©Journal of Sports Science and Medicine (2012) **11**, 502-509
http://www.jssm.org

Research article

Notational analysis of European, World, and Olympic BMX cycling races

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Abstract

The objectives of this study were 1) to describe the technical requirements of different tracks where classifying points are disputed for the Olympics as the European continent tracks (E), world championship competitions tracks (W), and Olympic Games track -Beijing, 2008- (O); and 2) to compare and establish differences or similarities between the three previous contexts. The sample used for this study was made of the 8 best qualifying male athletes from each competition (n = 48) during the 2007 and 2008 seasons (*pre*-Olympic and Olympic years). A descriptive design was used, based on systematic structured observation of the competitions filmed on video, paying attention to the different techniques used (overtaking skills, complete pedalling cycles and registered effort times). The results show that aerial techniques predominate over non aerial techniques on O and W type tracks more than on E tracks by ~20% ($p < 0.001$), pedaling cycles predominate in E vs. W and O by 11.85 and 24.23% respectively ($p \leq 0.05$), and effort times predominate in O vs. W and E by 6.50 and 12.94% respectively ($p \leq 0.01$). In conclusion, O and W tracks stand out because of the aerial component and greater technical complexity in comparison to E tracks, which has a decisive effect on the way the riders train in relation to the type of championship they aim to compete in.

Key words: Skills, track, competition, performance, notational analysis.

Introduction

Bicycle Moto-Cross (BMX), an Olympic discipline since the 2008 Olympics in Beijing, is a mode of cycling that consists of racing around a track in the shortest time and qualifying against other rivals. The BMX tracks, situated on flat ground with strategically placed obstacles are between 300 and 400m in length -Union Cycliste Internationale- (UCI 2012) and depending on the characteristics and the distribution of the obstacles, are completed in ~30 to 45 seconds (Mateo et al., 2011b; Zabala et al., 2008). The track starts with a descending ramp that allows the cyclist to rapidly reach race speed, the race being initiated when a gate, which holds back the cyclists in a starting line, drops (Mateo and Zabala, 2007; Zabala et al., 2008). The events are organized so that cyclists compete in series of rounds with up to 8 riders in each race with the winner and runners up passing through qualifying rounds, quarter finals, semi-finals until reaching the final. Between each qualifying heat there is a recuperation period of ~15-30 minutes (Zabala et al., 2009a).

BMX is a mixed sport; physiological demands and race performance are dictated by the combination of the physical characteristics of the track and cyclists interpretation of the tactical situations they are placed in. As such the combination of these factors affects the cyclist's ability to perceive and coordinate an appropriate physiological and tactical race strategy (Mateo and Zabala, 2009). Essentially, BMX can be characterized as consisting of periods of cyclical (pedalling) and acyclical (non-pedalling) (Mateo et al., 2011b) phases which predominately stress the phosphocreatine and anaerobic glycolytic pathways during race performance (Mateo et al., 2012; Zabala et al., 2008). Superimposed upon this basic framework is a series of complex terrestrial and aerial skills tasks that may differ according to the technical level of each track. As such different tracks may impose different metabolic and neuromuscular demands that the cyclists must respond to (Mateo et al., 2011b; 2012).

In spite of the obvious importance that track characteristics may have on cyclist's preparation and performance (Mateo et al. 2012), there is very little scientific literature about BMX. Since 2006, some studies have tried to simulate BMX races in the laboratory and analyze the mechanical factors of the acceleration phase (Bertucci et al., 2007), the influence of psychological variables (Paquet et al., 2006) or the effects of sodium bicarbonate (Zabala et al., 2008; 2011). Other studies have focused on optimizing the start technique (Mateo and Zabala, 2007) and more recently, on the effects of giving feedback to improve gate start performance (Zabala et al., 2009b) or pre-competitive anxiety (Mateo et al., 2011a). In general, priority has been given to the knowledge about the first moments of the competition (Bertucci and Hourde, 2011; Campillo et al., 2007; Debraux and Bertucci, 2011; Gianikellis et al., 2004; Mateo et al., 2010; Mateo and Zabala, 2007; 2009b). Recently, we investigated how different techniques influence the physical workload of BMX cyclists (Mateo et al., 2011b), pointing out that the less technical the track the higher the physical demand and vice versa (Mateo et al., 2012). Other authors have analyzed the movement patterns and time spent pedaling, jumping and "pumping" via notational analysis in the BMX Supercross series (Cowell et al., 2011; 2012).

