RESEARCH ARTICLE

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The acute effect of whole-body vibration on cycling peak power output

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Abstract

The aim of the present study was to determine if an acute bout of whole-body vibration (WBV) prior to sprint cycling would increase peak power output. Ten male cyclists, all familiar with maximal sprint cycling exercise performed, on two separate occasions, a ten second standing sprint on a cycle ergometer. For one trial the sprint was preceded by a 2 minute WBV intervention, requiring the participant to stand on a vibrating platform that produced sinusoidal oscillations. The frequency and amplitude of the vibration was set at 26Hz and 'high' (approximately 2mm) respectively. For the other trial participants stood in the same position, however the platform did not vibrate (no-WBV; 0Hz and 0mm for frequency and amplitude respectively). No significant difference was recorded for peak power output between trials (1458.0 + 283.7 W versus 1506.3 + 232.5 W for WBV and no-WBV respectively, P = 0.17). The results suggest that WBV prior to maximal standing sprint cycling does not increase peak power output.

Keywords: bicycle, performance, anaerobic, sprinting, warm-up, intervention

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Introduction

Exposure to vibration is believed to affect the neuromuscular system. When skeletal muscle is subjected to vibration, it is theorised that muscle spindles become excited, in turn recruiting receptors that activate α-motoneurons and thereby increasing the number of contracting muscle fibres that were previously inactive (Bishop, 1974). Such insight into this area suggests vibration stimulation at the neural level may provide post-activation potentiation (PAP). PAP is associated with an increase in muscle fibre excitability (Hodgson et al., 2005) which may improve muscular performance, particularly in exercises requiring high speed, force and power development.

The application of an acute bout of whole-body vibration (WBV), whereby athletes stand on a vibrating platform prior to exercise, has been shown to increase isometric leg extension strength (Torvinen et al., 2002), dynamic leg press force and power (Bosco et al., 1999), jump height (Cochrane & Stannard, 2005) and squat jump ability (Cardinale & Lim, 2003). These results suggest that WBV may help increase the force production capabilities of the lower body musculature following appropriate vibration exposure. Whilst all these studies observed a significant increase in performance it is important to highlight that the vibratory protocols all differed to some degree. For instance Torvinen et al. (2002) utilised an incremental increase in vibration frequency, starting at 15Hz and increasing by 5Hz.min^{-1} until 30Hz was achieved whilst maintaining a peak to peak amplitude of 10mm. Cochrane & Stannard (2005) maintained a frequency of 26Hz and 6mm amplitude during their protocol but utilised a range of standing positions that in total lasted for 5 minutes. Bosco et al. (1999) also used a frequency of 26Hz but set a peak to peak amplitude of 10mm for a duration of 10 minutes (10 times 60 s exposure followed by 60 s rest). Finally Cardinale & Lim (2003) observed success in their investigation when using a frequency of 20Hz and a peak to peak amplitude of 4mm for a duration of 5 minutes (5 times 60 s exposure followed by 60 s rest). It is therefore important to recognise that an appropriate WBV protocol is formed of a number of key variables; frequency, amplitude and exposure time.

Whilst these studies can be used to help develop training regimes and increase the workload of a given training session, the use of WBV has not, for the majority of cases, been applied to a sport specific event. One sport-specific event that may benefit from the use of WBV prior to competition is track sprint cycling. Short events at Olympic level, such as the 1000m time trial may benefit from an increase in PAP following WBV. The event lasts just over sixty seconds with approximately 50% of energy provided by the anaerobic pathway (Jeukendrup et al., 2000). De Koning et al. (1999) suggest optimal performance occurs when an individual achieves their highest anaerobic peak power via an all-out pacing strategy. As such, peak power is reached near the start of the race once the athlete has accelerated up to peak velocity as quickly as possible from a stationary start (Craig & Norton, 2001). It may therefore be that WBV has the potential to enhance the peak power production of a track sprint cyclist and / or the time to achieve peak power output. Furthermore WBV could be used as part of a cyclists warm up in order to reduce energy expenditure prior to racing. Tomaras and MacIntosh (2011) suggest the standard warm up of a 200m sprinter induces muscular fatigue when compared to a shorter specific protocol. Therefore WBV may be useful in preventing muscular fatigue whilst simultaneously increasing PAP.

