# The Acute Effects of Maximal Isometrics on Jumping Performance

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A project submitted in part fulfilment of the of the requirement for the BSc in Sports Coaching and Performance

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## Statement of originality and ownership of work

## Department of Health, Sport and Exercise Science

## BSc in Sports Coaching and Performance

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- Firstly, I would like to dedicate this to my Grandfather William who passed away a year before I started at WIT. I will forever cherish the memories I have of you as you were both my father figure and role model. You motivated me to become more, this is the reason I enrolled in the college.

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# Abstract

**Overview:** The purpose of this study was to investigate the postactivation potentiation (PAP) effect of a maximal isometric contraction on jumping performance. **Methods:** 15 recreationally trained individuals (age 24.8 ± 3.2 years, height 175.2 ± 7.3 cm, weight 79.1 ± 12.7 kg) performed a squat jump (SJ) and a counter movement jump (CMJ) after completing three repetitions of a three second maximal isometric back squat. Participants SJ and CMJ were tested after four minutes recovery (testing day one) and eight minutes recovery (testing day two) then compared with their baseline jumps. All participants followed the same warm up protocol and there was exactly 72 hours in between each of the sessions. **Results:** Following a paired samples t-test there was no significant difference found in SJ ($p = 0.455$) or CMJ ($p = 0.338$) after four minutes recovery or in SJ ($p = 0.830$) or CMJ ($p = 0.057$) after eight minutes recovery. The biggest mean improvement occurred in the SJ (+ 0.038 %) eight minutes after a conditioning activity (CA). **Conclusion:** SJ and CMJ performance does not significantly improve after four- or eight-minutes recovery following a set of maximal isometric back squats. There were variations in the individual's response to PAP with some participants benefiting and some not. The results of this study are in disagreement with previous studies. The individual strength differences should be considered in future research of PAP.

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# 1. Introduction

Postactivation potentiation (PAP) is a commonly used training practice amongst strength and conditioning professionals. The concept of PAP originated from researchers Güllich and Schmidtbleicher (1996). Prior to this study, there had been limited research assessing the short terms potentiation effects that a maximum voluntary contraction has on a muscular force. Robbins (2005) defines PAP as an immediate increase in muscular force due to various training methods such as complex training (CT). Robbins & Docherty (2005) describe CT as a combination of a heavy resistance exercise and a plyometric or power-based exercise that use the same muscle groups. According to Haff & Triplett (2015) CT is an effective training method for producing short term increases in power, thus potentially leading to increases in athletic performance. Resistance exercises are often referred to as conditioning activities (CA) within PAP literature. Various CA have been used to promote a PAP effect such as the back squat (Scott, Ditroilo & Marshall, 2018) and maximal isometric exercises (Feros, Young & Talpey, 2010).

Numerous researchers (Tillin & Bishop, 2009; Healy & Comyns, 2017) have outlined key mechanisms that may instigate a PAP effect. They underlying physiological mechanisms are; myosin phosphorylation of regulatory light chains, response of higher order motor units and changes in pennation angle. According to Mahfield, Franke and Awiszus, (2004) PAP may occur because of a mixture of the mechanisms. PAP is can also be influenced by different individual responses to a training stimulus. Joyce and Lewindon (2014) identify fatigue as a limiting factor in achieving potentiation. Moreover, variations in strength levels can produce variations in a person's aptitude to experience PAP (Seitz & Haff, 2016). Literature will be examined regarding different rest periods to inform best practice when implementing a pre-stimulus CA into a gym-based session.

Despite their being a large body of literature examining PAP, most of the studies fail to consider the impact of PAP from their own testing protocol. Scott et al. (2018) examined performance 30, 60 and 90 seconds after a CA. If PAP is produced from a heavy or power-based preload stimulus, then the multiple repetitions within this protocol may cause a PAP effect thus skewing the studies reliability. Similarly, Wyland, Van Dorin and Reyes (2015) tested sprint performance one, two- and four-minutes after a heavy loaded CA. Considering a maximal sprint may require extensive recovery, any improvements may be due to a PAP effect from protocol. Moreover, any performances decreased may be due to the fatigue from the multiple bouts of max sprints.

The overall aim of the study is to examine the effect maximal isometrics have on subsequent jump performance. However, to avoid any PAP or fatigue from the study design, each testing day will only assess pre and post jump performance after one recovery bout. Hopefully this will avoid both fatigue from excessive exercise bouts and a PAP effect occurring from anything other than the maximal isometric CA.

# 2. Literature Review

## 2.1 Mechanisms of PAP

### 2.1.1 Myosin Phosphorylation of Regulatory Light Chains

Myosin light-chain kinase is a protein that causes a smooth muscle contraction as it phosphorylates the myosin light chain (Gao et al., 2001). This aids the process of the muscle contraction by binding actin and myosin. Actin and myosin are two protein molecules necessary for force production within the muscles and their mechanical interaction is regulated by the troponin-tropomyosin complex (Sweeney, Bowman & Stull, 1993). Tillin and Bishop (2009) explain that the structure myosin is composed of two heavy chains otherwise referred to as the myosin heads, these contain a regulatory light chain (RLC) just below the myosin head. Szczesna (2002) states that RLC phosphorylation increases the sensitivity of the actin-myosin relationship with the myoplasmic $Ca2+$. According to Hodgson et al. (2005) the increased potentiation of a contraction occurs when phosphorylation displaces the myosin head from the thick filament backbone, this in turn changes the filament structure.

