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Effects of blood flow restriction combined with post-activation potentiation stimuli on jump performance in recreationally active males.

Brief running head: Blood flow restriction and post-activation potentiation

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ABSTRACT

Whole-body vibration and maximum voluntary contractions combined with blood flow restriction to augment post-activation potentiation have yet to be examined. Therefore, the purpose of this investigation was to examine the augmented effects of post-activation potentiation when whole-body vibration and maximum voluntary contraction are combined with blood-flow restriction. Twenty men (21.8 ± 2.6 years, 180.5 ± 6.2 cm and 84.5 ± 12.1 kg) completed the study. Participants completed three testing sessions in a randomized design that included one of the following: 1) control (CON), 2) whole-body vibration (WBV) and whole-body vibration combined with blood flow restriction (WBV+BFR), or 3) maximum voluntary contraction (MVC) and maximum voluntary contraction combined with blood-flow restriction (MVC+BFR). Jump height and power were recorded for three trials, PRE and POST Jump height (cm) means ± SD for each were: CON 58.9±8.6 and 57.9±8.6, WBV 58.2±8.1 and 59.9±8.1, WBV+BFR 58.7±7.6 and 60.2±8.1, MVC 59.7±7.4 and 60.2±8.6, and MVC+BFR 57.7±7.9 and 59.4±8.1. PRE and POST Jump power (W) means ± SD for each were: CON 1224.3±221.5and 1234.3±189.2, WBV 1251.1±230.4and 1266.1±215.7, WBV+BFR 1265.8±207.9and 1259±223.3, MVC 1264.7±211.9and 1263.5±236.5, and MVC+BFR 1252.3±222.0 and 1294.6±256.6. Significant differences were revealed in jump height between the five interventions ($p < 0.01$), WBV ($p < 0.01$), WBV+BFR ($p < 0.01$) and MVC+BFR ($p < 0.01$) revealed significant differences in time but no differences in jump power. In conclusion, the results of this study indicate that WBV, WBV+BFR and MVC+BFR significantly improve jump height and time in air but not jump power.

Keywords: KAATSU, whole-body vibration, maximum voluntary contraction, Tendo Unit.

INTRODUCTION

Following a skeletal muscle contraction, subsequent contractile performance is a direct result between the balance of fatigue and potentiation (16,17,26). Although neuromuscular fatigue can diminish performance, post-activation potentiation (PAP) can significantly improve performance (6,27,29). Indeed, fatigue and PAP may coexist, however achieving optimal muscular performance requires the reduction of fatigue with a simultaneous persistence in potentiation. (17,26). The optimal recovery time necessary for PAP to impose precedence over fatigue is still ambiguous. However, recent meta-analyses indicate that significant PAP has been achieved between zero and 20 minutes (30,34). Previous literature provides evidence that PAP can be accomplished following a maximal contractile activity. However, the most efficacious method for incorporating these findings into training and power based sports remains controversial (17,23,32,33).

When skeletal muscle achieves a maximum voluntary contraction (MVC), transient increases in peak torque are elicited via PAP (27,33). The PAP response is believed to occur through one of two mechanisms. The first mechanism suggests the PAP response arises through the phosphorylation of myosin regulatory light chains. The second mechanism suggests the occurrence of PAP via neural modulation through increases in motor unit recruitment and neural firing rates leading to increased force production (24). Previous literature has revealed the tendency of MVCs to elicit a significantly greater PAP effect, when compared to dynamic movements, prior to performing powerful movements. Currently, the cumulative body of literature regarding MVC and PAP is rather ambiguous, with results revealing both improvement and decrements in jump performance (4,7,8,12,15) therefore, further research is warranted to distinguish the role of MVC in provoking PAP.

Whole-body vibration (WBV) has also been employed to stimulate PAP. Recent literature has consistently revealed significant increases in vertical jump performance following the use of WBV (4,6,10,25). A variety of factors, such as body position and vibration frequency, have shown to contribute to the development of PAP from WBV (28). Post-activation potentiation occurs through vibrations transmitted from the platform throughout the body which stimulate sensory receptors, ultimately causing reflexive activation of alpha-motor neurons with increased spatial recruitment (2,3,5,18). To date, the optimal vibrating frequency and amplitude remains elusive, as varying degrees of both have yielded a PAP response (22).

