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# The Effects of Hip-Dominant Post-Activation Potentiation on Broad Jump Performance in Varsity Collegiate Football Players

Trevor Bradley-Dade

Merrimack College, [bradleydadet@merrimack.edu](mailto:bradleydadet@merrimack.edu)

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The Effects of Hip-Dominant Post-Activation Potentiation on Broad Jump Performance in

Varsity Collegiate Football Players

Trevor Bradley-Dade

Merrimack College

## Abstract

**(1) Introduction:** The purpose of this study was to determine the acute effects of hip-dominant eccentric post-activation potentiation (PAP) on broad jump distance, through the usage of dynamic (concentric) tempo and eccentric tempo conventional straight bar switch grip deadlifts. This study hypothesized that the experimental eccentric tempo deadlift protocol would result in greater improvements to broad jump performance than the experimental dynamic or control protocols. **(2) Methods:** Twenty-four varsity football players from Tufts University aged 18-22 years were recruited. Participants were assigned into three groups and cycled through one control protocol and two experimental protocols, over the course of three testing sessions within a three-week period. Informed consent was obtained from the participants and coaching staff. The control protocol consisted of a standardized dynamic warm-up, an active rest period, and a broad jump testing protocol. The experimental protocols consisted of a standardized dynamic warm-up, a dynamic or eccentric tempo deadlift protocol, an active rest period, and a broad jump testing protocol. **(3) Results:** The control protocol resulted in a maximum broad jump mean of  $102.12 \pm 7.53$  inches. The experimental dynamic protocol resulted in a maximum broad jump mean of  $101.77 \pm 6.55$  inches. The experimental eccentric protocol resulted in a maximum broad jump mean of  $102.58 \pm 6.93$  inches. A one-way (single factor) ANOVA test indicated no significant differences between any of the means, with  $p=0.92$ , and  $F_{crit} > F$  (where  $F_{crit}=3.12$  and  $F=0.08$ ), where a p-value of 0.05 was used to determine the significance of the results. **(4) Discussion:** The results concluded that neither experimental tempo deadlift protocol had a significant effect on broad jump performance. **(5) Conclusion:** While the results of this study and the previous literature reviewed found only mixed and inconclusive results concerning which specific skeletal muscle contraction is the most beneficial for triggering the physiological

mechanisms of PAP and improving power performance, there still remains a significant body of evidence supporting the effectiveness of PAP for enhancing power performance. Further research on the subject is strongly recommended.

## **Introduction**

### **Background**

Resistance-based strength training and plyometric training each have a long history of being used to supplement and enhance physical human performance. Over the past few decades, many strides have been made in the development of different resistance and plyometric training methodologies. Plyometrics, also known as jump training, refer to short duration maximal effort explosive movement exercises that are used to develop power, a combination of strength of speed. Popular and commonly-used examples of plyometric exercises include box jumps and hurdle hops. Plyometrics are often included in the strength and conditioning programs for the purpose of optimizing an athlete's explosiveness, by improving their muscular power (how quickly muscles can generate maximal force, also known as rate of force development), and by increasing the efficiency of their stretch-shortening cycle (SSC). The stretch-shortening cycle consists of stretching and lengthening a muscle through an active eccentric contraction, adding tension, and then rapidly shortening the muscle via an active concentric contraction. The stretch-shortening cycle is involved in almost all explosive athletic movements to some extent, and therefore plays an integral role in sports performance. Plyometrics can also serve the purpose of improving an athlete's jumping mechanics during takeoff, while in flight, and while landing.

Resistance-based strength training refers to exercises in which a person contracts their muscles in order to move an external resistance, with the purpose of strengthening the said muscles. Dynamic resistance-based strength training exercises are typically comprised of three

distinct components, a trio of different muscular contractions. These three muscular contractions are known as eccentric, isometric, and concentric contractions. Eccentric muscular contractions involve lengthening and stretching a muscle while under load, actively adding tension to that muscle. Eccentric contractions typically account for the “lowering” portions of many resistance training exercises. Isometric muscular contractions consist of an active contraction of a muscle, without involving any change in joint angle or muscle length. Concentric contractions involve actively shortening and adding tension to a muscle. Concentric contractions usually account for the “upward” component many resistance training exercises. It has been found that by placing an emphasis on each of these separate muscular contractions, different training effects and adaptations can be achieved.

