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Original Research

Effect of Upper- and Lower-Body Vibration on Recovery, Muscle Soreness and Performance

SVETLANA MEPOCATYCH[1†], GYTIS BALILIONIS[1†], and PHILIP A. BISHOP[2‡]

[1]Department of Exercise Science, Elon University, Elon, NC, USA
[2] Department of Kinesiology, The University of Alabama, Tuscaloosa, AL, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 7(1) : 33-44, 2014. The purpose of this study was to compare three types of recovery methods: control (CON), lower-body vibration (LBV) and upper-body vibration (UBV) on upper-body performance, perceived recovery, and muscle soreness. Eight physically active male volunteers participated in the study. In a crossover study design, participants completed three sets of push-ups to fatigue, a given recovery treatment, and two upper-body Wingate Anaerobic Tests to assess peak and mean anaerobic power. Rating of perceived exertion (RPE), and heart rate (HR) were measured after fatiguing exercise, the recovery treatment and maximal performance test. In Wingate 1, no significant mean differences ($p > 0.05$) were found among CON, LBV, or UBV in peak power (560 ± 121, 594 ± 116, and 588 ± 109 W, respectively), mean power, or fatigue index. In Wingate 2, no significant mean differences ($p > 0.05$) were found among CON, LBV, or UBV in peak power (570 ± 151, 557 ± 71, and 564 ± 120 W, respectively), mean power, or fatigue index. In addition, no significant mean difference ($p > 0.05$) was observed in perceived recovery and muscle soreness ($p > 0.05$). In conclusion, findings of the present study suggest no psychological or physiological benefits using LBV and UBV as a recovery modality

KEY WORDS: Peak power, mean power, perceived, recovery, pups-ups, arm cranking exercises

INTRODUCTION

Many sports rely on peak and mean power of the upper-body. Insufficient recovery time between training sessions or competitive events may lead to decreased performance or inability to complete required loads during training. High-intensity intermittent or resistance activity for a short period of time causes an increased break down of energy stores and accumulation of metabolic by-products such as lactic acid and inorganic phosphate due to increased anaerobic metabolism (31). Increased metabolic disturbances may lead to decreased muscle contractile function which eventually will lead to muscle fatigue (31). Sufficient recovery time is needed to replenish energy stores, and to remove metabolic by-products accumulated due to exercise. A wide range of recovery modalities are used by competitive athletes during a training session or in between sessions to speed recovery (3). In recent years, the focus of whole-body vibration (WBV) has been directed toward recreational and clinical settings for performance enhancement and rehabilitation. Lower-body (LBV) or upper-body vibration (UBV) could be an easy addition to existing recovery methods following strenuous exercise bout.

Improvements in mechanical power and neural activity of upper-body performance following UBV and WBV were previously observed by multiple investigations (5, 8, 18). Previously, Bosco et al. (5) in a performance based study observed significantly higher average mechanical power recorded during arm flexion following UBV treatment (5 x 60 s, 30 Hz, 6 mm) which occurred in conjunction with an increase in muscle activity (3). Similarly, Cochrane et al. (2008) observed a significant increase of 4.8% and 3% in peak power measured by prone-bench pull following UBV (5 x 60 s, 26 Hz, 3 mm) and arm cranking treatments, respectively, compared to no vibration. Additionally, Marin et al. (18) observed significant improvements in the number of elbow extension repetitions performed during low magnitude (30 Hz, 1.15 mm) and high magnitude (50 Hz, 2.51 mm) WBV treatment compared to no vibration. Thus, it was suggested by investigators that exposure to vibration via feet can provide sufficient stimulus to improve upper-body performance. Therefore, it may be implied that vibration treatment has a potential to benefit upper-body performance. However, another study by Cochrane and Hawke (8) observed no significant mean difference in the upper-body strength and power among climbers. Even though, the same protocol (5 x 60 s, 26 Hz, 3 mm) was implemented as in the previous study, there were no improvements observed in the medicine ball throw, hand grip strength, and campus distance suggesting no neuromuscular enhancements in performance provided by UBV (8).

