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Velocity Production in Elite BMX Riders: A Field Based Study Using a SRM Power Meter

Lee Rylands[1], Simon J Roberts[2], Mark Cheetham [1], Adam Baker[1]

[1]Department of Sport, Health and Exercise, University of Derby Buxton, Derby, United Kingdom, [2]Faculty of Education, Community & Leisure, Liverpool John Moores University, Liverpool, United Kingdom

ABSTRACT

Rylands L, Roberts SJ, Cheetham M, Baker A. Velocity Production in Elite BMX Riders: A Field Based Study Using a SRM Power Meter. **JEPonline** 2013;16(3):40-50. The aim of this study was to analyze the production of velocity in bicycle motocross (BMX) compared to other cycling disciplines. Six elite BMX riders, 5 males and 1 female who competed and trained regularly for a period of 12 yrs ± 2 agreed to take part in this study. Each rider performed 3, 50-m sprint tests and a single 200 m fatigue test. The riders' peak power, fatigue index, power to weight ratio, and cycling revolution per minute were analyzed using a Schoberer Rad Messtechnik (SRM) BMX power meter. The BMX riders' peak power and power to weight ratio were all found to be similar to those in other sprint cycling events. Peak power outputs of 1539 ± 148 W and 1030 W were recorded with mean power to weight ratios of 21.29 ± 0.84 W·kg^{-1} and 16.65 W·kg^{-1}. The BMX riders' power fatigue index was found to be higher than other sprint events as riders fatigued at a greater rate. Mean fatigue index was 61.19 ± 5.97 W·sec^{-1} for the male riders and 53.04 W·sec^{-1} for the female rider. A notable finding of this study was the relationship of cycling cadence (rev·min^{-1}), peak power (Watts) and velocity (mi·h^{-1}). This relationship suggests once a BMX rider achieves peak power their pedaling cadence becomes the major contributory factor to velocity production.

Key Words: BMX, Fatigue, Peak Power, Cycling

INTRODUCTION

Bicycle motocross (BMX) originated in southern California in the late 1960s as a substitute for motocross racing and was recognized as a bona fide cycle sport by the Union Cycliste Internationale (UCI) in 1993 (5). However, BMX racing was not officially introduced as an Olympic sport until Beijing (China) 2008 (23). Formal BMX competition consists of three qualifying heats called Moto's in which the fastest four riders from each group qualify for the 1/16, 1/8, quarter, semi, and finals. There are recovery periods of ~30 min between heats (17).

Each BMX course is unique in shape and distance. The typical course ranges between 200 m and 400 m in length and incorporates a variety of jumps, berms (corners), and flat sections (15). BMX racing is predominantly a sprint event (26) with races typically ranging from 30 to 50 sec in duration, although riders do not pedal continuously during the entire race (6). Competitions include an initial individual time trial for seeding purposes followed by a series of races in which 8 riders compete to complete the course as fast as possible. Riders progress through the rounds based on their previous finishing positions.

There are a number of physiological factors and performance characteristics that contribute toward the rider's ability to complete the course in as fast a time as possible. These include, but are not limited to skill, technique, and cadence (6), peak power and fatigue (17), and the power to weight ratio of the rider (18). Despite the popularity of BMX cycling (12) and its recent inclusion as an Olympic sport, there remains a dearth of physiological research dedicated to velocity production among elite BMX riders.

Previous BMX racing research has focused on injuries (4,21,22), performance characteristics, and determinants of the sport (17,26). For instance, Zabala et al. (26) demonstrated the effects of sodium bicarbonate ingestion on fatigue and peak power. While their research produced some interesting findings regarding the perceived influence of sodium bicarbonate on performance, it failed to fully explore peak power among the other components of power production. More recently, Mateo and colleagues (17) reported a correlation between velocity, power, and technical difficulty. However, the researchers concluded that a more valid method of recording power output such as Schoberer Rad Messtechnik (SRM) would have been advantageous. Thus, the purpose of this study was to investigate using a SRM power meter to record power output among elite BMX riders and, then, compare the findings to other cycling disciplines.