As time has passed, professionals in the field of strength and conditioning and exercise science research have discovered new ways of integrating these two training types together, to take human performance to new levels of success. One of the newer resistance and plyometric training integration models is *post-activation potentiation* (PAP). Post-activation potentiation is a concept theorizing that the force exerted by a muscle depends on its recent contractile history, and that the force of the subsequent contraction(s) of that same muscle can be increased based on the specifics of the said contractile history. Within the context of strength and conditioning, this concept is routinely applied in order to elicit marked improvements in muscular power outputs from athletes, often in the form of lighter, and more athletic and explosive movements. Thus far, the consensus seems to be that the most advantageous structure for the use of post-activation potentiation is complex training, where a non-fatiguing muscle contraction is performed at a high intensity, for a shorter duration, followed by a mechanically similar muscle contraction, which potentially yields some enhancement from its recent contractile history. Many of the peer-

reviewed studies encompassed in this review employ unique versions of this procedural structure. As the popularity and legitimacy of this union of training methods has increased, the ways in which it has been tested and employed have also grown, expanding into different movement patterns and programming structures. This literature review will explore the published scientific research on post-activation potentiation and its underlying components and mechanisms.

### **Literature Review**

The concept of post-activation potentiation can be broken down into a few foundational parts. Post-activation potentiation exists as a crossover between the more common training methods of resistance-based strength training and plyometric training. Without the creation, growth, and establishment of each of these respective training methods, post-activation potentiation would simply not exist as it currently stands. Resistance training and plyometric training are each responsible for eliciting the physiological mechanisms that make post-activation potentiation work in the first place.

Over the past century, resistance-based strength training has pushed itself to the forefront of sports performance preparation, with its prevalence perhaps outpacing any other form of more generalized and physically-inclined training. Resistance-based strength training encompasses exercise techniques in which the body's skeletal muscles are forced to contract against an external resistance, in order to control and manipulate its movement. Sufficient commitment to performing resistance-based strength training regimens can yield discernible advancements in muscle strength, power, mass, and endurance. Resistance-based strength training is typically employed with the purpose of increasing muscular strength and power capabilities, when used in conjunction with post-activation training methods. Resistance-based strength training is

commonly programmed and performed without any accompanying post-activation potentiation protocols, though the same cannot be conversely said of post-activation potentiation, because PAP requires *elements* of resistance training as a virtue of its deeper physiological mechanisms. The muscular strength enhancements yielded from resistance-based strength training have been shown to carry over positively into post-activation potentiation protocols, as Gourgoulis and Aggeloussis (2003) confirmed in their study examining effects of supramaximal half-squats on vertical jump, wherein they surmised that individuals with greater muscular strength exhibited greater improvements in vertical jump ability. This finding illustrates the importance of resistance-based strength training to post-activation potentiation, not only as a physiologically essential component, but as a potentially beneficial factor towards performance as well. Broader, additional studies, including ones falling outside the territory of post-activation potentiation study, have confirmed this positive relationship as well. A very recent study examining the relationship between back squat strength and static jump performance amongst athletes also found that greater muscular strength correlated positively with jump ability (Haun et al., 2017). Just this past year, a study covering the impact of isometric contraction-specific strength training on the muscular power performance of judo athletes revealed yet another positive correlation between muscular strength and countermovement jump performance (Campos et al., 2018). The published literature available regards the indicated positive relationship between muscular strength developed via resistance training and muscular power output ability as nearly indisputable. As such, resistance-based strength training should be considered an integral cog in the machine of sports performance and post-activation potentiation.

In addition to resistance-based strength training, plyometric training comprises the other foundational component of post-activation potentiation. Plyometric training is characterized by

explosive, athletic exercises, that are performed at a high velocity, and are short in duration. Training plyometrics on a consistent basis, through a properly programmed regimen, can improve an athlete's ability to develop maximal force, shortening their timetable for achieving optimal force production, thus making them more explosive, and likely improving their sports performance in the process. The purpose of post-activation potentiation is to further enhance an athlete's explosiveness, augmenting their muscular power by influencing the contractile history of the relevant musculature through resistance exercise, and engaging the physiological mechanisms necessary to improve force development and output. As they currently stand, post-activation potentiation complex training protocols typically consist of a heavier resistance exercise, followed by a mechanically similar plyometric exercise, performed at a substantially higher velocity (Maloney, Turner, & Fletcher, 2014). Because of this setup, and because of the physiological mechanisms that govern how the body operates, the plyometric component of the protocol conceivably yields the benefits of post-activation potentiation from the preceding resistance training component. However, it is worth noting that certain plyometric exercises have been used on occasion to create PAP responses, while preceding other plyometric exercises that would benefit from the said response (McBride, Nimphius, & Erickson, 2005). A cursory look at the existing literature reveals that the results of using plyometric training in order to create a PAP response have been mixed at best, though there is precedent (Bridgeman, McGuigan, Michael, Gill, & Dulson, 2017). Unique complex training protocols aside, plyometric training's main involvement in PAP is as a beneficiary of the effect created by resistance exercise, which triggers the appropriate physiological mechanisms for enhanced muscular power performance. To fully understand and appreciate the concept of post-activation potentiation, the underlying physiological mechanisms that make it work must be briefly examined. There are currently