As we have already pointed out, although the technical characteristics and thus difficulty imposed by BMX tracks may vary on an individual basis, track design rules can provide a generic classification of tracks based on their elements that are also related to UCI regulated com-

Received: 09 February 2012 / Accepted: 14 June 2012 / Published (online): 01 September 2012

petitions. It seems that the UCI alters tracks design for spectator viewing and TV coverage. We hypothesized that there are three levels of technical difficulty tracks in international BMX. As high difficulty tracks (Olympic games track) the starting ramp is significantly higher with the increased gradient and length that produces greater acceleration at the start, although reducing the possibility of developing maximum power in the acceleration phase (Mateo et al. 2011b). These tracks also could have a greater number of obstacles, with potentially higher frequency of aerial skill executions and very demanding technical actions. A second group is formed by the tracks of average difficulty (World championship tracks), where the gradient and length of the start ramp could be lower, with possibly more distance between obstacles and with slightly greater reliance on pedalling between obstacles. Finally, there are what may be termed low difficulty tracks (European championship tracks), which could have a smoother start ramp and fewer obstacles. These are the tracks where athletes with less technical skill but greater physiological training could benefit (Mateo et al., 2011b; 2012).

By means of a notational analysis, the aim of this paper is to compare the different technical skills during international competitive races at an elite level in BMX tracks of theoretically different technical difficulty. The objectives of this study were to describe the technical requirements of different tracks where classifying points are disputed for the Olympics as the European continent tracks (E), World championship competitions tracks (W), and Olympic Games track -Beijing, 2008- (O); and to establish differences or similarities between the three previous contexts.

Our hypothesis is that E track is less technical than W, and W less technical than O, because there could be respectively increasing number of obstacles that lead to a higher technical difficulty, increased flight time and lower pedaling phases.

Methods

Participants

The sample consisted of an analysis of the 8 qualifying male athletes in the finals of the European Championship, Romans -France- and Weiterstadt -Germany- (E) (age: 23.2 ± 3.1 years; world ranking position: 14.5 ± 11.0), the World Championship, Victoria, British Columbia -Canada- and Taiyuan, -China- (W) (age: 25.2 ± 2.3 years; world ranking position: 9.1 ± 4.3), and finally, the *pre*-Olympics and Olympics, Beijing, Laoshan -China- (O) (age: 25.1 ± 3.1 years; world ranking position: 8.1 ± 4.2). The analysis was made in the year prior to and during the year of the Olympics, which are both qualifying years for the Olympic Games (*pre*-Olympic and Olympic years, 2007 and 2008). A total of 48 series performed by the best world-class BMX cyclists were examined.

Materials

All participants were filmed and analyzed. The PAL video recordings were first transformed to 50 Hz via a frame-to-field method using two open source video-editing software (Avi Synth 2.5, Virtualdub 1.5). The same software was used for the video descriptive analysis of the technical skills executions and for registering the time corresponding values. A register table was designed for this purpose; the different values were stored using Microsoft Excel 2010.

Procedures

For the notational analysis carried out, the categorization of the different techniques was developed on the basis of a previously proposed classification and description of BMX cycling techniques (Mateo and Zabala 2009). Additionally the following complementary variables were observed: 1) Time related variables as effort time (ET1) -time spent from the start to the first obstacle-, time from start to the first curve (ET2), time to the first curve, and total time to complete the track (ET3) -from start to the finish line-; 2) pedalling cycles related variables as the number of the cycles from the start to the first obstacle (PC1), the number of cycles from the start to the first curve (PC2), and complete cycles to complete the track -from the start to the finish line- (PC3); and 3) others including the number of overtaking manoeuvres (OM) and the number of passes per curve (CP). No physical data was taken regarding the length of the track, as the main variable is the time spent on completing the track that depends on the quantity and type of obstacles that were actually analyzed.

Three observers viewed and analyzed the video recordings separately with more than 95% inter-observer reliability.

Technical elements of BMX

Analysis of the different technical skills followed the following classification definitions.