### 2.1.2 Response of Higher Order Motor Units

Lüscher, Ruenzel and Henneman (1983) described the process of recruiting higher order motor units as the transfer of signals to the spinal cord through the synaptic junctions. This has also been referred to as the H-reflex. The H-reflex can be measured by EMG. Güllich and Schmidtbleicher (1996) used EMG to measure the H-reflex in MVCs of the gastrocnemius muscle. An increase in the H-reflex occurred between five and thirteen minutes after the contraction. The engagement of more fast twitch motor units can increase MVCs or the rate of a contraction (Joyce & Lewindon, 2014). The greater the amount of motor units engaged the stronger the muscle contraction will be. Under heavy load, motor units are recruited in order of smallest to largest. This is known as Henneman's size principle (Henneman, 1957). The type of motor unit recruited depends on the difficulty of the task which provides a physiological advantage considering fast-twitch (Type II) fibres fatigue quicker. Researchers should use an appropriate muscle contraction to engage the intended muscle fibre type in their studies.

### 2.1.3 Changes in Pennation Angle

Tillin and Bishop (2009) stated that pennate muscle fibres attach obliquely to a tendon. The angle of pennation will directly impact the amount of force generated through the tendon. Pennate muscle contains fewer sarcomeres therefore the length of the fibres are shorter. Shorter fibre length allows for greater force production but a reduced range of motion. Folland and Williams (2007) describe the angle of pennation as the alignment of muscle fibres in relation to the tendons and connective tissue. Researchers have suggested that PAP can be influenced by the angle of pennation due to the amount of force that can be produced. According to Hodges, Pengel, Herbert, and Gandevia (2003), muscular activation may be used to measure the angle of pennation. Mahlfeld, Franke and Awiszus (2004) conducted research investigating the effect on the vastus lateralis muscle during MVCs. In this study, eight subjects performed a maximal isometric knee extension. It was established that the structure of the vastus lateralis muscle alters during a maximal isometric exercise. The angle of pennation increases and as a result, muscular force is directed towards the patella by the aponeurosis (Mahlfeld et al., 2004).

## 2.2 Conditioning Activities

Exercise modalities such as plyometrics, isometrics and resistance exercises are commonly used types of CAs throughout PAP literature. DeRenne (2010) reviewed the impact of a heavy stimulus in the warm up of multiple sports. Half squats, back squats, CMJs and isometric squats were recommended as CAs within a warm up, due to an increase in various performance measures such as peak power and jump height. Similarly, a review by Healy and Comyns (2017) assessed various exercise modalities as a possible pre-load stimulus. An increase in lower body power occurred when using plyometrics as a CA. Therefore, plyometrics are recommended within a pre-competition warm up for elite sprinters as it can enhance performance over 5– 50 meters.

Researchers such as Wyland et al., (2015) and Scott et al. (2018) have compared the PAP response of accommodating resistance against traditional resistance training. When a piece of equipment such as a band or a chain is added to a compound lift this is known as accommodating resistance (Zatsiorsky & Kraemer, 2006). Scott et al. (2018) investigated the PAP response from accommodating resistance when using hex bar deadlift and back squat variations as CAs. Participants completed 1 repetition using loads of 70-93% of their 1 repetition maximum (RM). Force, velocity and jump height were the metrics analysed during a counter movement jump. Scott et al. (2018) reported no significant difference ($p > 0.05$) when using either of these CAs. The recovery periods were 30, 90 and 180 seconds within the experimental study. Wyland et al. (2015) also utilized variations of a back squat as a CA. In this study the effects of standard back squats were contrasted with band resisted back squats on sprinting performance. Participants completed three sets of five repetitions of a back squat at 85% of their 1-RM. An improvement in sprint times occurred one, two, three and four minutes after performing either squat variation.

## 2.3 Complex Training

There have been several studies examining the benefits of CT. Docherty, Robbins and Hodgson (2004) state most of the studies focus on short-term effects on performance. Jensen and Ebben (2003) reported that CT can provide a boost in plyometric performance. Participants completed five counter movement jumps (CMJ) immediately after a set of five rep max (RM) squats which resulted in jump height increases in four of the five vertical jumps. Similarly, Bauer et al. (2018) demonstrated a potentiation effect in two groups implementing CMJs after performing moderate or high intensity back squats compared to a control group without a CA. Both studies reported that jump performance may be compromised immediately (10 & 15 seconds) after heavy resistance squats.

Jones and Lees (2003) measured muscular activation via electromyography (EMG), CMJ and drop jump (DJ) performance when participants performed heavy squats on a smith machine. Results conflicted with previous findings (Jensen & Ebben, 2003; Bauer et al., 2018) as CT provided minimal increases in jump height. Jones and Lees (2003) still recommended CT due to rise in muscular stimulation without any negative effects within a 20-minute period. CT can also enhance upper body power (Baker, 2003; Jones et al., 2018). Performing six repetitions of the bench press at 60% and 65% of a 1RM can enhance both bench throws and plyometric push ups.

