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CONTINUOUS WEIGHTED JUMPING: EFFECTS ON VERTICAL JUMP HEIGHT

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Abstract:
High intensity, near maximal exercise is a conditioning activity which can cause neural hyper-stimulation and lead to acute enhanced power production known as post-activation potentiation (PAP). Investigations need to be conducted to better understand the duration and intensity of the conditioning activity and subsequent effects on the fatigue-potentiation relationship. **Purpose:** To investigate the effect of 30 seconds of continuous vertical jumping while wearing a vest loaded with 30% of body weight on power output as measured with a maximal vertical jump (VJ). **Methods:** 14 volunteers (8 weight trained males [23.0+2.9 yrs, 79.8+13.8 kg, 179.9+8.6 cm] and 6 weight trained females [23.0+2.9 yrs, 69.9+13.3 kg, 171.6+7.0 cm]) participated in the study. Pre-testing consisted of each participant performing 3 VJs. The highest VJ was recorded as baseline. A weighted vest was then loaded equaling 30% of the individual's body weight; while wearing the weighted vest, participants performed 30 seconds of continuous VJs. Immediately after jumping participants were seated in a chair for 3 minutes; at 3 minutes, they performed a maximal VJ without the weighted vest in the same manner as done during pre-testing. Two additional VJs were repeated at 4 and 5 minutes post weighted jumping. A mixed design ANOVA with repeated measures was performed. **Results:** Results showed main effects for each of the independent variables tested, gender and jump. The posttest values at all 3 intervals for both males and females were significantly different from the pretest scores ($F [3, 36] = 21.74$, $p < 0.05$). Post hoc analysis indicated that the pretest VJ scores ($M = 280.1 \pm 18.6$ cm) decreased significantly

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at the 3 minute interval (M = 278.1±18.3 cm), followed by a significant increase in height at the 4 minute interval (M = 281.1±18.7 cm), and another increase at the 5 minute interval (M = 283.0±19.2 cm). Males jumped significantly higher than the females across all trials ($p<0.05$), however there was no significant difference between male and female VJ gain scores between pre-PAP VJ and 3, 4 and 5 minute post weighted exercise VJ. **Conclusion:** Results suggest that 30 seconds of weighted VJs causes fatigue which decreases VJ at 3 minutes post exercise. However, a PAP effect was seen at 4 and 5 minutes post weighted exercise significantly increasing VJ above pre testing. From a practical perspective, coaches must be aware of the complex nature of the fatigue-potentiation relationship when attempting to elicit a PAP effect in the individual athlete.

Keywords: post-activation potentiation; power; jump

1. Introduction

Post-Activation Potentiation (PAP) is a neuromuscular phenomenon which occurs when the nervous system is acutely hyper-stimulated and allowed to recover, resulting in increased muscular power output (5, 7, 12, 14, 17, 20, 22, 25, 30). Various types of conditioning activities (e.g., weighted jumps; functional isometrics; heavy lifting) have been used to hyper-stimulate the nervous system prior to performing an explosive movement (e.g., vertical jump, shot put, sprinting) (1, 3, 4, 10, 11, 16, 18, 21, 29, 31-33). Key to eliciting a PAP response is the fatigue-potentiation relationship (13, 19, 24, 26, 27, 30). Basically, this can be thought of as a balancing act; that is, with a stimulus or conditioning activity fatigue occurs inhibiting potentiation; as one recovers, fatigue is reduced and in theory potentiation takes over; if a potentiation state occurs, research suggests there is an optimal time window of potentiation which may elicit a PAP response in an acute exhibition of power (8, 12-14, 19, 22, 24, 26, 27, 30). The length of this time window of potentiation has been the subject of several recent investigations (e.g., 1, 8, 13, 19, 26, 27), whereas the duration of the conditioning activity has experienced less research focus (e.g., 6, 12, 14, 22). Studies indicate that a conditioning activity that is too long in duration (e.g., > 5 total repetitions or 5 seconds of total contraction time) causes too much fatigue and limits the PAP effect (12, 14, 22).

However, in contrast, our research group recently found that approximately 20-30 seconds of VJs (i.e., 10 repetitions in 1 set) while wearing a weight vest loaded with 20% of individual bodyweight elicited a PAP effect in female volleyball players performing an approach VJ (6). With that said, participants in Deneke et al.'s study were trained collegiate volleyball players who were accustomed to significant amounts of repeated VJs, and therefore may have confounded the results specific to this fatigue-potentiation question. We wanted to investigate if a similar fatigue-potentiation relationship would manifest itself in those not accustomed to repeat jumping.

