Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

OPEN ACCESS

A single-case study

A new approach to biomechanical analysis in cycling to introduce science to future data acquisition

Felix Imbery[1], Ulrich Schoberer[2], Peter Leo[2]

[1] University of Applies Sciences Aachen, Austria
2 University Innsbruck, Department Sport Science, Innsbruck, Austria

* Correspondence: (FI) felix.imbery@srm.de.

Received: 06 September 2021; Accepted: 8 October 2021; Published: 30 November 2021

Keywords: Cycling, Cycling analysis, Powermeter, Cycling

1. Introduction

With the invention of power measurement systems for cyclists by SRM, founded by Ulrich Schoberer in 1986, the training of riders and their equipment has been put to another level. Over time, more and more parameters for the assessment of physiological processes and biomechanical analysis have been established1), 2), 3). Biomechanical factors play a more important role in defining new indicators to search for the smallest detail and advantage4), 5), 6). The aim of this single case study is to show the improved power measurement and significant research benefit that will come up in the future using a new development of SRM. It will be demonstrated by evaluating a ride on an SRM Indoortrainer with an oval and round chainring and two rides of different training targets. The amount of the highly resolved recorded data has improved with the new SRM Powermeter what may also lead to many exciting discussions and approaches to introduce or rethink parameters.

2. Materials and Methods

The 22-year-old, 1.87 m tall and 72.1 kg male participant in the present study has years of experience in competitive cycling and triathlon. Using a prototype of the new SRM invention this research is designed as a single case study. Shown will be a ride on an SRM Indoortrainer with oval and round 56 teeth chainrings to proof the improved power calculation. For that, the rider executed a one-hour ride divided into two 30-minute parts at 250 ± 4 W and 73.5 ± 1 rpm cadence, changing between the round and oval chainring every five minutes. The difference between the 30-minute parts was the recording of the data using the IMU mode, where 200 Hz angular velocity and torque are recorded, and the rotation-based mode, where the average torque and angular velocity are used to determine the power after one complete crank revolution. In order to neglect the acceleration of the flywheel mass the last four the last four minutes of each interval were recorded. To get further usable data for this work the participant had to execute two outdoor bike rides on a BMC Teammachine SLR01. These two rides had a total length of

84.86 ± 0.82 minutes. One ride was completed as continuous riding at 218 W and an average cadence of 84 rpm. In the second ride the participant completed five six-minute intervals at 369 ± 2.59 W with a cadence of 89.07 ± 0.93 rpm and 3 minutes rest at 227 ± 6.9 W and a ten-minute effort of 322 W and 89 rpm with eight minutes rest at 203 W to the last six-minute effort. For the intervals the rider was supposed to find a flat road with as little turns as possible in order to keep a constant power output. Second by second power output and cadence have been displayed on a Powercontrol 8 from SRM to execute the given tasks. The power output has been measured by an SRM Spiderpowermeter prototype. Additionally, torque and angular velocity have been measured and recorded with associated angle every five milliseconds and have been stored in a mass storage device. SRM internal beta software was used to decode the recorded data into graphs and export them to Excel spreadsheets for further statistical analysis. With exporting the files to Excel to get the recorded data as well as the calculated respective current power, called "On Time Power" shown as their values, there have been several statistical analysis methods used to analyse the rides. For every file the mean, median and standard deviation have been calculated for every parameter. Because of the higher power, the intervals were looked at in more detail and highlighted in the analysis using the same statistical analysis methods.

3. Results

The most important finding of this paper is the more accurate power measurement as well as amount of collected datapoints. Collected datapoints being 1,010,479 for each timestamp, torque, angular velocity and angle in the interval method and 1,029,519 for the continuous method.

Table 1

(a)

No	Chain ring	Power /W	Cadence /rpm	Kin Energy Flywheel /J
1	Round	249	75	2024
2	Oval	247	75	2024
3	Round	251	74	1971
4	Oval	250	73	1918
5	Round	243	73	1918
6	Oval	243	72	1866

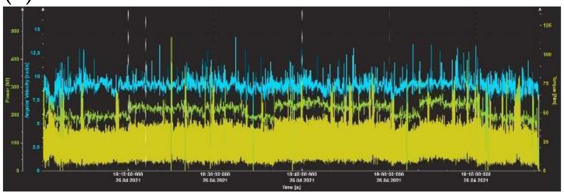
(b)

No	Chain ring	Power /W	Cadence /rpm	Kin Energy Flywheel /J
1	Round	246	72	1866
2	Oval	248	71	1814
3	Round	250	74	1971
4	Oval	259	74	1971
5	Round	250	74	1971
6	Oval	260	74	1971

Table 1 shows the measured power and cadence as well as the kinetic energy in the system of the Indoortrainer ride in the (table 1 a) IMU mode and (table 1 b) rotation-based mode. Noticeable is, that the measured power in the IMU mode does not vary greatly with either the round or the oval chainring, each with 248 $\pm$ 3 W for the round and 247 $\pm$ 3 W for the oval chainring. In table 2 b is striking that the power output with the oval chainring is always higher than with the round one although cadence and kinetic energy are nearly the same for every part. In numbers it is 256 $\pm$ 5 W with the oval one whereby it is 249 $\pm$ 2 W with the round chainring. Cadence does not distinguish a lot in both modes being 74 ± 1 rpm in IMU mode or 73 ± 1 rpm in the rotation-based mode.

