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# Induced Post-activation Potentiation and its Relationship to Performance Variables in the Block Start

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INDUCED POST-ACTIVATION POTENTIATION AND ITS RELATIONSHIP TO  
PERFORMANCE VARIABLES IN THE BLOCK START

by

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B.S., Illinois State University, 2002

A Research Paper

Submitted in Partial Fulfillment of the Requirements for the  
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RESEARCH PAPER APPROVAL

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## AN ABSTRACT OF THE RESEARCH PAPER OF

CHIDIRIAYI C. ENYIA, for the Master's of Science in Education degree in KINESIOLOGY, presented on \*JULY 1, 2014, at Southern Illinois University Carbondale.

TITLE: INDUCED POST-ACTIVATION POTENTIATION AND ITS RELATIONSHIP TO PERFORMANCE VARIABLES IN THE BLOCK START

MAJOR PROFESSOR: Dr. Michael W. Olson

Post-activation potentiation (PAP) is an induced physical state commonly utilized in training and competition environments. There are a wide variety of methods used to induce PAP but the mechanisms and most effective means specific to the different speed/power events need to be investigated further for the potential of maximizing performance. Therefore, the purpose of this study is to investigate the effect of drop jumps on maximum vertical ground reaction force on the push-off phase after the first touchdown step and its relationship to block start performance. Participants included 3 male and 3 female, Division I collegiate track and field athletes (mean  $\pm$  SD, age = 20.7  $\pm$  0.47 yrs., height = 168.5  $\pm$  5 cm, mass = 60.9  $\pm$  6.7 kg) who were currently in-season having at least two years of experience with block starts, strength training and plyometrics. Each participant performed two sets of 5 blocks starts under 3 conditions (control, bike and drop jump). Results of a univariate ANOVA indicated no significant difference in mean force between subjects per condition ( $F_{2, 179} = 2.179$ ,  $p > 0.05$ ). And a post-hoc analysis showed no significant difference in maximum force between the pre and post trials of each condition ( $F_{(1, 179)} = 1.726$ ,  $p > 0.05$ ). Although the result of this study did not show any significant difference in maximum vertical force output, further analysis of the data can be done looking into other neuromuscular and kinematic and time variables that may yield different results.

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## INTRODUCTION

Post-activation potentiation (PAP) is a physical state characterized by increased neuromuscular sensitivity to lower levels of myoplasmic calcium leading to greater rate of force development following a voluntary pre-conditioning exercise (Neale & Bishop, 2009). Examples of conditioning exercises include maximum voluntary isometric contractions (MVIC), loaded countermovement jumps, Olympic lifts and other exercises primarily performed above 85% of an individual's 1 repetition maximum (1RM). Mechanisms that may be involved in PAP include phosphorylation of myosin regulatory light chains within the faster, type II muscle fibers (Chui, et al., 2003), increased recruitment of higher order motor units (Luscher, Ruenzel, & Henneman, 1983) and changes in pennation angle (Folland & Williams, 2007). PAP studies in both humans and animals have been conducted to investigate its potential benefits on human performance and to determine whether or not it can be harnessed for that purpose. Olympic lifting, throwing events in athletics, sprinting, jumping and various sports tests such as vertical jump and 40 yard dash are activities where increases in mechanical power, the rate at which force can be generated through a range of motion for a specific period of time, in sports where repeated explosive efforts are needed is critical in improving performance. For example, an individual participating in the shot put may be able to increase the distance of an attempt following a conditioning exercise. A sprinter may experience greater power output leading to improved velocity at the start that may influence the quality of acceleration. If the quality of acceleration can be improved then it is possible that the sprint across the full distance may improve as well. At the elite level of sprinting, particularly in at the highest profile competitions in athletics,

performances are separated by tenths and hundredths of a second. Therefore, any slight improvement in rate of force development leading to improved mechanical power at the start would be beneficial provided other elements that contribute to decreased sprint times are present such as adequate levels of strength and power and coordination.

