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Acute Effect of Lower-Body Vibration as a Recovery Method After Fatiguing Exercise

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A B S T R A C T

The purpose of this study was to compare three recovery methods: control (CON), lower-body vibration (LBV) and LBV+ local muscle cooling (LBVC) on lower-body performance, perceived recovery, and muscle soreness. Physically active male volunteers (n=8) in a repeated-measures, counterbalanced design, completed three sets of squats to fatigue, each recovery treatment, and two Wingate Anaerobic Tests. Rating of perceived exertion (RPE), and heart rate (HR) were measured after fatiguing exercise, recovery treatment and Wingate Anaerobic tests. Peak and mean power, fatigue index, Delayed Onset Muscle Soreness (DOMS), and comfort levels were compared between each treatment. In Wingate 1, no significant differences (p=0.42) were found among CON, LBV, or LBVC regarding peak power (1119±239, 1097±225, and 1146±260 W, respectively), mean power (p=0.32), or fatigue index (p=0.47). In Wingate 2, no significant (p=0.17) differences were found among CON, LBV, or LBVC regarding peak power (1042±228, 1078±233, and 1110±268 W, respectively), mean power (p=0.38), or fatigue index (p=0.15). A significantly better (p=0.01) perceived recovery was observed after LBV (6±1) and LBVC (6±1) compared to CON (4±1). The study findings support psychological but not performance enhancing benefits after the use of LBV and LBVC as recovery methods.

Key words: *peak power, cooling, perceived recovery, Wingate Anaerobic Test.*

Introduction

Vigorous repeated exercise bouts lead to decrease in muscle peak and mean power, depletion of energy stores, and accumulation of metabolic by-products, which will eventually lead to muscle fatigue (Westerbald, Allen & Lännergren, 2002). Adequate recovery is needed to perform well during subsequent competition or training session (Bishop, Jones & Woods, 2008). However, sometimes there is not enough time available to recover adequately between the competitive or training sessions; thus, performance is impaired.

Various recovery modalities individually, or in combination, are often used by competitive athletes to enhance recovery, reduce muscle soreness, and improve performance (Barnett, 2006); however, there is limited research available assessing whole-body vibration (WBV) as a recovery modality. Studies evaluating the effects of WBV as a recovery modality have shown conflicting results. No performance benefits were observed in middle-aged male runners following acute 2x15 min intermittent low-frequency (12 Hz) WBV intervention session on time trial recovery following high intensity interval training session (Carrasco, Sanudo & de Hoyo, 2011). Although, performance was not improved, lower creatine kinase (CK) values were observed following WBV intervention (Carrasco et al., 2011). Also, no improvements in recovery or blood lactate removal were observed after high intensity exercise following low-frequency (20 Hz) WBV (Marin et al., 2012).

Other studies have shown reduced muscle soreness and faster recovery in countermovement jump (CMJ) ability in junior soccer players following cool-down exercises performed on WBV compared to no vibration (Marin et al., 2012). In addition, the application of high-intensity WBV of 50 Hz before down-hill walking reduced muscle soreness, lowered CK levels 24 hours post exercise and improved isometric force production (Bakhtiary, Safavi-Farokhi, & Aminian-Far, 2007). Another study found that application of WBV of 35 Hz before eccentric exercise reduced muscle soreness, lowered CK levels and the pressure pain threshold (Aminian-Far, Hadian, Olyaei, Talebian, & Bakhtiary, 2011). Stretches performed on a WBV plate lowered perceived pain in untrained individuals after a strenuous exercise session compared with static stretches performed without vibration (Rhea, Bunker, Marin, & Lunt, 2009).

Enhanced clearance of metabolic by-products as a result of WBV may help overcome fatigue, decrease recovery time, and help improve athletic performance (Tiidus, 1999, Weerapong, Hume & Kolt, 2005). Increased peripheral circulation, muscle and skin blood flow as previously observed following WBV (Lohman, Scott, Maloney-Hinds, Betts-Schwab, & Thorpe, 2007, Lythgo, Eser, Groo, & Galea, 2009, Maloney-Hinds, Petrofsky, & Zimmerman, 2008), may augment delivery of oxygen and nutrients and help remove accumulated metabolic by-products resulting from exercise (Tiidus, 1999, Weerapong et al., 2005). Although there seem to be more positive than negative results for WBV in recovery and performance, it remains unclear whether WBV would be a useful recovery modality used to enhance athletic performance and alleviate muscle soreness following fatiguing exercise.