1. Aerial techniques: technical actions that required both bike wheels to lose contact with the ground;

   a) Simple jump: Action of passing from one part of an obstacle to the other without making contact with the ground following the natural angle of flight the jump forces the rider to take. This was determined by the angle of the jump.
   b) Technical jump: Action of passing from one obstacle to the other modifying the angle of flight by pulling on the handle bars or altering angle of the rear of the bike in order change the flight time.
   c) Level jump: Action where both wheels leave the ground drawing and remaining parallel to the ground during the flight phase.
   d) Drawing jump: Action where the rider traces the parabola in the shape of the obstacle in order to achieve a minimum loss of speed and gain maximum speed after the drop.

2. Description of non-aerial techniques in the BMX bike discipline.

We defined non-aerial techniques as technical actions developed on the obstacles where at least one of the wheels remained in contact with the ground.

   a) Pedalling: Cyclical action of pedalling by pushing

b) the pedals using the feet.
c) Pull: Coordinated pushing action of the legs and arms used when descending the obstacles.
d) Curve pass: Action of taking the best curve-line path around the track in order to maximize performance (i.e. fastest time).
e) Gate start technique: Manoeuvres utilized to start the race once the starting gate is released.
f) Manual: Action of maintaining the front wheel balanced from the final part of the jump take off until landing;
g) Manual as a result of the obstacle: Resulting pushing technique (flexion/extension of the knees), which combined with the descending gradient of the obstacle produces the action of lifting the front wheel in order to pass/overshoot the next obstacle.
h) Nose-manual: Action of rounding the obstacle with the front wheel in order to propel the bike during descent.
i) Absorption: Technical manoeuvres which keeps the bicycle on the ground, avoiding unnecessary flights. It corresponds to the action of lifting the front wheel and keeping it balanced from the front of the jump ramp (≤ 1.5 m.). This wheel makes contact at the top of the ramp and/or at the start of the descent.
j) Complete absorption: Action of lifting the front wheel and keeping it balanced from the front part of the jump ramp (≤ 1.5 m.) until the start of landing, achieving an increase of speed during the action.

3. Mixed techniques: Actions that require a combination of aerial and/or non-aerial techniques

a) Aero-terrestrial techniques: Action of executing any aerial technique described and combining it with an action of landing on the back wheel.
   i. Aero-manual: Action of executing any aerial technique combining it with a landing action by using a manual technique.
   ii. Jump + Nose-manual: Combination of a jump action with nose-manual technique at landing.
   iii. Jump to Manual to jump. Combination of jump action with manual technique at landing, completing the manoeuvres with a jump by using the back wheel as the only support prior to jumping again.
b) Terrestrial-aerial techniques: Action of executing any non-aerial technique described combining it with taking off action.
   i. Bunny Jump: Combination of the absorption technique, completing the action with a jump using the back wheel as the only support during the impulse phase.
   ii. Complete Absorption + Jump: Combination of the complete absorption technique ending with a jump.
   iii. Manual Jump: Action of keeping the front wheel balanced from the final part of the jump ramp, taking advantage of the start of a new obstacle for taking off with a jump technique using the back wheel as the only support during the impulse phase.
   iv. Top Manual: Action of maintaining the front wheel balanced from the final part of the jump ramp until the decision to start an impulse action, with landing in the descent from the obstacle, maintaining balance by using the back wheel.
   v. Top Manual + manual: Action of maintaining the front wheel balanced from the final part of the jump ramp until the decision to start an impulse action with landing in the descent from the obstacle, maintaining balance with the back wheel.
   vi. Manual + bunnyhop + manual: Action of maintaining the front wheel balanced from the final part of the jump ramp until the decision to start an impulse action with landing in the descent from the obstacle, maintaining balance with the back wheel.

However, the fact that all the previous techniques have the two following general considerations in common was considered.

4. Common techniques: Technical actions effected in the development of any technique in view of the outcome of the particular technique used.

a) Traced line: Route or direction that is taken during the completion of a race on the BMX track. Aerial or Non-aerial.
b) Speed: Actions through which a variation in the amount of movement is achieved on the BMX track.

Statistical analyses

Descriptive statistics (mean ±SD) are reported for the measured variables. The Shapiro-Wilk Test was applied to test Gaussian distribution of the results, followed by the Levene test to verify the homogeneity of variance. The contrast test for independent samples (Mann-Whitney) was carried out between tracks (E vs. W, E vs. O and W vs. O) for the 2007 and, separately, 2008 seasons. Furthermore, the seasons 2007 and 2008 were compared through a test for related samples (Wilcoxon) because the performance data variables did not pass the normality test. Statistical significance was set at $p \leq 0.05$. All data was analyzed using SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA).

