Post-activation Potentiation: Increasing Power Output in the Block Power Clean

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Table of Contents

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Background: Post-activation potentiation (PAP) has been shown to increase both jumping height and sprinting performance over short distances after a ‘conditioning’ exercise (Wilson, et al., 2013).

PURPOSE: The purpose of this study was to examine if a PAP protocol could also enhance bar-velocity (m/s) in the block power clean, a movement commonly used in strength and conditioning to enhance explosive athletic attributes such as jumping and sprinting.

METHODS: ECU throwers (n=6, 67% male) participated in two sessions separated by three to 14 days. The first session consisted of a three-to-five repetition max of the block power clean using the Auto-regulated Progressive Resistance Exercise method, vertical jump, and a training history questionnaire. During the second session, participants performed a series of trials testing peak bar-velocity of the block power clean following a 6-second maximum voluntary isometric contraction (MVIC). Rest times were counter-balanced, varying between 15 and 120 seconds of rest between the MVIC and block power clean. Mean differences and effect sizes were calculated on the peak bar-velocities.

RESULTS: Our results indicate that 15, 30, 90, and 120 seconds rest increase the peak bar-velocity. The highest effect size (ES= 1.159) and mean difference (MD= 0.123) were seen with 90 seconds of rest compared to the baseline.

CONCLUSION: These initial findings suggest that the effects of post-activation potentiation can increase peak bar-velocity of the block power clean in collegiate athletes when given appropriate rest. These finding hold important implications for training applications, however, further analysis and testing is needed.

I. Resistance Training in Athletics

When done correctly, resistance training can greatly improve performance through size, power, and speed. Resistance training can improve various athletic parameters such as: muscular strength; power; speed; hypertrophy; and local muscular endurance in athletes when prescribed in a specific manner (Fundamentals of Resistance Training: Progression and Exercise Prescription, 2004).

NSCA's *Essentials of Strength Training and Conditioning 3rd edition* outlines a general process for ensuring that resistance training is prescribed properly (Baechle & Earle, 2008). The text states that the coach should begin by performing a needs analysis of the sport and athlete. This would include identifying which muscle groups are involved in the sport; ranking the importance of strength, power, size, and endurance in the sport; and lastly, where and why injuries commonly occur in the sport. One would also need to take into account the training experience and current performance abilities of the athlete in question. Based on these two analyses, the practitioner would determine the appropriate resistance training exercises to improve athletic performance. This would include the type of exercises, in what order they would be performed, at what level of resistance or load, and how often the athlete(s) would train. All of this is done in order to make sure that the resistance training program being performed will optimally improve the player in his or her "on-field" performance.

Strength and power are commonly the foundation of a training program for sport. That being said, strength is a broad term encompassing multiple forms of isometric and dynamic actions. Isometric strength can be described as the amount of force that one is able to produce in a static position where the joint angle and length of the muscle do not change (Laskowski, 2014). Isometric strength training is generally used as more of an assistance mode of training to dynamic strength as it only strengthens the subject in that specific position. It is however very useful when implemented properly, such as to help improve strength in the weakest area of the range of motion or improve stability (Laskowski, 2014).

Dynamic strength can also be broken down into eccentric and concentric contractions. An eccentric contraction occurs when the muscle is contracted while also lengthening (Types of Contractions, 2006). Eccentric training is becoming increasingly popular as it requires less energy and allows for a higher level of force to be produced than with standard concentric training (Bubbico & Kravitz, 2010). As with isometric training, eccentric training is a very valid tool, but isometric and eccentric strength are rarely the main focus of a training program for sport. Contrary, the general basis of most programs is concentric strength. Concentric strength can be defined as the amount of force that can be generated when a muscle shortens. When the muscle shortens, a load is lifted or pulled (Types of Contractions, 2006). This movement is most similar to sport and, based on the principle of specificity, is therefore the most necessary form of strength.

Sport, however, is most commonly dependent on how quickly a loaded movement can be performed, or power, rather than just how heavy of a load can be moved. The rate of doing work is called power and is crucial for translation of a training program to on-field performance. A basis of strength is necessary for a high rate of power to be produced and increasing strength can increase power, but the crucial component is still power in most circumstances (Wilson, Murphy, & Walshe, 1996; Cronin & Sleivert, 2005).