Some studies have compared the effect of CT against other training modalities (Fatouros et al.,2000; Kuan et al., 2018). The study by Kuan et al. (2018) examined the muscular power response to a CT programme and a resistance training programme in competitive male weightlifters. Results from CMJs and medicine ball throws were compared between the two groups before and after a six-week training programme that was either CT or resistance training based. The CT group experienced significant increases compared to the resistance group further suggesting that CT can increase muscular power. Fatouros et al. (2000) compared the effects of three different exercise programmes; (1) CT, (2) strength training and (3) plyometric training. Performance of Jump height, flight time and mechanical power were measured. Participants completed a 12-week training plan of three sessions a week, based on the training modality of their group. CT resulted in the greatest improvements in jumping performance in all metrics. Participants were classified as untrained in this study which is a potential limitation based on the contention of Docherty et al. (2004), who stated that subjects need multiple exposures to CT to maximise PAP benefits.

## 2.4 Isometrics

Feros et al. (2010) examined the effect isometrics (five repetitions of a five second contraction) has on PAP when included in a warm up protocol for elite rowers. An increase in mean power occurred during 500- and 1000-meter row times, indicating that isometrics can stimulate PAP. French, Kraemer and Cooke (2003) also investigated the use of isometrics as a potentiator. 14 athletes completed a single set of a maximal isometric knee extension followed by a set of DJs. The isometric knee extensions were either three reps of a three second contraction, or three reps of a five second contraction. Knee extensions were completed on an isokinetic dynamometer and EMG was used to measure muscular activation. An increase in both muscle activation and vertical jump performance occurred after the set of three repetitions of a three second maximal knee extension. French et al. (2003) recommends performing three reps of an isometric contractions rather than five as is provides no additional benefits. Furthermore, technique may actually begin to decline after an increased amount of sets due to the fatigue.

## 2.5 Rest Periods

There have been many different rest periods used to stimulate potentiation. Wilson et al. (2013) conducted a meta-analysis on PAP which categorised recovery periods as immediate (<2 minutes), short (3-7 minutes), moderate (7-10 minutes) and long (>10 minutes). Peak potentiation occurred after moderate recovery (7-10 minutes) in trained individuals. Kilduff et al. (2007) examined peak power outputs after 4, 8, 12, 16 and 20 minutes of recovery. The largest performance increases occurred after 8 minutes recovery with a mean increase of 6.7% (SD ± 7.2%), and after 12 minutes rest where the mean increased by 8.0% (SD ± 8.0%). Till and Cooke (2009) measured sprint and jump performance after rest periods of 4, 5, 6, 7, 8 and 9 minutes. It is worthy to note that the recovery periods are not examined in isolation throughout the literature, instead testing occurs sequentially after a variety of rest periods. This may cause a PAP effect from; the stimulus of each performance test or, familiarisation of the activity.

Chatzopoulos (2007) investigated the effect of 1-RM back squats on 10m and 30m sprint performance at different recovery periods. The sprint times were recorded after three and five-minutes recovery. The biggest improvement in sprint performance occurred after the 5-minute recovery period, the mean 10m sprint time decreased to 1.84s from a baseline time of 1.89 seconds. McCann & Flanagan (2010) assessed the effect of four and five-minute rest periods on vertical jump performance. Participants were divided into four different groups and randomly assigned to exercise groups performing a squat or a clean. Vertical jump height was measured in all of the groups over the four- and five-minute rest periods. The biggest increase to jump performance occurred after four minutes rest, the mean jump height of 52.84 cm (SD ± 12.80 cm) increased to 53.98 cm (SD ± 11.63 cm).

## 2.6 Factors Influencing the Response to PAP

According to Wilson et al., (2013); Seitz and Haff (2016) differences in individual's strength can impact the optimal recovery time for potentiation. Seitz and Haff (2016) report that between five- and seven-minutes recovery after a CA produced the greatest PAP effect in stronger individuals compared to eight minutes for weaker participants. Jo, Judelson, Brown, Coburn, and Dabbs (2010) also drew attention to performance differences in their study due to strength. Peak power and absolute power were assessed on a cycle ergometer at different rest periods. Participants complete an anaerobic Wingate test at 5, 10, 15- and 20-minute rest periods. The group of stronger individuals achieved their maximum performance increases between 5- and 10-minutes recovery, whereas the weaker RTI group required rest periods of 15-20 minutes to achieve their optimum PAP. Similarly, Seitz and Haff (2016); Jo et al. (2010) report that stronger individuals potentiate quicker and recover faster than RTI. Therefore, strength and conditioning professionals could implement PAP into their athlete's pre-competition warm up as they experience PAP benefits in less time than RTIs.

Joyce and Lewindon (2014) state that fatigue is another influential factor regarding an individual's response to PAP. Hodgson, Docherty and Robbins (2005) outline that there must be a balance between the stimuli and fatigue for a performance increase to occur. According to Zatsiorsky and Kraemer (2006) the presence of fatigue can greatly diminish the PAP response, therefore the effect from the CAs will be outweighed by short recovery periods. This correlates with Wyland et al. (2015) who reported a decrease in sprint performance directly after five sets of three back squats at 85% of subjects 1-RM. A baseline (9.1m) sprint time of 1.72 seconds increased to 1.74 seconds directly after the CA but after four mins rest, average sprint time was reduced to 1.68s. Further indicating that fatigue can supersede PAP without adequate recovery.