multiple physiological mechanisms that have been proposed as being responsible for PAP (Xenofondos, Lapidis, Kyranoudis, Galazoulas C, Bassa E., & Kotzamanidis, 2010). The more popular of these two theories is centered around the phosphorylation of myosin regulation light chains, and how this phosphorylation heightens the  $Ca^{2+}$  sensitivity of the myofilaments within skeletal muscle fibers (Sale, 2004). This increased sensitivity to  $Ca^{2+}$  released from the sarcoplasmic reticulum results in increased myosin crossbridge activity – enhancing the ability of the skeletal muscle to contract more efficiently and more powerfully, providing an obvious boon for sports performance. Another theory on the physiological mechanism driving PAP is that the stimulus an exercise provides excites several neurological mechanisms. Perhaps the most important of these neurological mechanisms is H-reflex potentiation. H-reflex is essentially a measurement of the excitability of skeletal muscle tissue, signifying the muscle's ability to reply to stimuli from motor neurons or hormones. Increased excitability is commonly associated with higher H-reflexes (Tillin & Bishop, 2009). When a muscle has higher excitability, its ability to develop to maximal force at a quicker pace is enhanced, thereby heightening its power and explosiveness, likely improving sports performance.

Both resistance-based strength training and plyometric training can involve three distinct variety of muscle contractions; eccentric, isometric, and concentric. The role that each of these muscular contraction types play in the process of post-activation potentiation is the subject of much research. Muscle contractions, and the stimuli they can provide in relation to post-activation potentiation, can be dependent on the tempo of the movement and the ensuing time under tension that the muscles withstand. As this study will examine the effect of eccentric and concentric contractions on post-activation potentiation and subsequent broad jump performance, the literature covering how different contraction stimuli effect post-activation potentiation is of

particular interest. Of the aforementioned contraction types, perhaps the most recognizable, is the concentric muscular contraction, in which the muscle actively shortens during what is commonly the “upward” or raising” part of the resistance training exercise. The eccentric muscular contraction accounts for what commonly comprises the lowering movement of an exercise, in which the skeletal muscle lengthens, also actively adding tension. Isometric contractions exist in the sometimes brief space in between concentric and eccentric contractions, where the muscle is actively tensed, but not changed in length, as no movement around a joint takes places. Research conducted on each of these muscle contractions, both separately and jointly, still paints a rather mixed picture of their effects on post-activation potentiation. A study conducted by Nibali et al. (2013), found moderate correlations between concentric contraction rate of force development in a strength training context, and subsequent muscular force/power output, when measured through back squats and subsequent jump squats within a post-activation potentiation training protocol. However, a different and more comprehensive study conducted by Esformes et al. (2011), comparing the effects of each of these muscle contractions types (including a combined dynamic concentric-eccentric parameter) on post-activation potentiation, found that only the isometric contraction strength training protocol yielded any significant enhancement in paired peak muscular force output. Relevant to this study is the fact that its specific training procedures only encompassed upper body exercises and performance, through barbell bench press and ballistic bench press throw. This differs significantly from the studies reviewed thus far, as each of those included lower body training components of some kind. Another study implementing more of a lower body focus, examining the effect of varying eccentric emphasis strength training stimuli on countermovement jump performance, concluded that multiple different eccentric contraction stimuli significantly improved muscular peak power. These eccentric stimuli were

applied through different intensities on the utilized hip sled exercise (Ong, Lim, Chong, & Tan, 2016). The effect of eccentric loading on post-activation potentiation response was later examined using very different lower body stimuli by Bridgeman et al. (2017), putting study subjects into an eccentric emphasis through the implementation of body weight and weighted drop jumps, before measuring their ensuing countermovement jump performance. The application of eccentric stimuli through ballistic exercises, specifically drop jump landings at body weight or loaded with dumbbells, is perhaps one of the most unique means of introducing an eccentric emphasis in existing relevant literature. The subjects in this study conceivably spent the lowest time under tension in the targeted pre-activation stimuli, as compared to their counterparts in other studies. Instead, the eccentric emphasis was created by the through the manipulation of drop jump height and total body mass during drop jump protocols. The study concluded that the accentuated eccentric loading dumbbell drop jumps resulted in greater significant improvements to countermovement jump performance, when compared to body weight drop jumps. It is worth noting that the presence of greater resistance in this scenario (dumbbell loading) provided more of a positive effect on subsequent jump performance. Overall, the literature reviewed indicates that all three contraction types were able to positively influence post-activation potentiation response and subsequent power/force output, throughout multiple studies. In light of these largely positive findings, it can be concluded that post-activation is generally an effective means of improving muscular power, though more research is needed if the scientific community is to reach clearer conclusions regarding the effect of specific muscular contraction types on post-activation potentiation response. Fortunately, this study will examine the effects of eccentric and concentric emphasis loading on post-activation potentiation