Blood flow restriction (BFR) exercise has emerged as a promising modality to elicit skeletal muscle adaptation. Low-intensity resistance training combined with BFR has revealed similar outcomes to those reported with high-intensity resistance training (1,11,21). Although BFR has undergone extensive research, the utilization of BFR to elicit a PAP response has yet to be evaluated. Furthermore, BFR combined with WBV or MVC may augment the acute PAP muscular response. Therefore, the purpose of this investigation was to examine the effect of BFR in augmenting PAP during jump performance when combined with WBV and MVC.

METHODS

Experimental Approach to the Problem

A randomized repeated measures cross-over design was used to investigate if the addition of BFR would enhance PAP during jump performance. Participants completed one familiarization session and three testing sessions. Two testing sessions served as the experimental interventions (WBV & WBV+BFR or MVC & MVC+BFR) and one session served as a control. Sessions were randomly selected by the participant at the beginning of each visit then later removed to ensure no testing duplication. Participants performed three CMJs prior to each intervention (PRE), rested for ten minutes then performed three additional CMJs after (POST). Jump height and jump power values for PRE and POST were averaged for each participant and then used for statistical evaluation. Each testing session required a minimum of 48 hours between subsequent testing to account for fatigue and allow full recovery.

Subjects

Twenty recreationally active males (21.8 ± 2.6 years; 180.5 ± 6.2 cm; 84.5 ± 12.1 kg) who had been performing lower body resistance exercise at least twice weekly during the previous six months and were at least six months removed from any lower extremity injury or ailment completed the study. Individuals who had disabilities preventing strength measurement or contraindications to whole-body vibration exposure were excluded from this investigation. Participants were required to fill out an informed consent, health status questionnaire, and a Physical Activity Readiness Questionnaire prior to the inclusion in the study. Study design and procedures are in accordance with ethical standards and the Declaration of Helsinki. Each subject was fully informed about the risks associated with study participation and gave written informed consent before the start of the study. Therefore, this study meets the ethical standards of the Journal of Strength and Conditioning Research (13). Data collection commenced with the approval of the Institutional Review Board at the University of Oklahoma.

Procedures

This investigation utilized a randomized repeated measures experimental cross-over design. Each participant completed four total visits. The initial visit provided a familiarization of each protocol which included one of the following combinations: 1) control (CON), 2) whole-body vibration (WBV) and whole-body vibration + blood flow restriction (WBV+BFR), and 3) maximum voluntary contraction (MVC) and maximum voluntary contraction + blood flow restriction (MVC+BFR). During the familiarization visit, each subject was taken through each protocol and introduced to each piece of equipment used during the investigation. Furthermore, subjects performed bouts of WBV, WBV+BFR, MVC, and MVC+BFR to become familiar with each protocol. Before each intervention, each subject was provided a demonstration and verbal instructions on how to perform each protocol. Additionally, interventions were randomized for each testing session, allowing WBV and WBV+BFR or MVC and MVC+BFR to be random in order of application between participants. During the WBV and WBV+BFR protocols subjects were asked to maintain knee flexion during the vibration exposure. When subjects performed the MVC and MVC+BFR protocols, subjects replicated the knee flexion position that was assumed during vibration exposure. Once the position was assumed, the smith machine barbell was fastened to the floor by an 8 mm chain in order to maintain similar knee flexion during the MVC stimulus. Deadlift was selected to perform the MVC's since it had not been previously used in similar investigations. Furthermore, it was also selected due to the ability to replicate knee flexion angle assumed during the WBV exposure as well as the ability to potentiate the greatest amount of muscle mass possible. Testing visits were randomly selected at each visit without replacement, to ensure no selection duplication. In addition, 48-72 hours was required between visits. At each testing session, participants performed three CMJs. Next, the participant performed the selected intervention (CON, WBV or MVC), followed by a ten-minute rest period where the subjects rest seated in a chair. Ten minutes' rest was chosen for the rest time as previous literature has indicated that PAP tends to peak between 8 to 12 minutes (17,30,34). Following ten minutes' rest after the initial intervention, participants completed three CMJs. After completing the initial intervention of the session, participants were provided 30 minutes of rest seated in a chair, and then completed the second intervention of the session. 2Upon completion of the second intervention, participants rested for ten minutes. Finally, the participant performed three additional CMJs (Figure 1). During the CON intervention visit, participants performed three CMJs, rested in the seated position for ten minutes and then performed three additional CMJs (Figure 2).

