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ORIGINAL RESEARCH

Power Analysis of Field-Based Bicycle Motor Cross (BMX)

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Introduction: Power meter is a useful tool for monitoring cyclists' training and race performance. However, limited data are available regarding BMX racing power output. The aim of this study was to characterise the power production of BMX riders and investigate its potential role on race performance.

Methods: Fourteen male riders (age: 20.3 ± 1.5 years, height: 1.75 ± 0.05 m, mass: 70.2 ± 6.4 kg) participated in this study. The tests consist of performing two races apart from 15-min recovery. SRM power meter was used to record power and cadence. Cyclists' fastest race was used for the data analysis. Heart rate was recorded at 1-s intervals using a Garmin HR chest strap. Lap time was recorded using four pairs of photocells positioned at the start gate, bottom of the start ramp, end of first corner (time cornering), and on the finish line.

Results: There was a large correlation between race time and relative peak power (r = −0.68, $p < 0.01$) as well as average power with zero value excluded (r = −0.52, $p < 0.01$). Race time was also significantly associated with time cornering (r = 0.58, $p < 0.01$). Peak power (1288.7 ± 62.6 W) was reached in the first 2.34 second of the race. With zero values included, the average power was 355.8 ± 25.4 W, which was about 28% of the peak power, compared to 62% when zero values were excluded (795.6 ± 63.5 W).

Conclusion: The post-race analysis of the power data might help the cyclists recognizing the need to apply certain strategies on pedalling rates and power production in certain portions of the BMX track, specially, at the start and around the first corner. BMX coaches must consider designing training programs based on the race intensity and power output zones.

Keywords: BMX race, cadence, heart rate, power binning

Introduction

Cyclists from a recreational to elite level use power meters to examine the power output profile of training and race performance.[1] For many scientists and coaches, a simple power analysis consists of visual inspection to identify peak power and time to peak power. However, for a more thorough evaluation of power data, type of the race, track condition, and quantifying variation in power output during the race should also be considered. For instance, in some sprint cycling events such as bicycle motocross (BMX), pedalling is intermittent throughout the race; consequently, riders' power production is sporadic.

A BMX race typically lasts between 30 -50 seconds in duration. Each BMX track is unique in shape and distance and ranges between 200-400 m in length, incorporating a variety of jumps, corners, and flat sections.[2] A BMX track can be categorized into three different phases. 1) Gate start acceleration phase, which is

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determined by the gradient of the ramp and the values of maximum power production. 2) Mixed central phase, in which riders combine impulse actions without pedalling when tackling the obstacles and then, when possible, pedalling to achieve the maximum power to increase or maintain the speed already accomplished. 3) Stamina phase, in which riders try to maintain their high cyclic power output and maximum speed by pedalling and coordination, therefore, velocity stamina plays a significant role in the final performance.[3] These phases affect the BMX race technical and conditional requirements and reduce the options for applying power.

A number of studies suggest an association between peak power and BMX race performance.[4–6] These research studies mainly focused on measuring performance over the first phase of the track or short distance sprints. For instance, Rylands et al[7] were the first to use an SRM power meter system and evaluated velocity production. They compared the results of six elite BMX riders power production over a 50 m and 200 m flat asphalt surface with other cycling disciplines. Riders in this study produced peak power of 1256 ± 276 (W), which was closer to the track sprinters and more than the power outputs of the endurance mountain bike riders. A major limitation with this kind of methodology is the lack of validity and transferability of the results, as they have not undertaken their research on an actual BMX track. The same issue applies for laboratory-based measures evaluating power production.[8,9] The lab results can evaluate the capacity, but it is unknown whether this is repeatable on the track. Clearly, there is the need for a more valid method of power output measurement in BMX racing.

To the best of our knowledge to date, only Mateo et al[3] have evaluated power under a BMX race condition. Their results showed that the average peak power applied in the BMX race was 85% of the laboratory-tested maximum power. These values decreased to 73% at the gate start and to 51% on the first straight. They concluded that the power profile of elite BMX riders is dependent on certain factors, including the phases and techniques of the race, and are significantly affected by the level of track difficulty. As track characteristics influence pedalling time and require multiple technical demands, power production varies through the race. Consequently, a more detailed analysis of power output data can determine how the volume and intensity of racing (and training) has been distributed.

