ELITE BMX CYCLISTS USE INDIVIDUAL STRATEGIES FOR A SUCCESSFUL START

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A fast start during BMX racing is strongly related to superior performance. The purpose of this study was to identify which aspects of starting technique were related to a further distance after 1 second, an indication of an advantageous starting position. Significant between-cyclists differences were found in set position kinematics and starting technique. Whilst each cyclist had specific aspects of the start related to superior performance, two of the cyclists had strong correlations with vertical velocity of the bicycle at gate drop and at 1 second, indicating the higher the wheel was lifted, the further the distance reached after 1 second. These data provide further insight into how BMX cyclists propel the bicycle from a stationary position to attain an advantageous position as quickly as possible.

KEY WORDS: racing, cycling, performance

INTRODUCTION: In BMX cycling, a fast start is strongly related to overall race performance. Specifically, data from four World Cup races identified a strong positive correlation between cyclists who were placed in the top three after 8 seconds and those placed in the top three at the end of the race (Rylands & Roberts, 2014). From a standing start position, the cyclist needs to attain race speed as quickly as possible to be faster than their opponents and place themselves in a favorable position (Gianikellis, Skiadopoulos, & Bote, 2011). The start of the race encompasses 2.5-3 pedal strokes and race analysis has revealed that male BMX cyclists can attain velocities at the bottom of the start ramp of on average 56.89 km/h attained within 2.62 sec (Cowell, McGuigan, & Cronin, 2012). For this reason, the ability to successfully propel the bicycle forward during the start is an essential performance indicator.

Despite this, there is a paucity of research on the technique during the BMX gate start to identify how the start is most effectively executed. This is likely due to the highly dynamic environment of BMX and the relatively new addition of the sport on the Olympic program.

Gianikellis, Skiadopoulos, & Bote (2011) investigated the starting technique of three elite male cyclists (small subject numbers) and identified between-cyclist differences including the presence of a countermovement and the direction of the bicycle when the gate drops. They determined that cyclists utilize their own unique methods to perform the start. This study, however, was conducted at 50hz, potentially missing crucial technique parameters and with one trial per cyclist were unable to determine which strategy was most predictive of a superior performance. Kalichova et al. (2013) expanded on the previously mentioned study and identified five distinct phases of the BMX start. The start technique of one male and one female elite cyclist were then collected (100hz) with the fastest time (from the red start signal until the end of the second pedal stroke) further analyzed. How these strategies were related to performance, however, was not investigated.

As there remains little biomechanical data of the start technique available, relationships between technique and performance have not been reported. As a result, coaches and scientist remain unsure about the optimal starting technique, identifying the need to investigate which techniques contribute to a successful BMX SX gate start. For this reason, the purpose of the current study was to determine the relationship between the technique of the standing start and performance in elite male BMX cyclists. It was hypothesized that there would be a significant positive correlation between velocity of both the bicycle and hips at gate drop and the distance attained in one second. A secondary purpose was to assess whether elite cyclists utilize different set starting positions and techniques.

METHODS: Three elite male BMX cyclists (age 23.7±2.5yrs, mass 91.5±2.12kg, height 188.0 ± 1.4cm) from the Netherlands National team participated in this study. This study was conducted on a start ramp (4.5m in length with a 16° incline) instrumented with an Olympic standard mechanical start gate and start signal (Pro-Gate) designed to practice starts and was not on a regulation BMX course.

Two calibrated high-speed cameras (240 Hz, CASIO Exilim) were positioned to provide a sagittal view of the athlete and the cycling path. The left camera was positioned 4m from the starting hill such that the midpoint of the starting hill was the middle of the camera field of view. This resulted in the cyclist's starting position being on the right third of the camera view. Due to the constraints of the environment, the camera on the right of the cyclist was solely used for measuring starting position kinematics. The start signal, located to the cyclists' right side, was visible in the left camera field of view. Each cyclist wore black fitted pants and joint centers were identified with white strapping tape. Markers were placed on the athlete's left and right lateral malleolus, lateral condyle of the knee, and hip joint center. In addition, a marker was placed on the middle of the wheel hub (on the left side) to provide bicycle velocity (Gianikellis, Skiadopoulos, & Bote, 2011). Using their own regulation bicycle, each cyclist raced independently. Following a warming up, each cyclist performed six maximum effort start trials. Due to technical difficulties, five trials were collected for Cyclist 1. Rest periods between each start were self-selected and a minimum of five minutes in length.

In line with previous research investigating the BMX gate start (Grigg et al., 2017), data was analyzed from the time of the red start light (time = 0 s). The cyclist starts in a stationary set position with the front wheel resting against the start gate. Bilateral lower body and trunk angles of this position were measured. The bicycle and left hip marker were digitized and Butterworth filtered with a 30Hz cut off frequency using analysis software (Biomechanics software version 21; Quintic Biomechanical Software v. 21, Quintic Consultancy Ltd, Coventry, United Kingdom). For each trial, the time per phase was calculated as defined by Kalichova et al. (2013) as; 1) time of the red light until movement initiation of the cyclist; 2) movement initiation until start of the first pedal stroke; 3) first pedal stroke until its finish; 4) time delay between the first and second pedal stroke; 5) second pedal stroke. A component of an effective start is for the cyclist's bicycle to move forward at the moment of gate drop (Kalichova et al., 2013). For this reason, the horizontal distance the bicycle travels backwards as well as the velocity of the bicycle and hips at the moment the start gate drops were analyzed. In addition, as the goal of the gate start is to obtain an advantageous position to lead the race, the horizontal distance the cyclist attained in 1 s after the start of the red light was used as performance criterion.

