Original Article

Effects of post activation potentiation on eccentric loading: Is it possible to do more repetitions after supra-maximal loading?

EZGİ SEVİLMİŞ[1], OZAN ATALAĞ[2]

[1]*The School of Physical Education and Sports, Kyrenia, Cyprus, Turkey*
[2]*University of Hawai'i at Hilo, United States of America*

ABSTRACT

The aim of this study is to investigate the effects of Post Activation Potentiation (PAP) on muscular endurance performance. 42 physically active male participants (PAP Group n=32, Control Group n=10) who have at least 1 year of resistance training experience and exercise min. times/week, participated in this study. First testing session were the same for both Control and PAP group. On the first session, 1 Repetition Maximum (1RM) of subjects was found. 65% of the 1 RM was calculated to find the weight that was going to be used for the muscular endurance test. Subjects completed maximal number of repetitions with 65 % of their 1 RM. On the second test session which was done 48 hours after the first session, PAP group did eccentric loading with Bench Press with their 120 % of 1 RM than rest 8 minutes to elicit the effects of PAP. After the resting period, muscular endurance test with 65% of 1 RM and time under tension were recorded. No statistical difference was found between the number of repetitions that were done in the first and the second test session for control group ($p>0.05$). Whereas significant increase was found for the PAP group ($p<0.05$). No relationship between training experience and the number of increased repetitions was observed ($p>0.05$). As a result of this study, supra-maximal eccentric loading was found to be an effective method to elicit the effects of PAP on muscular endurance. Therefore, PAP protocols in resistance training sessions might be considered to be used for athletes who want to improve their muscular endurance performance. **Keywords:** Bench press; Muscular endurance; Supra-maximal loading; Eccentric contraction.

Cite this article as:
Sevilmiş, E., & Atalağ, O. (2019). Effects of post activation potentiation on eccentric loading: Is it possible to do more repetitions after supra-maximal loading?. *Journal of Human Sport and Exercise*, *14*(3), 584-590. doi:https://doi.org/10.14198/jhse.2019.143.09

Corresponding author. *The School of Physical Education and Sports, Kyrenia, Cyprus, Turkey*.
E-mail: ezgi.sewilmis@gmail.com
Submitted for publication April 2018
Accepted for publication September 2018
Published September 2019 (*in press* November 2018)
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2019.143.09

INTRODUCTION

Even though there is a wide range of training methods that are being used to increase athletes' performance, there is always a search for new modalities to separate the best from the good. In recent years, post activation potentiation has been a popular area of research to understand whether this theory has effects on athletes' performance or not. (Hancock et al., 2015; Kilduff et al., 2007; Kilduff et al., 2011; Sandra, 2012).

PAP is a theory that purports that the contractile history of a muscle influences the mechanical performance of subsequent muscle contractions (Lorenz, 2011). It has been argued that fatiguing muscle contractions impair muscle performance, but non-fatiguing muscle contractions at high loads with a brief duration may enhance muscle performance (Stone, 2008). The peak torque of an isometric twitch in skeletal muscle is transiently increased after a brief maximum voluntary contraction (Hodgson, 2005; Sale, 2002). Thus, PAP is the increase in muscle force and rate of force development (RFD) that occurs as a result of previous activation of the muscle, as well as the force and power of evoked high velocity shortening contractions, and the maximum velocity attained by evoked shortening contractions under load (Mitchell, 2011; Judge, 2009). In other words, excitation of the nervous system produces an increase in contractile function due to a heavy load conditioning stimulus (Rixon, 2007). The most common indicator of PAP is increased evoked isometric twitch force observed following an evoked isometric tetanic contraction (Mitchell, 2011).

METHOD

Participants

Participants were 42 physically active male college students (PAP Group n=32, Control Group n= 10) who had at least 1 year of resistance training experience and exercise min. 3 times/week.

Before the test sessions, subjects, weight, age, height were registered. PAP group; age=24.44±5.88yrs, height=1.78±0.05m, weight=79.24±9.44 kg Control group age=22.9±3.14yrs, height= 1.78 ±0.05m, and weight= 77.09±7.15 kg.

Measurements and Procedures

Subjects participated in two different testing sessions with 48 hours in between. In the first testing session, after all participants ran 5 minutes with 6 km/h speed on the treadmill, a standard dynamic stretching protocol was completed. As a local warm up for maximal strength test for the bench press in Smith Machine, they did 8 repetitions with 30%, 6 repetitions with 50%, 4 repetitions with 70% and 2 repetitions with 85% of their self-estimated 1 repetition maximum (1RM). 2 minute-rest was given after 30% and 50% of 1 RM; 3 minute-rest was given after 70% and 85% of 1RM 1RM was attempted after local warmup and 2.5 kg increments were used until 1RM is established.