Power output distribution can be described within a race or training session using time spent in designated data bins or zones. Data bins are generated using percentage of total time spent within a power band. To present the data visually the bins can be plotted to produce a session histogram. Previous studies have used a data binning approach to investigate physiological responses during training and cycling competitions.[10] Ebert et al[11] used a similar comparison for two types of women's World Cup cycle road races and calculated the percentage of total race time spent within four data zones. Although simple, this method is excellent for the purpose of overall session comparisons. Due to the variable nature of the power output during BMX race, the use of data binning transposes the complex stochastic power meter data into a simple, easy to interpret output for BMX coaches.

Despite such monitoring, many BMX coaches and cyclists remain uncertain about the actual benefits of training based on power, and how to best implement the use of a power meter as a training tool. Hence, the aim of the current study was to characterise the power production of BMX riders in races. It was hypothesized that cyclists' race times would be significantly correlated with time cornering and power output of the race.

Methods

Participants

Fourteen sub-elite male BMX cyclists (age 20.3 ± 1.5 years, height 1.75 ± 0.05 m, mass 70.2 ± 6.4 kg, and training experience 6.5 ± 1.5 years) volunteered to take part in this study. Those with any recent injuries or medical conditions were excluded from the study. All cyclists were informed about the study protocol and potential risks and provided written consent by the Declaration of Helsinki. Parental written consent was obtained for subjects under-18 years old. This study was approved by the University of Canterbury's Human Ethics Committee (approval number: HEC 2018/83).

Experimental Design

Before starting the race, all cyclists' body mass (Seca Quadra 808 digital scales, Birmingham, UK) and height (Seca 213 stadiometer, Birmingham, UK) were recorded. Each cyclist then followed a structured warm-up including 5–10 standing-start cycle sprints, and dynamic stretching. After 5 minutes rest, cyclists performed two all-out BMX races from a 5-meter start ramp with a standard electronic start gate (Pro-Gate, Rockford, IL, USA). Cyclists had 15 minutes of passive recovery between races and their quickest race was used for the data analysis.

BMX Track

The track performance was described as the time taken to complete the all-out effort on a 342-meter outdoor BMX track with a 28° descent and 5-meter start ramp, four straights with several technical jumps, and three corners (Figure 1). The first straightaway is defined from where the start ramp meets the track surface till landing from the last jump. The second straightaway starts from the end of the first corner to where the rider landed from the last jump. The third straightaway is quantified as starting at the end of the second corner extending to the top of the final obstacle (small jump). The fourth and final straightaway begins as soon as the third corner is completed and extends to the finish line.[12] This track hosts BMX national competitions in the South Island of New Zealand.

Race Time Assessment

Race time was recorded using four pair of photocells (NEOtm Swift Performance, Queensland, Australia) positioned at the start gate, bottom of the start ramp, end of first corner (Time cornering), and on the finish line (Figure 2).

Power Analysis

In the current study, the SRM (Schoberer Rad Messetechnik) training system was used to measure power output during the BMX race. SRM has been shown to be a valid tool for measuring power output

Figure 1 A view of the North Avon BMX track.

