

# The Effect of Drop Jump Height on Post-Activation Potentiation as Measured by Vertical Jump Performance

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## Abstract

Post-activation potentiation (PAP) is an enhanced contractile response within the muscles due to prior voluntary activation. The optimal combination of volume, intensity, and rest that results in the greatest performance improvement when using PAP inducing exercises during a warm-up has yet to be determined.

**Purpose:** The purpose of this study was to compare the effects of two different drop jump heights on PAP as measured by subsequent vertical jump performance.

**Methods:** 76 male and female NAIA collegiate athletes (19.9±0.2yrs) completed three different testing session protocols. During the first session, the participants performed a pre-treatment vertical jump test and were familiarized with drop jumps. The second and final testing sessions included five drop jumps with rebound from an 18 or 30-inch box followed by a post-treatment vertical jump test. A repeated measures ANOVA was performed in order to examine differences in vertical jump height attained with no drop jump warm up, an 18-inch drop jump warm up, and a 30-inch drop jump warm up.

**Result:** The mean pre-treatment vertical jump was 58.1±1.8cm while the 18-inch treatment mean was 55.2±1.5cm and the 30-inch treatment mean were 55.6±21.5cm. A repeated-measures ANOVA comparing the vertical jump after the varying drop jump heights showed both treatment conditions to have significantly decreased vertical jump height.

**Conclusion:** Neither of the drop jump treatments were found to significantly improve vertical jump performance when compared to the pre-treatment vertical jump heights.

**Keywords:** Post-activation potentiation; Athletes; Vertical jump

## Introduction

Performance improvement is a primary goal of many athletes, whether they are actively competing or simply participating recreationally. Athletes and coaches make modifications in training, nutrition, and pre-competition routines in order to maximize the possibility of improving performance. By utilizing different strategies there is a greater chance of finding one method or routine that has a positive impact on performance. One such strategy is focusing on the type of warm-up used immediately before competition. There are many different forms of warm-ups and determining the effectiveness of each has the ability to lead to performance improvement for numerous athletes.

There is a long history of athletes participating in warm-ups before competition with the hopes of improving performance [1]. A warm-up has been defined by Fradkin et al. [2] as a period of preparatory exercise to enhance subsequent competition or training performance. The aim of warm-ups is to achieve optimal muscle power, coordination, and range of motion for the following competition [3]. These improvements are achieved through physiological changes such as increased muscle blood flow and temperature and increased muscle and tendon elasticity. Traditionally, warm-ups include a period of aerobic exercise followed by stretching and possibly several sport specific movements with maximal or near maximal muscle contractions.

The efficacy of warming up as a means of performance improvement is well-documented by research studies. In a study by Fradkin et al. [2] showed improvements in both aerobic and anaerobic activities, such as running, cycling, and vertical jumping, were demonstrated

after completing a warm-up. Seventy-nine percent of the studies analyzed showed an improvement in performance after the warm-up, while three percent showed no change and seventeen percent demonstrated a decrease in performance after the warm-up. While warm-ups have been shown to improve performance, the degree of improvement is largely dependent on what type of warm-up is utilized. Fradkin et al. [2] found that degree of improvement varied from one to twenty percent due to differences in the warm-ups used. Moreover, warm-up strategies tend to be based on trial and error experience of the athletes and their coaches. The need for continued research on which methods of warm-up are most effective for any given activity is clear.

Nevertheless, there is research that suggests that a dynamic warm-up may be most beneficial for activities involving explosive movements [4]. In addition to reducing the detrimental effects of static stretching prior to powerful anaerobic movements, the explosive movements typically performed during a dynamic warm-up may be successful in inducing a phenomenon called post-activation potentiation (PAP) that enhances subsequent muscle power for short periods of time [3-5].

Post-activation potentiation (PAP) is an enhanced contractile response within the muscles due to prior voluntary activation. The prior muscle activation is often referred to as a conditioning contraction and PAP is a recognized consequence of this prior activation. PAP increases the force of muscle twitch contraction after a maximum voluntary conditioning contraction because of increased phosphorylation of the myosin light chain [6]. When calcium is released in skeletal muscle, it activates the myosin light chain which makes the myosin heads more mobile, increasing the rate of cross-bridge formation when the muscle is stimulated. Increased cross-bridge formation allows a faster rate of force development in the muscles [1]. Since post-activation potentiation requires a form of maximal muscle contraction as the conditioning contraction, heavy resistance exercise and plyometric exercises are often utilized to induce PAP. The effectiveness of both isometric and eccentric contractions has been studied in regard to PAP and there appears to be advantages and disadvantages for both. In Hilfiker et al. [6] study, eccentric muscle action appears to have a stronger influence on subsequent muscle action than isometric contractions, but this trend is not demonstrated by all studies. Drop jumps require demanding eccentric muscle contraction, a form of maximal muscle action, in the muscles most used in vertical jumps and therefore

show promise for inducing PAP and improving vertical jump performance. Drop jumps are commonly used in training programs but their inclusion in a warm-up to create an immediate effect on performance, such as vertical jump height, is not widely used.