Figure 1

(a)



(b)

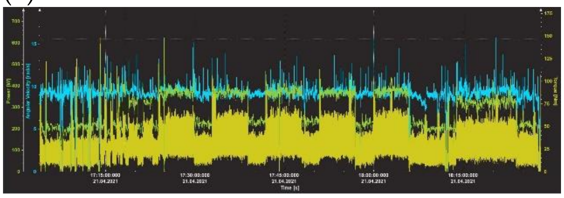


Figure 1 represents torque in yellow, angular velocity in light blue and power in green from both rides with (figure 1 a) being the continuous method and (figure 1 b) being the interval ride. One relevant aspect to address is the wide distribution of torque in every ride, whereby the angular velocity distribution takes place in a smaller range to get the nearly same power for a given time period.

Noticeable in figure 1a is that torque and angular velocity do not really change over duration except little peaks that occur from time to time. The distribution of torque seems to be the same throughout the ride, while the angular velocity is kept quite steady, so that the rider is able to deliver the required performance.

A closer look at figure 1 b shows that the angular velocity remains at the same level for the whole ride, although the power output increases considerably in the completed intervals. Comparing the first five intervals with a length of six minutes with the last interval of ten minutes, it becomes clear that the torque level rises but appears to be at the same level in the longer effort.

Table 2

	Torque [Nm]	
	Continuous method	Interval method
Mean	24.907	31.394
Median	24.813	29.5
Deviation Mean to Median [%]	0.38	6.03
Standard Deviation	11.56	15.43

Table 2 represents the mean, median, deviation of mean to median and standard deviation for torque of both rides. The mean and median value of torque show a deviation of 0.38 % in the continuous ride however differ notably in the interval session by 6.03 %. As a result, the standard deviation for torque increases from 11.56 Nm in the continuous ride to 15.43 Nm for the interval ride what can also be seen from the previously shown diagrams, as the torque level fluctuates.

Table 3

	Angular Velocity [rad/s]	
	Continuous method	Interval method
Mean	8.781	9.048
Median	8.938	9.196
Deviation Mean to Median [%]	-1.79	-1.64
Standard Deviation	0.95	1.02

Analysing the angular velocity, presented in table 3 reveals that the mean and median values in both rides have almost the same deviation with -1.79 % and -1.64 %, although the effort expended was very different. Their absolute mean values are practically the same with 8.781 ± 0.95 rad/s in the continuous ride and 9.048 ± 1.02 rad/s in the interval ride.

Table 4

	On Time Power [W]	
	Continuous method	Interval method
Mean	218	286
Median	221	269
Deviation Mean to Median [%]	-1.38	5.94
Standard Deviation	96	140

Taking a closer look at the calculated On Time Power output figures it is noticeable that the deviation of the mean and median value in the interval ride is nearly the same with 5.94 % than as it is in the torque values. The mean value 286 ± 140 W is considerably higher in the interval ride than in the continuous effort with a mean of 218 ± 96 W. Yet, the median On Time Power of the continuous method is 3 W higher than its mean whereby in the interval ride the median is 17 W lower than the mean value.

Table 5

(a)

No	Length[s]	Mean		
		Torque [Nm]	Angular Velocity [rad/s]	On Time Power [W]
1	360.29	38.750	9.47	368
2	361.10	40.309	9.17	368
3	360.92	39.470	9.35	369
4	359.09	39.560	9.34	368
5	360.33	40.356	9.31	374
6	600.38	34.746	9.31	322

(b)

No	Length [s]	Median		
		Torque [Nm]	Angular Velocity [rad/s]	On Time Power [W]
1	360.29	39.329	9.56	375
2	361.10	40.719	9.23	374
3	360.92	39.688	9.45	373
4	359.09	40.000	9.37	374
5	360.33	40.188	9.33	375
6	600.38	35.031	9.32	327

(c)

No	Length[s]	Standard Deviation		
		Torque [Nm]	Angular Velocity [rad/s]	On Time Power [W]
1	360.29	14.552	0.78	135
2	361.10	15.383	0.59	135
3	360.92	14.889	0.69	137
4	359.09	15.450	0.42	140