It has previously been shown that pre-cooling leg muscles with ice packs improved peak power output during intermittent exercise performance (Castle et al., 2006) and mean power output during high intensity cycling (Marsh & Sleivert, 1999). It was hypothesized, that local muscle cooling decreases skin

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and increases muscle blood flow which increases the delivery of needed nutrients and clearance of metabolic by-products, thus improving performance (Marsh & Sleivert, 1999). Therefore, the addition of local muscle cooling to vibration intervention during recovery could help enhance recovery and improve performance.

The purpose of the present study was to evaluate the effects of lower body vibration (LBV) and LBV plus local muscle cooling (LBVC) as recovery modalities on lower-body peak and mean power, perceived recovery, and muscle soreness following fatiguing exercise. We hypothesized that LBV and LBVC would provide benefits compared to control, increasing peak and mean power, perceived recovery and decreasing muscle soreness after fatiguing exercise.

Methods

Randomized cross-over, repeated measures design was used to evaluate the effects of LBV, LBVC or no treatment (CON) during recovery and performance trials. Before testing session participants provided written informed consent, completed the Physical Activity Readiness Questionnaire (PAR-Q) (Canadian Society for Exercise Physiology, 2002), and a current health status and training status questionnaire (American College of Sports Medicine, 2009). In addition, baseline data were obtained. Following baseline collection participants completed three performance trials in random order, separated by at least 5 days. Each trial consisted of: warm-up, three sets of back squats with 40% of body weight to volitional fatigue, one of three recovery treatments and two 30 second Wingate Anaerobic Tests (WAT). Power analysis suggested that with the sample size (n=8), we would be able to detect an effect for lower-body peak power of 150 W with an alpha level at 0.05 and power of 0.8 (Piface, by Russell V. Lenth, Version 1.72).

Participants

The study included eight physically active males (age 28±3 years; height 180±7 cm; body mass 85±17 kg; relative body fat 11±6%). The study protocol was submitted to and approved by local Institutional Review Board for testing human subjects. Participants were asked to refrain from vigorous physical activity for 72 hours after the session so as not to affect perceived muscle soreness response. Also, participants were asked to avoid heavy food consumption and energy drinks at least 4 hours before each session. Prior to the testing sessions, study design and procedures were explained, informed consent was obtained, screening procedures were completed, and height, weight, and percent body fat were recorded. Weight and height were determined using a beam scale (Detecto, USA). Body composition was assessed using three site skinfolds measured at the chest, thigh, and abdomen (Jackson & Polock, 1978). Relative body fat was estimated using the sum of skin folds and age (Jackson & Polock, 1978).

Performance Trials

Before back squat exercise, a warm-up was performed on the cycle ergometer for five minutes at a self-selected work rate. After the warm-up, three sets of back squats using an Olympic bar with ~40% of body weight were performed to volitional fatigue or until they could no longer maintain proper technique or cadence, with two minutes of rest between sets. A three-second cycle was used to perform squats, 1.5 s for the eccentric and 1.5 s for the concentric phase. Cadence was set at 40 beats per minute to control the pace. The total number of squats performed in all sets was recorded.

Immediately after the squats, recovery treatment was administered. Within next few minutes after the recovery treatment, two WATs were performed on an electronically-braked cycle ergometer (Velotron, Racer Mate, Seattle, WA) in order to evaluate peak anaerobic power (highest mechanical power generated), fatigue index (decline in power over the time from peak power to the end of the test) and total anaerobic capacity (total work performed during 30-s). The test started with a 20-s warm-up and then a 30-s "all-out effort" involving pedaling as fast as possible with resistance of 0.095 kp per kilogram of body weight (Tanaka, Bassett, Swensen, & Sampredo, 1993). Participants rested on cycle ergometer for four minutes before performing the second WAT. Participants were provided the same motivational encouragement to complete the test at their maximum effort.

