

The effect of 'Pumping' and 'Non-pumping' techniques on velocity production and muscle activity during field-based BMX cycling.

Abstract

The aim of the current study was to determine if a technique called 'pumping' had a significant effect on velocity production in BMX cycling. Ten National standard male BMX riders fitted with sEMG sensors completed a timed lap of an indoor BMX track using the technique of pumping, and a lap without pumping. The lap times were recorded for both trials and their surface sEMG recorded to ascertain any variation in muscle activation of the biceps brachii, triceps brachii, vastus lateralis and medial gastrocnemius. The findings revealed no significant differences between any of muscle groups ($p > 0.05$). However, significant differences ($p < 0.001$) were observed between the pumping and non-pumping trials for both mean lap velocity ($42 \pm 1.8 \text{ km.h}^{-1}$, $33 \pm 2.9 \text{ km.h}^{-1}$ respectively) and lap times ($43.3 \pm 3.1 \text{ s}$, $34.7 \pm 1.49 \text{ s}$, respectively). The lap times recorded for the pumping trials were $19.50 \pm 4.25 \%$ lower than the non-pumping. Whereas velocity production was $21.81 \pm 5.31 \%$ greater in the pumping trial when compared to the non-pumping trial. The technique of pumping contributed significantly to velocity production, though not at the cost of additional muscle activity. From a physiological and technical perspective, coaches and riders should prioritise this technique when devising training regimes.

Introduction

Despite the reported popularity of Bicycle Motocross (BMX), research surrounding the physiological demands of this cycling discipline remains

limited. Recently however, researchers have started to take a greater interest in this esoteric activity (14, 6, 7, 13). A large proportion of this research has concentrated on the contribution of the lower limbs on velocity production (i.e. power, torque, rate of force production (8, 17). There is, to date, however, a shortage of studies which have investigated the effect of the upper body on velocity production in BMX cycling (1, 16). This is in contrast with other cycling disciplines, where upper body muscle activation has been captured using surface electromyography (sEMG) (2, 10, 11, 15). For instance, Hurst et al. (2016) analysed the possible fatigue effect of wheel size on the upper body in cross country mountain bikers. Hurst et al. (2016) reported no significant difference in the upper body muscle activation between riders who rode with three different wheels sizes. Thus rejecting the hypothesis that larger wheels reduce muscle activity and as a result reduce fatigue. To date, no studies have analysed performance in BMX cycling using a sEMG, and only two studies have examined the contribution of the upper body on performance.

For example, Bertucci et al. (2005) analysed the effect of the upper body on performance in BMX cycling. Bertucci's study showed that 32% higher force was applied to the bicycle during standing sprints, when compared to seated sprints. Similar findings were reported in a study that compared laboratory sprints on a cycle ergometer to sprints performed on a BMX track when riders used their own bikes (16). Rylands et al. (2015) concluded that the laboratory cycle ergometer restricted the natural lateral oscillation of the bicycle and resulted in a mean reduction in power of 34 %. Both of these studies confirmed that the oscillation of a BMX bicycle is

only possible when a rider is pedalling, as the movement is used as leverage by the upper body (1, 16).

However, these oscillation movements are not the only upper body contributions reported to have an impact on BMX cycling. Cowell et al. (2012a) performed a skill and movement analysis on six male BMX riders. The authors reported that during a BMX race 31 % (9.64 s) of the race was spent pedalling, with 6.6 % of the time spent pedalling down the start ramp (2.62 s) in which upper body oscillation occurs. Cowell et al. (2012a) also noted other contributions of the upper body movement, and commented that during a BMX race 44 % of the time (17 s) was spent pumping.

Pumping is a term used to describe a technique performed by a BMX rider on the rhythm section of a BMX track during the race. The technique of pumping has been reported by competitive riders as a 'natural movement' or in academic terms an autonomous motor function (5, 12, 20). The rhythm section of the track where the technique is performed encompasses a straight section with a number of rolling mounds/hills (see Figure 1). The technique requires the rider to push down the front wheel of the bike at the top of a hill, in order to maintain maximum velocity during the rhythm section.