Recently, it has been shown that brief exposure to WBV increases peripheral circulation, as well as muscle temperature, muscle blood flow, and skin blood flow (10, 13, 15, 16). Therefore, it has been suggested that passive application of vibration may be beneficial to recovery and tissue healing process by augmented delivery of oxygen and nutrients needed for repair and increased removal of accumulated metabolic by-products, thus, these effects may help overcome fatigue, decrease recovery time, and help improve athletic performance (15, 17, 29, 30). Studies observed that a combination of traditional cool-down and WBV reduced muscle soreness and improved performance after exercise in soccer players (19). In addition, some studies reported improved recovery, reduced muscle soreness and lower levels of creatine kinase (CK) following WBV treatment (2, 19, 22). However, other studies reported no differences in the oxygen consumption, heart rate variability, running or cycling performance following WBV or a combination of WBV and lower-body vibration (LBV) (6, 11). Various types and methods of acute recovery using WBV were investigated, thus, the optimal duration and frequency of WBV and its effect on recovery and performance is yet to be determined.

With regards to the limited research available and contradicting results it is unclear whether WBV or UBV has a potential to benefit the recovery. Therefore, the purpose of the present study was to evaluate the effects of UBV and LBV as a recovery modality on upper-body peak and mean power, perceived recovery and muscle soreness after fatiguing upper-body exercise. We hypothesized that UBV and LBV would provide better actual and perceived recovery benefits compared to no vibration, thus, improved peak and mean power, perceived recovery, and decreased muscle soreness after fatiguing exercise.

METHODS

Participants

The study included eight physically active males between 19 and 40 years of age who participated in at least 300 minutes of moderate intensity physical activity per week including a combination of resistance and aerobic exercise. Most of the participants reported resistance training at least twice a week. Power analysis was conducted to determine an effect for upper-body peak power with alpha level at 0.05 and power of 0.8 (Piface, by Russell V. Lenth, Version 1.72).

Participants were provided written informed consent according to the guidelines of the local Institutional Review Board. In addition, participants completed the Physical Activity Readiness Questionnaire (PAR-Q) (21), current health status questionnaire which was based on American Heart Association (AHA)/ American College of Sports Medicine (ACSM) Health Fitness Facility Pre-participation Screening Questionnaire, and current physical activity status questionnaire (1). Participants were asked to provide frequency, time and type of physical activity performed per week and any upper or lower body injuries that they had in the past year that would affect their ability to perform upper-body exercise. Participants were asked not to participate in vigorous intensity physical activity and to avoid alcohol at least 24 hours prior to each testing session. In addition, participants were asked to refrain from vigorous physical activity for 72 hours after the session not to affect perceived muscle soreness response.

Prior to the study, the purpose and performance trials were explained, and the different types of treatments were introduced. Participants were verbally introduced to the study procedures prior to agreeing to volunteer and signing an informed consent form. Only physically active participants participated in the study; therefore, the study requirements did not exceed their normal efforts. There were no previous studies that reported serious adverse effects of vibration; however temporary edema has been reported, which resolved rapidly after walking around (7, 23, 27). Therefore, participants were informed of the potential side effects following vibration treatment such as itching and temporary edema.

Body composition was assessed using a skinfold caliper (Lange, Beta Technology Incorporated, Santa Cruz, California). Skin folds were measured at the thigh, chest, and abdomen (12). Three measures were taken at each site and the average of the three was recorded. Relative body fat was estimated using the sum of skin folds and age (12). Participants' age, weight, height, and percent body fat are presented in Table 1.

Table 1. Physical Characteristics of Participants (n = 8). Values are Mean ± *SD*.