Results

The results obtained from the descriptive statistical analysis and the comparative analysis for the differences of technical executions, temporal registers and pedalling cycles on each of the three types of tracks (E, W and O) during the 2007 and 2008 seasons are presented in Tables 1 and 2.

Non-aerial techniques (NAT)

There were no statistically significant differences between

Table 1. **Descriptive statistics of the different technical skills developed in the three different tracks, and total mean values (E, W & O). Data are means (±SD).**

	E			W			O			(E, W & O)		
	2007	**2008**	***Avg***	**2007**	**2008**	***Avg***	**2007**	**2008**	***Avg***	**2007**	**2008**	***Avg***
NAT	4.1 (4.0)	3.7 (1.9)	3.9 (2.9)	2.2 (1.9)	2.4 (1.8)	2.3 (1.9)	2.2 (1.8)	.8 (.8)	1.5 (1.3)	2.8 (2.6)	2.3 (15)	2.6 (2.0)
ABS	.13 (.35)	4.9 (.8)	2.5 (.6)	.75 (.89)	2.6 (.5)	1.7 (.7)	1.4 (1.2)	.5 (.5)	.9 (.9)	.8 (.8)	2.7 (.6)	1.7 (.7)
MAN	10.0 (2.2)	5.8 (1.0)	7.9 (1.6)	4.5 (2.0)	5.0 (.8)	4.8 (1.4)	4.5 (1.9)	1.6 (.5)	3.1 (1.2)	6.3 (2.0)	4.1 (.8)	5.2 (1.4)
PULL	3.6 (1.7)	2.1 (.8)	2.9 (1.3)	2.5 (.8)	1.6 (.5)	2.1 (.6)	1.9 (1.0)	1.3 (.5)	1.6 (.7)	2.7 (1.2)	1.7 (.6)	2.2 (.9)
ABS-C	2.5 (.9)	2.1 (.8)	2.3 (.9)	1.1 (1.0)	.4 (.5)	.8 (.8)	1.1 (.8)	0 (0)	.6 (.4)	1.6 (.9)	.8 (.5)	1.2 (.7)
AT	2.5 (1.2)	2.1 (2.0)	2.3 (1.6)	4.6 (3.3)	5.3 (5.1)	5.0 (4.5)	4.5 (3.5)	4.2 (4.3)	4.3 (3.9)	3.9 (2.8)	3.9 (3.8)	3.9 (3.3)
SJ	2.6 (1.4)	.25 (.46)	1.4 (.9)	1.0 (.8)	.4 (.5)	.7 (.6)	1.4 (.7)	0.0 (.7)	.7 (.7)	1.7 1.0)	.2 (.6)	.9 (.8)
TJ	2.4 (1.1)	4.0 (.8)	3.2 (.9)	8.3 (.9)	10.3 (.7)	9.3 (.8)	7.6 (1.8)	8.8 (.7)	8.2 (1.2)	6.1 (1.2)	7.7 (.7)	6.9 1.0)
MT & OM												
MT	-	.13 (.35)	.06 (.18)	.13 (.35)	-	.07 (.18)	.8 (.9)	-	.4 (.5)	.3 (.4)	.04 (.12)	.2 (.3
OM	1.4 (.7)	.6 (.7)	1.0 (.7)	1.6 (.9)	1.0 (.8)	1.3 (.8)	1.8 (.7)	1.3 (.7)	1.5 (.7)	1.6 (.8)	1.0 (.7)	1.3 (.8)
PC												
PC1	8.8 (.7)	3.9 (.4)	6.3 (.6)	6.4 (.7)	5.8 (.5)	6.1 (.6)	7.0 (.8)	5.1 (.6)	6.1 (.7)	7.4 (.7)	4.9 (.5)	6.2 (.6)
PC2	12.1 (1.0)	8.5 (.5)	10.3 (.8)	12.0 (.9)	8.4 (.5)	10.2 (.7)	12.3 (1.7)	5.3 (.9)	8.8 (1.3)	12.1 (1.2)	7.4 (.7)	9.8 (.9)
PC3	36.8 (4.1)	20.9 (.8)	28.8 (2.5)	31.9 (3.6)	20.0 (.8)	25.9 (2.2)	30.1 (2.2)	16.3 (.7)	23.2 (1.5)	32.9 (3.3)	19.0 (.8)	26.0 (2.0)
ET												
ET1	3.1 (.1)	3.3 (.1)	3.2 (.1)	2.2 (.2)	2.3 (.1)	2.3 (.1)	2.6 (.1)	2.8 (.1)	2.7 (.1)	2.7 (.1)	2.8 (.1)	2.7 (.1)
ET2	6.6 (.1)	8.1 (.1)	7.3 (.1)	6.5 (.1)	7.6 (.2)	7.1 (.1)	8.1 (.3)	7.8 (.2)	7.9 (.21)	7.1 (.2)	7.8 (.1)	7.4 (.2)
ET3	32.3 (.6)	33.6 (.4)	32.9 (.5)	34.7 (.4)	35.4 (.1)	35.1 (.3)	37.0 (.4)	37.3 (1.4)	37.2 (.9)	34.7 (.5)	35.4 (.62)	35.1 (.5)
CP	4	3	3.5	3	3	3	3	3	3	3.3	3	3.2