In order to achieve maximal power output, it is necessary to determine the optimal training load. According to the force-velocity curve, power is maximized at the intersection of force and speed, in the case of a power clean it is load and bar speed. Pennington et al. have determined the optimal load to achieve maximal power in the power clean. The study examined different loads of the power clean and measured power output at 10% increments of the one repetition max (1RM) between 30 and 90%. Twenty male college football players participated in a series of testing days. Day one consisted of anthropometric testing. On day two, the participants tested to determine their 1RM in the power clean and the snatch. On day three, after warming up, the power clean was performed at 30%, 40%, 50%, 60%, 70%, 80%, and 90% of each individual's 1RM. On day four, the same process as day three was repeated for the snatch. Power was recorded using the TENDO FitroDyne. It was determined that optimal load for peak power output in the power clean was 80, 90, or 100% however there was not a significant difference between 80, 90, or 100% (Penninton, Laubach, De Marco, & Linderman, 2010).

II. Post-activation Potentiation

After a bout of heavy resistance training the musculature will be fatigued, but it has also been hypothesized to be potentiated. By potentiated, it is meant that the musculature used will now experience higher efficiency due to increased sensitivity of actin and myosin to $Ca^{2+.}$ This potentiated state is called post-activation potentiation (PAP) (Robbins, 2005). There is, however, a continuing debate to when the effect of PAP is greatest and in which population. Wilson et al conducted a meta-analysis of the available literature of 32 studies on PAP. Their criterion to qualify for their analysis was that the study must have examined the effect of a heavy resistance conditioning exercise on an activity that requires high level of power, such as a vertical jump. Effect sizes were then calculated for all 32 studies with adjustments made for sample size bias. Afterwards, the effect sizes were organized and averaged (mean effect size) into multiple categories including anthropometrics, type of conditioning, and rest periods. Results showed that effect sizes were larger in males than females and trained participants saw greater effect sizes than untrained but athletes showed a much larger effect size than either. The meta-analysis also showed that isometric conditioning elicited PAP to a similar extent that a dynamic lower body conditioning activity did (Wilson, et al., 2013).

Rixon et al. studied the influence of gender, training experience and type of conditioning on PAP (2007). Fifteen men and 15 women participated in the trial with 20 being trained and 10 being untrained. They were separated into groups of trained or untrained and male or female. Each group performed baseline testing consisting of a 1RM back squat (DS), and maximal force in a maximal voluntary isometric squat (MVIS) using a fixed bar. On a second day, the participants returned to perform baseline testing in the counter-movement jump (CMJ) and also to perform CMJ testing in a complex set with the DS and MVIS. Test day two consisted of a five-minute warm up, 10 minutes rest, three sets of MVIS and CMJ, 30 minutes rest, and one set of three-repetition maximal (3RM) DS and then for the MVIS sets, the CMJ was performed three minutes after the three second isometric contraction and each complex set was separated by two minutes of each other. The CMJ was also performed three minutes after the dynamic back squat. Jump height was increased 2.9% after the MVIS and 1.7% after the DS in men. Jump height also increased by 2.2% after the MVIS and 0.7% after the DS in experienced lifters (Rixon, Lamont, & Bemben, 2007).

Kovačević, Klino, Babajić, and Bradić examined isometric contraction’s ability to potentiate nine female elite tennis players as measured by their performance in the vertical and broad jumps (2010). The participants completed three days of testing. The first day consisted of 10 minutes of aerobic running, five minutes of dynamic stretching, and then vertical and broad jump testing to serve as a baseline. The research team also collected anthropometric data. The second and third days consisted of 10 minutes of aerobic running, dynamic stretching, maximal voluntary isometric contraction, and then testing of power in the vertical or broad jump. The vertical jump was tested on the first testing day and the broad jump on the second. The conditioning exercise was a maximal voluntary isometric squat using a bar chained to the platform the participant would stand on. The bar was both adjustable for height and immovable. This participant performed the isometric squat for six seconds, rested, and then performed the power test that was conducted that day. This complex was repeated three times, with varying rest periods of 30, 60, and 90 seconds each completed once. The results show that vertical jump increased at all three time intervals, but that 90 seconds produced the greatest effect of 7% increase in height. Broad jump performance decreased after the first time interval, but then increased at 60 seconds and 90 seconds, with 90 seconds again producing the greatest improvement of 2% increase in distance (Effects of Maximum Isometric Contraction on Explosive Power of Lower Limbs, 2010).