Recovery Treatments

Recovery treatment was delivered for each trial, in counterbalanced order. The vibration treatment was delivered using a whole-body vibration plate (VibePlate, Lincoln, NE). Participants were seated with feet placed on the vibrating plate to avoid any weight-bearing effects. *LBV Treatment* - Vibration loading was 10-minutes of vertical vibration at a frequency of 35 Hz with amplitude of 2 mm, similar to that of Carrasco et al. (2011) *CON Treatment* – The protocol was the same 10-min duration as for LBV treatment; however, during the control-treatment the platform was not vibrating. *LBV and Cooling Treatment* - The protocol was the same as for the LBV treatment with the addition of cooling applied to the quadriceps and hamstrings muscle by a gel ice wrap. Ice wraps (IceWraps.Net, Lumberton, NJ) were placed around both quadriceps and hamstrings.

Perceptual Measures

Rating of perceived exertion (RPE) and heart rate (HR) were obtained immediately after warm-up, after each set of back squats, and after each WAT. Participants were asked to rate sessions using Borg's 15-point scale (6-20) (Borg, 1982). HR was recorded using a chest strap and watch (Polar Electro Inc., Lake Success, NY) immediately after warm-up, after each set of back squats, and after each WAT.

The scale similar to OMNI scale (0-10) was used to determine each participant's perceived recovery after each recovery treatment (0 - very poorly recovered to 10 - very well recovered) (Laurent et al., 2011). In addition, participants were asked to evaluate their recovery method experience and characteristics such as comfort, pain, intensity, time and change in performance ability. Visual Analogue Scale (VAS) 100-mm was used to record participants' responses for each of these. The left end was anchored by the words "not at all" representing the least amount of that quality and the right end was anchored by the words "very much" representing the most amount of that quality. Delayed Onset Muscle Soreness (DOMS) in the lower extremities was self-reported 24, 48 and 72 hours after the fatiguing squat session using VAS.

Statistical Analyses

Differences among the recovery treatments were analyzed using repeated-measures analyses of variance (ANOVAs) (SPSS Version 16.0, SPSS Inc., Chicago, IL, USA). Differences among the recovery treatments were assessed for these dependent variables: peak power, mean power, fatigue index, perceived recovery, and DOMS (24, 48 and 72 hours later). Repeated measures two-way ANOVA was used to analyze peak power (3x2), mean power (3x2), and fatigue index (3x2), DOMS (3x3), RPE and HR (3x6). Additionally, separate oneway ANOVAs were used to analyze number of squats, and perceived recovery. Least Significant Difference (LSD) post-hoc multiple comparisons were used in order to determine individual differences among the three different types of treatments for each analysis. Alpha was set at 0.05.

Results

Number of squats significantly declined after each set ($p<0.05$) (Table 1); however, it was not significantly different between the three conditions ($p=0.80$) indicating the same volume for all three sessions. A significant time effect was observed for peak power and mean power ($p<0.05$), but not for fatigue index ($p=0.75$). Peak and mean power were significantly higher for Wingate 1 compared to Wingate 2 as participants had only four minutes for recovery between the tests. However, no significant treatment or time x treatment effect was observed for peak power ($p = 0.27$, $p= 0.30$ respectively), mean power ($p=0.44$, $p=0.17$ respectively), or fatigue index ($p= 0.33$, $p= 0.29$ respectively). Group means for Wingate 1 and 2 peak power are presented in Figure 1 and group means for mean power, fatigue index, HR, and RPE are presented in Table 1.