Characteristics	Males n=8 Means ± *SD*
Age (y)	27 ± 3
Weight (kg)	81 ± 18
Height (cm)	176 ± 2
Relative body fat (%)	12 ± 7

Protocol

A crossover, repeated measures study design was used to evaluate the effects of UBV and LBV as a recovery modality on upper-body peak and mean power, perceived recovery, and muscle soreness after fatiguing exercise. A counterbalance technique was used to randomly assign participant to the order of recovery treatments. Sessions were separated by at least 96 hours. Each session consisted of: 5 minute warm-up, three sets of push-ups to volitional fatigue, one of three recovery treatments (CON, LBV or UBV) and two Upper-Body Wingate Anaerobic Tests on an arm-crank ergometer. Performance, psychological and physiological responses were recorded following warm-up, push-up sets, recovery and Wingate Anaerobic tests. Study design is presented in Figure 1.

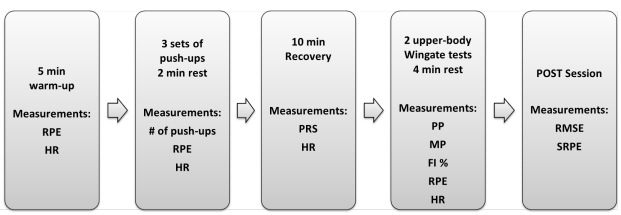

Figure 1. Study design. RPE – rating of perceived exertion, HR- heart rate, PR – perceived recovery scale, PP – peak power, MP –mean power, FI % - fatigue index percent, SRPE – session rating of perceived exertion, RMSE - Recovery Method Subjective Evaluation.

Warm-up – A brief warm-up was performed on an arm-crank ergometer (Monark 824, ERGOMED, Sweden) for five minutes at a self-selected work rate.

Fatiguing exercise – after warm-up, three sets of push-ups were performed to volitional fatigue or until they could no longer maintain proper technique or cadence with two minutes of rest in between sets. Participants were verbally encouraged to complete as many push-ups as possible during each set. The number and total time performing push-ups was recorded. A three-second cycle was used to perform push-ups, 1.5 s for the eccentric and 1.5 s for the concentric phase. A cadence of 40 was used to control the pace (20 push-ups per minute) with a metronome (SEIKO, Quartz Metronome, Seiko Instruments Inc., Hong Kong). Proper technique for the push-up was monitored: hands were shoulder width apart with elbows and body straight, low position with upper-arms parallel to the floor, and back straight.

Wingate Anaerobic Test on Arm Ergometer - After the recovery treatment (CON, UBV or LBV), two Wingate Anaerobic Tests on an arm crank ergometer (Monark 824, ERGOMED, Sweden) were performed with four minutes of rest in between in order to evaluate peak anaerobic power (highest mechanical power generated), fatigue (decline in power over 30-s period) and total anaerobic capacity (total work performed during 30-s) for the upper-body. The test started with a 20-s warm-up wherein the participant was asked to pedal an arm-crank ergometer at his own pace. Participant then performed a 30-s “all-out effort” involving pedaling as fast as possible with an applied predetermined resistance of 0.035 kg per kilogram of body weight (20). Two researchers were trained to provide verbal encouragement to the participants to provide equal motivation and maximal effort throughout Wingate Anaerobic Test.

Each treatment was delivered immediately after three sets of push-ups were completed.

Lower-Body Vibration Treatment – The LBV treatment was delivered using a whole-body vibration plate (VibePlate, Lincoln, NE). Participants were seated in the chair with their feet placed shoulder width apart in the middle of the vibrating plate with socks only. Vibration loading was 10 continuous minutes; vertical vibration form and the frequency of vibration was 30 Hz with amplitude of 2mm.

Upper-Body Vibration (UBV) treatment – The UBV treatment was delivered using whole-body vibration plate. Recovery treatment was administered with the arms placed on the whole-body vibration plate to provide sufficient vibration stimulus and reduce the dampening effect of soft tissue (8). Participants were seated in the chair with bare forearms placed shoulder width apart on the vibrating plate (plate was placed on a table). Vibration loading was 10 continuous minutes; vertical vibration form and the frequency of vibration was 30 Hz with amplitude of 2 mm similar intensity being previously used by Bosco et al. (5) in the upper-body performance study.