METHODS

Subjects

Six elite BMX riders, 5 males and 1 female who competed and trained regularly for a period of 12 yrs ± 2 agreed to take part in this study. The subjects' Mean ± SD for physical characteristics were as follows: age, 18 yrs; body mass, 67.1 ± 5.2 kg; and height, 169 ± 8 cm. All the subjects were performing at an international standard as members of the British Cycling's Olympic Development Program (ODP). The University Ethics Committee granted approval for the study. The subjects provided written consent to take part in the study. They were also informed that they could withdraw from the study at any time.

Procedures

In order to assess velocity production in 6 elite BMX riders, two test protocols were conducted. First, a maximal sprint test over 50 m was conducted to determine the riders' peak power. Second, a 200 m sprint test was administered to assess rider fatigue over a duration identical to a typical BMX race.

All tests were performed using identical test equipment (i.e., 20 inch BMX bike with a 43-16 gear ratio). The bike was mounted with a Schoberer Rad Messtechnik (SRM) BMX power meter. The power meter incorporated an eight strain gauge and a 175 mm crank arm. Prior to each test the power meter was configured in conjunction with the manufacturer's instructions. The subjects were familiarized with the test protocols and instructed to complete the outlined distances as quickly as possible. The shorter peak power performance test was completed first to reduce the effects of fatigue. The subjects refrained from physical activity 24 hrs prior to the test. They also abstained from eating 2 hrs before the testing protocols commenced.

Sprint Test Protocol and Familiarization

A flat asphalt surface was measured and marked to depict the start and finish points of the test area. The subjects conducted a 5-min self-paced warm-up immediately prior to the test. Following the warm-up, the subjects were pre-instructed to position themselves at the non-gated start-line represented by a section of luminous cones. The subjects were instructed to adopt the agreed start posture, which was represented by the subjects' dominant leg placed on the pedal at 90° (3 o'clock) position. The riders were then placed in a supported standing start with a 5-sec count down. The test was repeated three times for each subject with 15 min self-selected active recovery between repetitions. The peak power, mean power, velocity, and cadence were recorded via the SRM power crank and recorded via a data logger device referred to as the SRM power controller (positioned under the saddle). The power controller sampled at a rate of 0.5 Hz.

SRM Calibration

The SRM measurement tool used in this study was calibrated using a load factor similar to predicted power outputs of the cyclist. The utilization of this higher load eliminated the assumption that the load frequency relationship was linear. Jones and Passfield (13) investigated the linear relationship between load and frequency of SRM cranks at 13 braking loads with power outputs ranging from 90 to 625 W at a pedal rate of 1.5 Hz. They found a 95% linear regression inferring that between these power outputs the relationship between power and frequency is linear. No relationship has been ascertained between calibrating the SRM cranks at a lower load and testing at higher loads in excess of 1000 W.

The SRM cranks were calibrated following Wooles et al. (24) calibration factor protocol by a specialist sports science support team employed by British Cycling. A higher load was used to calibrate the SRM cranks in order to simulate equivalent loads predicted by sprint cyclists. The addition of the higher load eliminated the assumption that the relationship between applied torque and frequency for the SRM power meter is linear at higher loads. The slope was calculated using the following equation, here the frequency value represents the frequency output of the SRM cranks under an applied load. This required the calculation of both frequency and torque. The torque was calculated using the applied load (m) of 77.5 kg, radius of the chain ring used for calibration (0.17985 m) and gravity (g) at 9.81 $m \cdot s^{-1}$.

The weights utilised in the calibration were calibrated using UKAS certified weights. The calibration weight used in the present study was 77.5 kg, which is equivalent to a power output of 1718 W at a cadence of 120 $rev \cdot min^{-1}$ with a chain ring radius of 179.85 mm. Acceleration due to gravity was taken at 9.81 $m \cdot s^{-1}$. SRM output frequency readings were taken three times from points 90° apart and an average recorded.

The output frequency of the SRM cranks was measured using two variables: (a) the frequency measured with a load (LF); and (b) the offset (OF) frequency referred to by Schoberer Rad

Messtechnik (SRM) as the offset zero. The offset frequency is the output frequency of the SRM cranks under zero load. This offset zero was taken into account by establishing the actual output frequency of the cranks. The slope was calculated by dividing the output frequency (OF) by the torque. Power was calculated by an algorithm located in the SRM Power control software and used the cadence in the calculation Power = Torque. Angular Velocity (rad·s^{-1})

RESULTS

Power output

The physiological results from the 50-m peak power performance test are illustrated in Table 1. The results from the 200-m fatigue performance test are presented in Table 2. The tests revealed relatively low peak power outputs of 1539 ± 148 W (mean male value) 1030 W (female value). The BMX riders had a mean power to weight ratio of 21.29 ± 0.84 Watts/Kilogram (male) and 16.65 Watts/Kilogram (female) for the 3 sprint tests.