Therefore, the purpose of this study was to investigate the effect of 30 seconds of continuous vertical jumping (VJing) while wearing a vest loaded with 30% of body weight on power output as measured with a single maximal VJ in weight trained males and females. It was hypothesized that continuous VJing for 30 seconds with a weighted vest equal to 30% of a person's body weight would elicit a PAP effect and result in an increased VJ height at 3, 4 and 5 minutes post weighted jump exercise in these participants.

2. Methods

2.1 Participants

A total of 14 volunteers participated in this study (i.e., 8 weight trained males, 23.0+2.9 yrs, 79.8+13.8 kg, 179.9+8.6 cm; and 6 weight trained females, 23.0+2.9 yrs, 69.9+13.3 kg, 171.6+7.0 cm). Participants had at least 6 months of continuous weight training prior to the study, lifting 3-5 days a week and specifically including lower body exercises and able to back squat 1.25 to 2.0 times bodyweight. All participants were familiar with VJ testing protocols using a Vertec (Sports Imports, Columbus, Ohio), but were not accustomed to repetitive VJing. This study was approved by the University's Institutional Review Board and all subjects signed an informed consent before initiating the study.

2.2 Procedures

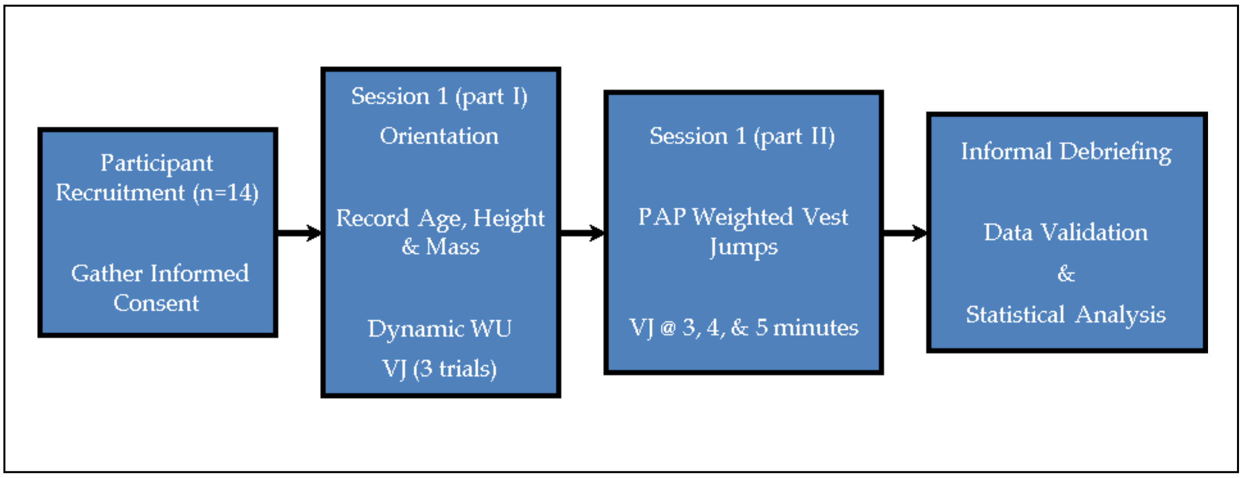

Figure 1: Study time line of events. PAP-post activation potentiation; WU-warm-up; VJ-vertical jump; Countermovement VJs wearing a weighted vest at 30% of body weight was used as the PAP conditioning activity

A. Study Introduction, Informed Consent, and Warm-Up

- Step 1 - Potential volunteers were asked to come to the Exercise Physiology Lab in a rested state (i.e., not having exercised their lower body for 48-72 hours). Next, they received a verbal explanation of the project; if they decided to participate, they reviewed and signed the informed consent form. Then on that one day, each participant performed the following:
- Step 2 - Descriptive data was collected on the participant.
- Step 3 - The participant performed a general dynamic warm-up.
- Step 4 - Vertical jump technique (i.e., countermovement VJ) with the Vertec was reviewed and participant was allowed 2-3 practice trials.
- Step 5 - After the warm-up and practice period, the participant sat down and rested for 3 minutes.

B. Testing Protocol

- Step 6 - After the 3 minutes of rest, the participant performed 3 maximal VJs with countermovement, each separated by 1 minute of seated rest. The best result on the Vertec was recorded.
- Step 7 - The participant sat down and rested for 3 minutes.
- Step 8 - At 4 minutes, participants were fitted with a weighted vest loaded to 30% of their body weight.
- Step 9 - At 5 minutes, participants performed 30 seconds of continuous weighted VJing.
- Step 10 - After 30 seconds of jumping, the weighted vest was removed and the participant sat down and rested for 3 minutes.
- Step 11 - After the 3 minutes of rest, the participant performed a maximal VJ in the same manner as was performed in the pre-test.
- Step 12 - The participant then sat down and rested 1 minute; and at minute 4 performed another maximal VJ.
- Step 13 - The participant then sat down and rested 1 minute; and at minute 5 performed one more VJ.