Sapstead and Duncan carried out a similar study using isometric mid-thigh pulls with resistance trained males. Eighteen males with mean resistance training of 5.9 years and who were free of injury participated. The participants tested on a total of three days each separated by 48 hours. Each day began with full-body warm up followed by four minutes of rest and then testing. On day one, the participants performed baseline testing of three squat jumps (SJ) from a static position to prevent the stretch reflex and three counter-movement jumps (CMJ).

On testing day two, the participants performed a five second maximal isometric mid-thigh pull and then following four minutes of rest performed both one repetition of CMJ and SJ. They then rested two more minutes and performed another round of CMJ and SJ. They then rested a third time for two more minutes and performed their last round of CMJ and SJ. This resulted in rest periods of four, six, and eight minutes before testing. On day three, the same protocol was followed but the initial rest period was extended to eight minutes, resulting in rest periods of eight, ten, and twelve minutes. The results of the study show that peak power is significantly improved following both four and eight minutes rest in the squat jump, but not in the counter-movement jump. The mean difference in in peak power for squat jump was 3.6 W/kg after four, six, and eight minutes rest and 5.2 W/kg after eight, ten, and twelve minutes rest when compared to the baseline. The mean SJ height, mean CMJ peak power, and CMJ height were all higher than baseline, but not by a significant margin (Sapstead & Duncan, 2013).

Post-activation potentiation can be elusive and effect sizes vary between populations and protocols. While effects can be seen in many populations, research indicates that PAP’s effect is greatest in trained males. An isometric conditioning activity can also produce slightly higher levels of potentiation than dynamic exercises and rest times between conditioning and the power activity must be varied, but effects are typically seen between one to eight minutes.

Methods

Participants

Four male and two female collegiate throwers were recruited for this study through word of mouth. Existing research indicates that PAP can be seen in a variety of populations, however, the effects are significantly higher in both males and trained athletes (Wilson, et al., 2013).

Protocol

The participants were tested on two different days separated by a minimum of three days and no more than two weeks between training sessions. Participants were asked to refrain from performing exercise for twenty-four hours prior to each session. On day one, participants signed informed consent, answered questions related to training experience, and underwent anthropometric assessments. Participants also self-reported their estimated one-repetition max for the block power clean (BPC). The participants then performed five minutes of cardiovascular exercise followed by five minutes of a dynamic warm up. Lower-body power was assessed via the vertical jump measured by the Vertec. Each participant was given two attempts from a standing position. If the participant's second jump was higher than the first they were given a third attempt. Lastly, the participants performed warm-up sets of block power clean and attempted a one to five-repetition max. The warm-up sets consisted of five repetitions at 50% of their self-reported one-repetition max, four repetitions at 60%, three repetitions at 70%, and two repetitions at 80%. Finally, a one to five-repetition max was attempted at 90% of their self-reported 1RM.

A successful test was determined by a max effort (ME) set of up to five repetitions. To ensure accurate load, we used the auto-regulatory progressive resistance exercise (APRE) protocol. Using the APRE protocol, if the participant was able to perform more than five repetitions weight was added and the test was repeated after a three-minute rest (See Table 1 below).

Table 1APRE adjustments

Repetitions Performed	Adjustment for next attempt (lbs.)
0	-5 to -10
1-5	No Change
6-7	+5 to +10
8 or more	+10 to +15

Table 1 APRE adjustments:

When one to five repetitions were completed the participant's one-repetition max would be predicted using the Epley equation- %1RM= ([0.033 x reps] x rep wt.) + rep wt. (Epley, 1985). Between all sets, participants were given two minutes rest.

