# 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 performed a timed lap of a 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. A within groups repeated measures of variance (ANOVA) between muscle groups for each technique was performed. The findings revealed no significant differences between any of muscle groups ($p > 0.05$). However, significant differences ($p = 0.001$) were found between the pumping and non-pumping trials for both mean lap velocity (42 ± 1.8 km.h-1, 33 ± 2.9 km.h-1 respectively) and lap times (43.3 ± 3.1 s, 34.7 ± 1.49 s, respectively).The lap times recorded for the pumping trials were 19.50 ± 4.25 % lower than the non-pumping. Whilst the velocity production was 21.81 ± 5.31 % greater than in the pumping trial compared to the non-pumping. The technique of pumping contributed significantly to velocity production, though not at the cost of additional muscle activity. As a result coaches and riders should prioritise this technique from a physiological and technical perspective 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). Understandably, 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)), whilst limited research has been undertaken as to the contribution of the upper body. However, two studies investigating the effect of upper body on velocity production (1, 16) have proposed that upper body could have a major influence on velocity production during a BMX race. Bertucci et al. (2005) analysed the effect of upper body on power production through investigating the differences in sprinting in a seated position, where riders were unable to use their upper body, and a standing position, where riders were able to use their upper body and oscillate the bike. Bertucci et al. (2005) reported a 32 % higher force was applied to the bicycle during the standing sprints, compared to seated sprinting during laboratory-based trials. Rylands et al. (2015) reported similar findings in a study that compared laboratory sprints on a cycle ergometer to sprints performed on a BMX track when riders used their own bikes. 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 authors noted that the oscillation of a BMX bicycle is only possible when a rider is pedalling, as the movement is used as leverage (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 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, 19). 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.

It was therefore hypothesised that pumping would have a significant impact on the production of velocity and muscle activity in BMX cycling when compared to non-pumping.

## Method

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 research project received ethical approval from the University of Derby Ethics Human Studies Board and was in accordance with the Declaration of Helsinki.

Experimental Design

In order to establish if upper body activity significantly affected velocity production, two separate 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, had 4 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.

