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Maximal torque and power pedaling rate relationships for high level BMX riders in field tests

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Abstract

The Bicycle Motocross race is an "all-out" sprint discipline with a race time not exceeding 40s. In high-level, the maximal power output during acceleration phase can be higher than 2000 W. The purpose of this study was to analyse the maximal torque- and power-pedaling rate relationships and anthropometric characteristics during 80m sprints. Seven elite riders performed three 80m sprints on a levelled ground. The maximal mechanical power output (P_{MAX}), the mean pedaling rate (PR_{mean}), the optimal pedaling rate (PRO_{pt}), the maximal theoretical pedaling rate (PR0), the maximal theoretical torque (T0), the time at 20m (t20) and the maximal velocity reached during 80m sprint (vMAX) were measured using PowerTap system and photoelectric cells. Moreover, the projected frontal area (A_p) was measured during the sprints by photographs. Significant correlations ($P < 0.05$) were observed between P_{MAX} and vMAX ($r = 0.99$), vMAX and PMAX•Ap-1 ($r = 0.87$), vMAX and T0 ($r = 0.97$), vMAX and PR_{mean} ($r = 0.98$) and t20 and vMAX ($r = -0.99$). Moreover there was a significant difference ($P < 0.01$) between PR_{mean} and PRO_{pt} with PR_{mean} significantly greater than PRO_{pt} (158 ± 9 vs. 122 ± 18 rpm). The main results of this study showed that PMAX, T0, PR_{mean}, A_p and t20 were significant determining factors of performance in 80m sprint. Furthermore, a lower value of PR_{mean} could permit to reduce the difference between PR_{mean} and PRO_{pt} in order to maximize the power output during the sprint.

Keywords: power, optimal pedaling rate, torque, BMX, field testing, sprint

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Introduction

Olympic sport since 2008 in Beijing, the Bicycle Motocross (BMX) race is an "all-out" sprint discipline that takes place on a specific track of 300 to 400m with bumps and curves of varying difficulty. Each Olympic format race does not exceed 40 seconds with a stationary start on top of an inclined ramp and followed by a straight line with a length at least 40m before the first obstacle. Because it is difficult to overtake the opponents during the race, the main objective of the riders is to be in the best position at the end of the straight line (Zabala et al. 2009). By doing this, they can better choose their trajectory and prevent other competitors from overtaking. This is why the start and the acceleration phase during this first straight line are significant to the overall performance (Mateo et al. 2011).

To our knowledge, little data are available concerning the determining mechanical factors in BMX Race. Bertucci et al. (2007) showed that the time performance of the first straight line was significantly ($p < 0.01$) correlated ($r = 0.83 – 0.85$) with maximal mechanical power output (P_{MAX}, W) in torque-velocity test on a cycle ergometer. As in track cycling, the explosive start and acceleration phase of the straight line require high neuromuscular factors, maximal strength and high amount of power ouput of the lower limbs (Dorel et al. 2005). These kinetics variables may contribute to the success of the race. The mechanical power output (P, W) has been described to vary curvilinearly with pedaling rate, consequence of the linear relationship between torque and pedaling rate (Gardner et al. 2009). The apex of the power-pedaling rate relationship represents P_{MAX} which occurs at optimal pedaling rate (PR_{Opt}, rpm). During a race, if the mean pedaling rate (PR_{mean}, rpm) is greater or less than PR_{Opt}, P will be lower than P_{MAX}.

As in track-cycling, the riders do not use any gear change system (Dorel et al. 2005), although this type of material is permitted by the UCI. This means that riders must choose their gear ratio before the race, which will influence the pedaling rate (PR, rpm) sustained during the sprint start and the mechanical power output. Since there is an optimal pedaling rate for each rider which elicits P_{MAX}, it is possible that the chosen gear ratio might be inappropriate. Dorel et al. (2005) reported for the 200m track sprint cycling performance that the mean pedaling rate (PR_{mean} = 155 ± 3 rpm) was significantly superior to PR_{Opt} (129.8 ± 4.7 rpm) meaning that the mean mechanical power produced during the sprint (P_{mean}, W) was inferior to P_{MAX} (1600 ± 116 W), as illustrated in Figure 1A. The authors concluded that a larger gear ratio could reduce the difference PR_{mean}-PR_{Opt} and increase P_{mean}. To our knowledge, no data are available concerning the optimal pedaling rate in BMX.

In addition, the maximal displacement velocity (v_{MAX}, $m{\cdot}s^{-1}$) of riders reached a few seconds after the start (world cup race) can be superior to 19.5 $m{\cdot}s^{-1}$ (personal data). At these velocities, aerodynamic drag (R_D, N) appears to be the main resistive force opposed to the displacement of the Rider-Bicycle system and almost 90% of the mechanical power is produced by the rider to overcome the total resistive force (di Prampero et al. 1979). For given atmospheric conditions, the projected frontal area (A_p, m^2) and the drag coefficient (C_D) of Rider-Bicycle system are the two main parameters with the velocity influencing R_D. Quantifying A_p of sprinting riders with field test method (Debraux et al. 2009) could be useful in order to enhance some aspects of the performance.