On day two, participants completed five minutes of cardiovascular exercise and then five minutes of dynamic warm up. Following the dynamic warm up, participants completed warm-up sets of the block power clean. This consisted of a set of five reps at 50% of the projected 1RM from day 1, a set of three reps at 60%, and a set of two reps at 70%. A baseline test for peak power was then tested for the block power clean using a TENDO dynamometer. Following this control test, participants performed a six-second maximal voluntary isometric contraction (MVIC) followed by a block power clean at

Figure 1Power Position

80% of 1RM. During the MVIC, peak force was measured using a Jackson Strength Evaluation System with the participant in the power position. The power position is defined as an athletic stance with hips, knees, and ankles flexed, torso approximately vertical, and arms fully extended so that the barbell hangs at approximately mid-thigh position as seen in *Figure 1 Power Position*. Participants performed five trials of 6 second MVIC followed by the block power clean with 15, 30, 60, 90, and 120 second rest intervals between conditions. Between each trial, two minutes of rest were provided. The trials were counterbalanced to avoid bias from possible fatigue or residual potentiation.

Measurements and Instrumentation

Reliability/Validity of Instruments- To measure muscular power during the block power cleans, TENDO FitroDynes (TENDO, Trencin, Slovakia) will be used. In 2005, Jennings, Viljoen, Durandt, and Lambert examined the reliability of the FitroDyne, a device that measures muscular power via bar speed of an exercise. To do this, men (n=30) aged 20 to 40 years old who had at least three months experience with resistance training completed three sessions, each separated by one day of rest, of squat jumps and biceps curls all of which were measured by the FitroDyne device. Each session consisted of six sets of three repetitions of squat jumps and six sets of three repetitions of biceps curls with one to three minutes rest between each set both using increasingly heavier loads. The FitroDyne was found to be reliable for both exercises with Intraclass correlation coefficients of R=0.97 for both squat jumps and biceps curls (Jennings, Viljoen, Durandt, & Lambert, 2005). Garnacho-Castaño, López-Lastra, and Maté-Muñoz investigated the validity of the TENDO power analyzer in 2015. A group of 71 men performed the back squat and bench press using the T-Force Dynamic Measurement System and the TENDO power analyzer. Following a prescribed warm up protocol, the participants performed four sets of each exercise, simultaneously measured by both instruments. The TENDO power analyzer was found to have a validity coefficient of 0.980 (Garnacho-Castaño, López-Lastra, & Maté-Muñoz, 2015).

The Jackson Strength Evaluation System (JSES) will also be used to measure peak isometric strength during the isometric conditioning component. Jackson tested 203 students at the University of Houston and an additional 246 applicants to the Brown and Root Medical Facility, administering two different pulling tests using the JSES, but in different positions. The intraclass coefficient for the total sample was 0.98. Dr. Jackson also found the validity of the instrument for pulling strength to be R=0.86 (1999).

Lower-body Power - vertical jump height was measured using a Vertec (Jump USA, Sunnyvale, California) which consists of a series of plastic "vanes" each one-quarter inch above the previous one. The participant positioned their self beneath and slightly in front of the instrument and without stepping, performed a counter-movement jump for maximum height. The highest vane touched was considered the raw vertical jump height. The difference of the raw vertical jump height and vertical reach was the vertical jump height. Current research indicates that the Vertec is reliable when the participants are familiar with the device and is commonly used as the gold standard against new vertical jump instruments are compared (Nuzzo, Anning, & Scharfenberg, 2011).

***Peak Power Output* -** peak power output was measured with a TENDO Power Analyzer when the participants performed the block power clean on day two for the control and test trials. The TENDO Power Analyzer (TENDO, Trencin, Slovakia) measures bar speed using a FitroDyne attached to one end of a barbell. The unit's processor can then measure peak power calculating the bar speed multiplied by the load which is inputted manually on the device. The research team input each load for the participant individually. Jennings, Viljoen, Durandt, and Lambert have shown that the TENDO has a high repeatability in both multijoint and single joint movements (2005)

***Peak Isometric Force Production* –** peak force production was measured by Jackson Strength Evaluation System during the MVIC (Lafayette Instrument, Lafayette, Indiana). A load cell in the instrument measures peak force production and average force production over a set amount of time, in this case six seconds. The load cell was chained from below to a three-quarter inch plywood platform and connected above to a pull-down bar using a chain that's length could be adjusted using a quick link.