******Insert Figure 1 about here******

******Insert Figure 2 about here******

Countermovement Vertical Jump Test

Vertical CMJ tests were used to assess lower body performance. Participants performed each jump trial using a Just Jump mat (Just Jump System, Probotics, Huntsville, AL, USA) in combination with a power and speed belt analyzer (Tendo Unit, Fitrodyne Sport Powerlyzer, Tencin, Slovak Republic). Vertical jump height was calculated via time in air and power was calculated by the Tendo Unit attached to a belt secured around the subject's waist. Participants were instructed to perform each trial positioned in the center of the mat; feet placed shoulder width apart, and subjects were allowed to bend their knees and swing their arms in order to exert maximal effort. After each trial participants were required to undergo one minute of rest prior to performing subsequent trials. Three CMJs were performed for each intervention; means for the three CMJs were calculated and used for statistical analysis.

Interventions

Whole-Body Vibration. Whole-body vibration was applied using a Power Plate vibration platform (Next Generation®, Power Plate USA, Northbrook, IL, USA). Participants completed three rounds of 20 seconds with one-minute rest between rounds at a frequency of 40 Hz and high amplitude at 4-6 mm peak to peak amplitude since previous literature within our laboratory suggests that this protocol can efficiently induce a PAP stimulus (18). Each participant was instructed to position themselves in the center of the plate, feet barefoot and shoulder width apart, knees flexed and hands placed on the handles.

Whole-Body Vibration with Blood Flow Restriction. When BFR was combined with WBV (WBV+BFR) each subject wore six centimeter wide BFR cuffs (Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan) at the most proximal portion of each leg. Prior to standing on the vibrating platform, cuffs were manually inflated to 160 mmHg (Kaatsu-Master, Sato Sports Plaza, Tokyo, Japan). This occlusion pressure was selected since previous literature has suggested that it will restrict arterial blood flow to the working muscle and occlude venous blood flow return (1). Once the cuffs reached the designated pressure, participants performed three rounds of 20 seconds with one-minute rest between rounds at a frequency of 40 Hz and high amplitude at 4-6 mm, peak to peak amplitude. Each participant was instructed to position themselves in the center of the plate, feet barefoot and shoulder width apart, knees flexed and hands placed on the handles. Between trials cuff pressure was maintained at 160 mmHg, immediately following the third round of vibration, the cuff pressure was released.

Isometric Maximal Voluntary Contraction. Maximal voluntary contractions were performed using an Olympic bar (Smith Machine, Cybex International Inc., Medway, MA, USA) with straps fixing the bar to the ground with an additional 180 pounds of plate weight added to the bar. The bar was fixed at a height that allowed for subjects to replicate the amount of knee flexion assumed during WBV. Between subjects, the straps were adjusted in order to move the bar up or down to increase or decrease the amount of knee flexion to replicate the flexed knee position during WBV. Participants positioned themselves in a dead lift position above the bar with their knees flexed to and were informed to pull up on the bar as hard as possible for ten seconds. One minute of rest was taken between each trial for a total of three trials.

Isometric Maximal Voluntary Contraction with Blood Flow Restriction. When MVC was combined with BFR the same inflation protocol for WBV+BFR was used. Once the cuffs were inflated to 160 mmHg, participants positioned themselves in a dead lift position, with knees flexed to a similar degree obtained during WBV, above the bar and were requested to pull up on the bar as hard as possible for ten seconds. One minute of rest was taken between each trial for a total of three trials and following the third trial, cuff pressure was immediately released.