While a combination of heavy resistance exercises and plyometric exercises are used in complex training in hopes of inducing PAP and producing long-term changes in muscle power generation throughout a training cycle, utilizing the acute effects of PAP in a warm-up to increase force production during competition is not a widely used practice [7]. For events that require explosive power, research has determined that static stretching is often contraindicated but PAP exercises seem to help fight the negative effects and they show promise in increasing subsequent performance. The precise combination of height, number of repetitions, and other variables regarding drop jumps and PAP remains unclear, indicating the need for continued research.

Additional research on the many components of PAP exercises as a warm-up is necessary to determine if PAP positively contributes to the effectiveness of a warm-up. Therefore, the purpose of this study was to compare the effects of two different drop jump heights on PAP as measured by subsequent vertical jump performance to pre-treatment vertical jump performance in female collegiate athletes

## Methods

### Participants

Seventy-six collegiate athletes ages 18-27 ( $19.9 \pm 0.2$  yrs) from St. Ambrose University women's softball, women's soccer, men's volleyball, men's and women's basketball were recruited. The racial, gender, and ethnic characteristics of the participants reflected the demographics of players recruited to participate in NAIA collegiate sports (softball, basketball, soccer, volleyball). Descriptive characteristics are explained in (Table 1) In order to participate, subjects were:

- A. Healthy
- B. Currently eligible for college athletics and participating on a specified collegiate team
- C. Able to complete an orientation and two experimental trials.

**Table 1:** Participant characteristics.

	Softball (n=17)	Soccer (n=9)	Basketball (n=26)	Volleyball (n=15)	All Participants (n=67)
Age (years)	18.9±.26	19.7±.33	20.7±.49	20.1±.29	19.9±.23
Weight (kg)	68.5±1.6	60.9±.97	80.2±2.5	84.1±2.3	75.5±1.5
Height (m)	1.7±.02	1.7±.02	1.8±.02	1.9±0.2	1.7±.02
Reach (m)	2.1±.02	2.1±.02	2.3±.03	2.4±.02	2.3±0.02

Subjects were healthy males and females free from any disease or conditions that would limit their participation in physical activity. The St. Ambrose University Institutional Review Board approved this investigation and informed consent was received from all participants.

### Protocol

A cross-sectional correlational counterbalanced design with multiple observations was employed. This investigation required three testing sessions:

- A. Session I (orientation);
- B. Session I
- C. Session III.
- D. Sessions I and III were randomized and included: 1) drop jumps with rebound from an 18-inch box 2) drop jumps with rebound from a 30-inch box. The two experimental trials were separated by approximately 24-72 hours.

### Orientation session

Upon arrival to the experimental trial, anthropometric measures were obtained including height (cm), body weight (kg), fat free mass (kg), and fat mass (% and kg). Height (cm) and weight (kg) were measured using a physician's scale. Body composition was assessed using a Tanita (Arlington Heights, IL) bioelectrical impedance analyzer (BIA) scale. The study protocol was explained to each participant and Informed consent was gathered.

Participants baseline vertical jump score was taken using a Vertec (Power Systems, Knoxville, TN). First, the participants reach height was obtained then they were asked to perform a standing vertical jump; they were given 3 attempts. If participant reach a higher height on 3<sup>rd</sup> try another attempt was given until participant was no longer able to increase results highest results were recorded. After the vertical jump test the drop jump with rebound was explained and demonstrated to participants. Participants were also given the opportunity to practice performing a drop jump.

### Experimental sessions

Following the orientation session, subjects were randomized into both experimental sessions I and II. All subjects were dressed in standard athletic clothing (short sleeve cotton t-shirt or mesh practice jersey and shorts) during each exercise session. For each experimental session, participants were taken through a standardized dynamic warm-up.

**Session two:** Following the standardized dynamic warm-up subjects were instructed to perform 5 drop jumps with rebound from an 18- inch box. Participants were given a 1-minute rest time following the drop jumps then subjects were then instructed to perform a vertical jump test using the same protocol as performed during the orientation session.