Statistical analysis

Descriptive data were used to quantify height (ft., in), weight (lb.), vertical jump height (in), predicted 1RM (kg), and maximal power output at 80% 1RM (watts) during all trials. Repeated measures analysis of variance (ANOVA) was used to examine differences in power amongst the various trials- 15, 30, 60, 90, and 120 seconds rest. Significance of each ANOVA test was adjusted using the Bonferonni procedure, dividing 0.05 by the number of trials (i.e., 0.05/5=0.01). In addition, the size of the difference between means was estimated with Cohen's delta.

Results

Descriptive statistics can be found in Table 1. All the participants reported having at least three months training with the block power clean and were 19-22 years old.

Table 1

Descriptive statistics

Variable	*Mean ± Standard Deviation*	
	Male	Female
Age (years)	19.75 ± 0.96	22 ± 0
Height (m)	1.87 ± 0.05	1.74 ± 0.07
Weight (kg)	108.85 ± 17.43	82.47± 11.34
BMI (kg/m^2)	31.19 ± 4.67	27.17 ± 2.46
Trained in BPC (%)	100	100

Day one's testing data can be found below in Table 2. The 1RM was calculated using the Epley equation based on a three-to-five repetition max and CMJ was measured as raw jump height minus reach. The male participants achieved higher CMJs and heavier 1RM calculations as well as subsequent testing loads at 80% of the 1RM BPC.

Table 2
Strength and Power of Participants

Variable	*Mean + Standard Deviation*	
	Male	Female
CMJ (cm)	81.60 + 9.70	61.38 + 6.26
1RM BPC (lbs.)	274.20 + 22.80	213.57 + 25.17
80% BPC (lbs.)	219.36 + 18.24	170.86 + 20.13

Effect size between the varied rest times were calculated using Cohen's delta. These effect sizes were calculated individually for male and female participants and can be found below in Table 3 (male) and Table 4 (female).

Table 3 Male Effect Sizes

	baseline	15	30	60	90
15	0.7181				
30	0.1554	-0.3731			
60	-0.0507	-0.6207	-0.1647		
90	1.1591	0.1048	0.5575	0.9204	
120	0.5599	-0.1353	0.2593	0.4920	-0.2841

Table 4 Female Effect Sizes

	Baseline	15	30	60	90
15	0.8832				
30	0.6190	-0.7638			
60	0.9189	0.2649	0.8713		
90	0.9768	0.2389	1.0055	-0.0705	
120	0.7704	0.0823	0.5786	-0.1214	-0.0806

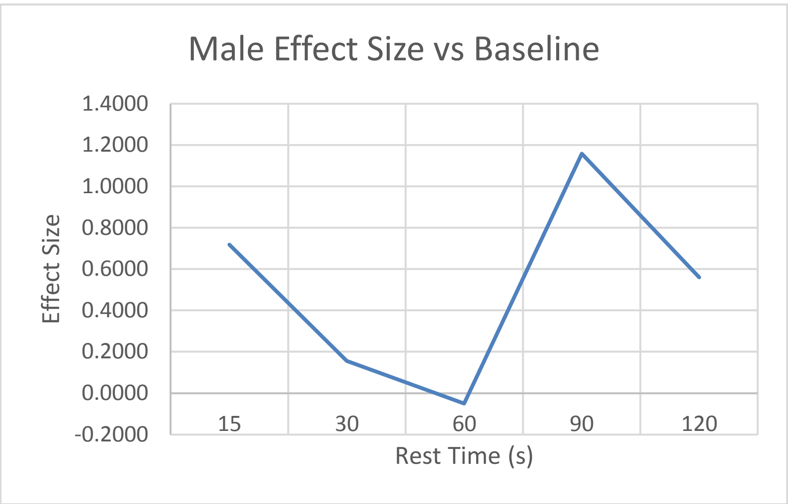
The results in the charts above illustrate that 15, 30, 60, 90, and 120 seconds of rest within the complex resulted in medium to large effect sizes, with the exception of 30 and 60 seconds in males. In addition, the highest effect size occurred after 90 seconds of rest for both males and females (ES_m= 1.16, ES_f= 0.98) when compared to the baseline. In males, the effect size decreased with 30 seconds of rest (ES=0.16) and was its lowest after 60 seconds of rest (ES= -0.05). In females, however, the lowest effect size was observed with 30 seconds of rest (ES=0.62).