In order to investigate whether there were between-cyclist differences in set position kinematics and starting technique, a one-way ANOVA was conducted (Microsoft Excel 2013). For each cyclist, the Pearson's product-moment correlation was used to investigate the relationship between starting technique and the distance travelled 1 s after the start signal. The significance of strong correlations over 0.5 were then determined. Statistical significant was set at $p<0.05$

RESULTS: In the set position, there was a between-cyclist difference in the magnitude of plantarflexion in the trail leg ($F=5.9845$, $p<0.05$). Significant between-cyclist differences in knee flexion were observed (Table 1; lead $F=4.2497$, $p<0.05$; trail $F=210.61$, $p<0.001$). Between-cyclist differences in lead ($F=16.77$, $p<0.001$ and trail ($F=88.591$, $p<0.001$) leg hip flexion and trunk flexion ($F=40.152$, $p<0.001$) were also observed.

Table 1: Set position kinematics for all elite male BMX cyclists (mean ± SD). Significant between-cyclist (*) differences were observed.

	Cyclist A	Cyclist B	Cyclist C
Lead leg ankle angle (°)	103 ± 3	111 ± 3	X
Trail leg ankle angle (°)	91 ± 7*	102 ± 3*	97 ± 5*
Lead leg knee flexion angle (°)	163 ± 1*	158 ± 2*	159 ± 5*
Trail leg knee flexion angle (°)	162 ± 3*	131 ± 2*	130 ± 4*
Lead leg hip flexion angle (°)	81 ± 2*	76 ± 2*	82 ± 2*
Trail leg hip flexion angle (°)	102 ± 2*	85 ± 2*	90 ± 1*
Trunk flexion angle (°)	5 ± 2*	7 ± 1*	14 ± 2*

Trunk flexion in reference to the horizontal; X due to environmental constraints this was not visible.

Significant between-cyclist differences were observed as Cyclist A moved his bicycle backwards away from the start gate the least, while Cyclists B and C move a similar, and further, distance away ($F=5.34286$, $p<0.05$; Table 2). There were strong, significant, positive correlations found between the vertical velocity of the bicycle at gate drop and the distance after 1 s in Cyclist A (r=.916, p<0.05) and C (r=.855, p<0.05). A significant between-cyclist difference was also observed in the linear velocity of the hip at the moment of gate drop (F=8.01322, p<0.05), although there was no significant correlation found between hip velocity and final distance in any of the riders. A significant positive correlation was observed in Cyclists A (r=.799, p<0.05) and C (r=0.9673, p<0.01) between instantaneous vertical bicycle velocity at 1 s and distance. No difference or correlation was found for linear hip velocity at 1 s. When comparing the fastest trial of each cyclist, if they started simultaneously, after 1 s Cyclist A would be ahead of Cyclist C by 3 cm and Cyclist B by 9 cm. Although these are small variations, a difference 9 cm would allow for Cyclist A to move his wheel in front of Cyclist B to obtain an advantageous position to lead the race. Between-cyclist differences were found in Phase 1 (reaction time), Phase 2 (preparation movements), and Phase 5 (second pedal stroke) (Table 2). No between-cyclist difference was found in Phase 3 (first pedal stroke) or Phase 4 (dead point pedal passage).

Table 2: Parameters for all elite male BMX cyclists (mean ± SD). Significant between-cyclist differences (*) were observed. Strong correlations were significant (#) with distance.