If indeed 44 % of the total time of a BMX race is spent pumping it could be hypothesised that the pumping technique is an important factor in the race. Based on such considerations, the aim of this study therefore, was to analyse the effect of pumping on the production of velocity whilst riding on a BMX track.

Methods

Experimental Approach to the Problem

The subjects were tested twice in a single day with 30 minutes rest between trials. Each rider was competent at performing the pumping technique and had the opportunity to familiarise themselves with the non-pumping technique. The trials were all performed on a purpose-built indoor BMX track at the National Cycling Centre in Manchester (UK). All of the riders were in the competition phase of their season, but had not raced for a minimum of three days prior to the test. Each rider ensured they had eaten a minimum of one hour prior to the test and consumed fluids throughout the day to maintain hydration.

Subjects

Ten national standard BMX cyclist (mean age 23 ± 3 yrs. body mass 71 ± 3 kg 175 ± 7 cm) participated in the study. All riders had competed at a national and an international level for a minimum of 8 years, and had race experience on the track used for testing (National Cycling Centre BMX Track, Manchester, UK).

A detailed description of the test protocol was issued to all riders and written and informed consent was obtained from each participant prior to the study. The riders were informed of the benefits and risks of the investigation prior to signing the consent form. The research project received ethical approval from the University of Derby Ethics Human

Studies Board and the study was conducted according to the recommendations of the Helsinki Declaration.

Procedures

In order to establish if the upper body activity significantly affected velocity production, two separate randomised trials were performed on the indoor BMX track. The indoor track had a 5 meter high start ramp with a 28° decent. The track measured 400 meters in length, comprised four straights, with a number of technical jumps on each straight section, and three berms (corners). The order of the trials were randomised and conducted on the same day.

//////////////////////////////////////insert figure 1 here//////////////////////////////////////

The riders performed a structured warm-up consisting of three 10-second sprints from a 5 meter high start ramp using a standard electronic start gate (Pro-Gate, Rockford, Illinois, USA). Randomised trial consisted of the riders completing a full lap of the track using a pumping technique or non-pumping. technique in two separate laps. A 30-minute rest period was provided between the trials to avoid fatigue. Both trials were recorded using a HD Camera (Panasonic HC- X900) with shutter speed of 1/8000th of a second. This device was also used to record the lap times.

Surface Electromyography

A surface electromyography (sEMG) was used to establish any variation in muscle activation between the trials

The sEMG data was recorded on the rhythm section of the BMX track. The surface electromyography (sEMG) was used at the biceps brachii, triceps brachii, vastus lateralis and medial gastrocnemius. To record the sEMG a wireless mobile electromyography system was also used (Delsys Trigno, Delsys, Massachusetts, USA), with data recorded at 1926 Hz. The sEMG sensors utilised two parallel bars at 1 cm spacing to reduce cross-talk between muscles (9) and were positioned following preparation of the muscles. This involved shaving the area of sensor placement, lightly abrading and then cleaning with alcohol wipes in order to minimise skin impedance. The sensors were all fitted medially to the left side of the rider's body running parallel to the muscle fibres. Placement of the sensors was in accordance with the Surface EMG for Non-Invasive Assessment of Muscles project SENIAM(18) recommendations. The sensors were held in place using elasticated bandages.

Post data collection, the sEMG data were full-wave rectified and then filtered at 20 Hz using a second order low pass Butterworth filter. Normalisation of data followed the method of Sinclair et al. (2012). Sinclair et al (2012) conducted a field study examining sEMG in running and stated that the environment did not allow the researchers to normalise the sEMG signal to a maximal voluntary isometric contraction (MVIC). The rationale being that the action of running involves dynamic muscular activity. As a result Sinclair et al. (2012) proposed that sEMG data should be normalised to a dynamic peak task (DPT) that being the peak amplitude observed during the field-based trials. As BMX cycling

also involves dynamic muscle activity this protocol was incorporated into this study. The peak amplitude recorded during the two trials was used as the (DPT) and all sEMG data are presented as a percentage of the DPT. Data were not captured from two of the riders due to unknown reasons. Therefore, sEMG data were analysed for the 8 complete data sets recorded, whilst all 10 riders lap times were used for analysis of differences between techniques.