Surprisingly, there appears to be limited research that has studied the effect of WBV on peak power output during cycling. Cochrane et al. (2008) have previously observed no significant difference in peak power output during a 5 s cycling test performed at a cadence of 110 revolutions per minute whilst seated and with a flying start. This was preceded by WBV, cycling or a warm bath as one of three warm-up procedures. The restricted cadence and seated position does not, however, reflect the nature in which track cyclists apply power to the pedals during the initial acceleration of a sprint. Typically, track cyclists will 'stand' on the pedals in order to utilise body mass in a bid to increase cadence and therefore speed as fast as possible. This 'all out' start strategy is not only limited to track cycling since other disciplines such as BMX racing also feature similar standing starts. Evidence has shown that greater power can be applied during a Wingate test if the participant is to perform the exercise in the standing rather than sitting position (Reiser et al., 2002). When performing this exercise on a track bicycle this will result in optimal acceleration and time to peak velocity, therefore enabling cyclists to adhere to an efficient all out strategy as described by De Koning et al. (1999). The purpose of this study was to determine if WBV, included as part of a warm-up, would increase peak power output during standing sprint cycling when compared to a warm-up that does not include WBV. It was hypothesized that cycling peak power would increase as a result of the WBV intervention.

Materials and methods

Participants

Ten experienced and highly motivated club level cyclists were recruited for this study (mean $\pm$ SD: age 30 $\pm$ 10 years, stature 179 $\pm$ 3 cm, mass 79.0 $\pm$ 9.4 kg). All cyclists were familiar with maximal sprint cycling tasks and anaerobic cycling power tests. Prior to participation all cyclists gave informed written consent, in line with the Institutional Ethics Committee requirements. The study had received approval from the Institutional Ethics Board and complied with the ethical standards of JSC (Harriss & Atkinson, 2011).

Design and Procedure

Participants visited the laboratory on two separate occasions, with at least 24 hours separating test sessions. Participants were asked to abstain from caffeine consumption up to 24 hours prior to testing. The two performance tests were allocated in a counter-balanced, cross-over design; one session included the use of WBV during the warm-up procedure whilst the other trial excluded WBV during the warm-up.

All cycling exercise, including both the warm-up and performance sprint, was conducted on an electromagnetically braked ergometer (Lode Excalibur Sport, Gronigen, The Netherlands). The ergometer was equipped with a racing handlebar and clipless pedals so as to enable athletes to wear their racing cycle shoes. Participants had previously measured the distance from the crank to the saddle tip and from the saddle tip to the handlebars of their racing bicycle in order for dimensional adjustments to be made accordingly on the ergometer. The saddle and handlebar could be adjusted both vertically and horizontally. Once the setup was complete all saddle and handlebar reference values were recorded from the ergometer control unit in order to maintain consistency of the cycle setup between tests.

Warm-up

Participants cycled (in a seated position) continuously for seven minutes against a torque of 0.12 $N.kg^{-1}$ whilst maintaining a cadence of 80rpm. A torque of 0.12 $N.kg^{-1}$ was selected as this was previously set by Torvinen et al. (2002) as part of their cycle warm-up prior to WBV exposure. After seven minutes participants were asked to stop cycling. At seven minutes and thirty seconds a five second standing sprint was performed from stationary against a torque of 0.834 $N.kg^{-1}$. The inclusion of a short warm-up sprint reflects the traditional warm-up procedure of a sprint cyclist (Tomaras & Macintosh, 2011) and may help increase high-intensity cycling performance (Burnley et al., 2005). Participants were instructed to apply maximal power and to increase pedalling cadence as fast as possible. After the five second sprint participants continued to cycle (in a seated position) for another three minutes at the previous torque setting of 0.12 $N.kg^{-1}$ whilst maintaining a cadence of 80 rpm. As soon as the final three minutes of cycling had been achieved, participants dismounted the ergometer, took off their cycle shoes and stood bare foot on a platform that was enabled to vibrate (Power Plate Pro5, Northbrook, Illinois, USA).

Whole body vibration protocol

Participants were informed to hold the hand rail of the vibrating platform at all times and to flex their legs at a 40° angle to help absorb the impact (the joint angle of a fully extended leg was classed as 0°; pilot tests suggested that an angle of 40° limited the vibration transfer to the upper body). Joint angle of the knee was measured using a goniometer (Cranlea, Birmingham, UK). Participants stood with bare feet positioned shoulder width apart and central on the platform. Exactly 30 s after terminating the cycle warm-up the participant was subjected to either 120 s of sinusoidal vibration (WBV), or 120 s of no sinusoidal vibration (no-WBV). The vibrating programme was set to a frequency of 26Hz and amplitude of 'high'. 26Hz is classed as a low vibratory frequency (Cardinale & Lim, 2003) and has been used in a range of previously successful interventions (Bosco et al., 1999; Cochrane & Stannard, 2005; Stewart et al., 2009). A duration of 120 s was selected since previous research suggests this may provide optimal exposure time (Stewart et al., 2009). An amplitude of ‘high’ was selected from the machines option menu, the largest amplitude the device could produce. Research from the test laboratory (unpublished) suggests this provides an amplitude of ~2mm. The ‘high’ amplitude was selected in order to replicate as closely as possible the vibratory intervention of Stewart et al. (2009). Following the 120 s protocol on the platform participants re-attached their cycle shoes, re-mounted the cycle ergometer and clipped their shoes into the pedals in preparation for the cycle test.