	All cyclists	**Cyclist A**	**Cyclist B**	**Cyclist C**
Phase 1 (reaction time) (s)	**0.163 ± 0.012***	0.152 ± 0.008	0.173 ± 0.009	**0.163 ± 0.010#**
Phase 2 (preparation movements) (s)	**0.305 ± 0.033***	0.341 ± 0.025	0.299 ± 0.024	0.281 ± 0.017
Phase 3 (first pedal stroke) (s)	0.315 ± 0.032	0.291 ± 0.032	0.318 ± 0.028	0.332 ± 0.026
Phase 4 (dead point pedal passage) (s)	0.040 ± 0.016	0.035 ± 0.020	0.043 ± 0.016	0.042 ± 0.014
Phase 5 (second pedal stroke) (s)	**0.325 ± 0.020***	0.315 ± 0.009	0.316 ± 0.014	0.344 ± 0.021
Distance bicycle goes backwards (cm)	**11.9 ± 2.2***	9.0 ± 2.0	12.3 ± 1.4	13.0 ± 2.0
Linear bicycle velocity at gate drop (m/s)	0.88 ± 0.22	0.84 ± 0.23	0.85 ± 0.24	0.95 ± 0.21
Vertical bicycle velocity at gate drop (m/s)	0.05 ± 0.24	**0.16 ± 0.23#**	0.04 ± 0.16	**-0.04 ± 0.31#**
Linear hip velocity at gate drop (m/s)	**1.50 ± 0.11***	1.59 ± 0.09	1.40 ± 0.08	1.54 ± 0.09
Linear bicycle velocity at 1 s (m/s)	**4.00 ± 0.37***	4.51 ± 0.17	3.90 ± 0.06	3.68 ± 0.15
Vertical bicycle velocity at 1 s (m/s)	-0.83 ± 0.27	**-0.87 ± 0.23#**	-0.89 ± 0.31	**-0.75 ± 0.29#**
Linear hip velocity at 1 s (m/s)	4.59 ± 0.17	4.64 ± 0.25	4.54 ± 0.13	4.60 ± 0.14
Hor distance 1 s (m)	**1.53 ± 0.06***	1.59 ± 0.04	1.49 ± 0.03	1.53 ± 0.08

DISCUSSION: During BMX racing, the start has been identified as a crucial component predictive of the final performance (Rylands & Roberts, 2014). At the start of a race, the cyclist is in a balance position with their feet and pedals at an angle such that they are able to generate maximum power once pedaling commences (Zabala, Sáchez-Muñoz & Mateo, 2009). Zabala and colleagues (2009) suggested that approximately 90° of ankle plantarflexion in the lead leg would meet this criterion. In the current study cyclists utilized a plantarflexion angle approximately 10° more than previously reported. Cyclist B and C displayed similar knee flexion magnitudes as found in previous male cyclists (Gianikellis, Skiadopoulos, & Bote, 2011; Table 1). Interestingly, Cyclist A employed a very different strategy where there was no difference in knee flexion between the legs. Previous research has identified for the hips to be positioned approximately 90° to the trunk (Cowell, McGuigan & Cronin, 2012). Cyclist A averaged 102° of hip flexion in his trail leg, likely as a result of the greater knee flexion angle in the trail leg. This set position suggests that Cyclist A's hips were translated in such a way for him to place his knees this position. In order to further understand the influence of this hip position on performance, we aim to include three-dimensional analysis in the future. Finally, whilst Gianikellis et al., (2011) identified trunk flexion of 15° to the horizontal, only Cyclist C employed a similar trunk flexion position. Cyclist A and B had less trunk flexion, indicating they kept their trunk lower to the ground. It is evident that individual set position kinematics are present, even at the elite level. Previous research (Kalichova et al., 2013) identified Phase 3 to be the longest (0.366 s). In the current study, on average, the longest phase was Phase 5 with Phase 3 being the second longest phase (Cyclist A 0.315 s and 0.291 s, respectably). Since the previous study also investigated an elite male BMX cyclist, the discrepancy in findings may be due to the differences in methodology or instrumentation.

To have an effective start after the start signal (red light), the cyclist should anticipate the start and react before the gate drops by moving their bicycle backwards using a countermovement. At the time of gate drop, however, the bicycle should be moving forward. In the current study, in his first trial Cyclist B was still moving backward at the moment of gate drop, instead of forward, suggesting that he needs to work on anticipating the start better and initiate movement earlier. The velocity of the bicycle at the moment of gate drop appears to be an important variable as there were strong, significant, positive correlations between the vertical velocity of the bicycle at that moment and the distance after 1 s in Cyclist A and C. As they are traveling down a start ramp, a negative vertical velocity indicates the bicycle was moving downwards and a positive vertical velocity indicated the bicycle was moving upwards, demonstrating the wheel was lifted. The higher the wheel was lifted at gate drop, the further the distance attained after 1 s. Although it is unclear why this is the case, this further distance is potentially due to the greater potential energy at gate drop being converted into mechanical work. Instantaneous vertical bicycle velocity at 1 s also appears to be an important variable of a successful start. In the furthest two cyclists (A and C), there was a significant positive correlation observed indicating that a further horizontal distance after 1 s also had less vertical velocity of the bicycle. As the wheel is still off the ground at this point, cyclists that were able to keep their wheel higher off the ground attained a further distance. The hips are an important component of transferring the cyclists' body mass forward to propel the bicycle forward. We found a significant between-cyclist difference in hip velocity at the moment of the gate drop. Further analysis should investigate the relationship between hip and bicycle velocity to determine how they are influenced and how they can be optimized during the BMX start.

CONCLUSION: In BMX cycling, a successful start is advantageous for the overall performance. The results of the current study indicate that at the elite level, male BMX cyclists employ individual techniques during the start. However, vertical velocity of the bicycle appears to be a discriminating factor for enhanced performance. However, these results are from a small population and future research should investigate a larger group of athletes to identify whether these variables remain present amongst all cyclists. Quantifying cyclist-specific starting strategies provides further insight for sports scientists and coaches into how each cyclist is producing the start and identifies which aspect may be optimized.

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