Full rest of 15 min. was given in order to negate any potentiation effects before the maximum repetition test with calculated for 65% of 1RM Subjects walked on the treadmill with 5 km/h at 1.5° incline to prevent possible cool down. Repetition tempo was set at 3 seconds; 2 seconds eccentric and 1 second concentric. Subjects were also informed that elbow extension has to be completed to have a valid repetition. Test was terminated when subjects either could not keep up with tempo or reached volitional failure. In 2nd testing session, same warm up conditions as the 1st session was applied for PAP and control group for warm up. But this time, after 3 minutes local warm up, subjects performed the supra maximal eccentric loading protocol with 120% of their 1RM They were instructed to lower the bar in 4 seconds with the help of a digital metronome and then push it up as soon as the bar touch their chest. During that process, 2 spotters unracked the bar for the

subjects and then helped them to rack it after eccentric loading attempt. 8-minute resting period after loading was done and subjects walked on the treadmill with 5 km/h at 1.5° incline to prevent possible cool down. After resting, maximum number repetitions that were completed at 65% of 1RM was recorded.

Table 1. 1st session protocol of PAP and control groups

KG	REPETITIONS	REST (min)	1 RM	LOAD	TOTAL REPETITION DURATION
%30	8	2			
%50	6	3			
%70	4	3			
%85-90	2	3			

Table 2. 2nd session protocol of PAP group

KG	REPETITIONS	REST (min)	LOAD	TOTAL REPETITION DURATION
%30	8	2		
%50	6	3		
%70	4	3		
%80	2	3		
%120	1	8		
%65				

1st and 2nd testing session for control group was exactly the same with the standard warm up (1x%30x8, 1x%50x6, 1x%70x4, 1x%85x2) followed by maximum repetition test at 65% of 1 RM.

Statistical Analysis

Statistical Analysis was performed with SPSS 22.0. The results are presented as mean ± standard deviation (SD). Paired Samples T-Test was used to find out differences between repetitions in 1st and 2nd sessions. Control group was evaluated with Wilcoxon Signed- Ranks Test as the number of subjects was relatively low. Kolmogorov Smirnov Test was used to determine the significance level of correlation between two variables and the relationship between variables was examined with Pearson Correlation Coefficient Test.

RESULTS

Descriptive statistics of all participants (PAP Group: 32, Control Group: 10) is shown in the table below:

Table 3. Descriptive stats

	Age (year) Avg ±SD	Height (m) Avg ±SD	Weight (kg) Avg ±SD	Training Age (year) Avg ±SD
Pap Group (n=32)	24.44±5.88	1.78±0.05	79.24±9.44	4.4±3.58
Control Group (n=10)	22.9±3.14	1.78±0.05	77.09±7.15	3.3±2.34

Table 4. Average weights and repetitions of 65% of 1RM

	Test Weights (kg)	Repetitions in 1st Day Session Avg ±SD	Repetitions in 2nd Day Session Avg ±SD
Pap Group (n=32)	66.8±10.34	17.25±3.93	18.28±4.11*
Control Group (n=10)	66.75±6.13	20.6±3.34	20±3.89

** Significant correlation p < 0.05*

Number of repetitions completed for PAP group at 1st and 2nd testing session was 17.25 repetitions and 18.28 repetitions respectively. Difference was found to be statistically significant at $p<0.05$ level. Repetition means for control group were 20.5 and 20.0 repetitions respectively and the difference was not statistically significant ($p<0.05$).

Table 5. Completed repetitions at 65% 1RM and time under tension

		Completed Repetitions 1st Session	Time under tension 1st Session(sec)	Completed Repetitions 2nd Session	Time under tension 2nd Session(sec)
Pap (n=32)	**Group**	17.25±3.93	32.74±4.82	18.28±4.1*	34.50±5.36*
Control (n=10)	**Group**	20.6±3.34	36.55±6.61	20±3.89	35.25±6.5

** Significant correlation p < 0.05*

Duration repetition mean of the control group was 36.55 sec. and 35.25 sec. on the first and second session respectively. No significant difference was found between the two sessions ($p>0.05$).

Individual analysis of the subjects showed that 21 of them increased their number of repetitions at 65% of 1RM in the 2nd testing session. An interesting finding that contradicts the PAP literature was that, there was no relationship found between training experience and number of increased repetitions ($p>0.05$). Mean training experience of the subjects who were able to increase their repetitions training was 2.8 years, whereas it was 5.6 years for the rest of the subjects which might indicate that less training experience being more advantageous for PAP applications.

Two groups named END1 (n=16) and END2 (n=16) were formed based on the number of repetitions completed. Mean repetitions for END1 was 20.5 while it was 14.0 for END2 group. No difference was found for the increased repetition for END1 and END2 groups between first and second sessions ($p>0.05$). Both groups were able to increase its mean repetition by 0.6±1.8 and 1.5±1.9 respectively but the difference was statistically significant ($p>0.05$).