response and muscular power. In doing so, more data and insight will hopefully be contributed towards the topic.

### **Summarization**

A review of the established literature on post-activation potentiation, and its relationship to the specific types of skeletal muscle contractions performed in the resistance exercise preceding its initiation, has revealed mixed and inconclusive results concerning which skeletal muscle contraction type is the most beneficial towards triggering physiological mechanisms of PAP. In light of this, additional peer-reviewed research on the subject is both needed and recommended. The author of this study is acting to contribute more to this topic by conducting said study. The purpose of this specific study will be to investigate the acute effects of eccentric and dynamic tempo conventional straight bar switch grip deadlifts on countermovement broad jump performance through hip-dominant post-activation potentiation. This study hypothesizes that if subjects participate in the experimental eccentric deadlift group, then those subjects will experience the greater acute improvements in broad jump performance, as compared to their counterparts in the experimental dynamic deadlift group, and active rest control group.

### **Method**

#### **Experimental Design**

A crossover quantitative research design will be used for this study, with the purpose of investigating the acute effects of hip-dominant eccentric post-activation potentiation on broad jump distance, via the usage of dynamic (concentric) tempo and eccentric tempo switch grip straight bar deadlifts. This study involves an acute training intervention. The intervention will be structured as follows: one familiarization session, followed by three subsequent testing sessions. The three testing sessions will be conducted across three weeks, exactly seven days apart. These

three testing sessions will be integrated into the Tufts football team's weekly Monday morning strength and conditioning session. Each testing session will account for roughly 25 minutes total time.

### **Participants**

Twenty-four men total, aged 18-22 years with previous experience in sports performance strength and conditioning training will volunteer to participate in this study. The subjects will be recruited from the NCAA Division III Tufts University varsity football team, using a voluntary sampling method. This study will be approved by the Institutional Review Board (IRB), and its participants will all have signed informed consent forms.

### **Measures**

Conventional straight bar switch grip deadlifts will be used for the deadlift component of the testing session, as they provide a safe means of performing heavy hip hinge movements without requiring a spotter, with subjects being able to drop the bar to the floor if the weight proves to be too heavy. Furthermore, conventional straight bar switch grip deadlifts are a common fixture within Tufts University varsity football strength and conditioning programming, allowing for the calculation of one-rep training maxes for the study, based on previously obtained true one-rep max numbers for this exercise. Percentages of one-rep training maxes will be used to calculate prescribed deadlift warm-up and working sets within this study. The hip hinge pattern of a straight bar conventional deadlift is comparable to the hip hinge pattern of a countermovement broad jump, conceivably allowing for the possibility that hip-dominant post-activation potentiation can be carried over and applied from a conventional straight bar deadlift into a countermovement broad jump, with positive effect on broad jump distance. Both conventional straight bar switch grip deadlifts and countermovement broad jumps can and have been used

reliably and validly as measurements of lower body strength and power in sports performance settings.

The broad jump test will be set up on the turf within the varsity weight room. There will be two broad jump testing stations set up, with each station extending vertically off of each a straight painted white line on the turf. Each station will have a fifteen-foot length of tape measure taped to the floor, with the feet and inches side face up, at a 90-degree angle to the white line, with the 0-inch mark aligned with the front edge of the white line. Subjects will be instructed to keep their toes behind the back edge of the white line, with their feet pointed forward roughly hip-width. Subjects will be instructed to perform a countermovement before performing a bilateral jump forward to a solid bilateral landing. Subjects will be instructed to stick the landing of each jump with two planted feet, maintaining control and limiting any staggering or false steps in any direction, while avoiding touching the floor with their hands to maintain or regain balance. Subjects will remain in place until the test conductor can successfully measure the distance of each broad jump. A wooden dowel will be used to measure the distance of each broad jump, by aligning the body of the dowel along the furthest back heel of the subject, at a 90-degree angle to the aforementioned tape measure. The number on the tape measure aligned with the front side of the dowel will be taken as the measurement for each broad jump. Upon completing each broad jump trial, subjects will return to the back of the line at their testing session, cycling through said line until their next broad jump trial. Subjects will follow this procedure until all three broad jump attempts are completed. The greatest distance achieved out of the three broad jump attempts will officially be recorded for data collection, for that testing session.