To date, the majority of PAP research has involved using variations of the squat and MVICs as the preconditioning exercises (Batista et al, 2007; Chatzopoulos et al, 2007; Chui et al, 2003; Gilbert et al, 2001; Gourgoulis et al, 2003; Hanson et al, 2007; Jensen & Ebben, 2003; Kilduff et al, 2007; Magnus et al, 2006; Rahimi, 2007; Rixon et al, 2007; Robbins & Docherty, 2005; Young et al., 1998). Dynamic exercises, such as vertical jumps are commonly used to assess lower body muscular power. Other methods have been used to assess the outcome measures of athletes involved in high intensity sports. Hilfiker, Hubner, Lorenz and Marti, (2007) added 5 modified drop jumps from a 60cm box to a standard ergometer warm-up using 13 elite men who had experience in training programs with high power demands. One minute following the warm-up the men were asked to perform 3 countermovement jumps (CMJ) and 3 squat jumps (SJ) with 20 seconds between each on a force platform measuring mean jump height and maximum power relative to bodyweight. The results showed a tendency for improvement in power output in both all groups but the most significant difference was present in the countermovement jump overall.

Although a conditioning contraction may produce PAP, neuromuscular fatigue, identified by decreased force generation following the conditioning contraction, is present at the same time. The relationships between fatigue and PAP determine



whether an actual enhancement of performance may occurred post-stimulation of the conditioning contraction (Sale, 2002). Kilduff et al., (2007) studied the optimal recovery time between the preload stimulus and subsequent enhancements in muscle performance in professional rugby players. Preload consisted of 3 repetition maximum of squat and bench press exercises. Following the preloading exercises participants were instructed to perform countermovement jumps at ~15 sec, 4, 8, 12, 16 and 20 minutes rest. A significant 8% increase in potentiation above baseline measures of peak power output was observed at the 12 minute mark for the countermovement jumps and 5.3% for the ballistic bench throws due to increased neuromuscular excitation. Gullich and Schmidbleicher, (1996) stimulated the tibial nerve and measured the H-wave amplitude at the gastrocnemius before and after a 5 second MVIC of the plantarflexors. They observed a depression in H-wave amplitude 1 minute after the MVIC but a potentiation of H-wave amplitude 5-13 minutes after the MVIC. This research indicates that sufficient recovery may be needed for significant potentiation. The effect of PAP may last up to 13 minutes after the conditioning contraction and fatigue declines at a faster rate than PAP.

Training history may also influence the magnitude of PAP but the research here is inconclusive. Morana and Perrey, (2009) studied the effect of training history on the time course of potentiation and fatigue using endurance trained (distance runners and triathletes) and power trained (rugby players and weightlifters) subjects. Muscle mechanical and electrophysiological responses of the knee extensors where induced by electrical stimulation of the femoral nerve and mechanical responses to the electrical stimulation and maximum voluntary contraction of the knee extensors were recorded

using an isometric ergometer. They found power trained subjects registered higher peak torque values than endurance trained within one minute of the exercise. Twitch maximal rates of torque development and relaxation were also higher in power trained subjects. Chiu et al., (2003) also investigated the training status effect on post-activation potentiation. The study involved a group of 12 men and 12 women who had a minimum of 6 months experience performing the back squat. Seven of the subjects were currently competing in a sport while 17 were recreationally trained. The control warm-up consisted of 2 sets of 5 unloaded jumps squats and 2 sets of 3 vertical jumps. The heavy group warm-up was the same as the control but also included 5 sets of 1 rep of squats at 90% 1RM with 2 min rest between sets. Two series of maximal effort rebound jump squats (RJS) and concentric-only jump squats (CJS) were performed with 30%, 50% and 70% 1RM at 1-minute intervals done afterwards. The first series was performed at 5 minutes following the warm up and the second 10 minutes following the first or 18.5 minute following the warm up, respectively. Results showed significant improvements in peak power using a single-component force platform to measure the propulsive phases in the athletically trained group more so than that of the recreationally trained in the concentric-only jump squats. They also indicated greater potentiation at the 18 minute mark after the heavy squats for the rebound jump squats shown by increases in average force, average power and peak power. Batista et al., (2006) concluded, after testing MVIC of track and field athletes, recreational strength trainers and physically active people on an isometric leg press machine, that PAP is unrelated to strength training experience. Similar to the previous studies, Khamoui et al., (2009)

found no significant changes in ground reaction force and impulse in vertical jump trials following different heavy back squat volumes in recreationally trained men.