In contrary with road and track cycling, only a few studies have studied the determining mechanical factors of the performance in BMX (Bertucci et al. 2007; Zabala et al. 2009; Mateo et al. 2011). The purpose of this study is to analyze during an 80m sprint on flat ground the torque- and the power-velocity relationships in world-level BMX riders and the total A_p, providing data for future comparative studies. The hypothesis that the total A_p is a relevant factor in the sprint performance is discussed in regards of the maximal cycling velocity during a 80m sprint (v_{MAX}, $m{\cdot}s^{-1}$) and P_{MAX}. Finally, PR_{Opt} and PR_{mean} on the 80m sprint are studied to observe whether these values are close or different and how they can affect the performance.

Materials and methods

Participants

Seven elite BMX riders (2 women and 5 men) volunteered to participate in this study. All were competing in international-level BMX races, including one winner of World championship and one silver medal in Olympic Games. The mean ± Standard Deviation (SD) age, body height (h_b) and body mass (m_b) were 20 ± 2 years, 1.73 ± 0.09 m and 68.7 ± 6.6 kg, respectively. Written consent was obtained from each subject after explanation of the purposes and associated risks of the study protocol. This study was approved by the university ethics committee for human studies, and all subjects signed an informed consent document to participate (Harriss et al. 2011).

Experimental design

All athletes were familiarized with the testing procedures. Each rider wore helmet and contest clothes and used its own bicycle equipped with PowerTap system (Professional model, CycleOps, USA). The PowerTap system is a reliable and valid powermeter (Bertucci et al. 2005). It uses 8 strain gauges located in the rear hub to measure the produced torque (T, N·m) and the angular velocity. This system samples at a frequency of 0.8 Hz the power output measurement. After a specific and standardized warm-up, all riders performed three 80m sprints on a leveled ground at maximal intensity with 5 min rest periods between each sprint. Leveled ground was chosen to study the mechanical characteristics of the riders pedaling while avoiding the potential effects due to the inclined ramp. The start was made stationary and the rider was held by an experimenter standing behind him. Three sprints were realized to increase the number of data and balance with the low sample frequency of the PowerTap. For each athlete, the torque- and power-pedaling rate relationships were plotted using all data of the 3 sprints.

The gear ratios used were 44 (front)/16 (rear) and 43/16 for men and women, respectively. Those were the exact gear ratios equipped in actual contest. The inertial loads (IL, $kg{\cdot}m^2$) produced were 50.2 ± 5.0 $kg{\cdot}m^2$ (see inertial load calculation below). According to Gardner et al. (2004) and the manufacturer's instructions, after the warm-up, the PowerTap torque was zeroed. The displacement velocity, the times in 20m (t_{20}, s) corresponding to the acceleration phase and 80m (t_{80}, s) were recorded with photoelectric cells (Racetime 2, Microgate, Italy, sensitivity: 0.01s).

From the linear Torque-Pedaling rate relationship, the maximal theoretical pedaling rate (PR_0, rpm) and the maximal theoretical torque (T_0, N·m) were obtained by extrapolation (Figure 1B). They correspond to the intercept of the torque-pedaling rate curve with the pedaling rate and torque axes, respectively. From the Power-Pedaling rate relationship which can be described by a quadratic relation (Gardner et al. 2007; 2009), P_{MAX} was determined as the apex and PR_{Opt} was the corresponding pedaling rate (Figure 1A). P_{MAX} was expressed relative to the body mass ($P_{MAX}{\cdot}m_b^{-1}$, $W{\cdot}kg^{-1}$) and to the total projected frontal area ($P_{MAX}{\cdot}A_p^{-1}$, $W{\cdot}m^{-2}$).

The inertial load represents the ability of acceleration of the rider-bicycle system. Larger inertial loads require longer duration to accelerate across any specified range of pedaling rate (Gardner et al. 2007). According Gardner et al. (2007), we defined IL as ½ IG^2 where G is the gear ratio (in m) and I is the moment of inertia for the rider-bicycle system. The moment of inertia was estimated as I = Mr^2 where r is the radius of the bicycle tire (0.254 m) and M (in kg) is the combined mass of the rider, the bicycle and twice the rims and tires in order to take into account both linear and rotational inertia.

The measurements of total A_p were obtained according to the method described by Debraux et al. (2009).

Digital photographs of each rider were taken during sprints performed during the warm-up using a digital camera with a resolution of 8 megapixels (Canon EOS 300D, France). The digital camera was placed 5m behind the finish line of the sprint and the picture was taken when the subject was about 15m before the finish line (Figure 2). Immediately after the finish line, the rider changed their trajectory to avoid the camera setup. The digital camera was mounted on a tripod and levelled to 1.1 m above the ground. The total projected frontal area was measured using a valid and reliable numerical field method described by Debraux et al. (2009). The numerical photograph is opened in 3D software (Pro/ENGINEER® Wildfire™ 2.0, PTC). The reference value is the width of the central bar of the BMX bicycle (0.23 to 0.25 m). The enclosed area of the rider and the bicycle is computed in square meters.