Table 1. Comparison of Physiological Variables of Fatiguing Exercise and Performance Test for LBV, LBVC and CON trials. (Mean ± SD)

	CON	LBV	LBVC
Set 1			
Squat (Nr)	70 ± 34	83 ± 71	77 ± 53
RPE (6-20)	16 ± 2	16 ± 1	15 ± 2
HR (b/min)	162 ± 18	164 ± 21	167 ± 15
Set 2			
Squat (Nr)	51 ± 41	42 ± 22	50 ± 31
RPE (6-20)	17 ± 1	18 ± 1	17 ± 2
HR (b/min)	166 ± 17	167 ± 16	173 ± 16
Set 3			
Squat (Nr)	46 ± 42	43 ± 32	45 ± 33
RPE (6-20)	18 ± 2	18 ± 1	18 ± 1
HR (b/min)	172 ± 11	172 ± 17	175 ± 12
Wingate 1			
Mean Power (W)	610 ± 86	589 ± 57	604 ± 68
Fatigue Index (%)	27 ± 10	25 ± 9	27 ± 9
RPE (6-20)	19 ± 1	19 ± 1	19 ± 1
HR (b/min)	181 ± 6	178 ± 12	180 ± 9
Wingate 2			
Mean Power (W)	535 ± 49	530 ± 46	544 ± 58
Fatigue Index (%)	25 ± 9	26 ± 9	28 ± 10
RPE (6-20)	20 ± 0	20 ± 1	19 ± 1
HR (b/min)	181 ± 5	177 ± 10	179 ± 7

Note: CON-control; LBV-lower-body vibration; LBVC-lower-body vibration + cooling; Nr-number; HR-heart rate; RPE-rating of perceived exertion.

Repeated measures ANOVA revealed no significant treatment, or time x treatment, effect for RPE and HR ($p=0.08$ and $p=0.69$, $p=0.90$ and $p=0.16$ respectively). There was a significant time effect for RPE and HR ($p<0.001$) see Table 1. As would be expected RPE and HR were significantly higher after fatiguing exercise and the WAT compared to warm-up. In addition, RPE and HR were higher after Wingate 2 compared to Wingate 1 indicating increased physiological and psychological strain.

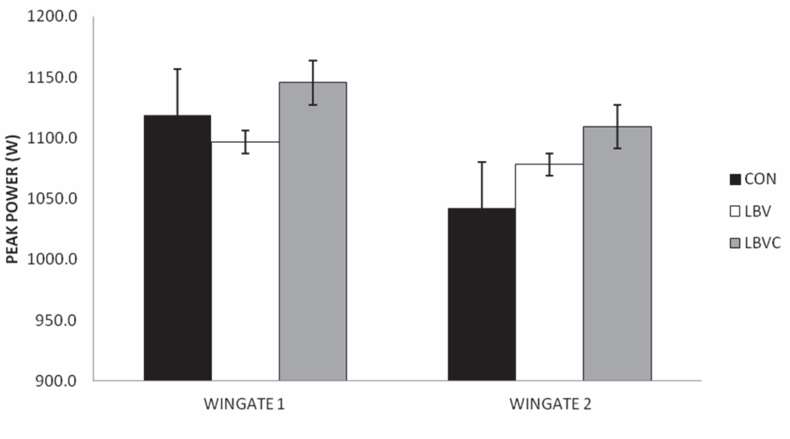

Figure 1. Peak power for Wingate anaerobic test 1 and 2 for CON, LBV, and LBVC recovery treatments (Mean±SD). CON-control, LBV-lower-body vibration, LBVC-lower-body vibration + cooling, W-watts

In addition, no significant treatment or time x treatment was observed for muscle soreness ($p=0.82$ and $p=0.82$ respectively). However, a significant time effect was observed in 24, 48 and 72 hours after recovery treatments ($p<0.001$). Muscle soreness gradually declined as time progressed following each session (Figure 2).