## **Procedures**

Over the Tufts University 2018-2019 winter break, 24 members of the college's varsity football team will be asked to obtain a one, three, or five rep-max on conventional switch-grip straight bar deadlift. These numbers will be used to calculate a deadlift training max for each participating subject. For safety purposes, this training max will be 85% of the performed or calculated one-rep deadlift max obtained from the subjects.

At the beginning of the Spring 2019 semester, all subjects will be taken through a familiarization session on the methods and procedures of the data collection testing sessions, in order to avoid any confusion or error on the actual scheduled testing sessions.

Across the three testing sessions, three groups of 7-9 subjects (Group A, Group B, Group C) will be cycled through the three different testing protocols (control broad jump, experimental eccentric tempo deadlift, and experimental dynamic tempo deadlift), so that by the time data collection concludes, each group will have been tested under each condition. This format will be utilized in lieu of simultaneous singular group testing due to logistical constraints. In testing session 1, Group A will serve as a control group, Group B as the eccentric group, and Group C as the dynamic group. In testing session 2, Group C will serve as a control group, Group A as the eccentric group, and Group B as the dynamic group. In testing session 3, Group B will serve as a control group, Group C as the eccentric group, and Group A as the dynamic group.

All subjects will be asked to refrain from training in the 24 hours before any testing session. Subjects from every group will perform a standardized dynamic warm-up together on an indoor wooden basketball court surface, before commencing their specific testing session. This standardized dynamic warmup will last roughly eight minutes in length and will be comprised of the following movements detailed in Table 1.

Table 1 Standardized Dynamic Warm-up.

Skipping Movements	Slow Dynamic Flexibility Movements	Fast Dynamic Movements	Ascending Intensity Runs
Forward high knee skip	Reverse lunge hip flexor hamstring	Buttkicks	50 % effort run
Right lateral skip	Alternating spider-man	Lateral shuffle right	75% effort run
Left lateral skip	Backwards RDL walk	Lateral shuffle left	90% effort run
Power skip		High knee run	
		Carioca right	
		Carioca left	

Each dynamic movement will be performed once across the fifteen-yard increment. After completing the warm-up, subjects will be provided a personalized printout from a Microsoft Excel file, detailing their group and accompanying procedures for each separate testing session.

Immediately following the standardized warm-up component of the testing session, subjects in the day’s control broad jump group will engage in exactly five minutes of active rest, in which they will perform accessory exercises for the shoulders and neck, considered non-fatiguing towards broad jump performance. At the conclusion of this five-minute active rest period, control group athletes will form into one line and follow the broad jump testing protocol, detailed in the Measures section. The control group broad jump testing session will last no more than five minutes, concluding before the subjects in the day’s experimental eccentric and dynamic groups enter to complete their broad jump testing session. After completing their broad jump testing session, the day’s control group will reenter the weight room and proceed with the remainder of their strength and conditioning program.

Following the standardized warm-up component of the testing session, subjects in the day’s experimental eccentric and dynamic groups will each complete a deadlifting component.



For organizational, logistical, and time purposes, each experimental group of subjects will be assigned to three platforms each in the varsity weight room (using six platforms total), with 2-3 subjects sharing each platform. Individual subject platform assignments will be determined based on similar weight ranges and training maxes, in order to ease the changing of weights and transition times. Deadlift operations on each individual rack will go as follows: subject 1 loads the weight for their first warm-up set of deadlift and performs it at the beginning of a 60-second interval; then subject 2 loads the weight for their first warm-up set of deadlift and performs it at the beginning of the next 60-second interval; then subject 3 loads the weight for their first warm-up set of deadlift and performs it at the beginning of the next 60-second interval. Then, subject 1 loads the weight for their second warm-up set of deadlift and performs it at the beginning of the following 60-second interval, and the cyclic process continues, allowing for adequate rest and efficient transitions between each set. As a result of this setup, each subject will rest at least approximately 90 seconds or more between sets of deadlift. A running clock will be managed by a strength and conditioning coach equipped with a stopwatch, ensuring that subjects can track their rest and transition times.