DISCUSSION

This study has been done to understand the possible effects of supra-maximal loading on local muscular endurance (defined as 15-20RM). After a thorough review of the sport and exercise science literature, we have seen that different rest intervals such as 4, 5, 6, 7, 8, 12 minutes were used to elicit the effects of PAP. It's been also noted that most effective duration range is between 6 and 9 minutes (Hancock et al., 2015; Kilduff et al., 2007; Kilduff et al., 2011; Sandra, 2012). 16, 24, 36 min. resting intervals were also studied but researchers found that 16 minutes and longer ones can negatively effect the subsequent performance (Dello Iacono et al., 2015). Furthermore, according to current meta-analysis; rate of effect is 0.49 for 5-7 minutes as 0.44 for 8-16 min. This meta-analysis concluded that short durations are not enough to get over fatigue and may decrease effect of PAP (Seitz, 2015).

After detecting 1RM, the intensity was determined as 65% of 1RM to see the differences between repetitions. To observe the possible change in performance, instead of higher percentages, 65% of 1RM which involves much more repetitions was preferred. With the higher percentages (testing weight close to 1RM), it was highly likely that slight changes in performance would not be shown as repetitions. Therefore, the difference in

performance could be noticed easily with this percentage. Lighter than 65% loads were also not preferred as potentiation effect might have been suppressed by fatigue.

Supra-maximal loading was determined as 120% of 1RM at first session. There were two reasons for this percentage; 1- Subjects would not be able to hold the bar long enough to have the potentiation effect with a heavier than 120%. 2- Injury risk is higher with heavier eccentric loads. With this percentage subjects were able to hold the bar and stay under tension long enough to have the potentiation effect. Repetition mean of PAP group was 17.25±3.93 and completed in 32.74±4.82 seconds at first session. 2nd session mean was 18.28±4.11 and completed in 34.50±5.36 seconds. Duration was significantly different between two sessions further showing the positive potentiation effect of supra-maximal loading ($p<0.05$). It was noted that this difference could have resulted due to increased repetitions at the second session. (Control group's completed repetition duration was in 36.55±6.61 and 35.25±6.50 seconds at first and second session respectively).

Hamada et al., found that there is a positive effect of PAP on the muscular endurance performance (Hamada et al., 2000) Hancock et al., on the other hand, found that, PAP is also effective at increasing 100 m swimming performance. Their study included 4 maximal sprints of 10 m swim with a 6 minutes rest interval to elicit the effects of PAP (Hancock et al., 2015).

Mitchell et al., performed a study to observe the effects of 5 RM squat effects on Counter Movement Jumping (CMJ) performance with 8 minutes PAP duration which showed a positive effect (Mitchell & Sale, 2011).

There are also some studies that do not show any positive effects of PAP on explosive performance. Winter et al., found that there is no positive effect of squat on CMJ (Witmer et al., 2010). Winter et al. used 3 minutes rest to see the effects of PAP which was found out to have positive effect on performance.

Kaiya et al., also performed a study to see the effects of squat on vertical jump. 5 minute rest was not enough to create a positive effect (Kaiya, 2014).

There were performed different studies and obtained positive results about understand the effects of squat on 30m sprint performances (Comyns et al., 2010; Beval et al., 2010).

Current meta-analysis by Seitz et al. included 47 studies with 135 groups and 1954 participants (Seitz, 2015). According to the results of this analysis, a positive effect was seen on sprint, jumping and ballistic throwing with small groups. One interesting finding from our study that, the PAP protocol had different potentiation effect on subjects and individual variability was relatively high. One of the subjects was able to increase 5 repetitions in the 2nd session whereas another one was able to perform 2 less. Furthermore, it is argued that there is a positive effect on participants who predominantly have type-II muscular fibres with PAP applications (Seitz, 2015). This might explain the 3-12 min. window for potentiation as Type-II fibres need relatively longer time to recover from fatigue, but further studies are needed to fully understand the causes of potentiation.

CONCLUSIONS

It was observed that, supra-maximal eccentric loading has a positive effect on the muscular endurance. This result was an addition to the body of PAP literature that shows an increase in performance. It was also observed that muscular endurance might improve with supramaximal eccentric loading. Therefore, this method might be used effectively by coaches and athletes to obtain muscular endurance. However further research is needed to understand which factors effects of PAP and what it does its effects rely on.