Control Treatment – The protocol was the same 10-min duration as for UBV treatment; however, during the control-treatment the vibration platform was not vibrating.

RPE – Rating of perceived exertion was obtained: immediately after warm-up, each set of push-ups, and after each Wingate Anaerobic Test. Participants were asked to rate sessions using Borg's 15-point scale (6-20) (4).

Heart Rate (HR) – Heart rate was recorded using heart rate monitors (Polar Electro Inc., Lake Success, NY) immediately after warm-up, each set of push-ups, after recovery treatment, and after each Wingate Anaerobic Test.

Perceived Recovery Scale – The scale similar to OMNI Scale (0-10) of perceived exertion was used to determine participant's perceived recovery immediately after UBV, WBV or CON recovery treatments (0 being very poorly recovered to 10 being very well recovered) (14).

Overall Session Rating of Perceived Exertion – The OMNI 0-10 scale was used and collected 15 minutes post session (26).
Delayed Onset Muscle Soreness (DOMS) – DOMS was self-reported 24, 48 and 72 hours after the session. DOMS recorded muscle soreness using a Visual Analogue Scale (100-mm scale).

Recovery Method Subjective Evaluation - Participants completed recovery evaluation questionnaire after thier second Wingate Anaerobic test. Visual Analog Scale was used to evaluate eight questions regarding recovery method. Participants were asked about their recovery method experience and characteristics of comfort, pain, intensity, time and improved performance ability.

Statistical Analysis
Participant data was expressed as means ± standard deviation (SD). Randomized crossover study design was used. Participants were randomly assigned to the sequence of recovery treatments. A repeated-measures analysis of variance measures ANOVA (SPSS for Windows Version 16.0, SPSS, Inc., Chicago, Illinois) were used to assess the differences among

the recovery treatments between mean values for the dependent variables. Repeated measures two-way ANOVA was used to analyze: peak power (3 x 2), mean power (3 x 2), fatigue index (3 x 2), DOMS (3 x 3), RPE (3 x 6), and HR (3 x 7). Main and time x treatment effects were analyzed. In addition, separate one-way ANOVA was used to analyze number of push-ups, perceived recovery, session RPE and RMSE responses. Assumption of equal variance was tested with Mauchly's Test of Sphericity. LSD (Least Significant Difference) post-hoc multiple comparisons were used in order to determine individual differences among the three different types of treatments for each analysis. Alpha value was set at 0.05.

RESULTS

No significant difference was observed for number of push-ups ($p > 0.05$) between three sessions (Table 2). In addition, no significant treatment effect or treatment x time interaction was observed for HR and RPE ($p > 0.05$) (Table 2). A significant ($p < 0.001$) time effect was observed for HR and RPE. HR and RPE increased following push-ups and Wingate tests and decreased following recovery treatment.

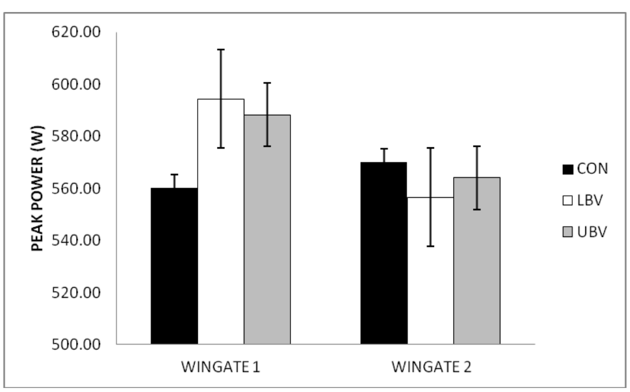

Figure 2. Mean Peak Power for Wingate 1 and 2 after CON, LBV and UBV recovery treatments (n = 8).