All warm-ups, VJ practice and VJ testing was performed under the direct supervision of a certified strength and conditioning specialist (National Strength and Conditioning Association Certified Strength and Conditioning Specialist – NSCA CSCS).

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2.3 Reliability

The VJ as measured by devices such as Vertec have demonstrated a reliability coefficient of ICC=0.95 (23).

2.4 Statistical Analysis

Descriptive statistics (mean ± SD) were performed on participants. A mixed design ANOVA (group x VJ) with repeated measures on the VJ independent variable was performed. Statistical significance was set at the $p < 0.05$ level. Post hoc comparisons were performed using paired sample t-tests. Statistical calculations and data management were conducted with Microsoft Excel 2013. The assembled spread sheet of test data was peer reviewed for errors prior to analysis as suggested by AlTarawneh & Thorne (2).

3. Results

Table 1: Participant Descriptive Information

	Age (years)	Height (cms)	Mass (kgs)	Pre-VJ	3-minute VJ	4-minute VJ	5-minute VJ
Female n=6	23.0±2.9	171.6±7.0	69.9±13.3	263.3±11.3	261.6±10.5*	264.4±11.7*	266.3±10.5*
Male n=8	23.0±2.9	179.9± 8.6	79.8± 13.8	292.8±11.4	290.5±11.7*	293.7±11.5*	295.6±13.6*

Participant means and standard deviations for descriptive information. *significantly different from pre-VJ p<0.05.

There was a VJ main effect F (3,36) = 21.74, $p < 0.05$, power = 1.00. Post hoc analysis revealed that 3 minutes post weighted exercise VJ was lower than pre exercise VJ, and 4 and 5 minutes post weighted exercise VJs were higher than pre exercise VJ (Table 1).

There was a group main effect F (1,12) = 21.98, $p < 0.05$, power = 0.99; male's VJ was significantly higher than female's VJ across all trials. But, there was no significant difference between male and female actual VJ gain scores between pre exercise VJ and the VJ at 3, 4 and 5 minute post weighted jump exercise.

4. Discussion

This study investigated the effect of 30 seconds of continuous VJing while wearing a vest loaded with 30% of body weight on power output as measured with a maximal VJ.

We hypothesized that these participants would experience a PAP effect resulting in an increased VJ height at 3, 4 and 5 minutes post weighted VJ exercise.

Results were mixed. At 3 minutes post weighted VJ, males and females decreased VJ height an average of 2.0 cm, indicating a fatigue state in the participants that limited performance and was opposite the hypothesis that predicted potentiation would overcome fatigue. At 4 minutes post weighted VJ, VJ height increased over pre exercise VJ height by 1.0 cm (3.0 cm over VJ at 3 minutes post); at 5 minutes post weighted VJ, VJ height increased by 2.9 cm above pre exercise VJ (4.9 cm over the VJ at 3 minutes post). These positive results at minute 4 and minute 5 confirm the hypothesis and indicate a potentiated state that overcame the fatigue which existed at minute 3, and improved performance post weighted VJ. As expected, males jumped higher; but, there was no significant difference between male and female actual VJ height differences between pre exercise VJ and 3, 4 and 5 minute post weighted exercise VJ. While we realize that this is a small study, this finding suggests a similar PAP response in males and females when exposed to this type of conditioning activity.

In relation, Deneke et al. (6) had a similar protocol (i.e., 10 maximal VJs while wearing a weight vest loaded with 20% of the individual's bodyweight, resulting in a total contraction time of ~ 20 to 30 seconds) that elicited a PAP effect in collegiate volleyball players. However, the VJ trials (i.e., 2 different VJ styles specific to volleyball performed 3 times each) commenced at 4 minutes post weighted jumps and lasted to minute 5:15 post weighted jumps (i.e., they were not assessed at 3 minutes post), and these women were accustomed to performing repetitive VJs. The current studies participants were not accustomed to repetitive VJing, but were relatively trained weight lifters who routinely performed front and back squats in training. Research suggests that individual characteristics (e.g., strength levels, training history, fatigue/recovery state, etc.) all impact the potential PAP response (1, 3, 7, 15, 16, 26, 27, 28, 30).

While participants did confirm that they reported to the lab in a rested state, study logistics precluded us from getting an actual one repetition maximum (1 RM) strength measure of the lower body (i.e., a 1 RM barbell back squat); participants did self-report squat 1 RM levels of 1.25 to 2.0 times bodyweight. In an attempt to induce fatigue and potentiation, we chose 30% of bodyweight as the weighted vest load per the high reported strength levels of the participants. Feedback from the participants indicated the conditioning activity elicited a high level of fatigue.

