MAP) values were estimated as the best record PO of 5 minutes from the season extracted from the RPP (Pinot & Grappe, 2014) of each cyclist before performing the PPP-test . Six cyclists were members of a 1st category elite-U23 road cycling team with an extended international calendar, competitions at an international level and boasting multiple successes during World Cups, World/European track Championships and Olympic Games with the Swiss national team. The others (n=2) were mountain bikers competing at an international level and riding for the Swiss national team at multiple occasion.

Data collection

Each subject trained and competed on his own road bike equipped with a power meter (SRM, Schoberer Rad Messtechnik, Jülich, Germany) recording power output data at 1Hz cycle computer with a cycle computer. Subjects were instructed to calibrate their SRM system, through the "zero offset" before every training session. Moreover, each SRM power meter was also statically calibrated (Wooles et al., 2005) before the start of each test session according to the instructions of the manufacturer.

All data from training and competition were transferred and stored in an online cycling monitoring platform (Training Peaks, Peaksware, CO, USA). Single data files were visually inspected and screened for potential outliers (mostly due to GPS signal errors influencing speed recording or because of drift in signals in extreme conditions (e.g., snow, heavy rain or big temperature changes during the rides). A dedicated open-source software (GoldenCheetah, v.3.5, retrieved from www.goldencheetah.org) was used to exclude outliers wrongly affecting power profile calculation (e.g. average power outputs above 2000 W). The visual inspection of each training file also allowed to categorize the cycling session as training or competition data in addition to the PPP test itself.

Field Peak Power Profile (PPP) test

Participants rode their own road bike to perform a single PPP field test. The PPP test was designed to include 5 successive bouts of respectively 5, 15, 30, 300 and 1200 s to define a hyperbolic profile of the maximal power sustained over the latter durations. Effort durations were selected considering the performance determinants in cycling disciplines to reflect the different energetic metabolism pathways (from rather anaerobic alactic sprints to longer aerobic intervals) and cover a wide span of duration where energetic pathways are generally mixed. Cyclists were not instructed about how to manage the efforts and recoveries of the PPP test. Their accumulated experience and the similitude between the PPP test protocol and a specific training session with successive all-out bouts allows them to pace their efforts adequately so that we did not expect any learning effect for this particular test. It is however unknown if the repetition of the PPP test would yield altered power outputs and this could be investigated separately. Participants were first requested to perform a warm-up lasting between 10-15 min at a self-selected pace based on their own perceived exertion with power output readings available before the first 5-s all-out effort. The self-selected pace was proposed to better mimic the individual warm-up strategies these elite cyclists are used to in their usual training. After active recovery phases, they performed successively 15 s all-out, 30 s all-out, and finally 5 and 20 min targeting the highest average power over the latter duration. Duration and intensity during the warm-up and recovery phases were self-selected to allow the cyclist to select the best terrain for safety and maximal performance (e.g., with an optimal slope), while recoveries were requested to last at least 5 min after the first two intervals, 10 min after the third and 20 after the fourth effort (See Table 2 for respective duration observed). With regards to the elite level of these cyclists, these durations were deemed sufficient to yield valid power output during the consecutive efforts, also allowing the PPP test to be ecological in its practical applicability and duration. Subjects were recommended to perform the PPP test on a sunny day, in windless conditions and at an adequate temperature on quiet uphill roads. Considering differences in their individual race calendar, all PPP tests were realized within one month but however conducted for all cyclists 14 days before the start of their competition period. The average power output for each effort was recorded except for the 15 s sprint were only the best 12 s power output was recorded (the first two seconds of acceleration and the last one, were not accounted for in the calculation). Road grade percentage, duration and intensities during warm-up and recovery phases were extracted and recorded as well.