The volume and intensity of the working set of deadlift will be the only difference for the testing session between the eccentric and dynamic groups. Each deadlifting session will be completed on a similar timeline, lasting roughly twelve minutes in duration, and include a standardized deadlift warmup. This standardized deadlift warmup will be completed before performing the working set of deadlift. Every set of the standardized deadlift warmup will be performed at a “normal” dynamic concentric tempo to limit unnecessary fatigue. Each subject’s standardized deadlift warmup and working set will be programmed relative to their calculated 1RM training max deadlift. The standardized deadlift warmup is detailed in Table 2 below.

Table 2 Standardized Deadlift Warm-up.

	Set 1	Set 2	Set 3
Reps	x4	x3	x2
% of Dynamic Training Max	60%	65%	70%

Upon completion of the standardized deadlift warmup, subjects in the experimental eccentric group will complete a final working set of deadlift. Subjects will be instructed beforehand to complete a full-stop on the floor between each rep. This final working set of deadlift is detailed in Table 3 below.

Table 3 Experimental Eccentric Tempo Deadlift Working Set

	Working Set
Reps	x4
% of Dynamic Training Max	72.5%
Tempo	5-second eccentric

Upon completion of the standardized deadlift warmup, subjects in the experimental dynamic group will complete a final working set of deadlift. Subjects will be instructed beforehand to complete a full-stop on the floor between each rep. This final working set of deadlift is detailed in Table 4 below.

Table 4 Experimental Dynamic Tempo Deadlift Working Set

	Working Set
Reps	x2
% of Dynamic Training Max	77.5%
Tempo	Normal

Upon completion of their group's specific deadlift testing procedures, and the standardized five-minute active rest period, subjects from each experimental deadlift group will complete a battery of three broad jump tests. Broad jump testing operations will remain the same

for the two experimental deadlift groups as it was for the control group, with the lone difference being that the experimental group subjects will be divided into 2 different lines, with each line corresponding to each deadlift group. Once in their appropriate lines, subjects will follow the same broad jump protocol described in the Measures section. Broad jump data will be collected on each subject's individually customized Microsoft Excel printout, which they received at the beginning of the testing session. Data collection for the experimental broad jump testing should last no more than five minutes. After completing their broad jump testing session, the day's experimental deadlift groups will reenter the weight room and proceed with the remainder of their strength and conditioning program.

### **Data Analysis**

Data for broad jump distance will be collected in feet and inches. Broad jump performance will be evaluated based on data recorded during broad jump testing sessions. Broad jump data will be analyzed using a one-way (single factor) ANOVA test, or analysis of variance, through the use of XL Miner Analysis ToolPak software on Google Sheets.

### **Results**

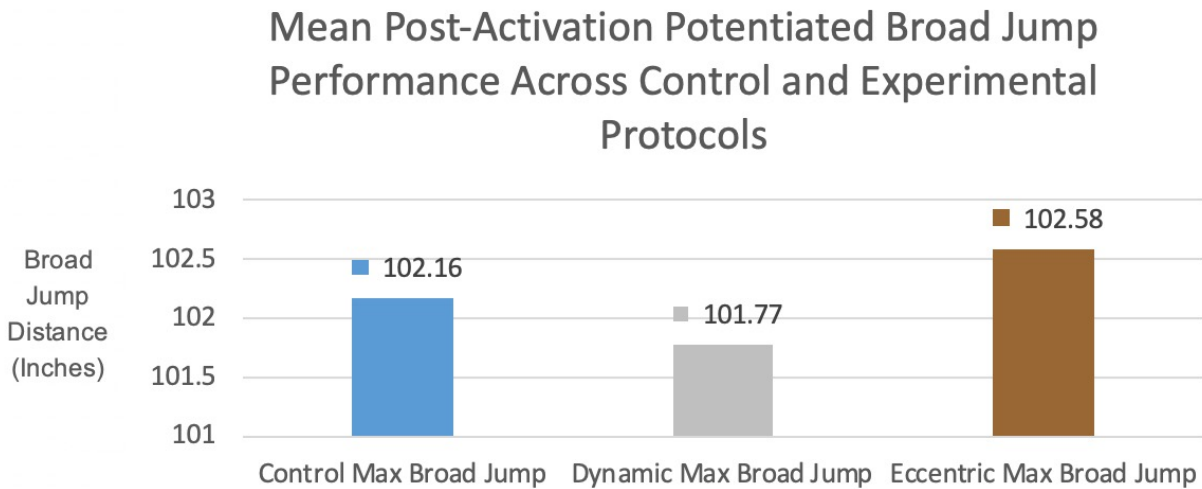
Completion of this study compiled broad jump measurements from twenty-four men on the Tufts University varsity football team, aged 18-22 years with previous experience in sports performance strength and conditioning training. The data collected and recorded was the longest broad jump measurement achieved for each individual, out of three total measured broad jump attempts, following completion of the prescribed protocol corresponding to each specific testing session. Over the course of the study's three testing sessions, individual subjects attained three separate longest broad jump measurements, one for each of the three study protocols; the control broad jump (CBJ), the experimental dynamic tempo deadlift (DBJ) and the experimental

eccentric tempo deadlift (EBJ). Means and standard deviations across each protocol are included. This information can be found in Table 5 below, and shown in graph format in Figure 1.