Drop jumps have been found to be an effective means of plyometric training to increase power output (Walsh, Arampatzis, Shade, & Bruggemann, 2004) due to an increase in positive energy transfer (Gehri, Ricard, Kleiner, & Kirkendall, 1998). Plyometrics are methods of jump training designed to increase the energy transfer qualities of the musculotendinous unit and neuromuscular system. A key component of the drop jumps are the energy utilization and power transfer from the muscles and elastic components during the eccentric phase. Komi and Bosco, (1978) who tested men and women in squat jumps, countermovement jumps and drop jumps reported that all subjects attained their greatest vertical jump heights during the drop jumps. Power has been shown to correlate with the acceleration phase of sprinting (Chelly & Denis, 2001) which is why drop jumps have been one of the most popular forms of plyometric training for sports (Gehri et al., 1998).

Current studies have looked at the potentiation of muscles during human sprinting. McBride, Nimphius and Erickson, (2005) observed faster 40 meter sprint times after a heavy squat protocol of 1 set of 3 repetitions at 90% 1RM in Division III football players, Chatzopolous et al., (2007) observed increased running speeds 5 minutes after a heavy back squat protocol, while Yetter and Moir, (2008) observed faster sprint times 4 minutes after a heavy back squat and heavy front squat protocol.

Usage of the starting block is beneficial in the sprints allowing the athlete to displace more rapidly because the center of mass (COM) is positioned much further ahead of the feet in the set position due to the placement of the pedals. With the COM

positioned in front of the hips, the athlete will be able to generate greater horizontal force. However, a major requirement for a successful block exit is the rate of horizontal peak force one can generate in order to overcome inertia and achieve maximum extension of the hip, knee and ankle for greater block clearance. This sequential order of events influences the distance between the starting block and the first ground contact. The ability to utilize energy absorbed by the muscles and series elastic components from the eccentric phase of the first movement is similar to that of drop jumps. Line of force characteristics are also similar to the drop jumps in that the resultant force vector will travel through the ankle, knee and hip joints prior to take-off in the drop jump and the each step in the acceleration. If there is increased muscular energy available to influence force-time characteristics for greater velocity of the first movement, there is a possibility subsequent early acceleration steps may be influenced as well which may lead to improvement in overall sprint times. Since PAP has been observed in various preconditioning contraction situations, but none have studied the block start, the purpose of this study is to investigate the effect of drop jumps on maximum vertical ground reaction force on the push-off phase after the first touchdown step and its relationship to block start performance. It is hypothesized that following a drop jump protocol an increased rate of force development leading to increased mechanical power production as well as an increase in peak force on ground contact will lead to improvements in the acceleration. The ultimate purpose of the acceleration, when executed well, is to dictate one's maximum velocity. For the majority, a well-executed start and acceleration tend to lead to more desired results because the average velocity will be higher throughout the duration of the sprint. Since one has to

have adequate levels of strength, power and coordination already in place, the ability to enhance the warm-up with very specific activities can provide coaches with an added tool for their athletes. Limitations of this study will be technical skill in the block starts and drop jumps between subjects and physical state of the athlete on the day of the trials depending on training and other factors beyond the experimenter's control. The rate of force development and peak force in the lab will be controlled to a great degree so the practical applicability will be affected by the inability to take into consideration various environmental factors surrounding competitions.

## METHODS

Participants included 3 male and 3 female, Division I collegiate track and field athletes (mean  $\pm$  SD, age =  $20.7 \pm 0.47$  yrs., height =  $168.5 \pm 5$  cm, mass =  $60.9 \pm 6.7$  kg) who were currently in-season having at least two years of experience with block starts, strength training and plyometrics to minimize the learning curve and ensure a high level of fitness. Prior to participation each subject signed a written informed consent form and the project was reviewed and approved by the Southern Illinois University Human Subjects Committee. Testing took place in the Southern Illinois University Biomechanics and Integrative Movement Lab.