**Session three:** Following the standardized dynamic warm-up subjects were instructed to perform 5 drop jumps with rebound from a 30- inch box. Participants were given a 1-minute rest following the drop jumps subjects were then instructed to perform a vertical jump test using the same protocol as performed during the orientation session.

### Statistical Analysis

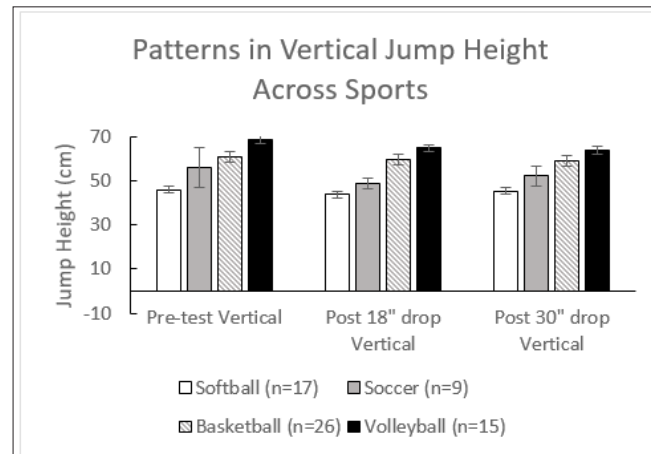
Following the data collection process, data were compiled and analyzed. A one-way repeated measures ANOVA was used to examine differences in vertical jump height at baseline and following the two warm-up conditions. Mean values and standard error of the mean was calculated and reported as well. All analysis was performed using SPSS. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science [8].

### Result

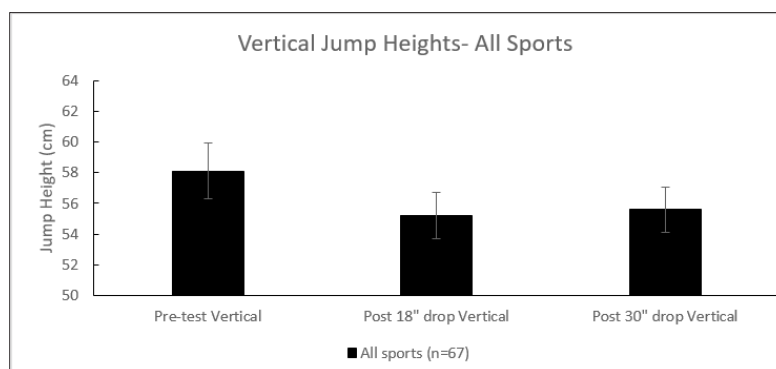
Subject characteristics are shown in Table 1. Of the 67 athletes who took part in this study, 39 were female and 28 were male. The participants had an average age of 19.9±0.23 years. Athletes were tested from four separate sports: softball, soccer, basketball, and volleyball.

Observable patterns exist between the vertical jump heights of each athletic team by sport. These patterns are shown in Figure 1. Volleyball players had a significantly higher vertical jump height than athletes of all of the other sports examined. Basketball players had significantly higher vertical jump heights than both soccer and volleyball players. Soccer players had significantly higher vertical jump heights than softball players. These differences existed under all three conditions (no drop jump, 15" drop jump, and 30" drop jump)

When all of the sports are combined together and drop height across all three conditions is examined, athletes' vertical jump heights were significantly decreased following a warm up of drop jumps from both 18" and 30" when compared to the initial vertical jump measurement without this type of warm up,  $F(2, 65)=6.736, p=0.002$  (Figure 2). T-tests were used to make post-hoc comparisons between the three conditions. A paired t-test indicated that there was a significant difference between the vertical jump height after a warm up not including a drop jump ( $M=58.1, SEM=1.8$ ) and after a warm up including an 18" drop jump ( $M=55.2, SEM=1.5$ );  $t=2.75, p=0.008$ . A second paired t-test was used to compare no vertical jump height with no drop jump warm up ( $M=58.1, SEM=1.8$ ) to vertical jump height following a warm up including a 30" drop jump ( $M=55.6, SEM=1.5$ ), which found these two conditions to also be significantly different;  $t=3.6, p=0.001$ . A third paired t-test found the two treatment conditions of 18" drop jumps ( $M=55.2, SEM=1.5$ ) and 30" drop jumps ( $M=55.6, SEM=1.5$ ) to be statistically similar;  $t=-0.85, p=0.401$ .