## 2.7 Summary and Rationale

The main goal of any training plan is to enhance a person's athletic capacity. Many strength and conditioning practitioners have implemented various PAP protocols, but the optimal method is still to be determined. PAP has been found to promote short term increases to the production of lower body force (Jensen & Ebben, 2003; French et al., 2003). This occurs when the appropriate CA is combined with an explosive/plyometric exercise, this is commonly referred to as CT. Exercises such as back squats, deadlifts, SJs and DJs have been used as CAs to promote PAP (DeRenne, 2010). There is limited research using maximal isometric exercises as CAs. This study aims to add to the current body of research by using a maximal isometric back squat as a CA.

The effectiveness of a PAP protocol can be affected by factors such as; individual strength levels, fatigue and recovery time. Stimulation of PAP can depend on the relationship with fatigue and the individual's ability to recover (Jo et al., 2010). Therefore, adequate recovery is necessary to achieve the maximum PAP benefits. Previous PAP studies have assessed performance variables after intermittent bouts of recover within the same session. This makes it difficult to assess the optimal recovery time to induce PAP. Therefore, testing PAP after one specific recovery bout per testing day may better inform the optimal potentiation recovery time. The purpose of this study is to determine if a maximal isometric contraction will enhance jumping performance. Two different rest periods (four and eight minutes) will be used within the study to establish what recovery period promotes a greater PAP effect. If so, maximal isometrics could be included in a power-based gym session as an alternative to using heavy resistance loads.

## 3. Research Questions

The Research questions of this study are as follows:

1. What effect will a maximal isometric contraction have on jumping performance after four minutes recovery?
2. What effect will a maximal isometric contraction have on jumping performance after eight minutes recovery?
3. Will there be a greater PAP effect following a maximal isometric contraction after four or eight-minutes recovery?

# 4.0 Methodology

## 4.1 Conceptual Framework

This pre and post, laboratory-based study was conducted using a quasi-experimental research design. The study examined the effect of maximal isometrics on jumping performance. Participant's pre-test scores where compared to baseline results after completing a maximal isometric exercise. The study took place over three separate days in the Kingfisher Leisure centre in Waterford City. Day one was a familiarisation session to ensure participants would be comfortable performing a SJ a CMJ and a maximal isometric back squat. The four-minute recovery testing protocol occurred on day two and the eight-minute recovery protocol took place on the third and final day. There was a 72-hour recovery period between sessions to minimize fatigue or any potential intra PAP effect.

## 4.2 Data Sources

The study population consisted of fifteen (n = 15) recreationally trained individuals (age 24.8 ± 3.2 years, height 175.2 ± 7.3 cm, weight 79.1 ± 12.7 kg). Participants were required to have a minimum of one years' experience with recreational resistance training and currently exercise at least three times a week. Participants were recruited from a poster placed on the notice board and in the gym and the reception area of the Kingfisher Leisure centre. Any volunteers for the study had to fill out an informed consent form (see appendix B) and a medical screening form (see appendix C).

## 4.3 Measurement Tool

Vertical jump height of a SJ and a CMJ were measured in this study using a Chronojump system (CS) contact mat. Look-in, Pinthong, Chaijenkij, Pagaduan and Limroongreungrat (2018) conducted a study assessing the validity of the CS. The CS was compared to a Kistler Type 9286BA force platform. A Bland and Altman plot was used to compare the variances between the devices. Minimal differences were reported for CMJ jump height and flight time thus indicating the CS is a valid and useful measure of jump performance. Pagaduan and De Blas (2004) assessed the reliability of the CS when measuring a CMJ. Reliability was assessed using intraclass correlation coefficient values with a 95% confidence interval. Strong intraclass correlation values were reported for both males

(0.86) and females (0.93). A CS was provided by the Waterford Institute of Technology upon request and used for this study.

## 4.4 Data Collection Methods

### 4.4.1 Familiarisation Day

On the first day of the study participants were required to fill out an informed consent form. They were then familiarised with the testing protocol and exercises in the study. After completing a standardised warm up, the subjects performed a maximal isometric back squat (three reps x three second contractions) with a barbell fixed into the squat rack. Next the individuals were instructed how to perform a bodyweight SJ and a CMJ with two minutes rest in between. Feedback on their technique was given throughout the familiarisation day whenever necessary. No data was collected on this day.

### 4.4.2 Testing Day One and Two

Participants completed a standardised warm up including exercises that focused on hip mobility and glute activation. The full warm up procedure can be seen in appendix A. The design of the study can be seen in figure 1, this was displayed in the gym on testing days to help the participants to understand the flow of the study.

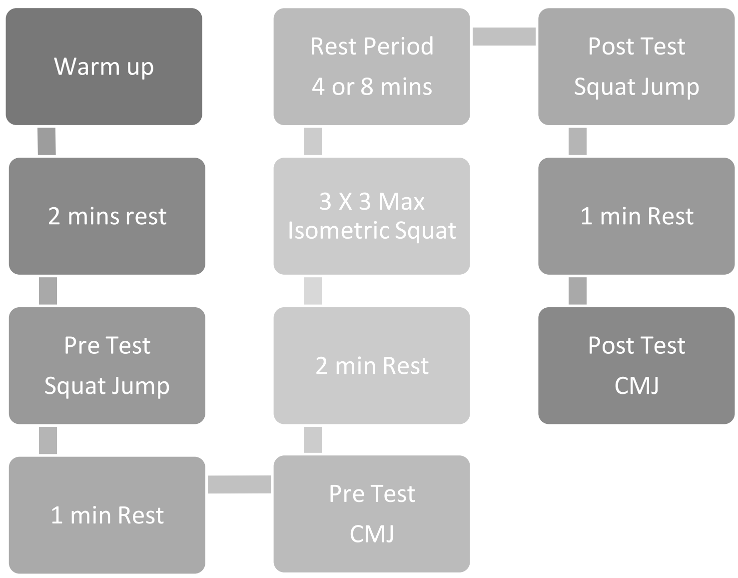


*Figure 1.* A visual representation of the data testing protocol.