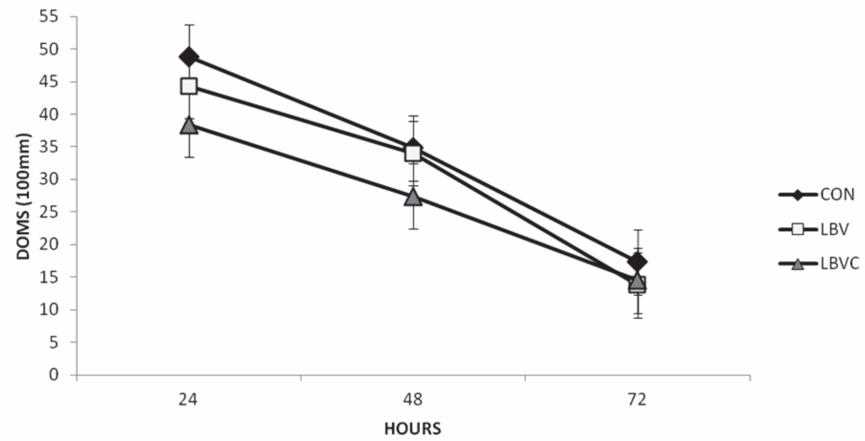

Figure 2. Delayed-onset muscle soreness (DOMS) Response 24, 48 and 72 hours for CON, LBV and LBVC recovery treatments (Mean±SD). CON-control, LBV-lower-body vibration, LBVC-lower-body vibration + cooling, mm-millimeters

Perceived recovery was significantly different ($p=0.01$) among the three treatment conditions (Figure 3). Participants felt better recovered following LBV and LBVC compared to CON. Participants reported that LBV and LBVC helped them recover better and improved their perceived performance ability compared to CON. Most participants reported that they would likely choose LBV and LBVC following an intense training session.

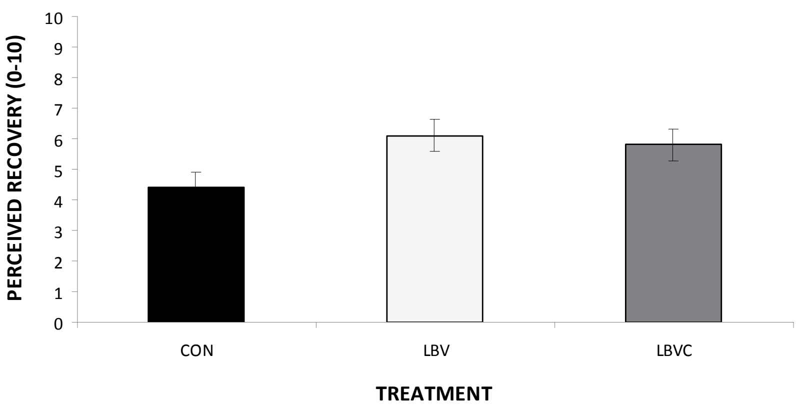

Figure 3. Perceived recovery response for CON, LBV and LBVC recovery treatments (Mean±SD). CON-control, LBV-lower-body vibration, LBVC-lower-body vibration + cooling. * LBV and LBVC significantly higher compared to CON ($p< 0.05$).

Discussion

Sufficient recovery is needed for an athlete to perform his or her best during competition or a training session. Despite evidence from previous studies (Bakhtiary et al., 2007, Marin et al., 2012) suggesting potential benefit, we found no significant mean improvements in peak power, mean power and fatigue index for either WAT after a single 10-min bout of LBV or LBVC recovery treatments, compared to no vibration and no cooling.

Findings of the present study supported the previous findings of Carrasco et al. (2011) and Edge et al. (2009) in cycling and running performance. Previous study (Carasco et al., 2011), evaluated the effect of LBV on recovery after 2 min of fatiguing cycling exercise and found no differences in cycling exercise test to exhaustion, distance covered, cycling velocity, blood lactate or maximum heart rate following 15 min low intensity (20 Hz, 4 mm) LBV treatment compared to no vibration. In addition, no significant improvements were observed in running a 3-km time trial, blood lactate, muscle damage or muscle inflammation markers following WBV treatment (Edge et al., 2009). In Edge's study (2009), low intensity WBV (12 Hz, 6 mm) was applied while alternating between standing and sitting, after exhaustive treadmill and outdoor running exercises.

Because in previous studies, lower vibration frequencies were insufficient to enhance recovery after fatiguing exercise and improve running or cycling performance; in the present study we chose a higher vibration frequency plus the addition of cryotherapy in one trial with no improvement observed during recovery.