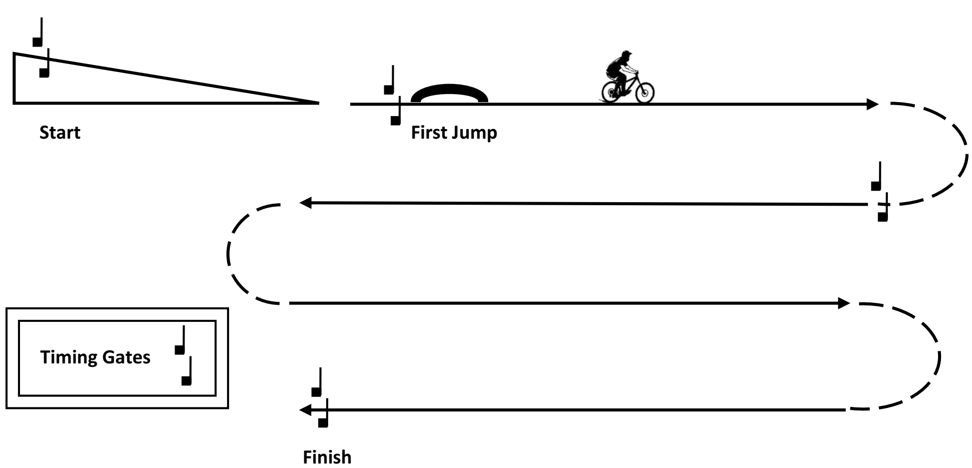

Figure 2 Schematic figure of the photocells positioning on the BMX track.

during field conditions.[13] SRM measures the power directly at the crank arm with precision strain gauges attached to the inside of a deformable disk, situated within the inner bolt circle of the crank arm. As force is applied to the cranks, the strain gauges convert this into a power value. The cadence is also assessed with every pedal revolution. This signal is then transmitted to a handlebar-mounted power controller.[13] For this test, the SRM system was set to record at 1-s intervals. Before each race, the zero offset of the power meter was re-entered into the power control unit in accordance with the manufacturer's guidelines. This offset zero was taken into account by establishing the actual output frequency of the cranks. The SRM power meter incorporated an eight-strain gauge and a 175 mm crank arm which were attached to the BMX testing bike (gear ratio of 43/16). All the relative data including peak power and cadence were downloaded after races using Power Control8 software (PC8DeviceAgent).

Binning Race Power Output

To describe the power output distribution within a race, the amount of time spent within chosen data bins was analysed. Data were then visually presented with the bins plotted as a session histogram.[11] The power bands were chosen to represent: 1) low-intensity cycling (<100 W), 2) moderate peak power (100–300 W), 3) high-intensity efforts (300–500 W) and sprints (>500 W).

Heart Rate

During the race, Heart Rate (HR) was monitored using a Garmin HR chest strap (HRM-Dual™, USA). The heart rate monitor was sampling at a rate of 1-s intervals.

Statistical Analysis

Data are presented as mean ± standard deviation (SD) and statistical significance was set at $P \leq 0.05$. All statistical analyses were conducted using SPSS 25.0 (SPSS Inc., Chicago, IL, USA). Pearson's product–moment correlation coefficient was used to determine the relationship between race variables including, race time, time to peak power, power output, cadence, and HR. During non-pedalling phase, all cyclists recorded zero values for both power and cadence. Therefore, data for average power and cadence are presented with both included and excluded zero values.

Results

There was a significant correlation between race time and relative peak power ($r = -0.68$, $p < 0.01$) as well as average power with zero value excluded ($r = -0.52$, $p < 0.01$). Race time was also significantly associated with time cornering ($r = 0.58$, $p < 0.01$). In the current study average cadence was significantly correlated with relative average power ($r = 0.68$, $p < 0.01$). There were no statistically significant associations between HR and other race variables. Mean ± SD of the race variables is presented in Table 1.

Power Output

As presented in Figure 3, power values fluctuated during the race. BMX cyclists' peak power (1288.7 ± 62.6 W) was reached in the first 2.34 second of the race. With zero values included, the average power was 355.8 ± 25.4 W which was about 28% of the peak power recorded in the race compared to 62% when zero value was excluded (795.6 ± 63.5 W). Figure 4 also showed the distribution of power production throughout the race. While non-pedalling phase contributed to ~40% of the race time, BMX cyclist generated high power (>500 W) in ~35% of the time.

Cadence

Cadence displayed a similar pattern to the power profile, as peak cadence of 131 ± 6 rev.min^{-1} occurred at 2.13s of the race. Again, with zero values excluded, the average cadence fell to 100 rev.min^{-1}. With no-pedalling periods included, the average cadence was 45 rev.min^{-1}, which equated to 22% of maximum cadence (Figure 3).