Statistical Analyses

Pearson product-moment correlation coefficients and coefficients of determination were used to determine significant relationships between the different variables measured during the 80m sprint (IL, P_{MAX}, PR_{Opt}, PR_{mean}, PR_0, the optimal torque (T_{Opt}), T_0, t_{20}, v_{MAX} and A_p). Kolmogorov–Smirnov normality tests were performed to confirm that the data was normally distributed. Therefore, a paired Student t-test was used to study if differences exist between PR_{Opt} and PR_{mean}. All data were analyzed using the software Statistica 7.1 (StatSoft, France). The significance level was set at $p < 0.05$. Data are presented as mean values ± SD.

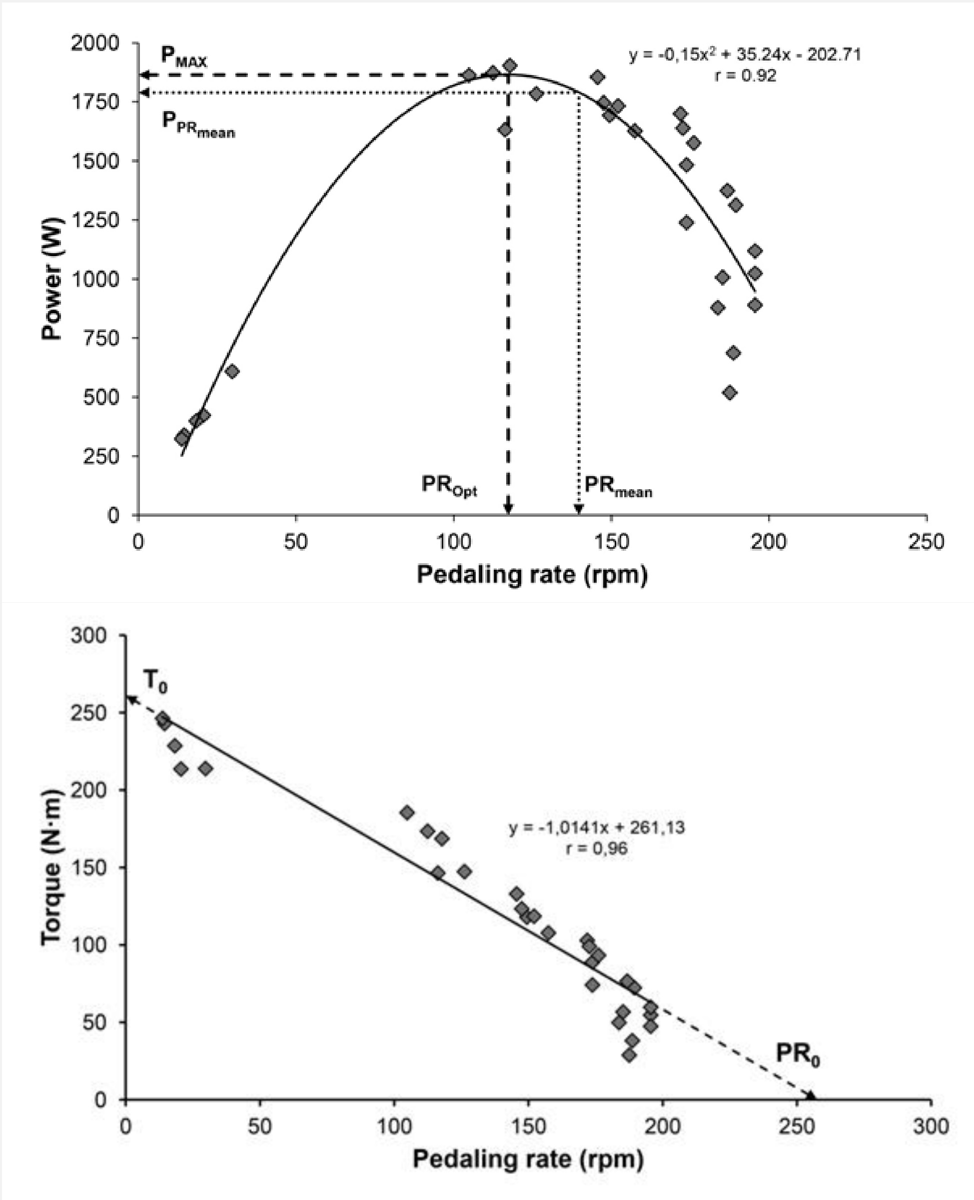

Figure 1. Torque- (a) and power-pedaling rate (b) relationships during a 80m sprint in BMX of one athlete using data from its 3 sprints. Determination of the maximal theoretical pedaling rate (PR_0), the maximal theoretical torque (T_0), the maximal mechanical power output (P_{MAX}), the optimal pedaling rate (PR_{Opt}) and the mechanical power output (P_{PRmean}, W) corresponding to the mean pedaling rate (PR_{mean}, rpm).