Statistical analyses

Data were reported as mean ± standard deviations (SD). Normality of the distributions was tested with the D'Agostino & Pearson test and an additional visual inspection of residual plots allowed excluding any obvious deviations from homoscedasticity or normality. Differences between performance outcomes in the three different conditions (Competition, Training, PPP-test) were assessed using a one-way general linear model repeated-measures ANOVA with all pairwise comparison (Holm-Sidak method). Pearson's correlation coefficients were calculated to assess the relationship between PPP test values with competition and training PO. Bland Altman plots were used to assess the agreement between conditions. The null hypothesis was rejected for $P<0.05$ (two-tailed). All statistical calculations were made using a dedicated XLSTAT data analysis (XLSTAT, 2017 Paris, France) add-on for the Excel software (Microsoft, Richmond, USA) and Bland Altman plots were done with a dedicated software (Prism, Version 9.2, Graphpad, La Jolla, California, USA).

3. Results

In total, 2500 files/sessions were analysed for the training and competition period between November 1st and October 30th on the consecutive year. In that period, the subjects covered an average total distance of 16021±4575 km over 211536±81289 m of elevation in 611±115 hours of cycling. The cyclists covered an average of 6580±2102 km over 54±15 days of competition.

Independently of the situation (training, competition or specific PPP test), cyclists reached a maximal power output of 1221±147 W over 5 s, 1087±107 W over 12 s, 869 ±123 W over 30 s, 457 ± 28 W over 5 min, and 373 ± 23 W over 20 min efforts. The relative power over 5 min of 6.8 ±04 W·kg^{-1}.

Over 5 s, PO was higher during training (1221 ± 147 W) than competition (1102±189, F=1.81, P=0.007) and the PPP-test (1163 ± 159, F=0.59, P=0.09). The latter was also higher than competition (F=0.40, P=0.16). Same situation over 12 s, where PO was higher during training (1087 ± 107 W) than in competition (955 ± 14 W, F= 4.29, P=0.008) and the PPP-test (1065 ± 16 W, F=0.18, P= 0.46). The latter was again higher than competition (F=2.02, P=0.04). Over 30 s, PO was higher during the PPP-test (869 ± 123 W) than training (857 ± 119 W, F= 0.03, P=0.63) and competition (756 ± 13 W, F= 2.68, P= 0.02). Over 5 min, PO was also higher during training (457 ± 28 W) than competition (433 ± 30 W, F=2.68, P= 0.03) and the PPP-test (439 ± 2 W, F=1.91, P=0.03). The latter was higher than competition (F= 0.19, P=0.54). Finally, over 20 min, PO was again higher during training (373 ± 23 W) than competition (360 ± 12 W, F=2.15, P=0.08) and the PPP-test (359 ± 2 W, F=1.51, P=0.02). On that range of effort, the values of competition were higher than the PPP-test (F=0.006, P= 0.88)

When comparing PO reached during the different conditions, values were in average 3.2±6.2% lower during the PPP test when compared to training and 5.5 ± 9.6% higher when compared to competitions.

Individual variations between conditions for all subjects are illustrated in Table 2.

When all durations were pooled, there was a significant correlation ($p<0.05$, $R^2=0.97$) between the PPP-test and the training PO illustrated in Figure 1.

Similarly, a significant correlation ($p<0.05$, $R^2=0.92$) was found between the PPP-test and the competition PO illustrated in Figure 2.

There was no significant difference between subjects for the duration and intensity of the recovery phases, nor for the self-selected slope of the road on which the PPP test efforts where performed (Table 3).

Table 1. Multiple comparisons table (Tuckey HSD) between the PPP test, training and competition results. * p< 0.05 for the absolute differences (in Watts) with PPP-test

Effort	Method i	Method ii	Mean Difference (i-ii) (Absolute W)	Standard Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
5sec	PPP-test	Training	-58	51.4	0.09	-171	49
		Competition	61	67.1	0.16	-102	182
12sec	PPP-test	Training	-22	42.8	0.46	-139	68
		Competition	110*	51	0.04	-93	218
30sec	PPP-test	Training	12	41.4	0.63	-66	104
		Competition	113*	45.9	0.02	-68	221
5min	PPP-test	Training	-18*	8.9	0.03	-42	6
		Competition	6	10.6	0.54	-30	44
20min	PPP-test	Training	-14*	6.9	0.02	-34	4
		Competition	-1	4.4	0.88	-15	25

Table 2. Individual differences (in %) for the absolute Power output (PO) reached during the specific peak power profile (PPP) test compared to the training and competition conditions. Values with grey background illustrate higher power outputs during the PPP-test.