Table 1 BMX Race Variables

Variables	**Mean ± SD 0-Values Excluded (0-Values Included)**
Time	
Race time (s)	34.23 ± 1.21
Time to peak power (s)	2.34 ± 0.16
Time cornering (s)	12.14 ± 0.34
Power/Cadence	
Peak power (W)	1288.7 ± 62.6
Average power (W)	795.6 ± 63.5 (355.8 ± 25.4)
Relative peak power (Wkg^{-1})	18.3 ± 2.3
Relative average power (Wkg^{-1})	11.3 ± 1.4 (5.0 ± 0.9)
Peak cadence (revmin^{-1})	131 ± 6
Average cadence (revmin^{-1})	100 ± 8 (45 ± 5)
Heart rate (beat min^{-1})	163 ± 2

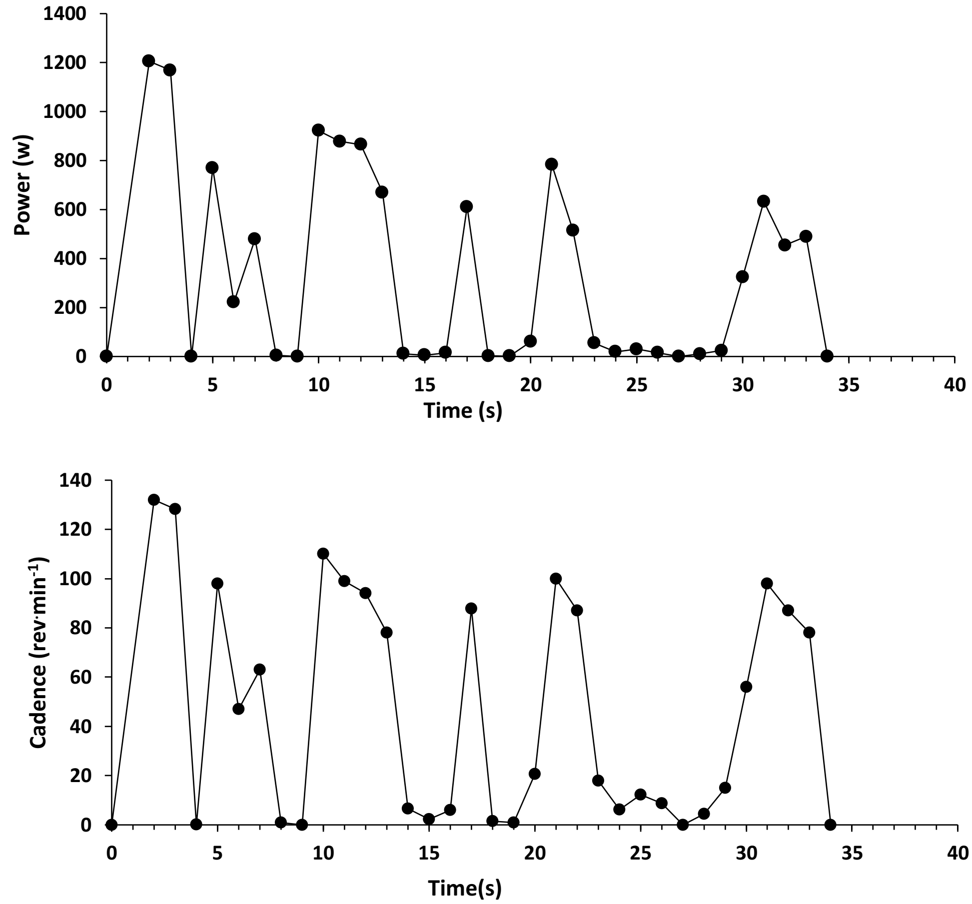

Figure 3 Mean power and cadence values recorded at 1-s intervals in the BMX race.