Table 2. Comparison of three sets of push-ups between the sessions (n = 8). Values are Mean ± *SD*.

	CON Mean ± *SD*	LBV Mean ± *SD*	UBV Mean ± *SD*
Set 1			
Push-up (#)	29 ± 9	29 ± 8	29 ± 7
RPE (6-20)	15 ± 2	15 ± 3	16 ± 2
HR (b/min)	146 ± 21	151 ± 18	148 ± 20
Set 2			
Push-up (#)	18 ± 7	18 ± 7	18 ± 7
RPE (6-20)	16 ± 2	17 ± 2	17 ± 2
HR (b/min)	152 ± 19	151 ± 17	155 ± 22
Set 3			
Push-up (#)	14 ± 8	14 ± 7	14 ± 7
RPE (6-20)	17 ± 2	17 ± 3	17 ± 2
HR (b/min)	149 ± 17	149 ± 19	149 ± 21

No significant mean differences ($p > 0.05$) were found among CON, LBV, or UBV regarding Wingate 1 peak power (560 ± 121, 594 ± 116, and 588 ± 109 W, respectively) and Wingate 2 peak power (570 ± 151, 557 ± 71, and 564 ± 120 W, respectively) (Fig 2). In addition, no significant differences were observed ($p > 0.05$) for group mean power, fatigue index, RPE, HR and session RPE (Table 3).

Table 3. Comparison of physiological variables of performance after CON, LBV, and UBV recovery treatments (n = 8). Values are Mean ± *SD*.

	CON Mean ± *SD*	LBV Mean ± *SD*	UBV Mean ± *SD*
Wingate 1			
Mean Power (w)	350 ± 59	354 ± 68	362 ± 64
Fatigue Index (%)	55 ± 9	58 ± 8	61 ± 11
RPE (6-20)	18 ± 1	18 ± 2	18 ± 1
HR (b/min)	178 ± 11	178 ± 15	172 ± 6
Wingate 2			
Mean Power (w)	316 ± 49	295 ± 56	312 ± 49
Fatigue Index (%)	61 ± 11	65 ± 10	63 ± 12
RPE (6-20)	20 ± 1	20 ± 1	19 ± 1
HR (b/min)	181 ± 10	177 ± 12	179 ± 5
Session RPE (0-10)	8 ± 1	8 ± 2	8 ± 0

Table 4. Recovery Method Subjective Evaluation (RSME) 100-mm scale for CON, LBV, and UBV treatments (n = 8). Values are Mean ± *SD*. Mean shown with higher score indicates "more likely".

	CON Mean ± *SD*	LBV Mean ± *SD*	UBV Mean ± *SD*	*p* - value
Do you feel using this recovery method helped you to recover better?	30 ± 19*	40 ± 24	65 ± 19	0.009
Do you feel using this recovery method improved your performance ability?	28 ± 19*	37 ± 21	67 ± 16	0.001
How did you feel about the intensity of the recovery?	6 ± 11**	28 ± 23	52 ± 28	0.002
How did you feel about the amount/time of recovery?	34 ± 14	42 ± 23	47 ± 20	0.11
Did you experience any leg discomfort during recovery period?	4 ± 7	12 ± 31	6 ± 16	0.57
Did you experience any pain due to recovery treatment?	10 ± 22	3 ± 4	1 ± 2	0.36
How likely would you be to choose this recovery method during training (between sets/intervals)?	56 ± 20	30 ± 30	50 ± 25	0.12
How likely would you be to choose this recovery method after a training session?	60 ± 22	41 ± 36	67 ± 17	0.13

CON - control, LBV - lower-body vibration, UBV - upper-body vibration. * RMSE response was lower after CON compared to UBV ($p < 0.05$). ** RMSE response was higher after LBV and UBV compared to CON ($p < 0.05$).