Baseline results were recorded for both the SJ and CMJ. Participants performed one practice jump of each before attempting their maximal effort. Only the maximal effort jumps were recorded. Prior to the jumps they were instructed to jump as high as they can. To avoid any bias, there was no verbal encouragement given during the pre or post jumps. The maximal isometric contraction consisted of a single set, three repetitions of a three seconds squat with a 20kg barbell. The barbell was set into a fixed position within a squat rack. Verbal instruction was given to apply maximal effort on the squat into the rack. Post SJ and CMJ testing occurred after a four-minute recovery period.

On the second testing day the protocol was repeated, the only variation was the rest time after the isometric contraction. The same warm up was used, baseline results were collected, and the same verbal cues were given. The rest period between the isometric squat and the post-test jumps was eight minutes. Data collected from the four- and eight-minute recovery periods was compared to with the baseline scores and presented in the results section.

## 4.5 Data Analysis

Data was analysed using SPSS Statistics for Windows, version 22.0 (IBM Corp, New York) and Microsoft Excel, version 16.0. A Shapiro-Wilk test was used to evaluate the data's normality, which indicated that the data was normally distributed thus parametric statistics would be used. A paired sample t-test was used to check for statistical significance between SJ and CMJ outcome measures. Significance level was set at $p < 0.05$ for all tests.

## 4.6 Ethical Considerations

All subjects were required to complete an informed consent form (see appendix B) and a medical screening (see appendix C) form before testing took place. This was to confirm participants understood the nature of the study and ensured that they were injury free prior to testing. Participants were free to withdraw from the study at any time without question or consequence. As the SJ and CMJ testing required maximal effort, all participants had to complete a standardised warm up protocol (see appendix A) to minimize the risk of injury. Participants anonymity was also maintained through the study as all data collected was stored in a password protected laptop.

# 5.0 Results

## 5.1 Differences in SJ and CMJ After Four Minutes Recovery

The following section outlines the overall findings for this study. Descriptive statistics for SJ and CMJ after four minutes recovery are displayed in table 1. Mean SJ improved from 26.09 cm (SD ± 7.68 cm) to 26.50 cm (SD ± 7.82 cm) after four minutes recovery. Mean CMJ also increased from 26.60 cm (SD ± 8.23 cm) to 27.14 cm (SD ± 8.43 cm). There was no significant difference between pre and post scores for SJ after four minutes recovery ($t$ (14) = -0.77, $p$ = 0.455) as seen in table 2. There was no significant difference between pre and post scores for CMJ after four minutes recovery ($t$ (14) = -0.99, $p$ =0.338).

*Table* 1.

Pre and Post Data for SJ and CMJ after Four Minutes Recovery.

| | Pre-SJ (cm) | Post SJ (cm) | Percentage change (%) | Pre CMJ (cm) | Post CMJ (cm) | Percentage change (%) |
|---|---|---|---|---|---|---|
| *M* | 26.09 | 26.50 | 0.016 | 26.68 | 27.14 | 0.017 |
| *SD* | 7.68 | 7.82 | | 8.23 | 8.43 | |
| Variance | 59.05 | 61.21 | | 67.70 | 71.11 | |
| Minimum | 14.69 | 14.40 | | 15.15 | 15.14 | |
| Maximum | 37.27 | 35.96 | | 37.65 | 39.34 | |

*Note: M* = Mean, *SD* = Standard Deviation.

*Table* 2.

Descriptive Statistics for SJ and CMJ After Four- and Eight-Minutes Recovery

| | *Df* | *T* | *P* |
|---|---|---|---|
| 4 Min SJ | 14 | -0.77 | 0.455 |
| 4 Min CMJ | 14 | -0.99 | 0.338 |
| 8 Min SJ | 14 | 0.22 | 0.830 |
| 8 Min CMJ | 14 | -2.07 | 0.057 |

*Note: df* = Degrees of Freedom, *T* = t – value, *P* = p – value.

## 5.2 Differences in SJ and CMJ after Eight Minutes Recovery

Descriptive statistics for SJ and CMJ after eight minutes recovery are displayed in table 3. There was a decrease in mean SJ after eight minutes recovery from 28.79 cm (SD ± 8.36 cm) to 28.67 cm (SD ± 8.15 cm). Mean CMJ increased from 29.03 cm (SD ± 8.01 cm) to 30.15 cm (SD ± 8.21 cm). There was no significant difference between pre and post scores (see table 2) for SJ after eight minutes recovery (t (14) = 0.22, p = 0.830). There was near to but no significant difference between pre and post CMJ after eight minutes recovery (t (14) = -2.07. p = 0.057).

*Table* 3.