Table 1 Mean Broad Jump Data with Standard Deviations.

	CBJ	DBJ	EBJ
Mean	102.1666667	101.7708333	102.5833333
Standard Deviation	7.536385171	6.552429298	6.938664591

Figure 1 Mean Post-Activation Potentiated Broad Jump Performance Across Control and Experimental Protocols.



The data that was collected during this study was analyzed using a one-way (single factor) ANOVA test, or analysis of variance, through the use of XL Miner Analysis ToolPak software on Google Sheets. The one-way ANOVA was conducted in order to determine if there was a significant difference in broad jump performance measurements following dynamic tempo or eccentric tempo deadlift PAP-inducing protocols, or the lack thereof. A p-value of 0.05 was used to determine the significance of the results that were obtained. The results of this study showed that neither the dynamic tempo deadlift PAP protocol, nor the eccentric tempo deadlift

PAP protocol, were effective at improving broad jump performance. One-way ANOVA analysis demonstrated no statistical difference among broad jump performances, regardless of the protocol conducted preceding broad jump testing, in spite of the introduction of two experimental PAP-inducing protocols,  $F(2, 69)=0.097$ ,  $p>0.05$ . With  $p=0.92$ , and  $F_{crit} > F$  (where  $F_{crit}=3.12$  and  $F=0.08$ ), the ANOVA test was *not* significant, failing to indicate any significant results or differences between the means, and eliminating the need for any follow-up post-hoc tests, to more carefully examine and compare every pair of groups. This information can be found in Tables 5 and 6 below.

Table 5 Variance Summary.

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
CBJ	24	2452	102.1666667	56.79710145
DBJ	24	2442.5	101.7708333	42.93432971
EBJ	24	2462	102.5833333	48.14492754

Table 6 ANOVA.

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	7.923611111	2	3.961805556	0.08037401496	0.9228574142	3.129643983
Within Groups	3401.15625	69	49.29211957			
Total	3409.079861	71				

## **Discussion**

This study hypothesized that participation in an experimental eccentric tempo deadlift protocol would yield greater acute improvements in broad jump performance, as compared to participation in either an experimental dynamic tempo deadlift procedure, or an active rest control protocol. Unfortunately, with  $p=0.92$  indicating no significant results or differences

between the means, this study did not yield any significant results, or prove its hypothesis correct, with its findings falling in line with the outcome of the accompanying comprehensive literature review; mixed and inconclusive results specifically concerning *which* skeletal muscle contraction type is the most beneficial for triggering the physiological mechanisms of PAP and subsequently improving power performance. This was despite this study's more directly comparative basis, as opposed to many of the individual studies previously reviewed.

While the literature covered employed many different approaches to measuring, analyzing, and comparing the effects of different muscular contraction types on PAP, few utilized quite the same structure and variables that this study did, wherein the effects of eccentric and dynamic (concentric) muscular contractions on PAP were contrasted directly. The study closest to resembling the comparisons made by this one was conducted by Esformes et al. (2011), which measured the effects of each of the three muscular contraction types (eccentric, isometric, and concentric) on PAP, and compared the resulting effects of each contraction type. In that study, it was found that only the isometric contraction strength training protocol yielded any significant enhancement to power performance. Of course, an isometric contraction training protocol was not included in the study conducted here. This perhaps could be a limitation of this study; it only accounted for the implementation of dynamic (concentric) tempo and eccentric tempo deadlift protocols, passing on the inclusion of an isometric tempo deadlift protocol, in the interest of various logistical constraints.

Somewhat conversely to the findings of this study and the one conducted by Esformes et al. (2011), studies conducted by Bridgeman et al. (2017) and Ong et al. (2016) demonstrated that multiple unique eccentric muscular contraction stimuli were effective in creating post-activation potentiated effects, and significantly and subsequently improving power performance. Also

contrary to the results of this study and the one conducted by Esformes et al. (2011), were the results of a study conducted by Nibali et al. (2013), which found that concentric muscular contractions were moderately effectual when it came to inducing PAP and enhancing subsequent power performance.

