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The post-activation potentiation Effect on Sprint and Jumping Performance among Collegiate Rugby Players

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ABSTRACT

Post activation potentiation (PAP) is a condition by which the force exerted by a muscle is increased due to its previous contraction. The purpose of this study was to determine the effects of heavy back squats and heavy front squats on the average speed and jumping performance. Fifteen collegiate rugby players voluntarily participated in the study and were randomly assigned to two intervention groups, back squat (BS) and front squat (FS). The experiment consists of 1RM back squat determination and completed four experimental trials within five different days with at least 48 hours rest between sessions. The heavy back squat (BS) and heavy front squat (FS) interventions consisted of performing back or front squat with 60%, 50% and 70% of the subject's 1 repetition maximum after dynamic warm up. The sprint trials were performed 4 minutes after completing the heavy back and front squat intervention, while the jumping trials were performed 5 minutes after both interventions. Results showed no significant difference in sprint times for both interventions, but there is a significant increase in jumping performance after heavy back squat intervention. The main findings are that the interventions Although this study failed to show any significant differences between these two interventions, the results showed that both exercises can still give benefit and improvement to the athletes. Future investigations should considered other factors such as intensity of the exercise, recovery time, and movement that mimic to the performance of the athletes to utilize this post-activation potentiation phenomenon.

Keywords: Squat, Post Activation Potentiation, Sprint, Jumping

INTRODUCTION

Athletes are always looking for various techniques to gain the competitive edge (Roden et al., 2014) The demand of physical ability becomes higher in order for the athlete to give maximum performance when the sports become more challenging (Weber et al., 2008). Speed, strength, and power are all important factor in athletic performance and their maximization in training or competition can be enhanced through a proper warm up technique (Till & Cooke, 2009). Warm up is thought to be a crucial factor and is frequently utilized by athletes in order to prevent from any injuries and achieve maximal performance during training and competition (Sotiropoulos et al., 2010). Contractile activity during a warm up leading up to an athletic event has the potential to alter explosive performance since the contractile history of muscle has an effect on subsequent performance (Hester et al., 2017).

According to a previous study by Tillin and Bishop (2009) the ability of the muscle to producing greater force is dependent on its contractile history and can improve immediately following voluntary contractions at maximal or sub maximal intensities. Sale (2002) stated that post activation potentiation (PAP) refers to phenomena by which muscular performance characteristics are acutely enhanced as a result of their contractile history. The researcher also reported that PAP can be defined as a condition whereby acute muscle force is increased due to previous high resistance exercise. The increased muscle force is due to an increase in myosin light chain phosphorylation and increased recruitments of high threshold motor units (Tillin & Bishop, 2009). Besides that, the efficacy method to use to elicit any PAP response is determined by the product of relationship between potentiation and fatigue. Therefore, although fatigue and PAP are concurrently present immediately after a conditioning protocol, fatigue subsides at a faster rate thus allowing PAP to be realized at some point during the recovery period (Tillin & Bishop, 2009).

New training techniques are always being used by an athlete in order to give them an advantage during competition. According to Roden et al. (2014),a constant development of new training techniques, or, in some cases, old training techniques are being reused, altered, and presented as "the next great thing". Unfortunately, some of this method can do more harm than good and it can be difficult for an athlete and coach to know what the best is in order to gain optimal performance level (Roden et al., 2014). Therefore, it is important to develop and identify an optimal method that will maximize athletes' ability in competition. According to Yetter and Moir (2008), there is a dearth of literature investigating the effects of heavy resistance exercise on subsequent sprint running performance, even the evidence supporting the acute potentiating effects of heavy resistance exercise on improving subsequent explosive performance are be shown. A previous study by McBride et al. (2005) reported that 40 meters sprint time during a single trial was significantly faster after three repetitions of back squats using a load of 90% of 1 repetition maximum (1RM). Despite some researchers have investigated PAP using a heavy back squat (≥80% 1RM) conditioning stimulus on vertical jump performance with some reporting positive effects (McBride et al., 2005), but there is an argument exist on the effect of PAP as there is no effects on jumping performance following PAP exercise (Hanson et al., 2007).