Pre and Post Data for SJ and CMJ after Eight Minutes Recovery

| | Pre-SJ (cm) | Post SJ (cm) | Percentage change (%) | Pre CMJ (cm) | Post CMJ (cm) | Percentage change (%) |
|---|---|---|---|---|---|---|
| *M* | 28.79 | 28.67 | - 0.004 | 29.03 | 30.15 | 0.038 |
| *SD* | 8.36 | 8.15 | | 8.01 | 8.21 | |
| Variance | 69.95 | 66.39 | | 64.20 | 67.43 | |
| Minimum | 16.89 | 16.59 | | 17.50 | 17.22 | |
| Maximum | 38.23 | 39.84 | | 39.69 | 41.58 | |

*Note: M* = Mean, *SD* = Standard Deviation.

## 5.3 Differences Between Four- and Eight-Minutes Recovery on SJ and CMJ

Figure 2 displays the individuals' responses to PAP from the SJ. Of the 15 participants in this study, 11 had a positive response to their SJ performance after four minutes and eight subjects had improvements after eight minutes of recovery. From assessing the individual performances of the CMJ (as seen in figure 3), eight out of 15 participants had an increase in their jump height after four minutes recovery whilst 11 out of 15 jumped higher after eight minutes recovery. None of the jumping variables had a significant improvement after four- or eight-minutes recovery, however the biggest mean improvement occurred in the CMJ (+ 0.038%) after eight minutes recovery.

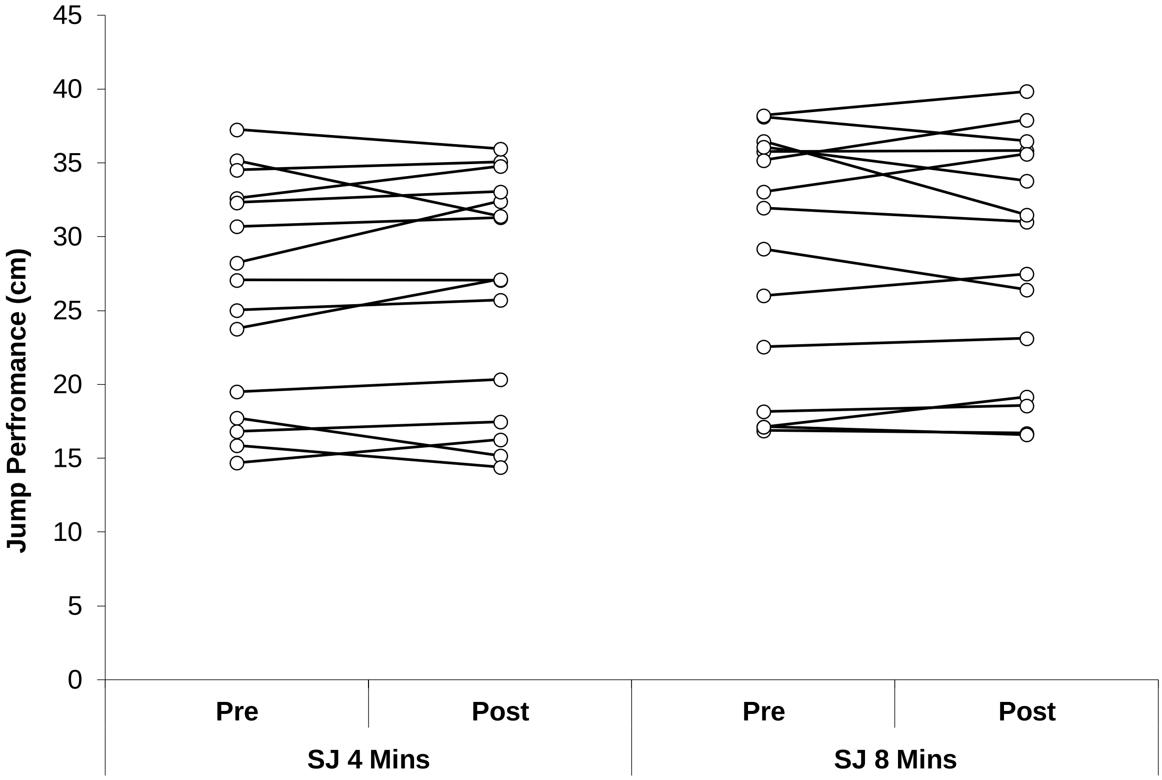


*Figure 2.* Pre and post data for individual SJ performance after four- and eight-minutes recovery.