Statistical Analysis

Statistical measures are reported as mean ± standard deviation. A 2x5 (time x condition) repeated measures analysis of variance (ANOVA) was used for both jump height and jump power. Following the two-way ANOVA, if significant difference were found, dependent samples t-tests were utilized to reveal where the differences occurred. Data was analyzed using SPSS statistical software package v.19.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set a priori at $p < 0.05$ and effect sizes were calculated and interpreted as trivial (0-0.19), small (0.20-0.49), medium (0.50-0.79) and large (0.80 and greater) (9).

RESULTS

Table 1 presents the PRE and POST jump power and jump height values for each of the five conditions. Two-way ANOVA revealed no significant time x condition interaction for jump power (p = 0.261). Additionally, there were no significant main effects for time (p = 0.118) or condition (p = 0.140). Jump height revealed a significant time x condition interaction (p = 0.001, *d* = 0.02). Further evaluation revealed significant differences between PRE and POST values for WBV (p = .004, *d* = 0.21), WBV+BFR (p = 0.005, *d* = 0.21) and MVC+BFR (p = 0.001, *d* = .25) with POST jump height values being significantly higher. There were no significant differences when evaluating the effect for condition (p = 0.10) but a significant time main effect for jump height was observed (p = 0.004, *d* = .22) revealing POST jump height values being greater than PRE jump height values.

****** Table 1 here ******

DISCUSSION

The results of this study revealed no significant changes in jump power across each of the conditions; however, when evaluating jump height, significant increases were revealed for WBV, WBV+BFR and MVC+BFR. The present findings are congruent with previous literature, indicating WBV and MVC can lead to increased subsequent jump performance by means of PAP. Furthermore, when evaluating the conditions that elicited a significant increase in jump height (WBV, WBV+BFR, MVC+BFR) the addition of BFR did not enhance the PAP response.

The results of this investigation indicate that the addition of BFR to WBV or MVC does not augment the PAP response.

The primary purpose of this investigation was to determine whether the addition of BFR would augment a PAP response. In order to evaluate the potential augmented effects, subjects were taken through two protocols implementing BFR. Previous literature indicates that an acute neuromuscular adaptation via BFR training is an increase in the recruitment of type II fibers which could serve as a postulated mechanism to induce a PAP response (35). Therefore, the significant increases in jump height from WBV and MVC combined with BFR may have been contributed to the increased fiber recruitment post BFR intervention. Thus the combination of a BFR with WBV and MVC may have allowed for a significant increase in jump height. However, it must be noted that WBV+BFR and MVC+BFR were not significantly different when compared to either modality without BFR.

Previously, WBV has been established as a modality to elicit a PAP response as well as enhance subsequent jump performance. The findings of this investigation are similar to that of additional investigations examining WBV and PAP. Similar to recent investigations, the intervention consisted of three 20 second rounds at high amplitude 40Hz at 4-6mm (6,14,23). This loading pattern seems to provide enough of a stimulus to elicit a PAP response. Furthermore, participants within this investigation were instructed to be positioned in the middle of the vibrating platform with their knees flexed. Previous literature indicates that body and foot position could play a role. When evaluating participant position on the platform; knees flexed and feet facing forward have been most beneficial at eliciting an EMG and PAP response (28).

The study design involved three testing visits for each participant for five interventions. Although a 30-minute resting period was incorporated during two visits (WBV/WBV+BFR and

MVC/MVC+BFR) the first testing measurement may have accumulated fatigue that could have factored into the testing of the second procedure following 30 minutes of rest. In order to account for the residual fatigue produced from the study design, there was a randomization aspect that was implemented for each session. The randomization allowed for the controlled version of each stimulus and the BFR version to change between being tested first and second for each individual. In comparison to similar recent investigations examining the possible protocols to elicit PAP, testing took place on separate days with at least 24 hours between sessions (4,10,24). In addition to the combined intervention testing, one of the strengths of the investigation called for ten minutes' rest post-intervention. This amount of time is within the most favorable window of opportunity previously determined from the literature. The review of previous research indicated eight to 12 minutes as the time frame for generating peak power output; therefore, ten minutes was the chosen rest period (17,30,34).