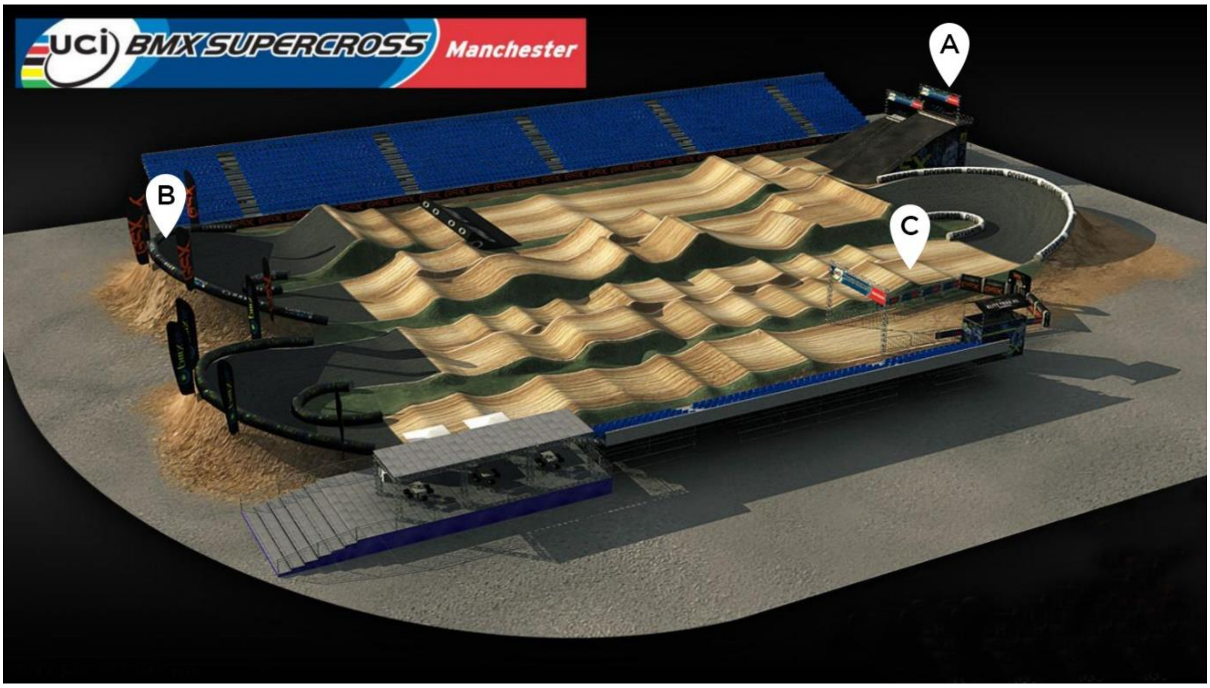


**Figure 1: Schematic diagram of the Manchester indoor BMX track. A) Start gate B) Berm C) Rhythm section.**

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). The first trial consisted of riders completing a full lap of the track using their normal 'pumping' technique. For the second trial the riders were required to complete a lap of the track, but were informed to avoid adopting the pumping technique at any point during the lap. Both trails were recorded using a HD Camera (Panasonic HC- X900) with shutter speed of 1/8000$^{th}$ of a second. This 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. It was theorised that riders would have a greater muscle activation during the 'pumping' compared to the

‘non-pumping’ trial due to the isokinetic muscle contraction. As a result the sEMG could be used to confirm the appropriate technique was performed in the appropriate trial.
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) 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. Several studies have investigated the effect of muscle activation on cycling performance using sEMG (2, 10, 11, 15), yet none have used sEMG for of analysis of BMX riders.

Data analysis

The independent variables in the analyses were pumping and non-pumping. 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. Within groups repeated measure analysis of variance (ANOVA) were then used to determine any statistically significant differences within muscle groups to determine if muscle recruitment differed by technique. Where a significant ANOVA test was observed, Bonferroni pairwise comparisons were used to determine where the differences lay and to control for type I errors. Effect sizes were determined using partial Eta$^2$ ($\eta^2$). 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 (18). Data are presented as mean ± 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 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 ± 4.25 % (34.7 ± 1.49 s, 43.3 ± 3.1 s respectively).

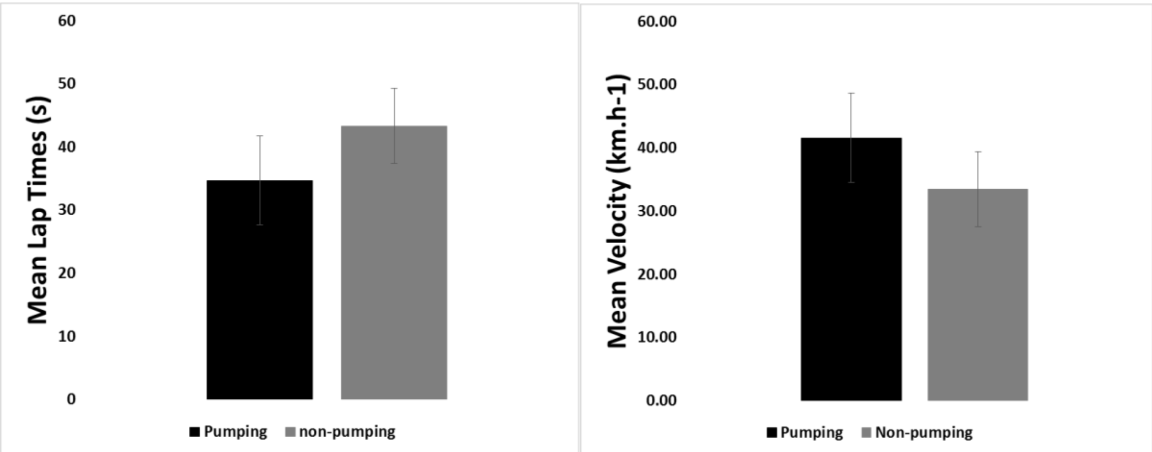


**Figure 2: Mean lap times and velocity for the pumping versus non-pumping trials.**

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 ± 5.31 % greater than the non-pumping (33 ± 2.9 km.h-1) trial.

The sEMG results showed 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 separately ($F(3,32) = .833$; $p = .49$; $\eta^2 = .08$).