	Effort	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8
PPP-test vs. Training	5s	-2.6	0.1	5.9	-17.1	-2.9	-7.6	-16.3	-3.7
	12s	4.4	-2.9	0.7	-9.4	-5.1	-2.3	-18.1	6.1
	30s	4.7	-0.2	-8.3	3.1	7.3	-2.4	-7.7	12.5
	5min	2.1	-7.4	-2.6	-11.5	0.2	-2.7	-5.8	-4.7
	20min	1.7	-7.2	-1.5	-11.4	-4.9	0.0	-2.9	-6.3
PPP-test vs. Competition	5s	1.72	7.97	10.86	6.64	22.43	4.59	-17.18	1.63
	12s	14.16	14.08	18.60	4.69	18.37	4.92	-18.42	18.00
	30s	24.02	25.53	14.78	-5.09	22.51	12.18	-10.59	17.61
	5min	4.88	5.16	11.96	-5.37	3.16	1.68	-7.61	-3.95
	20min	-2.56	2.49	8.33	-3.51	-3.36	2.06	-4.96	-1.92

Table 3. Duration and intensity of the warm-up and recovery phases during the PPP test with self-selected slope for the successive efforts. PO, power output; MPO, maximal power output

Efforts	% Road gradient	Duration (s) between efforts	PO during recovery (W)	Relative PO during recovery (% of 5 min MPO)
Warm-up	-	1648±470	201±19	44 ± 8
5 s	1.2±1.7	363±82	186±32	48 ± 14
12 s	1.0±0.8	470±81	190±45	52 ± 20
30 s	2.7±0.9	872±101	156±36	42 ± 16
5 min	7.5±0.6	1464±217	160±49	46 ±21
20 min	6.6±1.7	-	-	

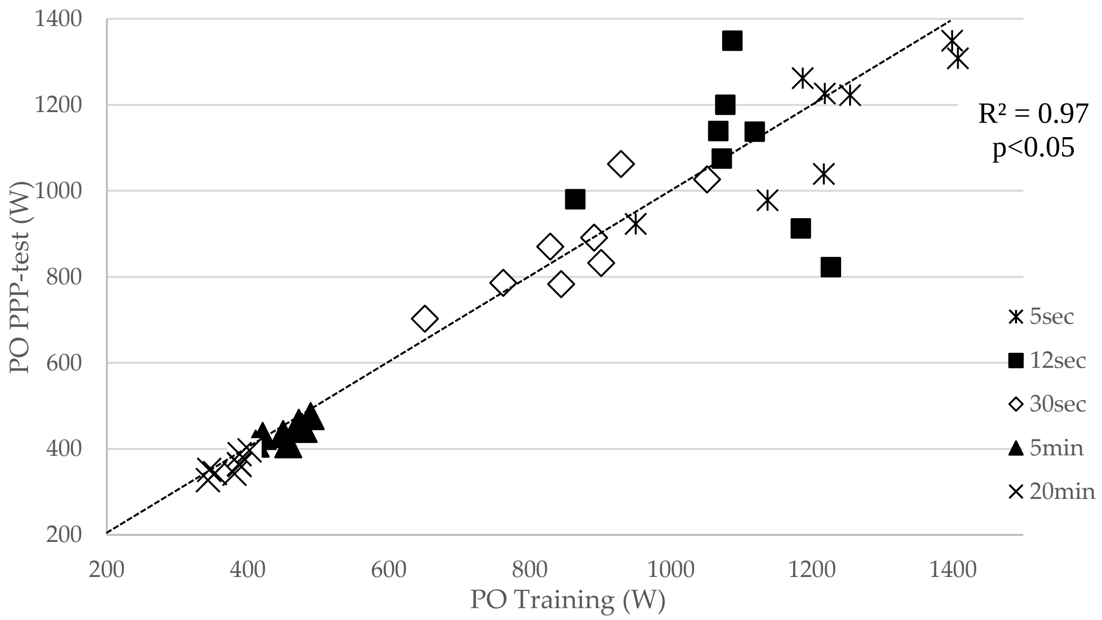

Figure 1. Correlation between the maximal power output (PO) reached during the Peak Power Profile (PPP) test and during training sessions