Performance Test

Exactly 30 s after the termination of the WBV or no-WBV protocol, participants performed a ten second standing sprint from a stationary position. Participants cycled against a torque of 0.834 $N.kg^{-1}$ and were instructed to apply maximal power throughout the test and to increase cadence as fast as possible. A torque setting of 0.834 $N.kg^{-1}$ was selected as this has previously been used by MacIntosh et al. (2003) when conducting stationary start Wingate tests. The authors have shown that a torque of 0.834 $N.kg^{-1}$ provides higher values for peak power from a stationary start when compared to a flying start and suggest an individualized optimal resistance is not necessary when initiating a sprint test from stationary. Power and cadence were recorded throughout the 10 s test via a computer that was interfaced with the ergometer. This data was used for subsequent analysis. Power was calculated with the moment of inertia of the flywheel taken into consideration.

Statistical Analyses

All data was tested for normality of distribution prior to conducting statistical analysis, determined by the Shapiro-Wilk test. A paired sample t-test was used to determine if a significant difference in peak power, time to peak power, peak cadence and time to peak cadence occurred between trials. Alpha was set at $P < 0.05$. SPSS version 19 (New York, USA) was used for statistical analysis.

Results

All data was normally distributed. No significant difference was found for peak power ($P = 0.17$), time to peak power ($P = 0.47$), peak cadence ($P = 0.46$) and time to peak cadence ($P = 0.18$) between trials (Table 1). The within-subject coefficient of variation between trials for peak power was 1.3%.

Table 1. Comparison of anaerobic cycle sprint performance variables following a bout of whole body vibration (WBV) or following a bout of no WBV (mean $\pm$ SD).

Performance variable	With WBV	Without WBV
Peak power (W)	1458.0 $\pm$ 283.7	1506.3 $\pm$ 232.5
Time to peak power (s)	2.07 $\pm$ 0.36	2.19 $\pm$ 0.46
Peak cadence (rpm)	140.8 $\pm$ 10.5	139.8 $\pm$ 10.0
Time to peak cadence (s)	6.21 $\pm$ 0.93	6.41 $\pm$ 1.08

W = Watt, s = seconds, rpm = $revolutions.min^{-1}$

Discussion

The main finding from this study is that the use of WBV prior to maximal sprint cycling does not increase peak power output. Although not statistically significant, peak power was found to be lower following a bout of WBV compared to no-WBV (Table 1). In turn, this probably reflects the shorter time taken to reach peak power (Table 1). As may be expected following no significant difference in power output, maximal cadence and time taken to reach maximal cadence remained comparable between trials (Table 1).

The lack of significant difference between trials for peak power in this study is comparable to the results observed by Cochrane et al. (2008) who also found no significant difference in 5 s cycling performance following the use of a WBV intervention as part of a warm-up. Participants in this study were, however, required to start from stationary, rather than using a flying start, and asked to stand during the exercise, rather than remain seated. Despite these differences in test protocols, the comparable results from this study and that of Cochrane et al. (2008) suggests that WBV does not increase anaerobic cycling peak power, irrespective of cycling position (standing or seated), and with or without a flying start. Cochrane et al. (2008) did, however, insure all warm-up interventions elicited the same muscle temperature prior to exercise as this formed the rationale for their study. In this study muscle temperature was not recorded, thus limiting further comparisons between test results. It is also possible that the repeated eccentric – concentric action that skeletal muscle undergoes during WBV may not be an appropriate intervention for the concentric only action of cycling (Cochrane et al., 2008). Previous successful intervention studies have utilised exercises that incorporate the stretch-shortening cycle during eccentric – concentric activity such as a countermovement jump performance (Cardinale & Lim, 2008; Cochrane & Stannard, 2005; Cormie et al., 2006; Torvinen et al., 2002).

Gregor et al. (1987) previously published evidence that suggested skeletal muscle stretch-shortening during the cycling action occurs within the gastrocnemius muscle. The authors observed an increase of 2.5% segment length during the ‘power phase’ of the crank cycle (0° - 90°). Furthermore peak electromyography (EMG) activity occurred at 104° of the crank cycle, which may be attributed to greater force production through the second quarter of the crank cycle (90° - 180°). The data of Gregor et al. (1987) suggests the possibility of a stretch-shortening reflex occurring during cycling exercise. If this is the case then the use of WBV may have assisted in optimising energy return during the crank cycle, thus enabling peak power production to be increased during high intensity anaerobic sprinting. If the stretch-shortening reflex does occur during the cycling action, as suggested by Gregor et al. (1987), it seems probable that it provides a minimal contribution to the total exercise. Any increase in power attributed to the stretch-shortening cycle following WBV may be less than the within-subject variation or typical error of measurement for this exercise (Hopkins, 2000) therefore preventing the detection of a meaningful difference in power production following WBV.