PAP protocol of 5RM back squats followed by 4 minutes rest, resulted in significant increases in vertical jump height (McCann & Flanagan, 2010). The difference in results between researchers can be due to methodological differences, such as recovery period used and training status of subjects. Heavy barbell squats as a modality have demonstrated the stimulus necessary in order to elicit the arousal needed to improve sprint performance; however, there may be other modalities that could prove superior to the barbell squat for eliciting PAP prior to sprinting (Larson et al., 2017). Front squats have been reported to have a more effect to achieve maintenance and maximal velocity of sprint running compared to back squats, due to production of greater hip extensor moment (Yetter & Moir, 2008b). Hence, front squat would induce PAP in speed and jumping performance much better compared to back squat. There is still a lack of previous studies to identify the effects of different heavy resistance exercise on speed and jumping performance. Therefore, the aim of the present study to determine the effect of difference exercise selection (heavy back squat and heavy front squat) superior to induce PAP response to increase speed and jumping performance among rugby players.

METHODOLOGY

Sampling

Fifteen collegiate rugby players (stature, 172.33±6.54 cm; body mass, 77.27±8.01 kg) participated in the study. All subjects had at least 12 months conditioning program experience, with all players introduces to resistance training. Participants were free from any musculoskeletal injuries or other health problems, signed informed consent and completed a Physical Activity Readiness-Questionnaire (Par-Q) before participation. Participants with any musculoskeletal injuries or other health problems were excluded from the study.

Instrumentation

Vertical Jump Testing
The reliability for Sargent Jump test has been reported r=0.99 (De Salles et al., 2012). Sargent jump is performed by marking the maximum height on a wall that they can reach with a piece of chalk. The subject then jumps and mark at the on the wall as high as they can. The distance between the two marks calculated as the jump height and a 4 minutes recovery was provided between jumps.

40 meters Sprint Test
40 meters sprint test is used to measure speed. According to Miller (2012), the reliability of short sprints has been reported to range from r=0.89-0.97.

Procedure

Subjects involved in five testing sessions: a 1RM back squat testing session and four PAP sessions (Heavy back squat (speed and vertical jump), and Heavy front squat (speed and vertical jump)). All subjects were required to perform the 1RM testing session before any of the PAP sessions. 80% of their 1RM back squat was used to determine the loads for 1RM front squat. Before the first PAP sessions, three-day rest was provided (Yetter & Moir, 2008b). All sessions began with a dynamic warm up comprised of low intensity exercises that the athletes were familiar with (400 m jog, 20 m lunges, 10 m side lunges both ways, 20 m of alternate-skips, 20 m of back-skips, 2x10 m leg swings (both front and side), 2x80 m submaximal sprint and walk back (Springall, Larson, and DeBeliso,2016).

Testing Protocol

After the warm up protocol, sprint test and vertical jump test were performed. Sprint times were measured at 40 meters, in which the subject performed three pre 40 meters sprint test followed by three minutes of rest separating each sprint trial. The PAP intervention which is either heavy back squat or heavy front squat performed by the subjects separated by two days rested before the next intervention. The subjects performed 5x30% of their 1 RM, then 4x50% 1 RM, and lastly 3x70% 1 RM. Two minutes' rest was provided between each of the loading sets. The subjects then walked for 4 minutes as active rested before performing the post 40 meters sprint test. After the sprint tests, the subjects performed three pre and post vertical jump with 30 seconds of rest separating each jump. In addition, the active rest for vertical jump is 5 minutes. The subject was provided two resting days between heavy back squat and heavy front squat treatment.

Statistical Analysis

Analysis of the data been analyzed by using Statistical Package for Social Sciences (SPSS version 27.0). Paired T-test were performed to assess the differences in performance of both pre and post for sprint and vertical jump test which had been performed by the subjects (N=15) to determine whether there were significant differences existed on both sprint and jump performance before and after the implementation of the exercise test for the subjects and the Independent T-test were used to identify the magnitude of differences in both speed and jumping performance caused by the heavy back squat and heavy front squat. The alpha level was set at $p < 0.05$.

RESULTS

Table 1 shows the scores of heavy back squat and front squat towards sprint performance among the rugby players. Post intervention sprint performance improved compared to pre intervention for back squat (pre = 5.42±0.28, post = 5.43±0.26) and front squat (pre = 5.43±0.28, post = 5.47±0.25). However, there was no significant difference between the mean for pre-test and post-test for the back squat and

front squat intervention (p>0.05).