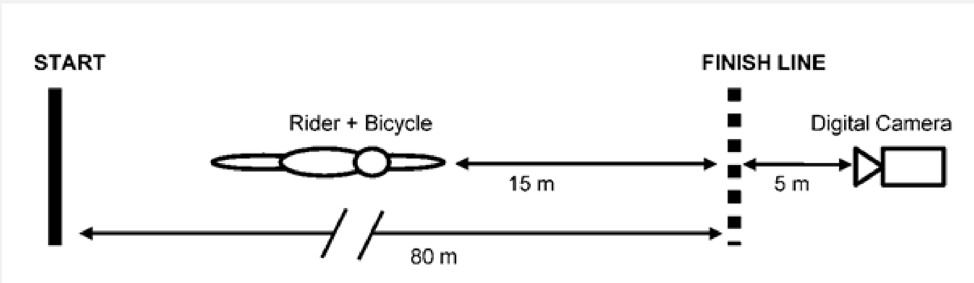

Figure 2. Illustration of rider's placement during the 80m sprint to take the photograph in order to measure the total projected frontal area.

Results

Values of mechanical variables measured during 80m sprints are presented in Table 1. Main significant correlations (p <0.05) during the 80m phase were found between P_{MAX} and v_{MAX} (r = 0.99) (Figure 3), v_{MAX} and T_0 (r = 0.97), v_{MAX} and PR_{mean} (r = 0.98), P_{MAX} and T_0 (r = 0.89), P_{MAX} and IL (r = 0.97).

No significant correlation was observed between v_{MAX} and PR_{Opt}, P_{MAX} and PR_{Opt} and P_{MAX} and T_{Opt}. During the 20m phase, main significant correlations (p <0.05) were observed between t_{20} and v_{MAX} (r = -0.99), and between t_{20} and T_0 (r = 0.98). Significant correlations (p < 0.05) were observed between and v_{MAX} and $P_{MAX}{\cdot}A_p^{-1}$ (r = 0.87) (Figure 4). The total A_p measured during the 80m sprints was 0.602 ± 0.069 m². PR_{mean} was significantly greater than PR_{Opt} (158 ± 9 vs. 122 ± 18 rpm).

Discussion

To the best of our knowledge, maximal torque- and power-pedaling rate relationships for high-level BMX riders have not previously been reported in the scientific literature. Our data for maximal power output, maximal torque and pedaling rate are in line with the few studies referring to the BMX. Bertucci et al. (2011) reported a maximal power of 1968 ± 210 W for French elite riders during standing sprint tests in field conditions. The difference with our study is mainly due to the presence of two female riders and only five male riders

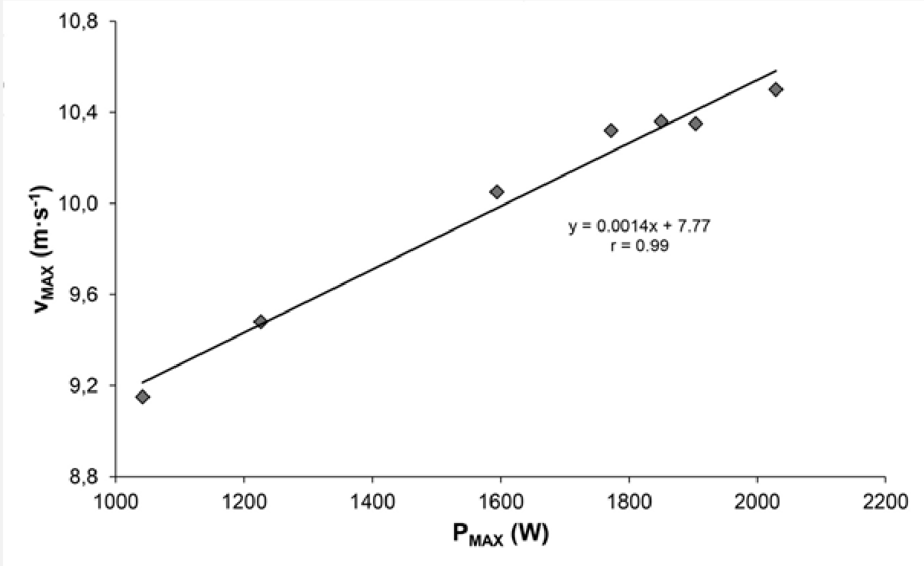

Figure 3. Relationship between the maximal velocity in 80m (v_{MAX}, m·s^{-1}) of the riders (n = 7) and the maximal mechanical power output (P_{MAX}, W).