NAT (Non Aerial Techniques): ABS (Absorption), MAN (manual), PULL (pull), ABS-C (complete absorptions); AT (Aerial Techniques): SJ (simple jump), TJ (technical jump); MT (mixed techniques), OM (overtaking). PC (Pedalling Cycles): PC1 (pedalling cycles to the first obstacle), PC2 (pedalling cycles on the first straight), PC3 (pedalling cycles in the complete race); ET (Effort Times): ET1 (effort time from gate start to first obstacle), ET2 (time from gate start to first curve), ET3 (time from gate start to finishing line); CP (curve passes).

non-aerial techniques for the 2007 season between thedifferent tracks ($p > 0.05$). However, there were significant differences for the 2008 season between E vs. W ($p = 0.007$) and between E vs. O ($p < 0.001$) -more non-aerial techniques in E type tracks-, and between W vs. O ($p < 0.001$) -more non-aerial techniques in W tracks-. When we analyzed the different non-aerial techniques individually in both seasons and tracks, although in the 2007 season in general statistical significance was not reached, there were differences for the techniques ABS-C (complete absorption) and MAN (manual) between E vs. W ($p \leq 0.017$), for the techniques ABS (absorption), MAN, PULL, ABS-C between E vs. O ($p \leq 0.015$), always in favor (more) of the E tracks, but not between W vs. O ($p > 0.05$). When we observed the results of the statistical contrast between the 2008 season for each of the non-aerial techniques and between the different tracks, we found that between E vs. W the differences were statistically significant for the techniques ABS and ABS-C ($p \leq 0.002$), between E vs. O for all techniques (ABS, MAN, PULL, ABS-C, $p \leq 0.012$), in favor (more) of the E tracks, and finally between W vs. O for ABS and MAN ($p \leq 0.001$) in favor of W tracks.

On the other hand, the contrast for related samples

Table 2. **Non-parametric contrast test for independent samples (Mann-Whitney) between tracks for 2007 and 2008 seasons; and non-parametric test for related samples (Wilcoxon) between the two seasons and each track. Data are p < 0.05.**

		NAT	ABS	MAN	PULL	ABS-C	AT	SJ	TJ	MT	OM	PC1	PC2	PC3	ET1	ET2	ET3	CP
Independent samples																		
	Year																	
E vs. W	**2007**	-	-	.002	-	.017	-	.027	.001	-	-	.001	-	.027	.001	-	.001	.000
	2008	.007	.001	-	-	.002	-	-	.001	-	-	.000	-	.05	.001	.001	.001	-
E vs. O	**2007**	-	.012	.002	.015	.012	-	-	.001	.027	-	.002	-	.004	.001	.001	.001	.000
	2008	.000	.001	.001	.012	.000	-	-	.001	-	-	.002	.001	.001	.001	-	.001	-
W vs. O	**2007**	-	-	-	-	-	-	-	-	-	-	-	-	-	.001	.001	.001	-
	2008	.000	.001	.000	-	-	-	-	.001	-	-	.045	.001	.001	.001	.015	.002	-
Related samples																		
	Race																	
2007 vs. 2008	**E**	-	.011	.018	.048	-	-	.017	-	-	-	.011	.010	.012	-	.012	.012	.005
	W	-	.016	-	-	-	-	-	.016	-	-	-	.011	.012	-	.012	.017	-
	O	-	-	.011	-	.024	-	-	-	-	-	.017	.011	.011	-	-	-	-
	E, W & O	.043	.003	.003	.001*	.003	-	.000	.001	-	.012	.000	.000	.000	.013	.000	.001	.005