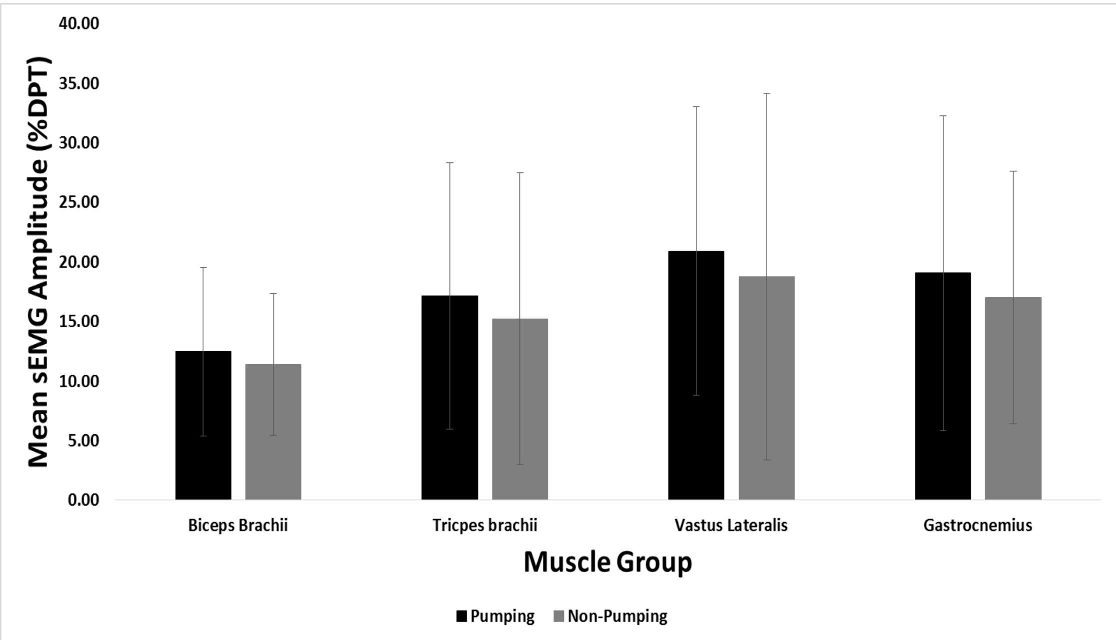


**Figure 3: sEMG data for all muscle groups during Pumping and non-pumping techniques.**

The difference in percentage of DPT when comparing the pumping to 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 results revealed that upper body did have a significant impact on velocity production ($p = 0.001$) with mean velocity in the pumping trial being 21.81 ± 5.31 % greater than the non-pumping.

However, the results from the sEMG data showed no significant differences in muscle activation between any of the muscle groups (see figure 3) during the pumping and non-pumping trials. There are two possible explanations for this; 1) the shift from isokinetic to isometric muscle contraction and 2) the change in technique causing a greater impact on the rider during non-pumping trials.

The technique of pumping requires a rider to push down on the bike at the top of a hill to potentially 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 isokinetic 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 are 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 decent 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 led to greater impact forces being transferred to the muscles and may possibly explain why the recorded sEMG data was comparable to the magnitudes observed during the more isokinetic pumping technique. During pumping, though the muscles were actively engaged in trying to increase velocity, the greater flex in the elbow, hip and knee joints visually observed may have also aided in the attenuation of forces upon landing. As such, further analyses of the two techniques is warranted using 3D kinematic assessments, in order to quantity any differences in biomechanics.

Analysis of the video recordings enabled the researchers to ascertain that the riders were performing both the pumping and non-pumping techniques in the respective trials. All 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. The mean result from the study found that 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 have been understated. If, as visually noted riders subconsciously did not fully commit to the non-pumping technique, the variation in the two trials could have been greater. This theory is supported by a study conducted by Cowell et al (2012a) in which the authors 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.

**Practical Application**

Coaches, riders and researchers are constantly seeking 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 begin to add to the understanding of the sport and give a possible insight into training priority. The findings in this study show that the technique of pumping potentially contributes 21.81 ± 5.31 % to the rider's velocity production. These findings should assist coaches, riders and researchers in the design of strength and conditioning training programmes, especially in those areas previously considered as less of a priority.

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