A critical analysis of this current studies intervention should be made, since the protocol applied to the WBV may not have optimised the performance test results. For example, previous research (Bazett-Jones et al., 2008; Cochrane et al., 2008) has observed successful performance results following the squat exercise being performed during a WBV intervention. This differs to the current study where participants stood in an isometric position on the platform during the intervention. Such differences propose that an ‘active’ exercise performed during WBV may positively affect performance, suggesting that the addition of a squat exercise during WBV in this study may have the potential to enhance cycling peak power. Other factors must also be considered about the intervention protocol, particularly the duration of exposure. Previous research shows that successful anaerobic power performance increases can occur following 45 s (Bazett-Jones et al., 2008) and up to 10 minutes (Bosco et al., 1999) of WBV exposure. The 2 minute exposure time for this study was based on previous research by Stewart et al. (2009) who observed the greatest increase in knee extensor strength following 2 minutes of WBV exposure. The authors do conclude that the optimal dose-response time remains unclear and, based on the range of previous exposure durations, it is not clear if 2 minutes represents an optimal duration prior to sprint cycling. Whilst beyond the scope of this study, a range of exposure durations would need to be applied in order to establish if any optimal duration exists in order to increase peak power output during cycling. The possibility remains that the 2 minutes of WBV used in this study may not have provided sufficient exposure time for the PAP effect prior to maximal cycling. In contrast 2 minutes of WBV exposure, preceded by a 10 minute cycle warm up, may have led to the onset of fatigue. It is extremely unlikely, however, that the 10 minute cycle warm-up induced fatigue since it was performed at a low intensity (with the exception of a 5s sprint) and remains relatively short in duration compared to the warm-up procedures of professional track cyclists (Tomaras & Macintosh, 2011). Furthermore, all participants were active cyclists who trained regularly and verbal feedback suggested the warm-up was of a ‘light’ intensity.

Despite WBV only occurring during one of the two trials, participants actively engaged major leg muscles (quadriceps, gluteus) during both interventions due to the isometric stance that was incorporated into the protocol (140° leg flexion). This isometric contraction during both trials may have negatively affected cycling performance since low-level sustained contractions can lead to muscular fatigue (Sjogaard et al., 1988). If this is the case, then WBV may still have the potential to increase PAP prior to maximal cycling, but must be administered in a non-fatigue inducing method. For instance WBV could be administered with the participant seated so only the legs are exposed to the vibration, therefore preventing any fatigue inducing isometric contraction in the process.

One final consideration of the protocol must be the duration given between completion of the 2 minute WBV intervention and the cycle performance itself. This was set at 30s for the current study as this was the minimum time possible for successful transition between the vibrating platform and the cycle ergometer. It has previously been described that any neuromuscular activity as a result of WBV may be lost within 5 minutes of the intervention (Adams et al., 2009), therefore performing the exercise task exactly 30s after vibration exposure should have ensured any PAP effect did not dissipate prior to the exercise. Adams et al. (2009) suggest the greatest effect of WBV on peak power occurs from 1 – 5 minutes post-treatment. The effect of post-treatment time prior to a peak power performance test does not appear to have previously been researched for the 30s time period. This is, however, a limitation of some previous investigations (Cochrane et al., 2010) due to the logistical time constraints associated with the test design. It is not known, therefore, whether or not such a rapid transition from treatment to performance, as observed in this study, occurred prior to an ‘optimal time point’ for the anaerobic exercise test. This variable requires further research.

Consideration must be given to the expected intra-variability or typical error of measurement (Jeukendrup et al., 2000) of peak power output during maximal effort cycling. The results from this study show that peak power following WBV was, on average, 48.3 W lower than without WBV (Table 1). The within-subject coefficient of variation (CV) between trials for peak power output in this study was 1.3%. Mendez-Villanueva et al. (2007) have previously shown that the CV of peak power for maximal sprint cycling tests may be up to 2.8%. The difference between trials in this study therefore falls within the expected standard intra-variability of repeated peak power output for sprint cycling.

In conclusion, it appears the use of a two minute WBV protocol (using a low frequency [26Hz] and 2mm amplitude) as an intervention prior to sprint cycling does not enhance peak power production. Further research is required using a range of WBV protocols as differences in exposure time, body position, frequency and amplitude during WBV treatment and duration between post-treatment and performance test may all affect the final performance result.

Practical applications

Based on the present research sprint cyclists should not include whole-body vibration as part of a warm-up regime. The optimal frequency, amplitude and duration of vibration exposure warrants further study when analysing the effect of whole-body vibration on cycling peak power output.

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