## INSTRUMENTATION

A force platform (Advanced Mechanical Technology Inc. ORG-6, Newton, MA) (data collection at a frequency of 1000 Hz) was used to collect ground reaction forces during the first step out of the blocks. Surface electromyography (EMG) was collected with Ag-AgCl gel single differential electrode pairs spaced 20 cm center to center of the  $1 \text{ cm}^2$  electrodes. Muscle activity (Motion Labs Systems MA-300, Baton Rouge, LA)

was recorded bilaterally from the (gastrocnemius lateral head, tibialis anterior, biceps femoris long head, gluteus maximus, rectus femoris, vastus lateralis and hip flexors). The skin was cleaned with isopropyl alcohol and abraded prior to electrode placement. The EMG signals were bandpass filtered at 20-500 Hz, with a common mode rejection ratio (CMRR) > 100 dB at 60 Hz and input impedance of > 10 Ohms. Data was recorded at 1000 Hz and converted with a 12 bit A/D board. Qualisys Motion Capture Systems (Gothenburg, Sweden) was used to observe kinematics at a collection rate of >100 Hz. Reflective markers were placed at the shoulders, hip, sacrum, knee, ankle, heel and fifth metatarsophalangeal joint on both sides of the body. For the purpose of this paper only the ground reaction forces were analyzed.

The drop jump (DJ) was used because of its high load on the muscles and elastic components (Siff, 2003; Zatsiorsky & Kraemer, 2006; Radcliffe & Farentinos, 1999). These exercises were also chosen as opposed to loaded exercises to minimize the injury risks and variation of strength and execution of technique. Participants were randomly assigned to three conditions; control, DJ and bike. This order was balanced so that all subjects performed the same standard warm up followed by 5 minutes rest for all three before the first set of block starts. Following the warm up and the first set of block starts, the control condition consisted of an additional 5 minutes of rest and a second set of 5 block starts. For the drop jump condition, 3 sets of 5 repetitions of DJ were performed with 15 sec between repetitions and 3 minutes between sets, 5 minutes of rest and the last 5 repetitions of block starts. For the bike condition one set of 10 minutes on the bicycle ergometer at 70 rpm followed by 5 minutes of rest and the last set of 5 block starts were completed after the standard warm up. The 70rpm set up was

determined with a RPE scale with each athlete describing the intensity to be “somewhat hard”. Block starts were separated by 2 minute rest periods from the end of the repetition to the start of the next. For DJ, each participant was instructed to step off of a 40 and 62cm box, for women and men, respectively, in a relaxed manner. Immediately following the landing, they were instructed to jump for maximum height as quickly as possible to minimize ground contact time.

#### DATA ANALYSIS

Data were reduced using the fourth order zero-lag Butterworth filter at 50 Hz and normalized to each individual’s body weight. For this paper only the normalized force was analyzed.

#### STATISTICAL ANALYSIS

Dependent measures are peak vertical ground reaction forces during push-off on the first ground contact from the force platform. Peak forces are compared before and after each condition (bike, control and drop jump). A univariate ANOVA was used to analyze the normalized and maximum force data between subjects at a level of significance of  $p < 0.05$  (Table 1).

#### RESULTS

Results indicate no significant difference in mean force between subjects per condition ( $F_{2, 179} = 2.179, p > 0.05$ ). There was also no significant difference in maximum force in the post trials per condition ( $F_{1, 179} = 1.726, p > 0.05$ ) (Table 1).

<b>Condition</b>	<b>Post</b>	<b>Mean</b>	<b>SD</b>
Bike	2	2.09	0.38

Control	2	2.11	0.35
Drop Jump	2	2.16	0.33

## DISCUSSION

The purpose of this study was to investigate whether drop jumps can be used to induce PAP to enhance warm up protocols leading to improved block start performance. Although it was originally hypothesized that maximum force outputs would be improved during push-off after the first ground contact from the starting blocks, we observed that performing drop jumps before block starts did not significantly affect peak maximum force.