Although only three of the interventions revealed significant increases for jump height, each intervention had higher jump heights compared to the control condition (Table 1). This could indicate that PAP was present but not strong enough to elicit a significant change in jump power. Furthermore, when determining an efficient PAP protocol the balance between fatigue and potentiation must be considered (16,17,26). Since the MVC intervention resulted in an increase in jump height, the balance between fatigue and potentiation would have favored potentiation and resulted in an increased performance (17,26,29). This could lead to the speculation of MVC generating a PAP response that was not strong enough to elicit a significant change, even though previous research has indicated that jump performance can be significantly improved following MVC (4,8,15,27,33). Furthermore, some of the interventions that displayed increases in jump height also reported decreases in jump power. This could be due to the manufacturer software calculating power (P) as work (W) over time (T) (P=W/T). In this instance, the increase in jump height would also increase the amount of time spent in air ultimately increasing the denominator in the formula leading to a decrease in overall power.

This investigation was not without limitations. Participants recruited for this investigation were recreationally active males who had been performing lower body resistance exercise at least twice weekly during the previous six months. Previous research has indicated that athletes or more rigorously trained individuals are likely to encounter a greater PAP response which may explain the minute increases in jump performance for these recreationally active males in this investigation. The increased PAP response for athletes may due to a great proportion of type II muscle fibers within those individuals (31). An additional limitation would include the knee flexion angle of subjects while on the vibrating platform. In the current investigation, subjects were instructed to flex their knees, however providing a uniform angle at which the knees were during vibration exposure may have altered the cumulative response. Several investigations have indicated that the neuromuscular response can be altered when varying knee flexion angle (2,6,28). Furthermore, subjects were asked to assume the same degree of knee flexion during WBV exposure and when performing the MVCs. Perhaps the inclusion of knee flexion measurement would have made the body position more uniform across interventions. Additionally, the implementation of 160mm Hg for blood flow restriction may have resulted in varying amounts of BFR between subjects because of differences in thigh size reported. Recent research with BFR has indicated that several factors may contribute to the overall stimulus provided by BFR such as cuff width and cuff pressure (19,20).

PRACTICAL APPLICATIONS

The results of this investigation indicate that the addition of BFR to WBV or MVC does not further enhance PAP. Although both of the BFR protocols revealed significant increases in jump height, they were not significantly different from their matched non-BFR interventions. Furthermore, previously establish protocols using WBV and MVC would be just as efficient for eliciting PAP with less discomfort from the cuffs. Due to the increases in jump height in both of the BFR groups, further research should manipulate additional variables (vibrating frequency, amplitude, BFR pressure, cuff width, etc.) and examine the manipulative effects on subsequent jump performance. In conclusion, this data reveals that WBV or MVC would serve as just strong as a role for providing PAP. However, the addition of BFR does not further elicit the PAP response.

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Table 1. Subject jump characteristics

	Jump Height (cm)		Jump Power (Watts)	
	Pre	Post	Pre	Post
CONTROL	58.9±8.6	57.9±8.6	1224.3±221.5	1234.3±189.2
WBV	58.2±8.1	59.9±8.1*	1251.1±230.4	1266.1±215.7
WBV+BFR	58.7±7.6	60.2±8.1*	1265.8±207.9	1259±223.3
MVC	59.7±7.4	60.2±8.6	1264.7±211.9	1263.5±236.5
MVC+BFR	57.7±7.9	59.4±8.1**	1252.3±222.0	1294.6±256.6

Mean ± SD, WBV: whole-body vibration; WBV+BFR: whole-body vibration + blood flow restriction; MVC: maximum voluntary contraction; MVC+BFR: maximum voluntary contraction + blood flow restriction. *p < 0.05, **p < 0.01.