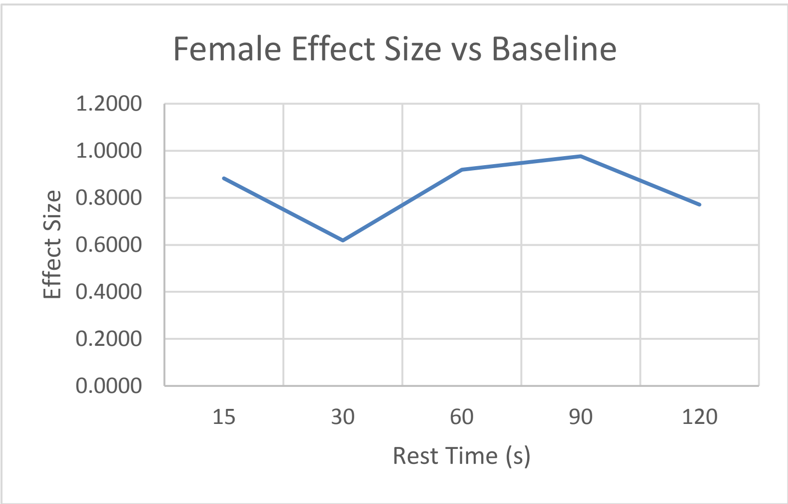
Ninety seconds of rest compared with 15 seconds of rest resulted in a small effect size in both male and female participants (ES_m= 0.10, ES_f= 0.24). Ninety seconds of rest compared to 30 seconds of rest showed a medium effect size in males (ES= 0.56) and a large effect size in females (ES= 1.01).

Discussion

A few studies have examined the effect of post-activation potentiation (PAP) on sprinting and jumping (Wilson J. M., et al., 2013). However, to our knowledge, no research team has studied the effect of PAP when a loaded movement is performed as the power movement. The purpose of our study was to determine if performance of a six second maximal voluntary isometric contraction (MVIC) could enhance the power output of a block power clean after 15, 30, 60, 90, or 120 seconds rest in collegiate student-athletes.

The results from the current study indicate that the effects of post-activation potentiation can increase power output in the block power clean with collegiate athletes when given appropriate rest. There appears to be an optimal time frame for rest between exercises of 60 to





120 seconds to maximize potentiation. Some potentiating effects occur almost immediately after the stimulus as indicated by the effect size at 15 seconds in both males and females, however, rest between 15 and 60 seconds rest may have decreased or negative effects and should be avoided.

This fluctuation of increased and decreased power output, as displayed above, has been seen in studies before and it has been proposed that this is caused by subsiding fatigue and post-activation potentiation levels, which subside at different rates allowing for these waves in performance (Tillin & Bishop, 2009). While Wilson et al. found there to be a greater effect size when the participants were given seven to ten minutes rest when compared to three to seven minutes or greater than 10 minutes, there is no current consensus on what the optimal time frame is for post-activation potentiation as a whole (2013). The literature is contradicting, showing both increased performance and little or no change in performance regarding the same or similar rest intervals (Tillin & Bishop, 2009). This can be attributed to the complex nature of post-activation potentiation. We propose that the effect of post-activation potentiation is affected by the metabolic conditioning and strength level of the participant as well as differing responses to conditioning activities.

Very little research before us has examined rest times as low as we examined, however, an article published after these trials has shown that greater effect sizes can be seen with shorter rest intervals in individuals able to squat more than 175% of their bodyweight (LB seitz, 2016). In addition, Seitz, published a second article showing that 90 seconds of rest between 4 complex sets of accommodating resistance box squats and standing broad jumps produced medium (sets 1,2, and 4) and large (set 3) effect sizes. These findings substantiate the results we found with such short rest intervals. Our study was limited by its small sample size. Further investigation is required to substantiate our findings regarding PAP's effect on loaded power movements. In addition, future research teams should examine the effect of accommodating resistance conditioning activities, such as resistance-banded mid-thigh pulls, on the block power clean.

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