Table 1. Mean Results from Three 50 m Peak Power Performance Test.

Measure	Female	Males	Combined
Mean Peak Power (W)	1030	1539 ± 148	1284.5 ± 254.5
Mean Power/Weight Ratio (W·kg^{-1})	16.65	21.29 ± 0.84	18.95 ± 2.3
Body Mass (kg)	61.90	72.3 ± 10.3	67.10 ± 5.2

Table 2. Result from 200 m Fatigue Performance Test.

Measure	Female	Males	Combined
Peak power (W)	978	1534 ±129	1256 ± 276
Minimal power (W)	315	585 ± 37	450 ± 135
Power fatigue index (W·sec^{-1})	53.04	61.19 ± 5.97	57 ± 3.98
Power fatigue score (%)	67.79	61.75 ± 0.815	64.77 ± 3.01
Velocity at maximal peak power (mi·h^{-1})	7.40	9.7 ± 0.65	8.55 ± 1.15
Velocity at minimal peak power (mi·h^{-1})	14.10	14.4 ± 0.40	14.25 ± 0.15
Velocity fatigue index (mi·h^{-1}·sec^{-1})	-0.31	-0.38 ± 0.075	0.34 ± 0.035
Velocity fatigue score (%)	-90.5	-48.55 ± 9.95	69.5 ± 20.97
Cadence at maximal peak power (rev·min^{-1})	99.0	121 ± 3.5	110 ± 11
Cadence at minimal peak power (rev·min^{-1})	178.0	181 ± 5	179.5 ± 1.5
Cadence fatigue index (mi·h^{-1}·sec^{-1})	-4.1	-4.8 ± 0.7	-4.45 ± 0.35
Cadence fatigue score (%)	-79.8	-51.7 ± 10.9	-65.75 ± 14.05

Fatigue

The mean power fatigue score for the male BMX riders was 61.75 ± 0.815% (fatigue index 61.19 ± 5.97 $W \cdot sec^{-1}$). The female rider had a fatigue score and power fatigue index of 67.79% and 53.04 $W \cdot sec^{-1}$.

The fatigue test also presented fatigue data in respect to velocity and cadence. The riders' peak and minimal velocity and cadence were recorded at the same time as their peak and minimal power outputs. The data revealed that as power decreased over the duration of the fatigue test the cadence and velocity increased over the same duration. This is demonstrated in Figures 1 and 2.