Figure 1. Intervention visit schedule.

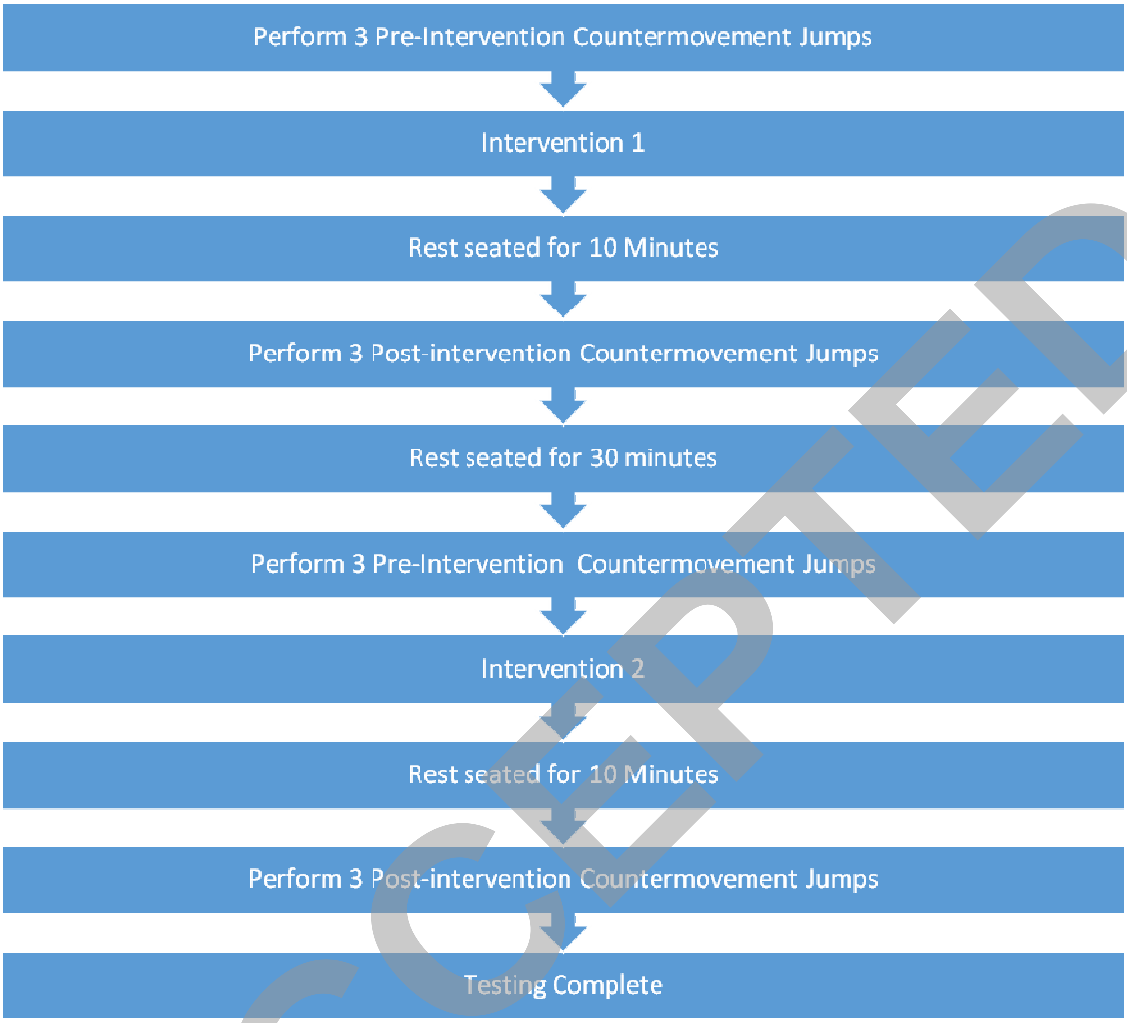

Figure 2. Control visit testing schedule