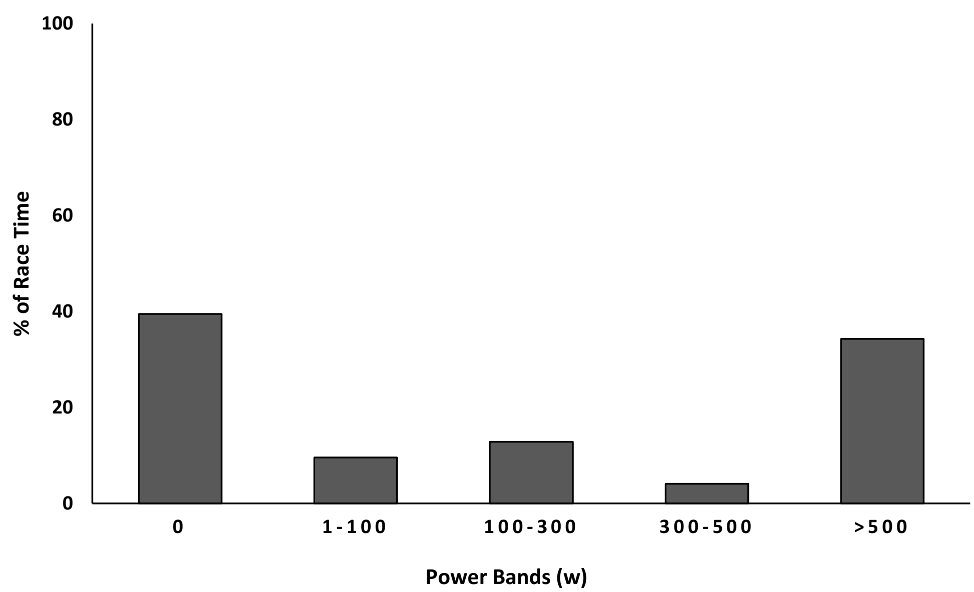

Figure 4 Power distribution in BMX race.

Herat Rate

HR reached its peak of 163 ± 2 beat.min^{-1} after 20 seconds and remained at this level for the rest of the race. As shown in Figure 5, BMX cyclists' race at ~80% of their maximum predicted HR (220-age).

Discussion

There are limited reports that have assessed BMX power performance over the range of a race. The present study was designed to analyse the power output of a BMX race and evaluate any associations between cyclists' race time and power-related variables on different parts of the track. Our results demonstrated a significant association between both peak and average power with race time, and highlighted the importance of the first straight in a BMX track and its impact on overall race performance. Furthermore, the current study provides the first report on the binning power data in BMX cycling, showing the distribution of riders' power over the race period. Time-course power analysis in the current study confirmed the previous beliefs around the intermittent nature of BMX racing.[14]

BMX cyclists in the current study reached the relative peak power of 18.3 ± 2.3 Wkg^{-1} which was significantly correlated with race time (r = −0.68, $p < 0.01$). This was in line with previous research highlighting peak power as an important determinant factor in BMX racing. Rylands et al[7] reported relative peak power of British elite male BMX riders over a 50 m flat surface 21.3 ± 0.8 Wkg^{-1}. The lower values of relative peak power are potentially due to the testing of sub-elite riders in the current study. Additionally, as Rylands et al,[7] measured performance over a flat surface and not in a BMX track, higher pedalling time would have resulted in higher power generation. Zabala et al,[8] reported peak power outputs of 1607 ± 310 W for Spanish elite BMX riders, which was 20% higher than the peak power achieved in the present study. It is worth noting that the results of Zabala and colleagues were derived from a Wingate test using a Monarck cycle ergometer, and the use of different power measuring equipment may limit transference between studies. Bertucci et al,[5] reported the peak power values (1968 ± 210 W) of the French elite riders over an 80-m field sprint and concluded that power output of the lower limb explained between 41% and 66% of the performance during the initial straightaway of BMX track. The sole study which measured power over the BMX track in three different track difficulties was conducted by Mateo et al,[3] which measured maximum power of 1343 ± 68 W in an 8-second sprint test using a Power Tap power meter among national Spanish BMX riders. Their race peak power was 1144 ± 28 W with an average time to peak power of 1.42 ± 0.02 seconds. In the current study, BMX riders reached their peak power after 2.34 seconds, but generated 12% more power in the race compared to Spanish riders. A possible explanation for these results may be the use of a different power meter, as well as testing on tracks with incompatible levels of difficulty.