Table 1. Scores between Back squat and Front squat towards sprint performance

Group		Mean (SD)	T	df	p
Back squat	**Pre**	5.42 (0.28)	-0.198	14	0.846
	Post	5.43 (0.26)			
Front squat	**Pre**	5.43 (0.28)	-1.901	14	0.078
	Post	5.47 (0.25)			

Table 2 shows the scores of heavy back squat and front squat towards jumping performance among the rugby players. Post intervention jumping performance improved compared to pre intervention for back squat (pre = 50.82±4.09, post = 51.22±4.01) and front squat (pre = 50.45±3.91, post = 50.60±3.90).

Table 2. Scores between Back squat and Front squat towards jumping performance

Group		Mean (SD)	T	df	p
Back squat	**Pre**	50.82 (4.09)	-3.061	14	0.008
	Post	51.22 (4.01)			
Front squat	**Pre**	50.45 (3.91)	-1.167	14	0.263
	Post	50.60 (3.90)			

Table 3 shows the scores for post-intervention of heavy back squat and front squat towards sprint performance among the rugby players. Based on the table above, the post result shows that there is a significant difference in the mean scores for heavy back squat (5.43 ± 0.26) and heavy front squat (5.47 ± 0.25). It showed that heavy back squat group had significantly better result compared to heavy front squat. However, this can be concluded that there is no significant difference between heavy back squat and heavy front squat among rugby players to improve sprint performance (p>0.05).

Table 3. Scores between Heavy Back Squat and Heavy Front Squat towards Sprint Performance

	Group	N	M	SD	t	p
Post	Heavy Back Squat	15	5.43	0.26	-0.432	0.669
	Heavy Front Squat	15	5.47	0.25		

Table 4 shows the scores for post-intervention of heavy back squat and front squat towards jumping performance among the rugby players. There is a significant difference in the mean scores for heavy back squat (51.22 ± 4.01) and heavy front squat (50.60 ± 3.90). It indicates that heavy back squat group had significant higher jump performance compared to heavy front squat. However, it can be concluded that there is no significant difference between heavy back squat and heavy front squat among rugby players to improve jumping performance (p>0.05).

Table 4. Scores between Heavy Back Squat and Heavy Front Squat towards Jumping Performance

	Group	N	M	SD	t	P
Post	Heavy Back Squat	15	51.22	4.01	0.431	0.670

Heavy Front Squat	15	50.60	3.90

DISCUSSION

The present study was undertaken to examine which exercise (heavy back squat and heavy front squat) is superior to induce PAP response to increase speed and jumping performance among rugby players. The current finding indicates that there was no significant effect between pre-test and post-test of heavy back squat on sprint performance among rugby players. The result of the present study indicate that heavy back squat and heavy front squat does not have significant different in term of effect on the sprint performance among the rugby players. However, our results shows that the sprint performance significantly better results with the heavy back squat group compared to heavy front squat. This is consistent with previous studies involving back squat failed to improve sprint performance (Lamont et al., 2011). A study by De Hoyo et al. (2016) investigated the effects of different intensity resistance exercise (65, 75, 85% 1 repetition maximum back squat) and found there was no significant effect on 50 meters sprint performance in highly trained adolescent track and field athletes. The lack of increment in sprint performance as a result of executing a PAP protocol warm up is not consistent with previous research which have shown that a PAP warm up can significantly increase power production for both upper and lower body (Tillin & Bishop, 2009). Previous literature by Sanchez-Sanchez et al. (2018) stated that training status of an athlete is the main factor required for a PAP warm up technique to be meaningfully exhibited. The lack of improvement in sprint performance as a result of implementing a PAP warm up strategy can be affected by relative strength and prior training status (Smith et al., 2014). The participants in this were student athletes that were at least 18 years of age and were at least one year experienced in resistance training or physical conditioning activity. Besides, the NSCA's PAP recommendations for relative strength of a back squat 1RM/ body mass equal to ≈ 2.0. (Sánchez-Medina et al., 2017). According to Sañudo et al. (2020), athlete with high strong level demonstrate a greater potential to potentiate, due to able to dissipate fatigue faster as strength level increase. In addition, they will develop fatigue resistance to high loads as an adaptation to repeated high load training. Hence, potentiation can be diminished and needed longer time to surpass the level of fatigue when relative strength is lower. Previous researchers stated that athlete with higher relative strength capable to become fatigue resistant, hence, has higher possibility to potentiate after following conditioning activity (Weber et al., 2008). In contrast, a study by McBride et al. (2005) found significant improvement in heavy back squat group in 40 meters after utilizing PAP protocol of 1 set of 3 repetitions at 90% of the participant's 1 repetition maximum.