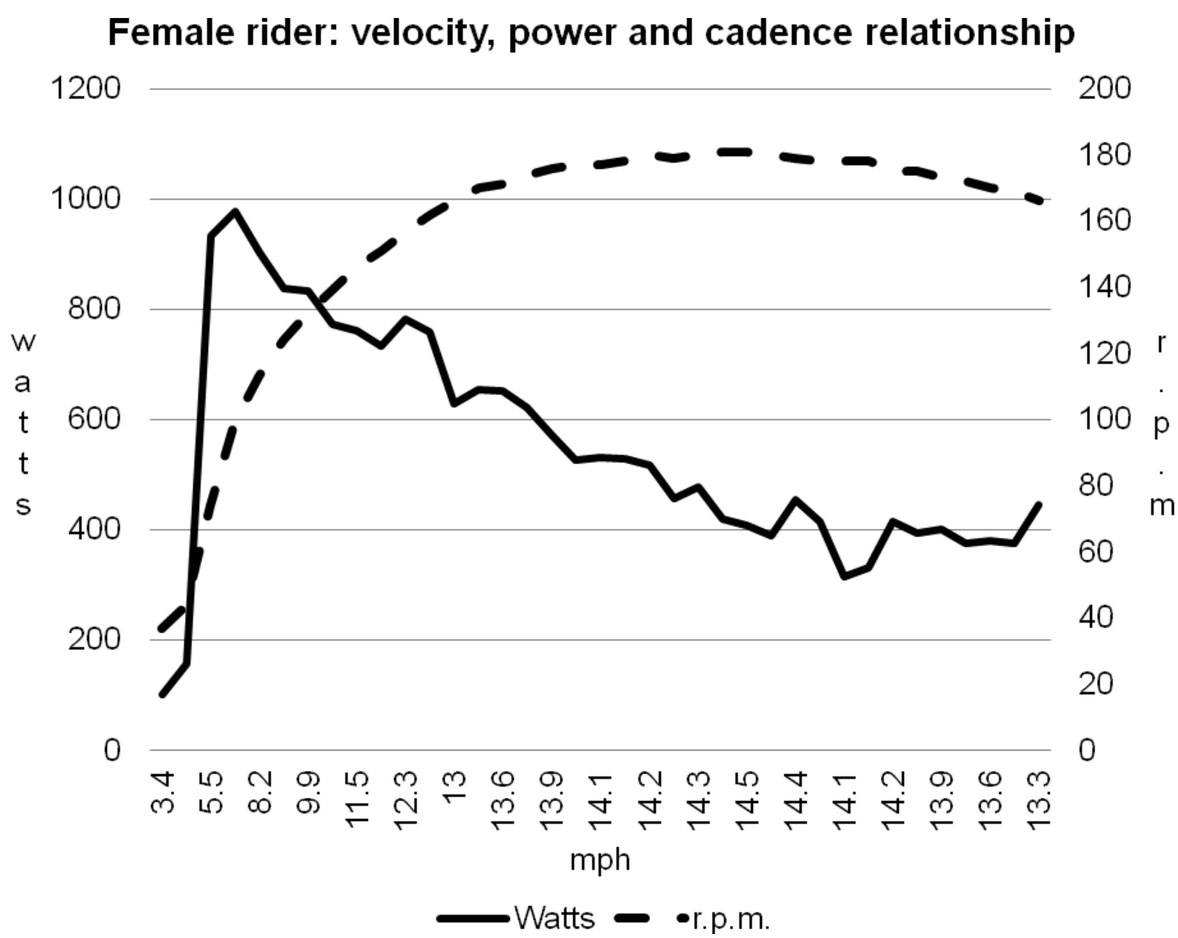

Figure 1. The Relation between Velocity ($mi \cdot h^{-1}$), Power (W), and Cadence ($rev \cdot min^{-1}$) during a 200 m Sprint Test.