Statistical Analyses

The independent variables in the analyses were pumping and non-pumping techniques. The dependant variables were lap time, upper body muscle activation and lower body muscle activation. Normality of data were first confirmed using a Shapiro-Wilk test. Differences in muscle activity were first determined between pumping and non-pumping techniques using paired sampled t-tests. To determine any statistical differences within muscle groups, and to establish whether muscle recruitment differed by technique, data were subjected to a within groups repeated measures analysis of variance (ANOVA). Where significant differences were observed, Bonferroni pairwise comparisons were used to determine where the differences occurred, and to control for type I errors. Effect sizes were determined using partial Eta² (η^2). Partial eta squared were interpreted based on their magnitude, where a value between 0.0 - 0.1 indicates a small effect, 0.1 - 0.3 a medium effect, 0.3 - 0.5 a moderate effect and >0.5 is a large effect (19). Data are presented as mean \pm standard deviation unless stated otherwise. All statistical

analyses were conducted using SPSS 21.0 (SPSS Inc., Chicago, Illinois, USA)

Results

The results showed a significant difference existed between the riders' lap times when performing the pumping technique when compared to non-pumping ($F(1,9) = 143.457$; $p = 0.001$; $\eta^2 0.941$). The mean percentage time difference between pumping and non-pumping was $19.50 \pm 4.25 \%$ (34.7 ± 1.49 s, 43.3 ± 3.1 s respectively).

//////////////////////////////////Insert Figure 2 here//////////////////////////////////

A significant difference ($F(1,9) = 2643.882$; $p = 0.001$; $\eta^2 0.997$) was also found between the velocity in the pumping and non-pumping trials, with riders mean velocity in the pumping trail (42 ± 1.8 km.h⁻¹) being $21.81 \pm 5.31 \%$ greater than the non-pumping (33 ± 2.9 km.h⁻¹) trial.

The sEMG results revealed no significant differences when comparing muscle activity between pumping to non-pumping for each muscle group; Biceps Brachii $t(7) = .319$, $p = .76$, Triceps Brachii $t(7) = .730$, $p = .49$, Vastus Lateralis $t(7) = .398$, $p = .702$ and Gastrocnemius $t(7) = -.492$, $p = .64$. Furthermore, no significant differences were found between muscle groups when comparing muscle activation within the pumping technique ($F(3,32) = .797$; $p = .51$; $\eta^2 = .08$) and within the non-pumping technique ($F(3,32) = .833$; $p = .49$; $\eta^2 = .08$).

////////////////////////////////////Insert figure 3 here////////////////////////////////////

The difference in percentage of DPT when compared to the pumping and non-pumping trials was also not statistically significant $t(31) = .306$, $p = .76$. Despite the lack of statistically significant differences between muscle activity for pumping and non-pumping, the mean percentage differences were 9.12 % (Biceps Brachii), 11.85 % (Triceps Brachii), 10.98 % (Vastus Lateralis) and 11.42 % (Medial Gastrocnemius), respectively.

Discussion

The purpose of this research study was to:

- a) Ascertain if upper body activation had a significant impact on velocity production in BMX cycling
- b) To quantify the level of contribution made by pumping if an impact was found.