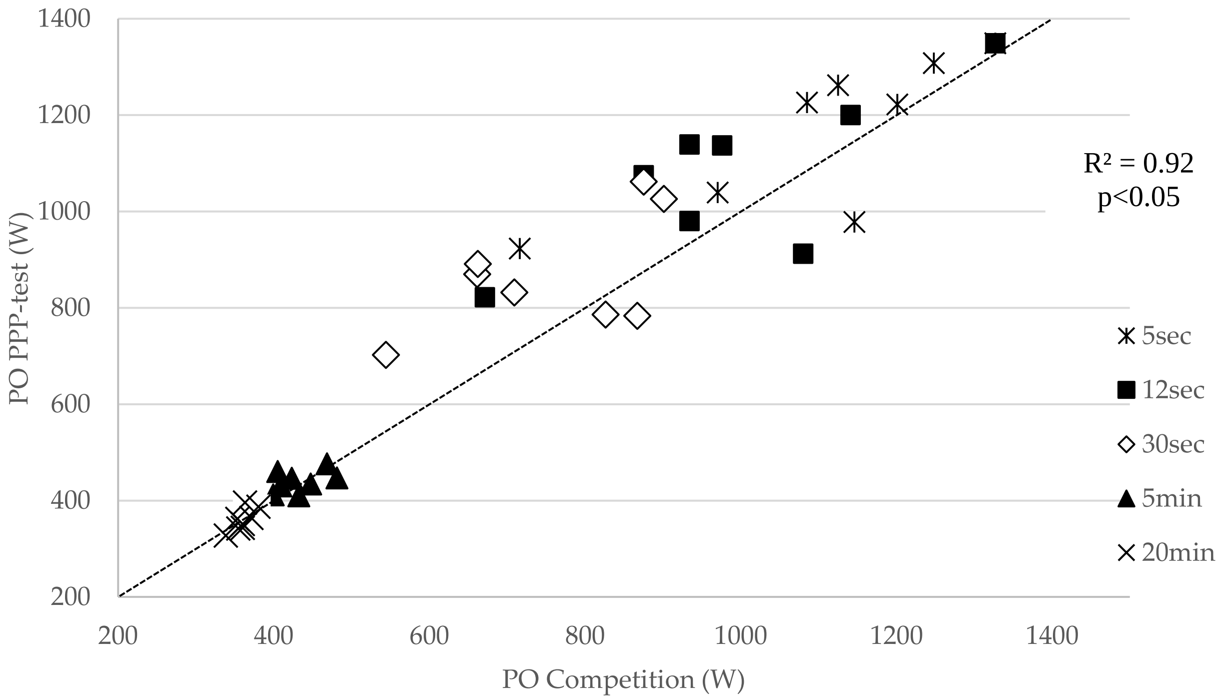

Figure 2 Correlation between the maximal power output (PO) reached during the Peak Power Profile (PPP) test and during competitions