REFERENCES

Bevan, H. R., Cunningham, D. J., Tooley, E. P., Owen, N. J., Cook, C. J., Kilduff, L. P. (2010). Influence of postactivation potentiation on sprinting performance in professional rugby players. J Strength Cond Res, 24(3), 701-705. https://doi.org/10.1519/JSC.0b013e3181c7b68a

Comyns, T. M., Harrison, A. J., Hennessy, L. K. (2010). Effect of squatting on sprinting performance and repeated exposure to complex training in male rugby players. J Strength Cond Res, 24(3), 610-618. https://doi.org/10.1519/JSC.0b013e3181c7c3fc

Dello Iacono, A., Padulo, J., Eliakim, A., Gottlieb, R., Bareli, R., Meckel, Y. (2015). Post activation potentiation effects on vertical and horizontal explosive performances of young handball and basketball athletes. J Sports Med Phys Fit, 56(12), 1455-1464.

Duncan, M. J., Thurgood, G., Oxford, S. W. (2014). Effect of heavy back squats on repeated sprint performance in trained men. J Sports Med Phys Fit, 54(2), 238-243.

Hamada, T., Sale, D. G., Macdougall, J. D. (2000). Postactivation potentiation in endurance-trained male athletes. Med Sci Sport Exer, 32(2), 403-411. https://doi.org/10.1097/00005768-200002000-00022

Hancock, A. P., Sparks, K. E., Kullman, E. L. (2015). Postactivation potentiation enhances swim performance in collegiate swimmers. J Strength Cond Res, 29(4), 912-917. https://doi.org/10.1519/JSC.0000000000000744

Hodgson, M., Docherty, D., Robbins, D. (2005). Postactivation potentiation: Underlying physiology and implications for motor performance. Sports Med, 35, 585–595. https://doi.org/10.2165/00007256-200535070-00004

Judge, L. W. (2009). The application of postactivation potentiation to the track and field thrower. Strength Cond J, 31(3), 34–36. https://doi.org/10.1519/SSC.0b013e3181a62960

Kaiya, S. S., Charles, J. F. (2014). Acute post-activation potentiation in NCAA division II female athletes. Int J Exer Sci, 7(3), 212-219.

Kilduff, L. P., Bevan, H. R., Kingsley, M. I., Owen, N. J., Bennett, M. A., Bunce, P. J., Cunningham, D. J. (2007). Postactivation potentiation in professional rugby players: optimal recovery. J Strength Cond Res, 21(4), 1134-1138. https://doi.org/10.1519/00124278-200711000-00026

Kilduff, L. P., Cunningham, D. J., Owen, N. J., West, D. J., Bracken, R. M., Cook, C. J.(2011). Effect of postactivation potentiation on swimming starts in international sprint swimmers. J Strength Cond Res, 25(9), 2418-2423. https://doi.org/10.1519/JSC.0b013e318201bf7a

Lorenz, D. (2011). Postactivation potentiation: an introduction. Int J Sport Phys Theory, 6(3), 234-240.

Low, D., Harsley, P., Shaw, M., Peart, D. (2015). The effect of heavy resistance exercise on repeated sprint performance in youth athletes. J Sport Sci, 33(10), 1028-1034. https://doi.org/10.1080/02640414.2014.979857

Mitchell, C. J., Sale, D. G. (2011). Enhancement of jump performance after a 5-RM squat is associated with postactivation potentiation. Eur J Appl Physiol, 111(8), 1957-1963. https://doi.org/10.1007/s00421-010-1823-x

Rixon, K. P., Lamont, H. S., Bemben, M. (2007). Influence of type of muscle contraction, gender, and lifting experience on postactivation potentiation performance. J Strength Cond Res, 21, 500–505.

Sale, D. G. (2002). Postactivation potentiation: role in human performance. Exer Sport Sci Rev, 30, 138–143. https://doi.org/10.1097/00003677-200207000-00008

Sandra, L. (2012). Post Activation potentiation: Effect of various recovery intervals on bench press power performance. J Strength Cond Res, 26(3), 739-744. https://doi.org/10.1519/JSC.0b013e318225f371

Seitz, B. L., Haff, G. G. (2016). Factors modulating post-activation potentiation of jump, sprint,throw, and upper-body ballistic performances: a systematic review with meta-anlysis. Sport Med, 46(2), 231-240. https://doi.org/10.1007/s40279-015-0415-7

Stone, M. H., Sands, W. A., Pierce, K. C., Ramsey, M. W., Haff, G. G. (2008). Power and power potentiation among weightlifters: preliminary study. Int J Sport Physiol Perform, 3(1), 55–67. https://doi.org/10.1123/ijspp.3.1.55

Tobin, D. P., Delahunt, E. (2014). The acute effect of a plyometric stimulus on jump performance in professional rugby players. J Strength Cond Res, 28(2), 367-372. https://doi.org/10.1519/JSC.0b013e318299a214

Witmer, C. A., Davis, S. E., Moir, G. L. (2010). The acute effects of back squats on vertical jump performance in men and women. J Sport Sci Med, 9(2), 206-213.