The major finding from this study was that the upper body did have a significant impact on velocity production ($p = 0.001$), with the mean velocity in the pumping trial being 21.81 ± 5.31 % greater than the non-pumping trial. Based on this result, the technique of pumping can be considered to be an important contributing factor towards velocity production in BMX cycling. The mean results from the study found that the riders using the pumping technique (34.7 ± 1.49 s) completed a lap 19.50 ± 4.25 % faster than compared to the non-pumping (43.3 ± 3.1 s) lap. Although the results from the current study show that the technique of pumping is a significant factor in BMX cycling, the degree to which this

has an impact could still be somewhat understated. For example, analysis of the video recordings revealed that the riders were performing both the pumping and non-pumping techniques in the respective trials. All the riders in the study were competent at pumping, however, several of the riders did find the implementation of the non-pumping technique challenging. This may be due to the technique of pumping being an autonomous motor function. If, as visually noted, the riders did not subconsciously commit to the non-pumping technique, the variation in the two trials may have been even greater. This supposition is supported by Cowell et al (2012a) who analysed the time spent performing a number of skills and movement patterns in 26 elite male riders at the 2010 BMX World Championships (Pietermaritzburg, South Africa). Cowell et al. (2012a) stated that 44 % of the duration of a race was spent pumping whilst the current study only found a variation of 19.50 ± 4.25 % in lap times between the pumping and non-pumping trials.

sEMG was used in the study to confirm that the appropriate technique was performed in the appropriate trial. It was anticipated that the pumping trial would produce a relatively greater muscle activation, thus confirming the pumping technique was being implemented. The results from the sEMG data, however, revealed no significant differences in muscle activation between any of the muscle groups (see figure 3) during the pumping and non-pumping trials. This is despite confirmation that the technique was implemented appropriately through the video analysis of the trials. There are two possible explanations for the non-significant differences in muscle activation; 1) the shift from dynamic to isometric

muscle contraction and 2) the change in technique causing a greater impact on the rider during non-pumping trials.

The pumping technique is a dynamic movement that requires a rider to push down on the bike at the top of a hill, in order to gain extra velocity from the downward slope. According to Cowell et al. (2012b) the whole body is utilised when pumping, including the lower body, although riders have commented that the contribution of the upper body 'feels' greater. Force is generated in the lower body through a single hip and knee extension on the downward slope of a hill, whilst force is applied simultaneously to the bars of the bike by the upper body. As a result, this transfer of force from the rider to the bicycle results in the production of velocity. This movement pattern requires dynamic muscle contraction in both the upper and lower body. When the riders refrain from pumping, they isolate their upper and lower body maintaining a standing position on the pedals of the bike, with the rider's arms and legs extended and held in this position.

The second possible explanation for the non-significant sEMG data recorded, may be the influence of the change in technique and resultant impact on the rider. As previously explained, the fluid action of the pumping technique when riding the rhythm section limits impact on the rider. When riders refrain from performing the pumping technique the impact of the bicycle wheels on the ascent and descent of the hills in the rhythm section are transferred through the bicycle to the rider. As a result this could have been recorded by the sEMG as the muscles have to stabilise the body to remain upright on the bike.

The findings of the present study would appear to support this supposition, and it is proposed that these isometric contractions contributed to greater impact forces being transferred to the muscles, and may explain why the recorded sEMG data was comparable to the magnitudes observed during the more dynamic pumping technique. During pumping, although the muscles are actively engaged in trying to increase velocity, the greater flex in the elbow, hip and knee joints may have aided the attenuation of forces upon landing. As such, further analyses of the two techniques is warranted using 3D kinematic assessments, in order to quantify any biomechanical differences.

Practical Application

Coaches, riders and researchers are constantly looking for new and novel areas of training that can elicit and increase performance in athletes. BMX cycling is no exception, however, there is limited academic knowledge for the intervention of training in the sport. The implications of the current study include further advances into the sport, and offer a new insight into training priority. The findings from this study demonstrate that the technique of pumping contributes 21.81 ± 5.31 % to the rider's velocity production. These findings should assist coaches, riders and researchers in the design of BMX training programmes. A multidisciplinary approach could be adapted to support technique and strength development. The implementation of an upper body strength-training program that develops the riders functional stability, could result in a more effective kinetic chain. Thus aiding the rider to perform the

technique of pumping more effectively. Whilst technique development needs to be addressed by the technical coach to enhance performance.