ABS (Absorption), MAN (manual), PULL (pull), ABS-C (complete absorptions), SJ (simple jump), TJ (technical jump), MT (mixed techniques), OM (overtaking), PC1 (complete pedalling cycles in the race), PC2 (pedalling cycles to the first obstacle), PC3 (pedalling cycles on the first straight), ET1 (effort time from gate start to first obstacle), ET2 (time from gate start to first curve), ET3 (time from gate start to finishing line), CP (passes per curve).

showed that significant differences did not exist between the 2007 vs. 2008 seasons in general for NAT for any tracks. However, when we contrasted the different NAT techniques individually between the different tracks finding significant differences between both seasons for ABS and PULL, in favor of 2008, and in MAN technique in favor of 2007 for E track ($p \leq 0.04$), in favor of ABS on the W track in 2008 season ($p = 0.16$), and in favor of 2007 in MAN and ABS-C on O track ($p \leq 0.024$).

Finally and even more important, when we matched all the tracks together from 2007 vs. 2008 significant differences were shown between all the NAT techniques ($p \leq 0.043$) with higher values in the 2007 season (*see* Table 2).

Aerial techniques (AT)

The results have shown that significant differences did not exist between aerial techniques for any of the seasons ($p > 0.05$). When we compared the different aerial techniques individually between seasons and between tracks, there were differences for 2007 season in SJ (simple jump) and TJ (technical jump) techniques between E vs. W ($p \leq 0.027$), in favor of the W track, and in TJ technique between E vs. O ($p \leq 0.001$), in favor of the O track. When we look at the results of 2008 season we find significant differences for TJ when comparing all the tracks ($p = 0.001$) in favor of W and O vs. E, and in favor of W vs. O. Moreover, the contrast for related samples did not show significant differences between the 2007 vs. 2008 season in general for AT. However, when we analyzed the different AT individually between the different tracks significant differences were found between seasons for SJ techniques on E track in 2007 ($p \leq 0.017$), and for TJ on W track in 2008 season ($p = 0.016$).

Finally, when we compared all the tracks together between 2007 and 2008 seasons significant differences ($p < 0.001$) were found between SJ (in favor of 2007) and TJ (in favor of 2008) (*see* Table 2 and Figure 1).

Mixed techniques (MT) and overtaking maneuvers (OM)

The analytical results for MT and OM show that there were no significant statistical differences for the majority of cases when we make contrast between track types within the same season. Differences emerge for MT only in the *pre*-Olympic year 2007, between E and O tracks ($p = 0.027$), in favor of the track type O. Overtaking manoeuvres varied across the three types of track according to the season they are compared ($p = 0.012$) (*see* table 2).

Pedalling cycles (PC): The results showed statistically significant differences in PC1 for the 2007 season between E vs. W and E vs. O ($p \leq 0.002$) in favor of E, but not for W vs. O. On the other hand, 2008 season results showed statistical significance for all the comparisons between the different tracks (E, W and O, $p \leq 0.045$) for PC1, in favor of W track, while O was second and E in third place.

When we compared PC2, we found statistical significance for 2008 season between E vs. O (in favor of E) and W vs. O (in favor of W, $p = 0.001$). On the other hand, when we analyzed the results for PC3 statistically significant differences were found for the 2007 season between the E vs. W and E vs. O by 11.85 and 24.23% respectively ($p \leq 0.027$) in favor of E. When we compared in 2008 season all the PC techniques (PC1, PC2 and PC3) results showed statistical significance between the different tracks (E, W and O) for the three PC ($p \leq 0.05$).

The contrast for related samples showed that significant differences exist between the 2007 vs. 2008 season for PC1, PC2 and PC3 in all types of track (E, W and O, $p \leq 0.017$), except for PC1 on the W track that showed a trend towards significance ($p = 0.059$). Finally, when matching the results of the three tracks between both seasons (2007 vs. 2008) for the PC (PC1, PC2 and PC3 together) statistical significance was highly significant in all the relationships ($p < 0.001$) (*see* Table 2).