No significant mean difference (p = 0.61) was found for perceived recovery after CON (5 ± 2), LBV (6 ± 2) and UBV (6 ± 2). No significant treatment effect or treatment x interaction (p > 0.05) was observed for DOMS (Fig 3). However, muscle soreness declined with time as observed with a significant time effect (p < 0.001). No significant difference was observed for session RPE (p = 0.66). Recovery method subjective evaluation for CON, LBV, and UBV recovery treatments are presented in Table 4.

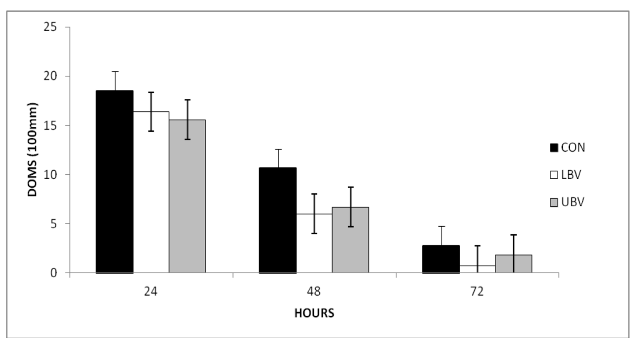

Figure 3. Delayed-onset muscle soreness response (DOMS) after 24, 48 and 72 hours after CON, LBV and UBV recovery treatments (n = 8). CON - control, LBV - lower-body vibration, UBV - upper-body vibration, mm - millimeters. Values are Mean ± *SD*.

DISCUSSION

To our knowledge this is the first study evaluating the effects of UBV and LBV as a recovery modality on upper-body peak and mean power, perceived recovery, and muscle soreness after fatiguing exercise. We hypothesized that UBV and LBV would provide better actual and perceived benefits compared to no vibration, thus, improving peak and mean power, perceived recovery and reduced muscle soreness. However, we observed no significant mean differences in peak or mean power, perceived recovery or muscle soreness after a 10-minute bout of UBV or LBV recovery treatment compared to no vibration.

There are a limited number of studies investigating the effects of UBV on upper-body performance and yet recovery as opposed to whole-body vibration. In a recent crossover design study, Marin et al. (19) observed significant improvements in lower limb explosive force among soccer players following WBV treatment at 50 Hz (2.4 mm) and 35 Hz (1.15 mm). Athletes were able to recover quicker after high intensity exercise session following stretching exercises performed on the WBV platform in conjunction with traditional soccer cool-down. In addition, a study by Bakhtiary et al. (2) observed better performance in isometric maximum voluntary contraction (IMVC) force and reduced creatine kinase (CK) levels following high intensity vibration treatment of 50 Hz compared to no vibration. Despite the possible benefits of WBV on performance and recovery, results of other studies reported no benefits of WBV on physiological recovery following cycling (6) or high intensity interval training exercise (11). A study by Cheng et al. (6) compared 10 minutes of low frequency (20 Hz, 0.4 mm) and high frequency (36 Hz, 0.4 mm) WBV to no vibration. No significant differences in excess post-exercise consumption, heart rate variability or blood lactate 30 or 60 minutes post exercise were observed. Moreover, Edge et al. (11) observed no differences in running performance, CK, or blood lactate after 2 x 15 minutes low frequency WBV (12 Hz, 6 mm) compared to no vibration. Results of our study also indicate that UBV or LBV treatment had no actual or perceived benefits on upper-body performance and recovery compared to no vibration.

The discrepancies between the present study and aforementioned studies should be considered including recovery mode, frequency modality, duration, performance tests, perceived stimulus following UBV and LBV. Higher frequencies were used by Marin et al. (19) and Bakhtiary et al. (2), thus UBV and LBV used in the present study may have been insufficient to provide changes needed to aid recovery and improve performance. On the other hand, we used 10 continuous minutes of UBV and LBV which may have been too demanding and contributed to further fatigue instead of promoting recovery. Prolonged exposure to vibration may cause increased motor unit recruitment which eventually may lead to fatigue and reduced muscle contraction efficiency. Earlier, it has been reported that WBV increases electromyography (EMG) response (5, 28), oxygen consumption (24, 25) as well as oxygenation of the muscle (32) indicating increased muscle metabolic demand.