Besides, the present study also indicates that there is no significant difference between pre-test and post-test for the heavy front squat intervention, which some researchers that have proven in their study that there is no significant effect of heavy front squat on sprint performance. Previous literature stated that there were no significant differences in average speed during the each 10-m interval of 40 meter sprint trials caused by front squat treatment (Yetter & Moir, 2008). It should be noted that the loads for front squat were calculated roughly from 1RM back squat rather than measured 1RM front squat directly. Thus, lower loads utilized during the heavy front squat intervention may hinder the generation of post activation effect (Yetter & Moir, 2008). The researchers found that intensities lower than 90% failed to induce post activation potentiation effects. According to Hanson et al. (2007)four reps at 80% 1RM identified failed to produce PAP effect when the volume was slightly lower. PAP effects found successful when the intensities used at or above 90% 1RM (Hanson et al., 2007). The results also been influenced by inadequate rest period provided after conditioning exercise. Previous researchers reported that recovery period needed to potentiate the muscle and counteract the effects of fatigue at least 5 minutes (McCann & Flanagan, 2010). Present study used 4 minutes recovery time after following conditioning activity, which may play a role in the lack of improvement on sprint performance. A study by Tillin and Bishop (2009) suggested that the balance between potentiation and fatigue determined the efficiency to produce PAP effects. Fatigue plays a dominant role during the early phase but diminished at a faster rate than PAP enable the potentiation and enhancement of the power output occur. If the amount of fatigue higher than PAP, cross-bridge activity will be disturbed due to disruption to the sensitivity and release of calcium ion (Sale, 2002). Hence, calcium ion sensitivity

declined caused by decreased calcium ion and actin-myosin binding affinity, and decreased production of force during the contraction activity.

According to the result, there was a significant difference between the mean for pre-test and post-test for the back squat intervention. A study by Mitchell & Sale (2011), discovered countermovement jump height was enhanced after a 5RM back squat with a recreationally trained participant. Furthermore, in an investigation of NCAA Division I female volleyball athletes, found that a PAP protocol of 5RM back squat followed by 4 min rest, found an increment in vertical jump height (Sygulla & Fountaine, 2014). Previous studies by Duthie, Young, and Aitken (2002) found a significant improvement in both peak power and maximal force when PAP protocol of 3RM half squats followed by 5 min rest was implemented. The possible explanation for the improvement of the muscle power performance will probably be connected to either the theory of myosin light chain phosphorylation (Sale, 2002) or by an increased recruitment of higher order motor units, which in turn activate alpha motor neuron elevates the excitation potentials and enhanced generation of force of the required muscle groups (De Luca & Hostage, 2010). During muscular contractions, a regulatory light chain (RLC) is catalysed by the enzyme myosin light chain kinase which is initiated when calcium ion released from sarcoplasmic reticulum (Ito et al., 2022). A regulatory light chain (RLC) phosphorylation make the interrelationship between actin-myosin become more responsive to myoplasmic calcium ion produced from sarcoplasmic reticulum. Furthermore, increased recruitment of active motor units, increased synchronization of motor unit and or decreased presynaptic inhabitation results in increased actin-myosin binding within the muscle and enable more production of force at the muscle (Ito et al., 2022). Contrast with present study which discovered that PAP protocol failed to potentiate subsequent jump height after performed 3 repetitions at 90% 1RM followed by a 5 minutes rest period (Sygulla & Fountaine, 2014). A literature by Mitchell & Sale (2011) also reported there is no significant improvement on subsequent jump heights or ground reaction force after utilized a PAP protocol of 5RM back squats followed by countermovement vertical jumps at 10 sec, 1 min, 2 min, 3 min, and 4 min post squat jumps.

However, the current study indicates that there is no significant difference between pre-test and post-test for the heavy front squat intervention. Previous researchers highlighted that the post activation potentiation (PAP) effect to be highly individualized as individuals with a higher percentage of fast twitch muscle fibre have a greater possibility to have a positive PAP effects on enhancement of the power performance (De Luca & Hostage, 2010). Fast twitch muscle fibre are assumed to have more likelihood to achieve higher degree of phosphorylation after following conditioning exercise and potentiated compared to slow twitch fibres. According to Ito et al. (2022). type II fibres able to recruit higher order motor units and increase the possibility to potentiate the muscle and increase power performance. The athletes training level and muscular strength also may influence the lack of improvement in performance (De Hoyo et al., 2016).