5	360.33	15.533	0.45	141
6	600.38	13.212	0.49	120

Table 5 shows (table 5 a) mean, (table 5 b) median and (table 5 c) standard deviation of all completed intervals. For all intervals mean torque ranges around 38.865 $\pm$ 1.921 Nm and median is very similar at 39.159 $\pm$ 1.895 Nm. The angular velocity numbers with 9.32 $\pm$ 0.09 rad/s in mean and 9.38 $\pm$ 0.11 rad/s in median are also very equal. Comparing the six-minute efforts with a higher power output of 369 $\pm$ 2.59 W to the ten-minute effort with an average of 322 Watt the applied torque is only 4.943 $\pm$ 0.596 Nm higher despite a higher power output of 47 W. Every calculated On Time Power output is lower in its mean value than in median, irrespective of the interval duration. Interestingly the fifth six-minute intervals mean and median value of On Time power output is nearly the same. Standard deviation for every quantity is nearly the same being 15.161 $\pm$ 0.379 Nm, 0.59 $\pm$ 0.14 rad/s and 138 $\pm$ 2 W in the first five intervals and 13.212 Nm, 0.49 rad/s and 120 W in the ten-minute effort.

Figure 2

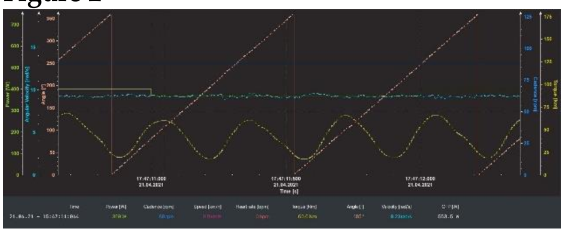


Figure 2 shows two crank repetitions as an example for the high resolution of the recorded data. Taken out of the third interval with a power output of 369 Watt at an 88 rpm cadence, it gets visible that the torque graph follows a sin function but is not even over the whole time. By definition, in the first 180 ° of a crank repetition the right leg is dominant and in the second 180 ° the left leg pushes the pedal down. The graph shows a higher unevenness for the left leg phase. Over the presented figure the angular velocity is varying minimal.

4. Discussion and practical applications

From the previously stated results a few new findings and practical applications can be found and can be considered helpful for future research. Most striking is the more accurate measurement of power with the IMU mode never mind if a round or oval chainring is used. The highly increased amount of acquired data can also be used for a more detailed training evaluation and might also lead to new parameters for cycling analysis. Furthermore, studies can not only be executed under laboratory conditions but also outside with the same required data. Mean and Median values of torque, angular velocity and On Time Power can be used to analyse a cyclists' biomechanical pedal pattern in more detail. Moreover, the high resolution of the recorded values shown in graphs can be used to optimise a riders' pedal pattern. The deviation of mean and median allow to analyse the evenness of a ride or interval. Peaks could play a role in sprints or other short intervals. Torque can be a very useful tool in track cycling as the starts are often out of a standstill and also can be implemented in or as new training tools. Another possible use of the Powermeter 9 could be found in the medical sector. At this a patient's muscle functionality or progress in rehab could be analysed by controlling the sin course of torque. Further, the data could be used to check, if the rider has certain damage in coordination after a crash. A negative point of the Powermeter 9 might be that it measures both applied torques at the same time and so only the sum of both values can be displayed. Therefore, it cannot be differentiated if one leg is applying more force or whether the other one is counteracting more or less.

5. Conclusion

To summarise this single case study, this Powermeter calculates power more accurate and the collected data can be used to develop new parameters, indicators or even methods to improve the performance of a cyclist. Furthermore, it surely can find use in other sectors such as the medical. Future research needs to be done to find a scientific use of the values and to develop a user-friendly way to process and demonstrate all relevant data. **Conflicts of Interest:** The authors declare no conflict of interest.

References

1. A. Margherita Castronovo, Silvia Conforto, Maurizio Schmid, Daniele Bibbo and Tommaso D'Alessio (2013). How to assess performance in cycling: the multivariate nature of influencing factors and related indicators doi: 10.3389/fphys.2013.00116
2. Coyle EF, Feltner ME, Kautz SA, Hamilton MT, Montain SJ, Baylor AM, Abraham LD, Petrek GW (1991). Physiological and biomechanical factors associated with elite endurance cycling performance. PMID: 1997818.
3. Asker E. Jeukendrup and James Martin (2012). Improving Cycling Performance: How should we spend our time and money
4. W. Bret Smith (2018). Marginal Gains. SAGE journals. Doi: 10.1177/1938640018790160
5. This Coach Improved Every Tiny Thing by 1 Percent and Here’s What Happened (2018). Retrieved from http://www.activeedgewellness.com/wp-content/uploads/2018/11/ActiveEDGE-linking-story-Winter2018-News.pdf
   David Hall, Derek James and Nick Marsden (2012). Marginal gains: Olympic lessons in high performance for organisations.