Other studies investigating the fatigue-potentiation relationship have a wide variability in the duration, choice, and intensity of the conditioning activity, making it difficult to make direct comparisons. For example, Berning et al. (3) used functional isometrics (FIs) as the conditioning activity. FIs combine maximal dynamic and isometric muscle actions using weight loads in excess of the 1RM. Specifically, Berning and colleagues used a 3-second FI squat at a load of 150% of 1 RM in an attempt to elicit a PAP in weight trained and untrained men. While the FI squat had no effect on the untrained subjects, the trained subjects significantly increased VJ post FI squat. Ah Sue and colleagues (1) used a 5 RM back squat as the conditioning activity; this resulted in a significant increase in VJ for over 10 minutes in female collegiate volleyball players. Duration of this conditioning activity was not reported, but when simulating a 5 RM back squat, duration of the set is approximately 15-25 seconds (i.e., 3-5 seconds per rep including setting under the load and taking a deep inhalation between repetitions and including eccentric, concentric, and isometric muscle actions). Similarly, Tano et al. (28) used the back squat performed for 4 repetitions at 85% of 1 RM (per above calculations this typically represents 12-20 seconds of total contraction time) to significantly improve sprint speed and weighted sled push speed in high school football players. Dolan et al. (8) investigated the effects of the hang power clean on shot put performance. After warm-up, participants performed 3 sets of hang clean and jerks (3 repetitions @ 80% 1-RM) with 3 minutes of rest between each set; shot put performance was improved after 8 minutes of rest. The fact that a rest occurred in-between each set of the conditioning activity confounds interpretation; but, similar to above, the last set of 3 repetitions typically lasts approximately 9-15 seconds. Similarly, Hamilton et al. (15) used 5 sets of progressive DLs as the conditioning activity with a 3 to 5 minute rest in-between each set (i.e., sets x repetitions x 1 RM load): 1 x 5 x 60%; 1 x 4 x 70%; 1 x 3 x 80%; 1 x 2 x 85%; 1 x 1 x 90%. Participants were then given 7 minutes of rest before performing a hang power clean. Results demonstrated a significant improvement in performance. Per this protocol, one could argue that the last set of 1 repetition actually represented the conditioning activity, making this either a very short (i.e., 1 x 1) or very long conditioning activity (i.e., the entire warm-up protocol).

As one can see from these examples, comparisons related to duration and intensity of the conditioning activity are complicated by many factors including time and type of muscle action, load, choice of exercise used, and interpretation of the entire conditioning activity (e.g., warm-up and final stimulus) each with a potential impact on the fatigue-potentiation relationship and subsequent PAP effect. In relation to the duration of the conditioning activity, the above studies, examples of timing, and discussion confound interpretation of the recommendation (22) to limit the activity to sets of 5 or less repetitions or 5 seconds of contraction time.

Related to the complicated interpretation of PAP research, Enoka and Duchateau (9) highlight that fatigue is a complex trait to assess and requires one to look at both performance and perceived fatigue, as both may impact different parts of one's overall outcome. While we cannot identify the cause or locus of the decreased VJ height at 3 minutes post weighted jump, the VJ is an ecologically valid measure of performance that involves ballistic action of the stretch-shortening cycle. And, we did get the participant's anecdotal perceptions of fatigue via simple conversation (e.g., that was hard; I'm tired). With that said, we recommend future studies include formal measures of perceived exertion to help quantify fatigue to better represent the individual's entire state of both performance outcomes and perceptual indications (9).

There are a few limitations of this study that need to be highlighted: 1) lack of VJ measurements post 5 minutes; 2) the use of self-reported maximal back squat levels (i.e., we did not test 1 RM back squat); 3) not using a formal assessment of perceived fatigue and effort; and 4) inability to control for individual characteristics such as strength levels, resistance to fatigue, past training history, etc.

In conclusion, these results demonstrate that 30 seconds of weighed VJs elicited a significant decrease in VJ height at 3 minutes post exercise but a significant increase in VJ height at 4 and 5 minutes post weighted exercise, a relationship consistent across genders. We hypothesize that this represents the dynamic nature of the fatigue-potentiation relationship when attempting to elicit a PAP effect with a conditioning activity.

5. Practical Application

These results suggest that the practitioner or coach needs to pay careful attention to the fatigue-potentiation relationship when attempting to elicit a PAP effect. This protocol, while increasing VJ at 4 and 5 minutes post weight jumping, decreased VJ at 3 minutes post. Therefore, while there may be validity in using this technique to assist an athlete during training or immediately prior to competition in increasing acute power output in VJing, individually assessing the protocol's effects prior to the event is key. The PAP effect is complex, and apriori, individualized assessment related to fatigue and potentiation needs to be carried out to optimize implementation in practical settings.

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Conflict of Interest Declaration
No funding was received for this research. The authors have no conflict of interest related to this research.

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