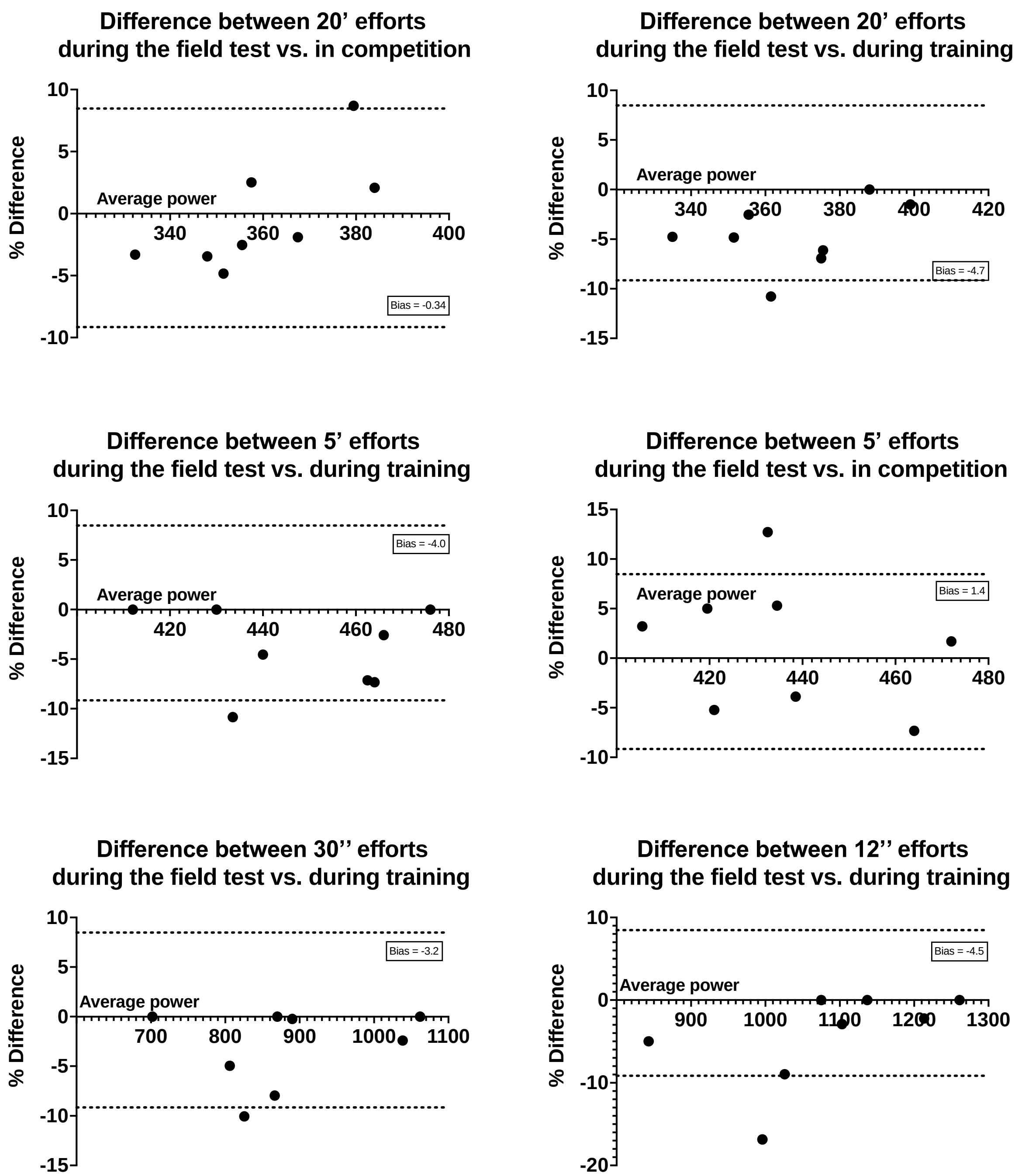

Figure 3 Bland–Altman plots with the comparison between the power recordings obtained during the field test vs. during training or in competition, respectively. The difference in % are represented as function of the average power recorded with the 95% limits of agreement (dotted lines), computed as the mean difference (bias) plus or minus 1.96 times its SD.

4. Discussion

The main finding of this study is that a single field test evaluation yields sufficiently high-power outputs to allow a valid peak power profile to be established. Power outputs obtained during the field PPP test were highly associated with data recorded during training and competition conditions.