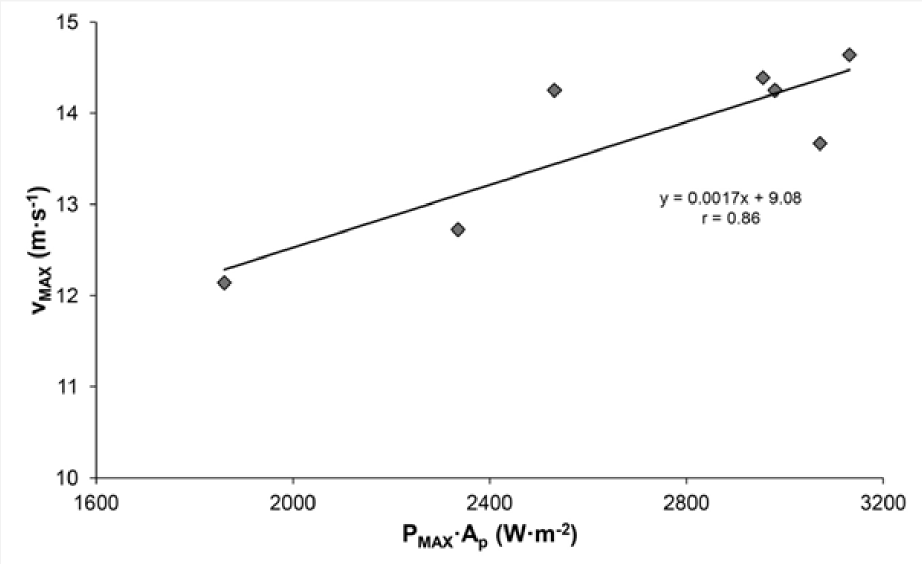

Figure 4. Relationship between the maximal velocity in 80m (v_{MAX}, m·s^{-1}) of the riders (n = 7) and the maximal mechanical power output normalized by the total projected frontal area ($P_{MAX}{\cdot}A_p^{-1}$, W·m^{-2}).

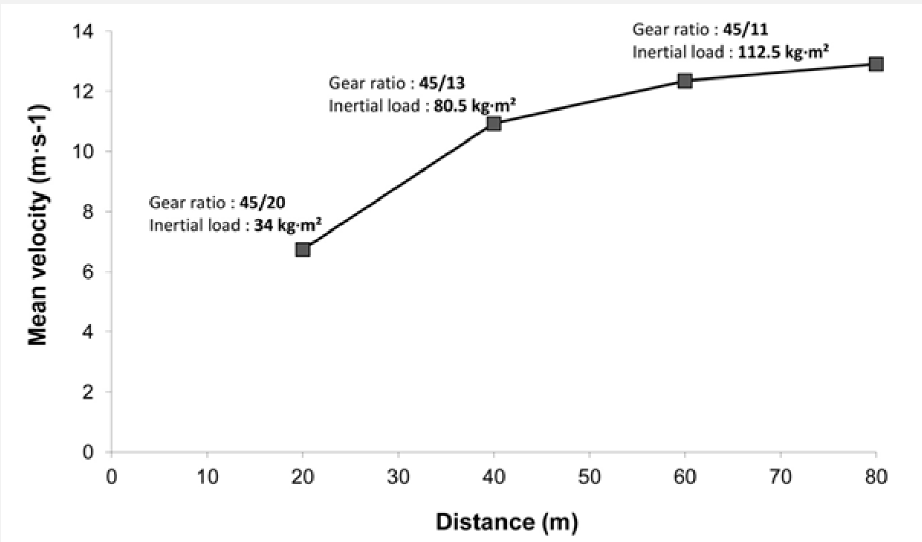

Figure 5. Evolution of the optimal gear ratio to reduce the PR_{mean}-PR_{Opt} difference as function of the mean velocity and the distance during 80m sprint.

whereas Bertucci et al. (2011) reported these data for nine male riders. Our results were higher compared with the results of Mateo et al. (2011) (1343 ± 68 W) and similar compared with the results of Zabala et al. (2009) during Wingate tests (1607 ± 310 W). Both studies reported data from the BMX elite Spanish team. Finally, our results were lower than those reported by Herman et al. (2009) (2087 ± 156.8 W) assessed in five elite male American riders including two Olympic medalists.

During 80m sprint on flat ground, our results show significant correlation between P_{MAX} and v_{MAX}. To overcome the inertia and the resistance opposed to the motion and developed a great displacement velocity, the riders have to produce high level of mechanical power output. As stated by Bertucci et al. (2011), maximal power output seems correlated with the level of riders in competition. However, the BMX races require also high technical skills depending on the difficulty of the track and influencing the production of power and the velocity of displacement (Mateo et al. 2011). Improving the maximum power must be coupled with the technical skills of the riders in order to maintain the acquired velocity as long as possible.

Moreover, the power output, torque and pedaling rate data are in line with those reported in track cycling studies. During a 200m sprint cycling with elite French track cyclists, Dorel et al. (2005) reported a maximal power output of 1600 ± 116 W, a maximal theoretical torque of 235.7 ± 19.1 N·m (vs. 213 ± 31 N·m in our study) and an optimal pedaling rate of 129.8 ± 4.7 rpm (vs. 122 ± 18 N·m in our study). During 65m sprints with the Australian track cycling team, Gardner et al. (2007) measured maximal power output of 1792 ± 156 W, a maximal theoretical torque of 266 ± 13 N·m and an optimal pedaling rate of 129 ± 0.2 rpm. Those results were obtained with a gear ratio of 48/14 (vs. 44/16 and 43/16 in our study) which produced inertial loads of 69.7 ± 3.8 kg·m² (vs. 48.4 ± 4.9 kg·m² in our study). PR_{Opt} has been reported to be strongly correlated ($r = 0.88$, $p < 0.01$) with the relative contribution of types I and II fibers composition of the knee extensor muscle (Hautier et al. 1996). According to these authors, higher the percentage of type II fibers, greater PR_{Opt} will be. Our results are in line with those of Dorel et al. (2005) and Gardner et al. (2007).