Synthesizing the findings of this study, along with those of the literature previously published, reveals that placing emphasis on individual muscular contractions can be either demonstrably successful or unsuccessful when it comes to enhancing power performance through PAP. Throughout the studies conducted, concentric, eccentric, and isometric muscular contractions all proved to be effective for stimulating PAP and augmenting power performance, while also failing to have the same significant effect on other occasions, within other studies. As a result, the outlook regarding which specific muscular contraction emphasis is best for inducing PAP and enhancing power performance still remains rather unclear. In light of this, it is recommended that more research be conducted on the subject.

In retrospect, this study had multiple limitations, which may have adversely affected the accompanying results and findings. The most significant limitation was perhaps the flawed programming design of the two tempo deadlift protocols. With a ratio of three identical warm-up sets, to only one tempo-specific working set for both protocols, it is possible that the time spent under tension for each muscular contraction may have been too insufficient in volume to induce a true PAP effect and yield any discernibly significant results. The lack of additional deadlifting volume was an extension of two other limitations to this study, those being time and space. As study testing sessions were integrated into the Monday strength and conditioning sessions of the Tufts University varsity football team, limited time was allotted for study protocols and data collection to take place, due to the subjects' mandatory commitment to participate in their team's

programmed training for that day. To resolve this quandary, deadlift protocols could've perhaps been modified to replace warm-up sets with additional tempo-specific working sets. Space was yet another constraint, as the Tufts University varsity collegiate weight room only had a limited number of platforms and equipment available for deadlifting, meaning that not all twenty-four subjects could feasibly deadlift simultaneously, at the proper pace, with equal rest periods between sets. Ideal study conditions would've allowed every individual subject to participate in one specific study protocol together (eccentric tempo deadlift, dynamic tempo deadlift, or control), within a single testing session, instead of cycling assigned subject groups through each different study protocol on a weekly basis, as structured in the study, out of necessity. Arguably another limitation was the choice methodology of data collection; subjects were given three attempts to test broad jump performance per study protocol/testing session, with their maximum broad jump distance out of each of those three attempts being recorded for that testing session. It is possible that the study may have yielded more significant results if the *average* of three broad jump attempts for each study protocol/testing session was collected for data analysis instead.

The synthesis of the study's results and reviewed literature, along with the retrospective analysis of possible limitations to the study, can contribute to potential future practical applications related to research on specific muscular contractions and post-activation potentiation. First, as aforementioned, conducting more research on the subject is both recommend and required, if a distinct conclusion on which muscle contraction best facilitates PAP and subsequent power performance is to be developed. Future research should take into the account the significance of time under tension during loaded exercise stimuli preceding power performance testing. This means that programmed tempos for specific muscular contractions should be adequate enough in duration, thereby emphasizing the said muscular contraction, and



theoretically triggering the physiological mechanisms of PAP. Sufficient volume (sets and reps) for these loaded exercises should also be programmed into study protocols, in order to ensure enough of a training effect is created to stimulate PAP. It is suggested that individual future studies encompass all three muscular contraction types, comparing the effects of each of them on PAP and power performance, in the interest of being as comprehensive as possible. These implications and recommendations for future research can be applied practically outside of research settings as well; strength and conditioning professionals will also want to ensure that time under tension and volume are appropriately programmed and accounted for, for all loaded exercise stimuli preceding power performance work, regardless of which muscular contraction(s) they might be trying to emphasize.

### **Conclusion**

The procedures of this study conclusively resulted in no significant differences between the effects of experimental dynamic (concentric) tempo or eccentric tempo deadlift protocols on broad jump performance via post-activation potentiation, with  $p=0.92$ . Neither experimental protocol was successful in significantly improving broad jump performance compared to the control protocol utilized. These findings were generally in line with the outcome of the accompanying comprehensive literature review conducted, which concluded that there are mixed and inconclusive results concerning *which* specific skeletal muscle contraction type is the most beneficial for triggering the physiological mechanisms of PAP, and subsequently improving power performance. Synthesizing the findings of this study with those of the literature review still paints a rather unclear picture as to which specific muscular contraction emphasis is best for inducing post-activation, and thereby enhancing power performance. In light of this conclusion, it is strongly recommended that further comprehensive research be conducted on the subject,

ideally encompassing all three muscle contraction types (concentric, isometric, and eccentric), and taking into account sufficient time under tension for loaded resistance training exercises preceding power performance testing. Lastly, while the results of this particular study did not exhibit any beneficial effects of post-activation potentiation, there still remains a significant body of evidence supporting the effectiveness of the post-activation potentiation phenomenon, and therefore strength and conditioning professionals should not be dissuaded from implementing its use, based on the findings of one individual study.

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