On the other hand, using a similar vibration frequency observed improved recovery in CMJ ability following WBV intervention among soccer players (Marin et al., 2012). Participants performed CMJ, maximal voluntary isometric contraction (MVIC) during leg extension, and a repeated-sprint ability test followed by a WBV cool-down. In contrast to the present study, stretching exercises were performed during 15 min recovery period which may have aided in recovery and performance. In addition, Bakhtiary et al. (2007) observed lower MVIC force and higher CK levels in their no-vibration group compared to 50 Hz vibration group. In addition, vibration treatment was applied directly to the muscle before eccentric exercise. Similar findings were observed by another study (Aminian-Far et al., 2011). Less reduction in maximum isometric and isokinetic torque and lower CK levels were observed when 60s WBV treatment (35 Hz, 5 mm) was performed before exercise. Thus, it may be suggested that higher intensity and peak amplitude vibration applied locally prior to the exercise may be needed in order to elicit positive benefits of WBV on performance.

In the present study, ten minutes of treatment may have been too short for participants to recover from fatiguing exercise. However, athletes frequently perform multiple events, or play in multiple innings or quarters during competition and have only 15 min to recover and get ready for the next event or second half of the game.

Most of the previous studies evaluated the effects of WBV as a pre-activation warm-up routine before squat jump or CMJ where participants were standing or doing exercises on the WBV plate, whereas we used passive recovery with participants sitting in the chair with their feet-only on the plate. In the present study, passive application was used so as not to elicit additional fatigue due to increased muscle metabolic demand caused by WBV treatment. No benefits were observed of adding cooling to LBV treatment in the present study.

This study found that DOMS was not different after 24, 48 and 72 hours post exercise sessions among the recovery treatments. The muscle soreness peaked at 24 hours for all three recovery treatments and proportionally decreased thereafter. Although, there was a trend toward slightly lower perceived muscle soreness seen after LBVC recovery treatment, it did not reach statistical significance. The current findings are inconsistent with previous research (Aminian-Far, et al., 2011, Bakhtiary et al., 2001, Kosar, Candow, & Putland, 2012, Marin et al., 2012, Rhea et al., 2009) who found significantly lower levels of reported perceived muscle soreness 12, 24, 48 and 72 hours when vibration treatment was administered before or immediately after exercise. Reduced muscle pain and improved performance were observed among soccer players while performing traditional cool-down combined with stretching exercises performed on vibration platform (Marin et al., 2012). Other studies observed reductions in muscle soreness and pain pressure threshold following vibration application prior to eccentric exercise (Aminian-Far, et al., 2011, Bakhtiary et al., 2001).

Psychological responses may play a major role in an athlete's performance. Participants felt moderately recovered after LBV and LBVC compared to somewhat recovered after no vibration. In addition, participants felt that using LBV and LBVC helped them recover better and improved their perceived performance ability. In addition, participants indicated that they would choose LBV and LBVC as a choice of recovery treatment after intense training session. If an athlete feels better recovered, it may help override peripheral signals and perception of fatigue and possibly improve performance. However, no improvements in the group mean performance were observed.

It would be hard to argue that our study lacked sufficient statistical power, despite our relatively small sample. Our observed power differences were very small. In the present study we had sufficient power to readily detect time effects, and thus should have detected any true treatment differences of similar effect size.

The results of the present study indicate that acute exposure to LBV or LBVC did not provide greater benefits as a recovery modality after fatiguing squat exercise. However, due to individual variability, it is important to consider not only group means but also individual results. Therefore, we recommend that coaches and athletes test the stability of the individual responses to any given recovery treatment and determine whether it helps to overcome fatigue, enhance recovery and improve performance. Due to individual variability recovery treatment duration, intensity and mode need to be determined for each individual athlete in order to provide the most effective recovery routine. In addition, based on the present study participants seemed to feel better recovered and believed that it improved their performance ability. If athletes need to recover in a short period of time LBV or LBVC may have potential psychological benefits but does not appear to aid performance under the conditions of the present study.

In conclusion, LBV or LBVC recovery treatments did not provide greater benefits for peak or mean power after fatiguing exercise compared to no vibration as indicated by group means under the conditions of this study. With a limited amount of literature available, the optimal time, mode and intensity of vibration for use as a recovery modality needs to be determined in order to develop an effective recovery treatment routine.

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