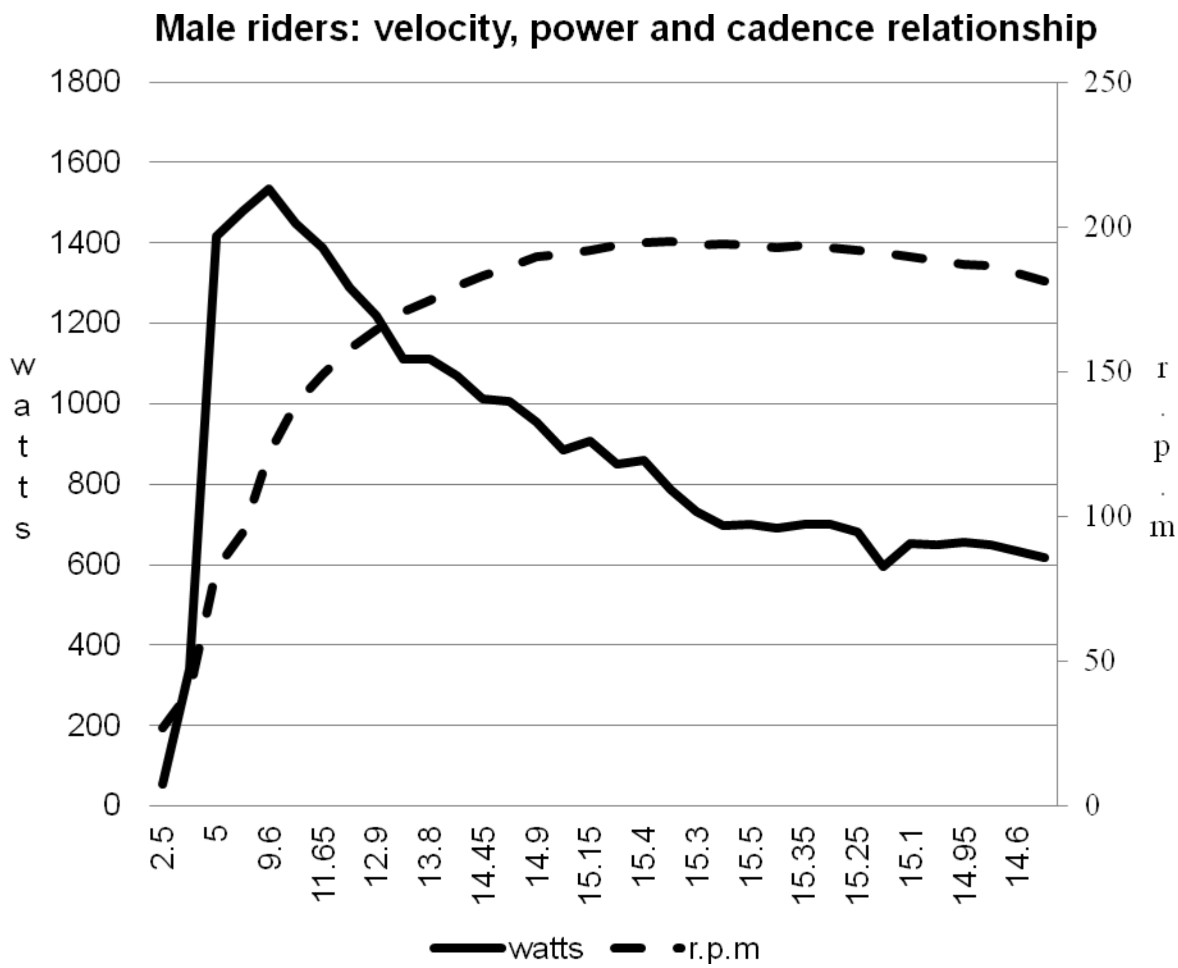

Figure 2. The Relation between Velocity ($mi \cdot h^{-1}$), Power (W), and Cadence ($rev \cdot min^{-1}$) during a 200 m Sprint test.

DISCUSSION

Gardner and colleagues (9) recorded peak power output values ranging from 1729 to 2282 W in male elite track sprinters. Lower peak power values have been reported in endurance mountain bike riders. In fact, Vitor and De-Oliveira (24) reported peak power outputs of 886.9 ± 66.7 W in 6 elite Brazilian mountain bike cyclists. However, the peak power outputs of the BMX riders in the present study were closer to the track sprinters than the power outputs of the endurance mountain bike riders. As BMX racing is predominantly a sprint discipline, this finding is perhaps not surprising. It is important to note that as this is the first study to examine peak power outputs of BMX riders using a SRM measurement specifically.

Zabala et al. (26) reported peak power outputs of 1607 ± 310 W in 9 Spanish elite BMX riders, which approximates the lower part of the Gardner et al. (9) range in male track sprinters. It is worth noting that the results of Zabala and colleagues were derived from a Wingate test using a Monarck 834E cycle ergometer. In contrast, Mateo, Blasco-Lafarga, and Zabala (17) recorded peak power outputs of 1177 ± 189 W using a Power Tap (power measurement tool built into a bicycle rear wheel) in BMX riders on a BMX track. Clearly, there is the need for a more valid method of recording power output such as an SRM power meter. Macintosh et al. (16) concluded that a cycle Monarck 834E ergometer did not provide accurate power readings due to incomplete load transmission to the flywheel of the Monarch cycle ergometer. To highlight this point, Bertucci et al. (3) performed a comparative study between PowerTap and SRM power measurement tools and concluded that the results showed a good validity of the PowerTap during sub-maximal intensities between 100 and 450 W. Mean power output difference was -1.2 ± 1.3% when it was compared to the scientific SRM model.

The peak power outputs recorded in the present study using SRM cranks provide a valid and robust insight into the production of velocity of an elite BMX rider, but on their own do not fully explain how the rider produces velocity. An analysis into other variables, including but perhaps not limited to, fatigue index, cadence, and power to weight ratio provides a more informed insight into velocity production.

The relatively low peak power outputs reported in the current study could be attributed to the relatively low body mass of the BMX riders (mean for males, 72.3 ± 10.3 kg; mean for female, 61.9 kg). This relatively low body mass is comparable to the results found in elite mountain bike cyclists (69.1 ± 2.1 kg), however the BMX riders did report increased levels of peak power (24). In addition Gardiner et al. (8) reported an increased body mass of 91.5 ± 9.5 kg in international standard track sprinters and higher peak power, which are both higher than the BMX riders in the present study.