**Figure 1:** Patterns in vertical jump height across sports. Between the four sports measured, jump heights varied.



**Figure 2:** Comparison of vertical jump heights in all four sports. Reported in cm, the treatments of a set of 18" drop jumps and 30" drop jumps resulted in a decreased vertical jump height versus the baseline of a warmup not including drop jumps.

## Discussion

Both of the drop jump treatments were found to significantly decrease vertical jump performance when compared to the pre-treatment vertical jump heights. Therefore, these results do not support the use of this volume of 18 inch or 30-inch drop jumps to induce PAP in collegiate level athletes and the hypothesis that the 30-inch drop jump treatment would result in greater vertical jump performance is not supported.

The present findings and research suggest that Fatigue masked PAP, either from previous athletic practices or from the volume of drop jumps may have affected the ability of the drop jumps to induce PAP. The contractile history of a muscle affects following neuromuscular performance [9]. MacIntosh et al. [1] writes that there are two consequences of prior muscle activation, fatigue and potentiation, which are respectively responsible for diminishing and enhancing the contractile response. Despite their opposing effects on force production, fatigue and PAP can coexist in skeletal muscles. Nevertheless, when both fatigue and potentiation are present, fatigue will predominate as the muscle is stimulated. Therefore, if drop jumps are to be used as a component of a warm-up, the volume and number of repetitions should not be too intense as to cause fatigue in the athlete's muscles [2].

The findings also suggest that the intensity (box height) was

not effective in inducing PAP. In regard to drop jumps and eliciting PAP, the volume or number of repetitions, and intensity or height of the jumps, need to be great enough to cause PAP but not too great as to counter the effects through fatigue [3]. In a study by Stieg et al. [4] volumes of zero, three, six, nine, and twelve drop jumps were used, and vertical jump height was used to measure PAP. There was a difference in vertical jump performance between drop jump volumes of nine and twelve compared to volumes of zero, three, and six, but they were not found to be statistically significant. The decrease in performance after nine and twelve drop jumps, while not statistically significant, indicates that fatigue may have masked the effects of PAP under those conditions. Furthermore, the boxes used in this study were equal to the height of the participants' lateral femoral condyle and may not have been high enough to induce PAP [4]. In another study by Hilfiker et al. [6] a volume of five drop jumps were performed from a height of 60cm, which is also a relatively low intensity. Athletes are typically exposed to higher intensity stimuli during training and competition so any effects on the muscles were probably not great enough to be observed [6].

Another limiting factor related to the results of the current study is that vertical jump performance is an indirect measurement of PAP and may not have been an effective method to determine if PAP was present.

The rest time provided to subjects during this study was 1 minute this could have also affected results of the study. The increased contractile function and force production produced through PAP as a result of a maximal conditioning contraction may last for up to thirty minutes, but maximal effects are more likely to be seen within five to ten minutes of the conditioning contraction [9]. Furthermore, any phosphorylation of the myosin light chain is likely lost after five to six minutes of inactivity. Therefore, performance improvement due to PAP is most possible within a short time frame of one to five minutes after the conditioning contraction. Nevertheless, the problem of PAP and fatigue co-existing still exists and there is likely an optimal time in which the muscle is recovered from fatigue but still potentiated. The challenge of determining this optimal recovery time is increased by the likelihood that it is variable among individuals, something that may mask PAP in group design studies [7].

Despite the promise shown, there are several difficulties in researching PAP and drop jumps. The possibility of individual variation for each variable that may affect drop jumps increases the difficulty of determining an optimal height or volume of jumps to be used as a warm-up. Also, directly measuring PAP is not always an option, so the mechanism of performance improvement, or detriment, cannot always be completely attributed to PAP. Nevertheless, many studies do show enhanced performance when components meant to induce PAP were included in the warm-up. This outcome of enhanced performance is important, regardless of mechanism, because it provides information that may be used by coaches and athletes in their warm-up routines. Future studies can explore whether there is an optimal combination of height, number of repetitions, and rest periods for drop jumps to induce PAP.

## Conclusion

Due to the focus of athletes and coaches on performance improvement, research on strategies that produce such an improvement is a useful tool for those involved in any sort of athletics. Warm-ups, a proven method in performance improvement, come

in many different forms and determining an optimal warm-up for each type of athletic activity is crucial to athletic success. Post-activation potentiation shows promise for inducing greater force production in events requiring explosive power and much research has been done to determine the most effective way to induce PAP as part of a warm-up. While further research is needed on optimal height, volume and rest periods before competition in regard to drop jumps as part of a warm-up prior to events requiring explosive power, they do appear to show promise in eliciting PAP.

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