In the present study, we investigated the effects of passive UBV and LBV as a recovery modality compared to a warm-up routine and in combination of stretching exercises as used in the previous studies. Upper-body performance exercise was performed after fatiguing upper-body exercise, contrary to Bakhtiary et al. (2) applied vibration treatment prior to the eccentric exercise as a warm-up. In addition, Marin et al. (19) performed stretching exercises while administering WBV, thus, this may suggest that vibration treatment may have beneficial effect on recovery and performance if performed in conjunction with traditional cool-down. Also, shorter performance tests such as IMVC and vertical jump were used in the previous studies (2, 19) which may have been more sport specific compared to a 30 second arm cranking exercise.

In the present study, slightly higher perceived muscle soreness following no vibration compared to UBV or LBV was observed, however, it was not statistically significant. Earlier, it has been shown that combination of WBV and WBV in conjunction with stretching exercises were effective in reducing perceived pain of muscle soreness after strenuous exercise (2, 19, 22). Marin et al. (19) observed reduced perceived muscle soreness among soccer players following a single high frequency WBV and stretching treatment performed after repeated-sprint ability test. In addition, in the study by Rhea et al. (22), it has been shown that perceived muscle pain was attenuated by whole-body vibration (35 Hz, 2 mm) and stretching treatment. Participants performed stretching routine on the platform twice per day for a total of three days. Thus, the lack of improvements in the present study could be partially explained by insufficient exposure and perceived stimulus to UBV or LBV. Performing stretching exercises during vibration treatment may provide additional relief for muscle soreness and benefit recovery. A single exposure to vibration may not be adequate, thus, multiple exposures to UBV or LBV following high intensity workouts may be needed to gain any benefits.

In addition, Bakhtiary et al. (2) observed reduced muscle soreness after intense running downhill exercise. However, a high frequency vibration treatment was directly applied to the quadriceps, hamstrings and calf muscles before exercise. Thus, it may be suggested that vibration treatment has to be locally applied before exercise at a higher frequency to augment delivery of oxygen and nutrients needed for repair and increase removal of accumulated metabolic by-products to aid recovery and improve performance.

Even though, actual and perceived recovery did not differ among recovery treatments, participants felt using UBV helped them recover better and improved their performance ability compared to no vibration as indicated by the Recovery Method Subjective Evaluation (RMSE) questionnaire. Although, UBV and LBV were perceived as higher intensity recovery treatments, no significant differences in the HR response after recovery treatments were observed suggesting similar physiological responses. The repeatability of the responses on the RMSE questionnaire following UBV, LBV and CON treatment should be further investigated, as a result, this investigation should be considered as preliminary. In addition, a small sample size, performance variability, and motivation among the participants may have reduced our ability to detect any significant changes following UBV or LBV. Therefore, UBV and LBV cannot be considered a useful recovery modality under the conditions of this study.

Muscle recovery between training and competition sessions is of a great concern to the athletes that heavily rely on upper-body performance, train multiple times a day, and participate in multiple events during competition. Muscle soreness and impaired muscle function will negatively affect athlete's performance quality during training and competition. Thus, finding the best recovery treatment for an athlete that works the best in a short period of time could be a key to successful performance. The results of the present study indicated that we cannot expect, on average, acute exposure to UBV or LBV to enhance recovery and reduce muscle soreness compared to no vibration based on the protocol used in this study. However, coaches and athletes should acknowledge that this is the first study evaluating the effects of UBV and LBV as a recovery modality.

In conclusion, UBV and LBV recovery treatments did not benefit group mean performance, perceived recovery, and muscle soreness after fatiguing upper-body exercise compared to no vibration. Therefore, we recommend that future investigations, coaches, and athletes test for optimal recovery mode, duration, frequency, and stability of recovery method.

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