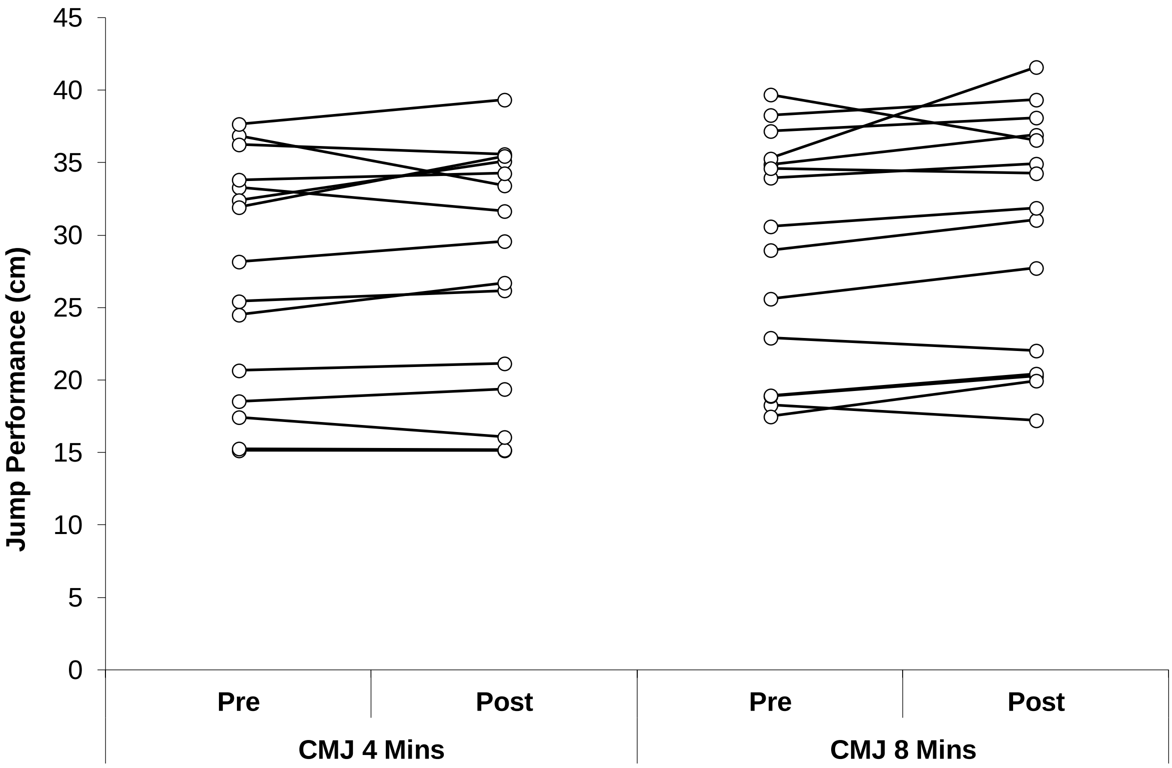


*Figure 3.* Pre and post data for individual CMJ performance after four- and eight-minutes recovery.

# 6.0 Discussion

The purpose of this study was to assess the effects of a maximal isometric PAP protocol on subsequent jump performance (SJ and CMJ) after four- and eight-minute recovery bouts. Mean improvements occurred in SJ after four minutes recovery, CMJ after four minutes recovery and CMJ after eight minutes recovery. However, present data show that SJ and CMJ performance did not significantly improve after four- or eight-minutes recovery. As outlined, PAP may be influenced by factors such as participant strength levels, recovery periods and fatigue. Seitz and Haff (2016) indicated that the reaction to PAP may be dependent on the individual being a responder or a non-responder.

Variations between subject's response to PAP were observed which may be due to individual strength differences. Jo et al., (2010) reported a similar finding where stronger participants experienced PAP between 5-10 mins post CA, compared to 15-20 minutes for weaker individuals. Studies from Till and Cooke (2009) and Kilduff et al. (2007) used multiple rest periods to assess the optimal time that PAP is achieved. This may cause a PAP effect from performing multiple repetitions within these studies. In this study four- and eight-minute rest periods were assessed over two separate testing days to avoid any intra PAP effect. The back squat is a widely used CA within the literature (Bauer et al., 2018; Chatzopoulos, 2007; Scott et al., 2018). This study adds to the previous body of work by using a maximal isometric version of back squat as a CA. Feros et al. (2010) did use a maximal isometric contraction as a CA in their study but participants did so on a rowing ergometer.

## 6.1 The Effect of a Maximal Isometric Contraction on Jump Performance After Four Minutes Recovery

After completing statistical analysis of this study's results, it was established that a maximal isometric back squat will not enhance SJ or CMJ height after four minutes post CA recovery. Based on the mean difference from baseline there is a slight improvement, but the results are not statistically significant. This is in disagreement with McCann and Flanagan (2010) as their participants achieved the greatest improvements in vertical jump performance after four minutes recovery. Individuals differences showed a variation among participants with 11 of the 15 seeing slight improvements in the SJ and 9 of the 15 seeing a slight increase in the CMJ. These results are in agreement with Seitz and Haff (2016) and Wilson et al., (2013) who stated that variations in strength levels can impact the PAP effect. Zatsiorsky and Kraemer (2006) indicated that the presence of fatigue can reduce the PAP response. Considering the participants might not have been highly trained, performing a CMJ two minutes after a SJ may have actually created some fatigue due to the shorter post CA recovery.

## 6.2 The Effect of a Maximal Isometric Contraction on Jump Performance After Eight Minutes Recovery

Statistical analysis of the SJ and CMJ variables denote that eight minutes recovery did not effectively promote PAP. Using a maximal isometric back squat as a potentiating CA did not improve jump performance. The SJ post CA performance (28.67 ± 8.15) decreased from the baseline score (28.79 ± 8.36), whilst CMJ performance improved (30.15 ± 8.21) post CA from the initial baseline (29.03 ± 8.01). CMJ after eight minutes recovery was near to significant, however neither SJ or CMJ where statistically significant. From assessing the individual performances, 8 out of 15 participants had an increase in their post SJ height whilst 11 out of 15 had improvements in their post CMJ height. Seitz and Haff (2016) stated that weaker individuals experience a PAP effect after eight minutes recovery. Kilduff et al., (2007) also reported a significant PAP effect after eight minutes recovery but the results of this study conflict with these findings. Although CMJ after eight minutes yielded the biggest improvement, no strength testing was carried out prior to this study to determine the maximal strength of the participants.