Moreover, Driss et al. (2002) suggest that T_0 is a good indicator of the maximal force of the lower limbs, and it could permit to estimate the level of strength training of the athletes. Dorel et al. (2005) found a correlation between T_0 and lean leg volume. These results assume that T_0 could be a determinant parameter for the starts. Our results reinforced this assumption with strong and significant correlation observed between T_0 and t_{20} ($r = 0.95$), v_{MAX} and T_0 ($r = 0.97$) and between T_0 and P_{MAX} ($r = 0.89$). During the sprint phase of acceleration, higher is the maximal theoretical torque, faster will be the acceleration performance at the start. These results confirm the high level of the athletes tested in our study. The assessment of the torque- and power-pedaling rate relationships in BMX elite riders provide a reference for the minimum level requirements expected for international riders and can be used for future comparative studies.

In analyzing PR_{Opt} and PR_{mean} in 80m sprint, it appears that PR_{Opt} and PR_{mean} are significantly different ($p < 0.01$) with PR_{mean} 30.0 ± 14.8 % higher than PR_{Opt} among BMX riders. Moreover, a significant relation was found between v_{MAX} and PR_{mean} ($r = 0.98$). Using the Power-Pedaling rate relationship, it is possible to determine the power output corresponding to PR_{mean} in 80m sprint (P_{PRmean}) (Figure 1A). Since PR_{mean} is significantly higher among all riders, this means the mechanical power output at PR_{mean} is lower than P_{MAX} produced at PR_{Opt}. Thus, it seems important to reduce the difference PR_{mean}-PR_{Opt} in increasing PR_{Opt} or in reducing PR_{mean}. A pedaling rate closer to PR_{Opt} could increase the mechanical efficiency and decrease the energy cost of the lower limbs muscles. The low inertial load and the standing pedaling may cause the increase of pedaling rate and thus decrease the mean power output. In BMX, the stationary start play an important role is the overall performance and the gear ratio is often chosen to allow a fast start. An increase of the gear ratio could reduce the PR_{mean}-PR_{Opt} difference. However, a larger gear ratio would cause an increase of inertial load. This will require longer duration to accelerate at the start and may cause the loss of precious second to be in good position during the race. Since the muscular strength of the lower limbs is correlated with T_0, strength training should be focused on the enhancement of the maximal muscular strength. It could permit a better adaptation to the increase of the inertial load. In order to obtain the specific training effects, the use of inertial muscular assessment with accelerometer (e.g. Myotest, Acceltec, Sion, Swiss) or linear transducer (e.g. GymAware, Kinematic Performance Technology, Canberra, Australia) may allow to individualize the training loads to each rider (Jidovtseff et al. 2007). Furthermore, on one hand, in actual BMX track, the start is at top of an inclined ramp which allows potential energy to be held by riders. We can assume that it may increase the PR_{mean}-PR_{Opt} difference. On the other hand, the inclined ramp could be useful to enhance the acceleration due to the kinetic

Table 1. Mean values of mechanical variables measured during the 80m sprints using a PowerTap in elite BMX riders (n=7).

	Values ± SD	Min – Max
Inertial load ($kg \cdot m^2$)	48.4 ± 4.9	39.1 – 52.2
P_{MAX} (W)	1631 ± 368	1042 – 2029
$P_{MAX} \cdot m_b^{-1}$ ($W \cdot kg^{-1}$)	23.5 ± 3.4	18.9 – 26.1
$P_{MAX} \cdot A_p^{-1}$ ($W \cdot m^{-2}$)	2695 ± 471	1861 – 3131
PR_{Opt} (rpm)	122 ± 18	101 – 146
PR_{mean} (rpm)	158 ± 9	144 – 167
PR_0 (rpm)	253 ± 21	216 – 278
T_{Opt} (N·m)	127 ± 24	97 – 155
T_0 (N·m)	213 ± 31	167 – 241
v_{MAX} ($m \cdot s^{-1}$)	13.7 ± 0.9	12.1 – 14.6

m_b: Body mass; A_p: Total projected frontal area; P_{MAX}: Maximal mechanical power output; PR_{Opt}: Optimal pedaling rate; T_{Opt}: Optimal torque; PR_0: Maximal theoretical pedaling rate; T_0: Maximal theoretical torque; PR_{mean}: Mean pedaling rate in 80m; v_{MAX}: Maximal velocity in 80m.

energy, thus a combination of strength training and larger gear ratio could be considered. The increase of gear ratio, the range of relative loads to use in strength training of BMX riders and how it would affect the performance and the mechanical variables deserves further investigation in actual condition.