Whereas, a single test was previously proposed to determine a preliminary record power profile (RPP) (Deutsch et al., 2011, Grappe et al., 2012), our study is the first to our knowledge to evaluate the validity of such a test in comparison to both training and competition data. Interestingly, as opposed to the previous proposals, the cyclists in our study were requested to perform successive maximal bouts but with self-selected duration and intensity for the recovery phases to allow for the best possible adaptation to the available terrain for the field test. This approach may complement single laboratory tests defining for example critical power 23/02/2022 08:17:00 or functional threshold power (Borszcz et al., 2018). Obviously, power outputs determined in different conditions may not be used interchangeably even when showing high statistical correlations (Karsten et al., 2021). A field test is hence a very ecological alternative and presents the advantage of providing rapidly to the athlete with the power output he is able to produce over several durations in very ecological conditions and with the power meter he is used to.

The correlation between values from the PPP-test and competition PO (Figure 2) are in accordance with previously published results with a laboratory test where training data was however not considered (Quod et al. 2010). From our results, training sessions represented the most frequent situation to reach a peak power output whereas there was no difference in the latter values when compared to the PPP test for duration < 5 min.

The advantage of the proposed PPP-test lies in the ability for the cyclist to perform it in optimal conditions with self-selected slope and recovery phases to provide the best terrain for each successive effort. This is however only valid in elite athletes with sufficient experience to adopt adequate recovery phases and select optimal terrain (Nimmerichter et al., 2010) while less trained cyclists may require longer recovery phases to avoid compromising subsequent power output readings after intense intervals (Karsten et al., 2017). Performing a 20 min maximal effort at the end of the PPP test may however alter the previous 5 min effort with an intuitive pacing of that effort for the cyclists (de Koning et al., 1999; Hettinga et al., 2006). This is reflected by the 4% lower PO for the maximal 5 min effort during the PPP test compared to training. While two subjects reached their best5-min PO during the PPP test, it may be recommended to perform the 20 min effort in a single bout on a separate day to maximize the result. There was however only 3% (14 W) difference between the best PO during training and the PPP-test indicating that the PPP-test may reflect the potential of the cyclist for that duration in competition where accumulated (central and peripheral) fatigue may influence the ability to maximally perform (de Koning et al., 1999; Hettinga et al., 2006). The latter may however not preclude using the maximal 5 min PO as a proxy of maximal aerobic power to define the related adequate training intensities (Pinot & Grappe, 2014) bearing in mind that the actual maximal 5 min power might be slightly higher in a highly competitive condition.

Further, when comparing training with PO reached during competitions, for 12 and 30 s efforts, our results are in accordance with Pinot & Grappe (2011) where record lower PO obtained during competition than in training. It was suggested that such short efforts were maximally produced in the final part of the race with residual fatigue affecting the maximal PO. Other variables such as the bike position (standing or seated) and the peloton's position (front position or drafting) can influence the aerodynamic drag area, and subsequently the power required for a given speed (Martin et al., 2007). For peak powers reached in a laboratory conditions, reduced lateral oscillations on a laboratory ergometer (Quod et al. 2010) and the associated reduction of the ability to apply a perpendicular force to the pedals whilst accelerating (Bertucci et al., 2005) were proposed for altered values in a single test setup.