Power to weight ratio is a method of comparing one athlete's ability to produce power to another athlete (14). Power to weight ratio can also be calculated using maximal and submaximal power outputs. Maximal power to weight rations in elite mountain bikers have been recorded between 14.2 $W{\cdot}kg^{-1}$ and 14.9 $W{\cdot}kg^{-1}$ (2,10). Similar findings have been demonstrated in elite road cyclist of 15.0 ± 0.8 $W{\cdot}kg^{-1}$ (19). While comparatively higher figures have been found in track sprinters (8), there are no figures available for power to weight ratio in BMX riders.

The male BMX riders in the current study had a mean power to weight ratio of 21.29 ± 0.84 $W{\cdot}kg^{-1}$, this contrasts with the female rider 16.65 $W{\cdot}kg^{-1}$ for the 3 sprint tests. The results suggest that the BMX riders have a power to weight ratio similar to elite track sprinters (8)(21.83 ± 0.76 $W{\cdot}kg^{-1}$). These figures were substantially greater than those found in elite mountain bikers (2,10). The power to weight ratio of the BMX riders is also a component that may have an effect on the production of the BMX riders' velocity. The power to weight ratio may not have had a substantial effect on the outcome of this study as all tests were performed on a flat surface.

However, while competing on a BMX track there are a number of environmental variables that affect velocity in relation to the riders' power to weight ratio. The BMX race track has a number of sections in which the rider leaves contact with the track and can travel up to 20 m in the air before coming back into contact with the track. The lower the rider's peak power and greater body mass the lower the duration of time spent in the air. Johnson and Bahamonde (11) suggested that there are a number of variables that can affect jump height. The variables include peak power and body mass. Thus, it could be assumed that power to weight ratio influences flight time and distance travelled while not in contact with the track by a BMX rider during competition.

Fatigue data are presented in two formats: (a) fatigue index; and (b) fatigue score. Fatigue index is a term used to express the reduction in performance of one or more quantifiable variables (e.g., an athlete's reduction in $W{\cdot}sec^{-1}$). Fatigue index can also be expressed as a reduction in other variables such as time and distance, velocity or in cycling muscular contractile speed (revolutions per minute

($rev \cdot min^{-1}$). When representing data based on measuring power, fatigue index (Fi) can be expressed in an equation as:

$$\text{Fi (Watts/Second)} = \text{peak power (Watts)} - \text{minimal power (Watts)/time (sec)}$$

According to Oliver (20), a more reliable method of expressing the data is as a percentage decrement score. This method of presenting fatigue is expressed as a percentage decrement of power from peak to minimal power production. Previous fatigue index studies of 8 male World and Olympic standard track sprint cyclist revealed that the riders had a fatigue score of 55.4 ± 6.4% with a peak mean peak power of 1959 ± 233 W (7). However, a fatigue score of 36.3 ± 3.1% was reported by Vitor and De-Oliveira (24) in 6 elite male mountain bikers. Zabala et al. (26) established a fatigue index of 44.8 ± 7.9 $W \cdot sec^{-1}$ in 9 Spanish elite BMX riders.

The current study established a higher level of power fatigue than the track sprinter, mountain bike riders, and the Spanish BMX rider (see Table 2). There are two plausible reasons for this outcome. First, the use of a Monark cycle ergometer to determine power outputs, as discussed previously may be unreliable. The second relates to the demands of the track / cycling disciplines and specificity of BMX physiologic adaptations accrued over years of training. However this supposition is speculative and requires additional scientific support.

When analyzing the demands of BMX racing in relation to other cycling disciplines, it is evident that power fatigue is less of a contributing factor to success in the sport. The duration of pedaling required in a BMX race is substantially shorter than that of a mountain bike and a track sprint race. For instance, a BMX rider would pedal for 3 to 6 sec at the start of a race and then for 2 to 3 sec for a limited frequency throughout the race. The overall race duration would be ~30 to 50 sec (6). During a track sprint event (Match sprint) of 750 m, riders predominantly sprint for 10 to 11 sec in the closing part of the race (7). The group with the greatest resistance to fatigue is the mountain bike riders as they are endurance based athletes with the duration of the race being substantially greater than that of BMX and track sprint events. Therefore, the necessity of a BMX rider to have a greater power fatigue threshold is lower than that of a track sprint and mountain bike rider.