In comparison in the mean scores for heavy back squat and heavy front squat, there is a significant different between two interventions. Based on the mean scores between two interventions, heavy back squat significantly produced faster sprint time. However, this can be concluded that there is no significant difference between heavy back squat and heavy front squat among rugby players to improve sprint performance ($p>0.05$. According to Yetter and Moir (2008), there was no significant difference between the average speed produced by the heavy back squat and heavy front squat treatment during 10 to 20 m interval. Previous literature by McBride et al. (2005) also stated that 10 m to 30 m sprint times were not significantly changed. The type of post activation movement may have crucial factor to induce the PAP effects. The improvement of the power output can occur when the potentiating activity is biomechanically similar with the power activity. Several studies discovered influence of body segments and similar muscles used and activated towards performance of conditioning activity such as squatting, jumping, and running (De Luca & Hostage, 2010). Front squat exercise activating more hip extensor moment compared to back squat exercise; however the knee and ankle moments are similar. Hence, this factor may have a greater effect on the achievement and maintenance of maximal velocity during sprint performance. However, current finding failed to produce PAP effect, which may cause by lower loads used. Lower loads used during the front squat may cause the hip extensors failed to be activated (Yetter & Moir, 2008). The loads that utilized for the front squat was estimated from 80% 1RM back squat of the athletes'. Hanson et al. (2007)found four repetitions at 80% 1RM failed to induce

PAP effect and the intensities lower than 90% failed to have positive effects to potentiate the muscle (Yetter & Moir, 2008). Previous literature also found PAP effects become successful when 90% 1RM intensities were utilized (McBride et al., 2005). Even though similar body segments used required potentiating, PAP also can be associated with neural mechanisms which are increase in H-reflex, in which enable to recruited higher number of motor units (De Luca & Hostage, 2010).

The present study also indicates that heavy back squat group had significant higher jump performance compared to heavy front squat. Generally, it can be concluded that heavy back squat had significantly better result and higher jump compared to heavy front squat. However, it can be concluded that there is no significant difference between heavy back squat and heavy front squat among rugby players to improve jumping performance ($p>0.05$). A literature by Mitchell and Sale (2011) showed there is no significant effect on following jump height or ground reaction force after utilized 5RM back squat followed by countermovement vertical jump at 10 sec, 1 min, 2 min, 3 min, and 4 min after squat jump. The back squat has been a dominant exercise used in almost all strength and conditioning activities. Back squat exercise has been found as a tool to develop great lower body strength and power and become good measurement of vertical jumping capability. Previous literature discovered that PAP protocol using 5RM back squat followed by 4 minutes rest found a significant improvement in vertical jump height (McCann & Flanagan, 2010). The possible factors that affect the inconsistency of PAP effect are the training status of the athlete, the intensity of the potentiating activity, and also recovery period after conditioning activity. Previous study found that athletes with higher relative strength have a higher potential to potentiate, which is hypothesized because the muscle able to become fatigue resistant when the strength level increases (Sañudo et al., 2020). The National Sports Conditioning Association (NSCA) highlighted that the intensity of the contraction is the crucial factor that needs to consider for the selection on a potentiating activity (Sygulla & Fountaine, 2014). The lack of improvement on jumping performance in the current study may be related to the exercise intensity used especially for the front squat treatment.

CONCLUSION

Post activation potentiation can be used as a new technique to improve the power performance. Despite most post-activation potentiation studies on ergogenic effect on performance, there is some studies have reported no ergogenic effect. As indicated in a review by Arabatzi et al. (2014), the training history and strength of the participants are important factors in the outcome of post-activation potentiation studies. In the present study, we observed that there are no significant effects on sprinting and jumping performance when heavy back squat and heavy front squat exercise being applied. Although this study failed to show any significant differences between these two interventions, the results showed that both exercises can still give benefit and improvement to the athletes. Mostly the post activation potentiation effect depends on the physiological response of the athletes towards the training stimulus. Athletes with a predominantly fast twitch muscle fiber, higher relative strength, may have more benefit and positive effect of a PAP warm up. In conclusion, the results of the present study indicate that the sprint and jumping performance is not enhance following heavy front squat and heavy back squat intervention. As a recommendation, other factors that need to be considered such as intensity of the exercise, recovery time, and movement that mimic to the performance of the athletes to utilize this post-activation potentiation phenomenon.

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