## 6.3 The Difference in PAP Between Four- and Eight-Minutes Recovery on Jump Performance

After conducting statistical analysis of this study’s results, a maximal isometric back squat was deemed ineffective at promoting PAP or acutely increasing jump performance. Large variations in individual responses (see figure 2 & 3) occurred after both the four- and eight-minute recovery bouts. This may have happened as individuals can be a responder or non-responder to a PAP protocol (Seitz & Haff, 2016). More of the individuals in this study experienced an increase in jump performance after four minutes recovery. This is in agreement with results from McCann and Flanagan’s (2010) study, however this paper only assessed performance after four- and five-minute recovery bouts. The biggest increase in performance occurred in the CMJ after eight minutes recovery. Whilst it was near to significant, there was still no statistical significance difference.

## 6.4 Conclusions

As outlined, PAP has been used to acutely enhance jumping performance, but this study has conflicting results. Neither four or eight-minutes recovery following a single set of (three x three second repetitions) a maximal isometric back squat was effective at significantly inducing PAP. There was no statistical significance between pre and post data after using this PAP protocol. The biggest increase in performance occurred in the CMJ after eight minutes but the individual differences further highlight how varied the response to PAP can be. The participants may have been affected by the presence of fatigue or a difference in their individual strength levels. Variations in their training age and level may have also impacted the PAP response (Zatsiorsky & Kraemer, 2006). In previous studies (Till & Cooke, 2009; Kilduff et al., 2007) the concurrent effect from multiple jumps may have potentiated subsequent jump performance. This study was designed to avoid this effect by assessing performance after a single rest period, per testing day.

## 6.5 Limitations

There may be some potential limitations within this study. Firstly, participants were not required to test their maximal strength beforehand. Considering strength level can greatly influence time to achieve PAP (Seitz & Haff, 2016; Wilson et al., 2013) testing may have allowed for grouping of the participants based on strength levels. To take part in the Kilduff et al., (2013) study participants had to be able to back squat at least 150% of their bodyweight for one repetition.

The level and type of training may have also been a limitation. The RTIs required 1 years' experience with resistance training however the different types of training, sports they may play, and level of their training was not considered. As a result, the study population may be very different in terms of their athletic capabilities. Considering that stronger, more athletic individuals recover faster, fatigue may influence the optimal recovery for potentiation (Hodgson, Docherty & Robbins, 2005). To avoid this, a more extensive inclusion criteria for training level could have been used.

The small sample size (n = 15) of this study may have been a limitation. This appears to be a limitation of many PAP studies, McCann and Flanagan (2010) had a sample size of 16, Till and Cooke (2009) had a sample of 12 and Chatzopoulos et al., (2007) had a sample of 15. Using a larger sample may have led to a more significant change to jump performance after the isometric CA.

## 6.6 Recommendations for Practice and Further Research

Although there were no significant potentiating improvements on SJ and CMJ height in this study, a PAP protocol using a maximal isometric may still be useful within the weights room. Considering Isometrics are not as physically demanding as traditional resistance training or plyometrics, strength and conditioning practitioners may use isometric contractions to enhance jump performance. Maximal isometric contractions can be used to potentiate explosive exercises in a gym session. Using three repetitions of a three second maximal isometric back squat can be used to enhance jumping performance; however further research is required to determine the optimal rest period and the individual response based on strength level.

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## 8. Appendices

**Appendix A**

| Warm Up |
|---|
| Air Squats x 10 |
| Lunges x 5 each side |
| Banded Abduction x 10 each side |
| Banded Good Mornings x 10 |
| Lunge and Reach x 8 |
| Alternating Pigeon Stretch x 8 each side |

## Appendix B

# Informed Consent Form

**Researcher Details:** Jamie Dalton Jamiedalton1989@hotmail.com 087-2931452

**Declaration of Consent**

- I voluntarily agree to take part in this study
- I have the details of this study explained to me and am satisfied that I have had the opportunity to ask questions about the study
- I understand that my participation is entirely voluntary, and I am entitled to withdraw at any time without question or repercussion
- I understand that under freedom of information legalisation I am entitled to access the information I have provided at any time while it is in storage as specified above
- I understand that the signed consent forms and all data collected will be kept in a secure file on a password protected laptop
- I understand that I will not directly benefit from being involved in this study
- I understand there are physical activities involved such as jumping and resistance training
- I understand that I may contact any of the people involved in the study at any time for more information if required
- I understand this research may be written and publicized

Participants Name Date Signature

_____________________ _____________ _____________________

Researchers Name Date Signature

_____________________ _____________ _____________________

**Appendix C**

# Medical Screening Form

| **Please tick yes or no to the following** | **Yes** | **No** |
|---|---|---|
| Arthritis | | |
| Asthma | | |
| Diabetes | | |
| Epilepsy | | |
| Fainting/Dizziness | | |
| Heart Issues | | |
| High/Low Blood Pressure | | |
| Joint issues | | |
| Muscle Pain or injury | | |
| Pregnant or have been in the last 6 months | | |
| Recent Injuries | | |

Are you currently taking any form of medication that may impact exercise? If so, please specify:

____________________________________________________________

____________________________________________________________

Date Signature

________________ ________________________