Effort times (ET) and passes per curve (CP): The

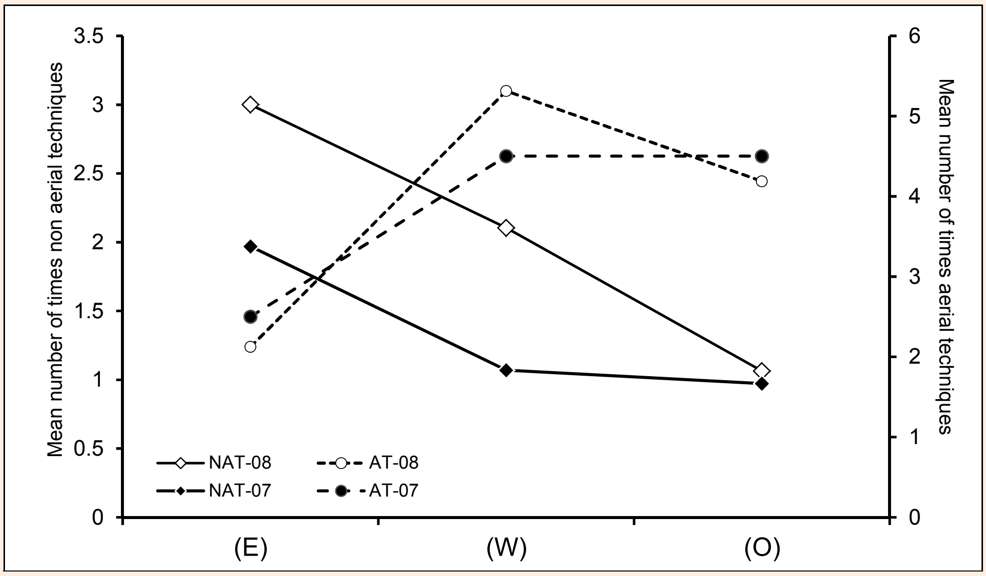

Figure 1. Comparison of aerial and non-aerial techniques (mean number of times) in the three tracks of 2007 and 2008 seasons.

results of time of effort have shown statistically significant differences between the different tracks E vs. W, E vs. O and W vs. O for 2007 and 2008 in the three parameters measured (ET1, ET2 and ET3; $p \leq 0.015$), with the exception of ET2 in the 2007 season for E vs. W, and in the 2008 season in E vs. O. When we compared the two seasons we found significant differences between E and W tracks for ET2 (in favor of E) and for ET3 (in favor of W) ($p \leq 0.017$). Finally, when the contrast was made between the three tracks in both seasons according to the three ET (ET1, ET2 and ET3 together) significant differences were found in all cases ($p \leq 0.013$) (*see* table 2), in favor of O, secondly W and finally E (ET of 37.31, 35.06, and 32.92 respectively) with percentage differences between O vs. W and E of 6.50 and 12.94% respectively.

The CP variable only showed significant differences for the 2007 season between E and W, and between E and O ($p < 0.001$), in favor of E track (*see* Tables 1 and 2). When the comparisons between seasons were made, only for E track statistical differences were found ($p = 0.005$) (*see* Tables 1 and 2).

Discussion

The central finding of this study indicates that BMX track design significantly impacts upon the technical difficultly and the execution of differing BMX skills. The first important observation is that the newer W and O track designs increase the frequency of aerial technique execution (AT) with a concomitant reduction in the frequency of NAT relative to the traditional European track design. These observations support the view that on E type tracks where qualifying points are contested for the Olympic Games rankings, riders who demonstrate higher levels of physiological conditioning (Mateo et al. 2011b; Mateo et al. 2012) may be advantaged relative to the rider with better aerial bike handling skills. These E and W tracks present a start ramp with a lower gradient (~15% in both cases) compared to the O track (that starts at ~17% in the first third of the ramp and then 27% in the rest of the ramp). This may affect the acceleration in the first meters of the race. Also, E track requires greater initial pedaling effort in order to achieve the first obstacle that is later than in W and O tracks (more meters pedaling at the start), requiring also a greater number of pedal cycles throughout the race and registering a lower flight time in the aerial phases that also require the application of a high degree of physical effort in the execution of different NAT techniques. Conversely, in W and O tracks the main technical action required is that of the jump, incline and acceleration with less pedalling effort initially to the first obstacle (that is located 3-5 meters closer to the starting hill than in the E track) but also throughout the event, features which may predispose towards riders with greater technical ability rather than physical conditioning. In both contexts the time from the start gate to the first obstacle is significantly lower in the latter type W and O relative to type E track. In this regard, the technical level of participants in the three competitions is almost the same, and the final result is mainly due to the acceleration phases, especially at the start.