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Reference list

1. Bertucci, W, Taiar, R, and Grappe, F. Differences between sprint tests under laboratory and actual cycling conditions. *Journal of Sports Science and Medicine* 45: 277-83, 2005.
2. Blake, OM, Champoux, Y, and Wakeling, JM. Muscle Coordination Patterns for Efficient Cycling. *Medicine and Science in Sports and Exercise* 44: 5, 926-938, 2012.
3. Cowell, JF, McGuigan, MR and Cronin, JB. Movement and skill analysis of Supercross BMX. *The Journal of Strength & Conditioning Research* 226: 6, 1688-1694, 2012a.
4. Cowell, J, McGuigan, M and Cronin, JB. Strength Training Considerations for the Bicycle Motocross Athlete. *Strength & Conditioning Journal* 34:1, 1-7, 2012b.
5. Csikszentmihalyi's, M. Flow: The Psychology of Optimal Experience. New York: Harpur Row, 1990.

6. Debraux, P and Bertucci, W. Determining factors of the sprint performance in high-level BMX riders. *Computer Methods in Biomechanics and Biomedical Engineering* 14:1, 2011a.
7. Debraux, P and Bertucci, W. Muscular determinants of performance in BMX during exercises of maximal intensity. *Computer Methods in Biomechanics and Biomedical Engineering* 14:1, 2011b.
8. Debraux, P, Manolova, AV, Soudain-Pineau, M, Hourde, C and Bertucci, W. Maximal torque and Power Pedalling Rate relationship for High Level BMX riders in field Testing. *Journal of Science and Cycling* 2:1, 51-57, 2013.
9. De Luca, CJ, Kuznetsov, M, Gilmore, LD, and Roy, SH. Inter-electrode spacing of surface EMG sensors: reduction of crosstalk contamination during voluntary contractions. *Journal of biomechanics* 45: 3, 555-561, 2012.
10. Egaña, M, Ryan, K, Warmington, SA, and Green, S. Effect of body tilt angle on fatigue and sEMG activities in lower limbs during cycling. *European Journal of Applied Physiology* 108: 649–656, 2010.
11. Hurst, TH, Sinclair, J, Atkins, S, Rylands, LP and Metcalfe, J. Influence of wheel size on muscle activity and tri-axial accelerations during Cross-Country mountain biking. *Journal of Sport Sciences (ahead of print)*. 2016.
12. Jackson, S.A. Factors influencing the occurrence of flow state in elite athletes. *Journal of Applied Sports Psychology* 7: 138-166, 1995.
13. Louis, J, Billaut, F, Bernad, T, Vettoretti, F, Hausswirth, C and Brisswalter, J. Physiological Demands of a Simulated BMX.

Competition. *International journal of sports medicine* 34: 6, 491-496, 2013.

14. Mateo, M, Blasco-Lafarga, C, Zabala, M and Herná'ndez, M. Pedalling power and speed production Vs. Technical factors and track difficulty in bicycle motor cross cycling. *Journal of Strength and Conditioning Research* 25: 12, 3248-3256, 2011.
15. Matsuura, R, Arimitsu, T, Yuncki, T and Yuno, T. Effects of resistive load on performance and surface sEMG activity during repeated cycling sprints on a non-isokinetic cycle ergometer. *British Journal of Sports Medicine* 45: 10, 820-824, 2011.
16. Rylands, LP, Roberts, SJ and Hurst, HT. Variability in laboratory versus field-testing of peak power, torque and time of peak power production amongst elite BMX cyclists. *Journal of Strength and Conditioning Research* 29: 9, 2635–2640, 2015.
17. Rylands, LP, Roberts, SJ, Cheetham, M and Baker, A. Velocity production in elite BMX Riders: A field based Study Using SRM power meter. *Journal of Exercise Physiology* 16:3, 14-23, 2014.
18. <http://www.seniam.org>
19. Tolmie, A, Muijs, D, and McAteer, E. Quantitative methods in educational and social research using SPSS. *Berkshire, England: Open University Press, 2011.*
20. Wulf, G, Chiviacowsky, S, and Cardozo, PL. Additive benefits of autonomy support and enhanced expectancies for motor learning. *Human movement science* 37: 12-20, 2014.