Multiple studies have been able to induce PAP following a variety of conditioning exercises. For example, Weber et al., (2008) found 4.7 % and 4.6% increases in peak jump height and peak GRF following back squats at 85% of the subjects 1RM. Batista et al (2007) witnessed a 1.3 Nm elevation in peak torque following unilateral knee extensions on an isokinetic dynamometer. Additionally, Rahimi (2007) also observed significant improvements in 40m sprints times following moderate (60% 1RM) and heavy (85% 1Rm) squats. In this study, a number of variables may have contributed to the outcome. The statistical power (0.137 – 0.359) indicated that there needed to be more subjects. And a post-hoc analysis did not show any significant difference between subjects (Table 2).

<b>Table 2. Vertical ground reaction force comparison between conditions</b>						
(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Bike (B)	C	-0.08	0.07253	0.786	-0.257	0.0937



Control (C)	DJ	-0.13	0.07253	0.201	-0.309	0.0417
	B	0.08	0.07253	0.786	- 0.0937	0.257
Drop Jump (DJ)	DJ	-0.05	0.07253	1	- 0.2274	0.1233
	B	0.13	0.07253	0.201	- 0.0417	0.309
	C	0.05	0.07253	1	- 0.1233	0.2274

Rest periods between trials within each condition may have to be manipulated differently to induce PAP. Given the volume (15 repetitions) and intensive nature of the drop jumps, subjects may need rest periods longer than five minutes for there to have been a significant change in the maximum force outputs. For example, Kilduff et al. (2007) observed a significant peak power outputs in countermovement jumps and bench throws at the 8 and 12 minute rest periods following 3RM of back squat and bench press respectively. This may indicate that higher intensity pre-conditioning exercises require recovery times greater than 5 minutes.

Preconditioning exercise selection that is more similar in movement patterns to the activity being tested is a factor that can influence the results a well. For example, in the study performed by Chiu et al., (2003), improvements in average force, average power and peak power where found to be most significant in the group that performed the heavy squats (90% 1RM) prior to a series of rebound jump squats . Also notable is that the most significant result was observed at the 18 minute mark after the squats which address the issue of recovery time. It is possible that a different preconditioning exercise more similar to the block starts, such as heavy resisted starts with a modified sled, would yield a different result.

As mentioned earlier, the potential to enhance warm-ups that can lead to greater performances in different sporting activities, but specifically in sprinting is the motivation that led to this specific study. Improvements in 40 meter sprints times after heavy squats (90% 1RM) (McBride, Nimphius and Erikson, 2005), 10-30 meter running speed following heavy squats (90% 1RM) (Chatzopolous et al., 2007) and 10-20 meter and 20-30 meter intervals after heavy back squats (30, 50 and 70% 1RM)(Yetter and Moir, 2008) may encourage coaches and trainers to implement similar protocols into the training and preparation of their athletes.

There were limitations to this study such as the small number of participants, physical state of the athletes and limited analysis of additional dependent variables. The number of participants was too small for a strong analysis to be done to determine if there were any significant differences between the conditions which is why the statistical power is low. Also, it is difficult to account for the athletes' physical states on any given day. Even though data were collected well into the season enough for the participants to be fit and acclimated to their training and blocks starts, levels of fatigue could vary from subject to subject for reasons beyond experimental control on any of the test days which could influence the results. EMG data were collected for potential analysis of muscle firing patterns and rate of force development and its influence on both vertical and horizontal peak force values could be gleaned from the force platform. Also, velocity of the pelvis or ankle may be investigated given, the motion capturing data collected, and could provide information specific to the block exit. Time from the starting block to first ground contact to go along with a measurement of the peak velocities and

rate for force development to influence that time could be the subject of future studies with the data collected for this study.

### CONCLUSION

Previous studies have indicated that PAP can be an effective way to enhance warm ups for improved performances. The result of this study however did not show any significant difference in maximum vertical force output. Further analysis of the data can be done looking into other neuromuscular and kinematic variables that may yield different results.

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Research Paper Title:

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