Besides, PO during competition was either lower or similar than during training sessions and the PPP-test (Table 2), confirming that the highest PO developed by cyclists during a race is not necessarily the maximum they can reach (Pinot & Grappe, 2011) However, in contrast to the latter study, outlining a majority of the record POs during races, only 17,5% of the record POs were reached during competitions vs. 55% during training. Our results do indeed also contrast with recent findings of higher power profiles recorded during racing than training in professional U23 athletes (Leo et al., 2020) . While cyclists in our study performed at an elite level, their role as teammates riding for a leader or sprinter fighting for the win may have had an impact on their aptitude to maximally perform thus reflecting poorly their real potential in competition (Menaspà et al., 2015). Nevertheless, maximally sustained PO over different effort times is influenced by several heterogeneous competition factors such as team tactics, type of terrain and environmental conditions. The latter highlights the need for a field test to allow for ecological situation allowing the cyclists to maximally perform in a safe environment as proposed in our study. This was indeed recently confirmed in a study with professional U23 cyclists supporting the use of field data to evaluate their maximal performance over several durations as a proxy of their overall work capacity (Leo et al., 2021). Performing a test in stable conditions but outdoors may be considered as an important argument to help increase the motivation (Zeidenitz et al., 2007) and to possibly obtain better results than in a laboratory setup (Slapsinskaite et al., 2016). Moreover, a current trend to use different sports social network, in order to share and compare results on specific uphill segments with others cyclists may positively impact the potential of a field test with a competitive aspect (Shei, 2018) not present in a laboratory where only physiological variables (e.g., aerobic power or lactate) can be reported.

The main interest in performing a PPP-test is to establish the potential of a rider at a given time point and provide useful information on progress or validity of training content (Faria et al., 2005; Hawley & Stepto, 2001; Rønnestad et al., 2017). While discrepancies may exist between the peak power reached during specific training sessions or in competition, there is certainly a great interest to use repeatedly a field PPP-test to evaluate training progress by scheduling the test at an adequate moment in a tight training schedule independently of the availability of a laboratory and its scientific personnel.

We also need to acknowledge the small sample size for our study while we were able to recruit highly trained elite riders thus allowing us to provide a useful insight of the potential of a single field test evaluation for rider with a very high ability level. Further, we designed the testing protocols with freely self-selected warm-up and recovery bouts. While most cyclists included sufficiently long recoveries at adequate intensities, some riders may expect a higher level of guidance (e.g. "perform a 15 min recovery phase at 200 W") to feel more confident in their successive efforts.

5. Practical Applications

This study outlines the validity of a single field evaluation including successive maximal efforts of 5 s, 12 s, 30 s, 5 min, and 20 min to establish a record power profile in elite cyclists. The statistical association between maximal power output obtained during the field test and during training or competitions make the PPP-test a reliable tool for cyclists and trainers to define training regimens and target power zones. This study was conducted with road, track and mountain bike cyclists, and it may represent a limitation in the interpretation of our results since athletes may require different metabolic profiles in their respective disciplines. With the evidence of very specific demands in certain discipline, there is however a common basis with a high volume of road cycling training and all cases competitions with efforts lasting more than the longest (20 min) interval investigated in our study. An expert trainer or physiologist may hence definitely decide to define a field test with the longest effort lasting 10 min for athletes competing in shorter events (e.g., cyclocross or track omnium).

The freely self-selected warm-up and recovery bouts did not differ between subjects. However, a further study may investigate if a standardized protocol (e.g., imposed recovery times and road gradients) and ideally in cyclists at various performance levels would allow for a better interpretation of individually defined record power profiles. The latter illustrates that a field test allowing to cope with the terrain to maximally perform does not necessarily alter the test results and may even allow to increase motivation. where the subjects have to complete a warm-up and a series of high efforts with recovery phases.

Repeating a field PPP-test throughout the season may hence definitely help elite cyclists and trainers, to objectively assess if improvements occur with racing and training. However, the underpinning strong focus needed to reach ones peak power output over successive durations during one single test may induce some fatigue altering performance for a final effort lasting 20 min. Depending on the situation (e.g., prior fatigue or upcoming performance goals), it may be recommended to either perform the 5 and/or 20 min effort in a separate specific training session not to compromise an optimal recovery. In addition, performing another performance test (e.g., critical power test) may represent a better surrogate for specific physiological benchmarking and complement adequately any field test. Finally, the comparable 20-min PO during long efforts between the field test and in competition underlines the potential of the PPP-test to predict sustainable power in competition when fatigue is accumulated. Further research could evaluate if a similar PPP-test protocol with short and long efforts ≤10 min may allow to better predict the success potential of highly-trained cyclists.

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7. Conflict of Interest

The authors have no conflict of interest to disclose.

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