Another important finding of the current study was that the average power (zero value excluded) showed a significant association (r = −0.52, $p < 0.01$) with the

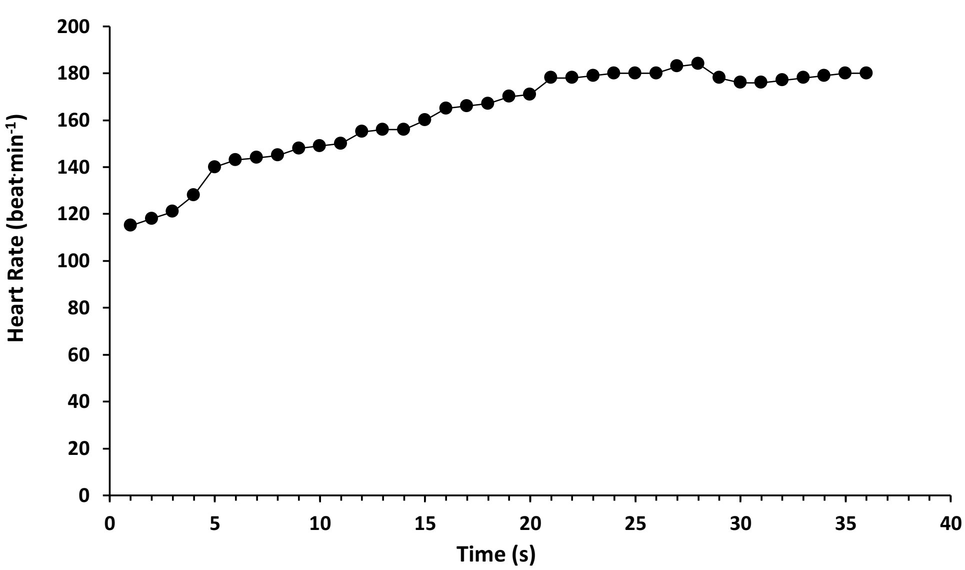

Figure 5 Mean heart rate values recorded at 1-s intervals in the BMX race.

race time. In a BMX race, pedalling is often blocked by jumps, curves, and other changes in the track, which affects the power production. However, generating power in the track corners, or when pedalling is possible, would assist riders to maintain their speed and overcome the upcoming obstacles. Therefore, besides the importance of a powerful start, and generating maximum power in the first few seconds of the race, maintaining power and velocity is another critical factor in a BMX race. There is limited data available regarding power profile of a BMX race. Only Mateo et al[3] have reported the average power of 329 ± 83 W for the entire BMX track, which was compatible with the results of current study 355 ± 25 W with zero values included. The authors indicated that on a difficult track, riders' average power dropped as there was less opportunity for pedalling and more technical sections in the race. The overall average power of a race gives insight into the actual stress imposed by a given workload, since fluctuations in power are further exaggerated by tactical considerations or track shape. Data obtained via racing with a power meter can be used to evaluate BMX performance, and consequently to evaluate the load of training and to determine what changes might need to be made to a riders' program.

Time cornering in the current study demonstrated a positive correlation with riders' overall race time ($r = 0.58$, $p < 0.01$). Our data also showed that second peak power (72% of race peak power) occurred while riders pedalled around the first corner, after an explosive power production at the start. Previous studies have highlighted the importance of the first straight in a BMX race; however, our data showed that time cornering is another important factor associated with overall race time. Cowell et al,[12] analysed the time trial event of the 2010 BMX World Championships and reported time cornering of 13.92 ± 0.42 s, while total time on the first straight was 9.16 ± 0.21 s. These authors concluded that in a BMX race, each section of the track requires a slightly different skill set and the performance on one section is likely to influence performance on subsequent sections. Based on our results, riders who had shorter time cornering were more likely to have a better overall race performance. This result may be explained by the fact that while the initial power helps BMX riders to pick up the best position in the track, their pedalling performance in the first corner can minimize any loss in speed, and provides a chance to maintain their speed by generating more power.