These track design modifications have been implemented generally to increase the spectacle of high-level BMX competitions by the UCI. The increase in jump execution and greater aerial time theoretically allows for a more spectacular television and spectator experience. However, this may not be the case. Current data indicate that despite greater track complexity there may actually exist a propensity for reduction in overtaking/positional challenge that would facilitate the spectacle. We speculate that these technically difficult tracks (W and O) ensure that after the initial first few obstacles the positional jockeying that was a feature of type E racing is removed and that only 3-4 of the riders who achieved a positional advantage out of the start gate or into the first obstacle can compete for victory (Herman et al., 2009). It is, therefore, important for the rider that they attain a position on the starting gate, or out of the starting gate that advantages them in terms of optimizing their position going into the first obstacle and bend.

Qualification processes for Olympic riders thus requires riders to compete on several track types that require them to have/execute widely differing physical and technically differing skill sets. From an athlete's perspective, the greater complexity and amplitude of the type W and O track design leads to a concomitant need to improve their techno-tactical and conditioning preparation to overcome such issues as detailed above. Initially the technical optimization of BMX athletes could prevent typical injuries (Brøgger-Jensen et al., 1990; Worrell, 1985) arising from the lack of technique in complicated tracks that many times finish in an accident.

A systematized process of technical and tactical training evolving from the type E tracks to the W and new O tracks is needed. As such the optimal type of preparation must be focused on working on the predominant techniques requested in each track type, specifically taking into account that the starting gate generally shows greater slope in O tracks.

It is possible that the less experienced Junior category riders could be the most adversely affected if they compete at W and O championship tracks, because the opportunity to practice on these tracks in Europe is limited (unless replica tracks are designed as has been the case for British Cycling prior to the 2008 Beijing Games and recently for the 2012 London Games). Special importance should also be given to the strategies for dealing with the increase in anxiety and self-confidence that this type of track can generate in these riders because of the increase of the tactical complexity, technical difficulty, speed and risk of injury that the new designs may impose.

Conclusion

The current study suggests that the "modern BMX" type tracks (W and O) that the UCI establishes for its most important competitions differ significantly from "classical BMX" type tracks (E). Bicycle motocross cyclists develop a greater percentage and significantly higher values of AT in W and O tracks compared with the E track, and consequently reduced NAT. World and Olympic class tracks are much more technical than E tracks, and show lower physical demands. Also, O tracks seem to be even more technical than W tracks, mainly because of the more difficult and decisive jumps. For these reasons, a revision in the prescription of technical and conditional training is necessary according to the objectives established for each athlete, and also taking into account the type of tracks that are going to be faced during the season.

Acknowledgements

Special thanks to Allistair McRobert (Liverpool John Moores University, UK) for reviewing previous versions of the manuscript. The authors declare no conflict of interest.

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Key points

- European tracks involve more non aerial techniques than world and Olympic tracks, respectively; more non aerial techniques are associated with more pedaling effort time.
- Bicycle motocross cyclists develop greater values of aerial Techniques in World and Olympic tracks compared with the European tracks and, consequently, reduced non aerial techniques.
- European tracks involve less technical jumps but more simple jumps. World tracks involve more technical jumps than European and Olympic tracks, but Olympic track jumps, despite being less in number, are more difficult and decisive than the rest.
- Olympic and World class tracks involve less physical demand than European tracks because of the greater technical requirements and less pedaling cycles.
- Training should be developed according to the objectives established for each athlete taking into account the type of track in which the competition is going to take place.

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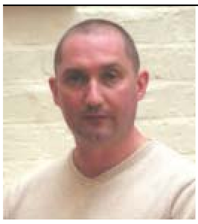

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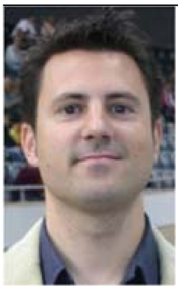

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