Furthermore, to avoid the waste of time during the first few seconds due to a great inertial load, it would be interesting to investigate the possibility of using a system placed on the frame with a selection of different gear ratios. This system would facilitate the start and then the rider could also adapt the gear ratio as function of the phase of the race in order to reduce the PR_{mean}-PR_{Opt} difference as long as possible during the race. Assuming that the rider velocity at the end of the initial straight line would be equal to v_{MAX} (13.7 $m \cdot s^{-1}$) for an optimal pedaling rate of 123 rpm with wheels of 20 inches, the corresponding gear ratio can be computed. In this case, the distance travelled by the bicycle in one pedal revolution would be 6.7 m. That would correspond to a 45/11 gear ratio. The Figure 5 shows a simulation of the of the gear ratio evolution during the 80m sprint considering the velocity, the pedaling rate and the traveled distance. Knowing that such system increase mechanical friction resistance, further studies should be conducted to determine if it would be optimal to use it and what gear ratios should be chosen during a BMX race.

The maximal velocities recorded during our study are lower compared to those of Dorel et al. (2005) (13.7 ± 0.9 vs. 19.24 ± 0.48 $m \cdot s^{1}$, respectively). It can be explained by the difference in materials and aerodynamic between BMX riders and track cyclists. And contrary to the 200m flying start in track cycling, in BMX, the start is realized with no initial velocity. That confirms the importance of the maximal mechanical power output during sprint in BMX. The significant correlation between v_{MAX} and $P_{MAX} \cdot A_p^{-1}$ shows that A_p appears to be an important parameter to optimize. Because of the standing position on the pedals during sprints, BMX riders have an important total A_p (0.602 ± 0.069 m). The mean total A_p is higher than that reported by Heil (2001) for road cyclists seating in upright position with a total A_p of 0.525 ± 0.01 m². Dorel et al. (2005) reported a mean total A_p for track cyclists in dropped position of 0.531 ± 0.014 m². The largest total A_p in the BMX riders can be first explained by their standing position during pedaling which exposes a greater portion of the body. The standing position does not allow riders to bring closer the elbows of the body, which could then reduce A_p. In addition, equipment and clothes maximize A_p. Traditionally, the dress code of BMX riders was borrowed to motocross riders: helmets and large motocross clothes. The helmet contributes between 2 and 8% of R_D (Alam et al. 2007; Blair and Sidelko 2008). Wearing a helmet with a smaller projected frontal area and with a visor could reduce the effective frontal area (A_pC_D, m²). This decrease of R_D could allow for a given mechanical power output to increase the displacement velocity. In BMX races, starts are performed in downhill. The resistance due to gravity facilitates the initial acceleration and the velocity gain. When the displacement velocity becomes high (i.e., > 19.5 $m \cdot s^{-1}$, personal data), with a classic gear ratio (i.e., 44/16), the pedaling rate should be about 268 rpm. In this condition, the additional production of mechanical power is low. Moreover, this pedaling rate is a high value that all riders cannot reach (Table 1). In these conditions, there is less interest for the riders to pedal. Minimization of A_p in adopting an aerodynamic position (e.g., arms closed to the body, torso parallel to the ground) and in decreasing the A_p due to the equipment and clothes could reduce the loss of velocity at certain step of the race, especially in race with higher gradient incline ramp (like in the World Cup races or Olympic Games).

To our knowledge, this is the first description in high-level BMX riders. However our study has several limitations. Despite the fact that this study was not conducted on actual BMX track, the descriptive analysis of the torque- and power-pedaling rate relationships was possible by removing the effect of the inclined ramp on kinetic energy. Moreover, the sample size was limited by the high level required to participate in this study. The results of this study should be considered with care when applied to largest population of different level. Finally, the powermeter used in our experiment has a low sample frequency. Three sprints were performed to try to compensate this lack of data. In future investigations, more sensitive powermeter should be used (e.g., SRM, G-Cog, etc.).

The BMX is a complex cycling discipline mixing acceleration phase with high level of maximal power production and phase requiring high technical skills to jump, avoid the others opponents and maintain their maximal velocity (Mateo et al. 2011). Although our results put in perspective some aspects of the mechanical variables in relation with the performance, further investigations are necessary to verify our assumptions in actual conditions on a BMX track.

Practical applications

The use of maximal torque- and power-pedaling rate relationships is a useful tool for trainer and scientists to study the most important aspects of the BMX activity. It requires usual equipment and devices already in use in cycling team as powermeters and photoelectric cells. The main results of this study show that P_{MAX}, T_0, PR_0, PR_{mean}, $P_{MAX} \bullet A_p$-1 and t_{20} are significant determining factors of performance in 80m sprint. It has also been shown that PRmean was significantly greater than PROpt. Based on these observations, it appears that the gear ratio is not adapted and there is a need to increase it. That would result in a decrease of the difference between PR_{mean} and PRO_{pt}, an increase in maximal mechanical power output and displacement velocity. Strength training session could permit to develop the maximal dynamic force of the lower limbs of BMX riders to enhance the determining factors of the 80m sprint and adapt optimally the gear ratio. The optimization of the aerodynamics also seems a parameter to study more thoroughly in BMX. The $P_{MAX}•A_p$-1 is an indicator of the performance in 80m sprint. The aerodynamic of the system rider-bicycle should be studied to minimize the aerodynamic drag as function of the limits of the discipline. This needs further investigation in actual conditions.