The present study provided a deeper analysis of BMX race power output distribution by data binning. There is a various range of power production in a BMX race. Riders spent ~35% of the race time in <500 W sprint zone which highlighted the importance of the anaerobic energy system in a BMX race. On the other hand, the non-pedalling period of a race equated for ~40% of the race time, as well as a period of producing very low power <100 W which can be considered insignificant power output. The data binning strategy has been used with road cyclists previously, where Ebert et al,[11] reported the power distribution during the Women's World Cup in road racing. Riders in their study spent ~5% of the race time in the sprint zone, where ~45% of the race time was under peak power value. One of the advantages of racing and training with a power meter is that it provides an easier way to precisely control the overall training load. By continuously recording power output, the exact demands of each race can be more accurately quantified, and the intensity or duration (or both) of subsequent training sessions can be modified. These findings help BMX riders to have a clearer understanding of power production in a BMX race and the importance of <500 W sprint zone. BMX coaches should also consider training program with high metabolic stress levels such as high-intensity interval training that could possibly improve repeated races performance.[15] Future research needs to provide data from elite riders during international BMX competitions. That would have an insight into the fitness standards required to be competitive and successful at an elite level and may offer a screening tool for coaches and sport scientists in talent identification processes.

Another finding presented in our study was the significant correlation between average cadence with relative average power ($r = 0.68$, $p < 0.01$) and this demonstrated a similar pattern to the power profile during a BMX race. Cadence has been highlighted as one of the key factors contributing to power production, and mechanical power output in cycling is dependent upon cadence.[16] However, as BMX bikes are not equipped with a gear shifter system, and riders elect to use a single-speed system, data regarding the optimal cadence and peak power is contradictory. For instance, Herman et al[17] reported that power cadence relationship could have an effect on a BMX riders' finish line placing, as the relationship occurs in the first 1.6 s of a race. Riders in this study reached peak cadence of 212 ± 4 revs.min^{-1} with peak power of 2087 ± 156 W. Debraux et al[18] analysed peak power and cadence during the 80-m sprint test and reported an optimal theoretical cadence of 122 ± 18 revs.min^{-1} that elicited peak power. In a laboratory-based study, Rylands et al[9] analysed the optimal cadence for peak power and time to peak power production, where each elite BMX rider completed three maximal sprints at a cadence of 80, 100, 120 and 140 revs. min^{-1}. These riders produced peak power (1105 ± 139 W) at 100 revs.min^{-1} and shortest time to power production were attained at 120 revs.min^{-1} in 2.5 ± 1.07 s. In the current study, riders' average cadence was 100 ± 8 rev.min^{-1}, but peak power was achieved at higher cadence (131 ± 6 rev.min^{-1}). The reason for this is that during periods when pedalling was possible, such as less technical sections or flatter areas of the track, riders appeared to generate or maintain power and velocity by relying on cadence. However, during non-pedalling phases, the majority of time was spent with the pedals static, acting more as a support platform than a dynamic performance component. Our data provided a deeper analysis on cadence and power production compared to previous studies as we measured the performance over an actual race. It is important for BMX coaches and riders to be aware of the cadence role in a race and this will provide an insight for their training intensity as well as gear selection.

The present study has several limitations. Firstly, the relatively small sample size of sub-elite BMX riders, which most likely affected our statistical power. Future studies using a larger sample size including elite BMX riders are needed to confirm these findings. Secondly, it is important to monitor BMX performance over repetitive races, which usually consists of six races in a BMX tournament, and to compare this data with other physiological variables including the aerobic and anaerobic capacity. Finally, in the current study, our power meter sampling rate was low and could potentially affect our power measurement. Using a power meter with higher sampling rate in future research would help to accurately assess field power in BMX.

Conclusions

Overall, this study strengthens the idea that power output is a critical variable in BMX race performance and should be measured over the range of the whole track under a race condition. As power is highly variable in a BMX race, the average power beside peak power provides more insight into the actual stress imposed. Therefore, BMX coaches must consider designing training programs based on the race intensity and power output zones. The post-race analysis of the power data also helps the cyclists recognize the need to apply certain strategies on pedalling rates and power production in certain portion of the BMX track. Specifically, at start of the race, time cornering and around the first corner. Furthermore, such data provide insight into cyclists' relative strengths and weaknesses. Comparison of the power profile from race to race and its association with time may indicate whether they were dropped due to accumulative fatigue if the power dropped, or would be due to the technical performance.

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Disclosure

The authors report no conflicts of interest in this work.

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