The fatigue test revealed a greater power fatigue index in the BMX riders compared to both track sprinter and endurance mountain bikers. The mean fatigue score for the male BMX riders was 61.75 ± 0.815% (fatigue index, 61.19 ± 5.97 $W \cdot sec^{-1}$). The female rider had a fatigue score and fatigue index of 67.79 and 53.04% respectively. These figures are lower than studies performed on male track sprinters 55.4 ± 6.4% (9) and male mountain bike riders 36.3 ± 3.1% (24).

The fatigue test also presented fatigue data in respect to velocity and cadence. The BMX riders' peak and minimal velocity and cadence were recorded at the same time as their peak and minimal power outputs. The data revealed that as power decreased over the duration of the 200 m (males, 61.75 ± 0.815% 61.19 ± 5.97 $W \cdot sec^{-1}$, female, 67.79 $W \cdot sec^{-1}$ and 53.04%) cadence and velocity increased over the same duration (males, -4.8 ± 0.7 $rev \cdot min^{-1} \cdot sec^{-1}$, -0.38 ± 0.075 $mi \cdot h^{-1} \cdot sec^{-1}$; female, -4.1 $rev \cdot min^{-1} \cdot sec^{-1}$, -0.31 $mi \cdot h^{-1} \cdot sec^{-1}$). A similar study conducted on track sprint riders by Gardener et al. (9) found a power fatigue index of 55.4 ± 6.4% during a 200 m time trial. The authors suggested that a major influence on the riders' fatigue was the reduction in power and cadence relationship due to the gear selection. The riders could not produce and maintain high power outputs as peak cadence was achieved. The study concluded by stating the optimization of gears election can have a marked influence on cycling cadence.

The final variable studied in relation to velocity production of elite BMX riders was their pedaling revolutions per minute. It has been demonstrated previously that a cyclist's revolution per minute will change based on a number of factors, such as the environment they ride in and the event they are competing in. Abbiss, Peiff, and Laursen (1) found rider's cadence varied from 80 to 120 rev·min^{-1} while optimal rev·min^{-1} occurred at 100 to 120 rev·min^{-1} when sprinting. They also found that during prolonged events, such as a time trial, average cadence were lower and occurred at 90 to 100 rev·min^{-1}.

Variation in cadence between track cycling events also highlighted a similar trend with 200 m sprinters having a higher average cadence of 150 rev·min^{-1}. While track team pursuit riders, predominantly an endurance event, has a lower average cadence of 122 rev·min^{-1} (7), the BMX riders in this study recorded peak cadence of 99 to 125 rev·min^{-1}, which is comparable to endurance riders. The contribution of cadence to velocity production appears to be relatively low for a predominantly sprint event. However, when looking at the relationship between cadence, peak power, and velocity the importance of cadence becomes clearer. This relationship suggests peak power is achieved in a short period of time while velocity and cadence continue to increase. The continuation of velocity production after peak power may be a result of an increase in cadence.

CONCLUSIONS

The BMX riders in this study had low peak power and comparative power to weight ratios to track sprinters. However, they fatigued at a greater rate than track sprinters and mountain bike riders. The riders produced velocity initially using power and cadence, but reduced their power production and relied on cadence to continue velocity production. This may be due to the resistive force of the gear ratio being overcome in a relative short period of time. Therefore, the peak velocity and power may not be the actual peaks the riders are physically able to perform. This is important as the gear ratio used in this study was a standard race gear ratio (43 to 16 gear ratio).

Increasing the gear ratio may have an effect on the riders' peak power and as a result increase their peak velocity. The transfer of any increase in peak velocity to a race situation would need to be researched further to determine a significant effect on a BMX race. The increased gear ratio may also have a positive effect on the fatigue index of the riders if peak and minimal power outputs increase. Therefore, increasing the resistive force by increasing gear ratio may aid the riders in maintaining a higher velocity and reducing the fatigue index.

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Address for correspondence: Lee Rylands, Department of Sport, Health and Exercise, University of Derby, 206 Lismore Villas, Devonshire Campus, 1 Devonshire Road, Buxton, SK17 6RY;
Phone 01332 594709; Email: L.rylands@derby.ac.uk.

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