References

1. Alam F, Subic S, Akbarzadeh A, Watkins S (2007) [Effects of venting geometry on thermal comfort and aerodynamic efficiency of bicycle helmet] Impact of technology on sport II. In: Fuss FK, Subic A, Ujihashi S (ed). London: Taylor & Francis, 773-780
2. Bertucci W, Duc S, Villerius V, Pernin JN, Grappe F (2005) Validity and reliability of the PowerTap mobile cycling powermeter when compared with the SRM device. International Journal of Sports Medicine 26:868-873
3. Bertucci W, Hourde C (2011) Laboratory testing and field performance in BMX riders. Journal of Sports Science and Medicine 10: 417-419
4. Bertucci W, Hourde C, Manolova A, Vettoretti F (2007) Mechanical performance factors of the BMX acceleration phase in trained riders [in French]. Science and Sports 22:179-181
5. Blair KB, Sidelko S (2008) [Aerodynamic performance of cycling time trial helmet] The engineering of sport 7. In: Estivalet M, Brisson P (ed). Springer, 2008: 371-377
6. Debraux P, Bertucci W, Manolova AV, Rogier S, Lodini A (2009) New method to estimate the cycling frontal area. International Journal of Sports Medicine 30:266-272
7. di Prampero PE, Cortili G, Mognoni P, Saibene F. Equation of motion of a cyclist (1979) Journal of Applied Physiology 47(1):201-206
8. Dorel S, Hautier CA, Rambaud O, Rouffet D, Van Praagh E, Lacour J-R, Bourdin M (2005) Torque and power-velocity relationships in cycling: Relevance to track sprint performance in world-class cyclists. International Journal of Sports Medicine 26:739-746
9. Driss T, Vandewalle H, Le Chevalier JM, Monod H (2002) Force-velocity relationship on a cycle ergometer and knee-extensor strength indices. Canadian Journal of Applied Physiology 27: 250-262
10. Gardner AS, Martin DT, Jenkins DG, Dyer I, Van Eidjen J, Martin JC (2009) Velocity Specific Fatigue: Quantifying Fatigue During Variable Velocity Cycling. Medicine & Science in Sports & Exercice 41(4):904-11
11. Gardner AS, Martin JC, Martin DT, Barras M, Jenkins DG (2007) Maximal torque- and power-pedaling rate relationships for elite sprint cyclists in laboratory and field tests. European Journal of Applied Physiology 101(3):287-92
12. Gardner AS, Stephens S, Martin DT, Lawton E, Lee H, Jenkins D (2004) Accuracy of SRM and power tap power monitoring systems for bicycling. Medicine & Science in Sports & Exercise 36(7):1252-1258
13. Harriss DJ, Atkinson G (2011) Update – Ethical Standards in Sport and Exercise Science Research. International Journal of Sports Medicine 32:819–821
14. Hautier CA, Linossier MT, Belli A, Lacour JR, Arsac LM (1996) Optimal velocity for maximal power production in non-isokinetic cycling is related to muscle fibre type composition. European Journal of Applied Physiology 74:114-118
15. Heil DP (2001) Body mass scaling of projected frontal area in competitive cyclists. European Journal of Applied Physiology 85:520-528
16. Herman C, McGregor S, Allen H, Bolt E (2009) Power capabilities of elite bicycle motocross (BMX) races during field testing in preparation for 2008 Olympics. Medicine & Science in Sports & Exercise 41: 306-307
17. Jidovtseff B, Croisier J-L, Scimar N, Demoulin C, Maquet D, Crielaard J-M (2008) The ability of isoinertial assessment to monitor specific training effects. The Journal of Sports Medicine and Physical Fitness 48:55-64
18. Mateo M, Blasco-Lafarga C, Zabala M (2011) Pedaling power and speed production vs. technical factors and track difficulty in bicyle motocross cycling. The Journal of Strength and Conditioning Research 25(12): 3248-3256
19. Reiser II RF, Maines JM, Eisenmann JC, Wilkinson JG (2002) Standing and seated wingate protocols in human cycling. A comparison of standard parameters. European Journal of Applied Physiology 88: 152-157
20. Vandewalle H, Peres G, Heller J, Panel J, Monod H (1987) Force-velocity relationship and maximal power on a cycle ergometer. Correlation with the height of a vertical jump. European Journal of Applied Physiology 56:650-656
21. Zabala M, Sanchez-Munoz C, Mateo M (2009) Effects of the administration of feedback on performance of the BMX cycling gate start. Journal of Sports Science and Medicine 8:393-400
22. Zabala M,Requena B, Sanchez-Munoz C, Gonzalez-Badillo JJ, Garcia I, Oopik V, Paasuke M (2008) Effects of sodium bicarbonate ingestion on performance and perceptual responses in a laboratory simulated BMX cycling qualification series. The Journal of Strength and Conditioning Research 22: 1645-1653