POSTACTIVATION POTENTIATION AND CHANGE OF DIRECTION SPEED IN ELITE ACADEMY RUGBY PLAYERS

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ABSTRACT

This study investigated the effect of preceding pro-agility sprints with maximal isometric squats to determine if postactivation potentiation (PAP) could be harnessed in change of direction speed. Sixteen elite under-17 rugby union players (age: 16 ± 0.41yrs; body mass: 88.7 ± 12.1kg, height: 1.83 ± 0.07m) from an Aviva Premiership rugby club were tested. Subjects performed a change of direction specific warm-up, followed by two baseline pro-agility tests. After 10 minutes recovery, 3 x 3-second maximal isometric squats with a 2 minute recovery between sets were completed as a conditioning activity (CA) on a force plate where peak force and mean rate of force development over 300 milliseconds were measured. The pro-agility test was repeated at set time intervals of 1, 3, 5 and 7 minutes following the CA. Overall pro-agility times were significantly slower ($p < 0.05$) at 1-minute post-CA compared to the baseline (3.3%), with no significant differences occurring at 3, 5 or 7 minutes post-CA. Therefore, it appears that performing multiple sets of maximal isometric squats do not enhance pro-agility performance.

Key Words: Agility, potentiation, rugby, pre-conditioning

INTRODUCTION

Within many team sports, power and sprint speed are some of the most sought after athletic abilities. A theory that has been proposed to acutely enhance these components is that of postactivation potentiation (PAP), which describes the short-term enhancement of an athlete's peak force (PF) and rate of force development (RFD) (6, 21). At a physiological level, the two mechanisms suggested to create PAP are the phosphorylation of myosin regulatory light chains, which subsequently increase myofibrillar sensitivity to calcium secretion from the sarcoplasmic reticulum, and recruitment of higher order motor units (6). This method typically involves performing single or multiple sets of a resistance exercise at a high load (>85% 1RM), followed by an exercise at a lower load carried out in a plyometric or ballistic fashion (1, 2, 11). Previous studies have found relationships between maximal strength and the ability to express PAP, as well as stronger individuals being able to take advantage of this phenomenon earlier than their weaker counterparts (12, 16, 20, 22, 25, 31), thus justifying strength as a key physical attribute. However, when attempting to utilise PAP, several other variables must be considered, namely the type of conditioning activity chosen, rest period and potentiated activity (9, 31).

A key variable when utilizing PAP is which type of contraction to use for the maximal strength exercise – also termed the 'conditioning activity' (CA). PAP effects have been shown to be evident after performing both dynamic (>85% 1RM) and isometric CA's (2, 20), with both methods proving adequate to harness augmented performance within biomechanically similar tasks. With this said however, it has been shown that isometric contractions have a lower metabolic cost than dynamic contractions (5), and that isometric contractions will activate a greater number of muscle fibres due to the nature of the movement demanding "maximal intent" (7). Consequently, this reduced metabolic cost is likely to alter the timeframe (post-CA) when performance enhancements may be realised and thus, warrants further investigation.

The recovery time between the CA and the following activity is also an important factor to consider, since a balance appears to exist between fatigue and potentiation in order for PAP to occur (2, 12). This closely resembles the theory of the fitness-fatigue paradigm (34), which suggests that fitness and fatigue occur concurrently, and only when fatigue has dissipated does the former become apparent and thus, athlete preparedness can become optimized. As a result of isometric contractions having a reduced metabolic cost, it may be plausible for an isometric activity to have a lower optimal recovery time than a dynamic activity, this previously suggested as between 8-12 minutes for enhancements in CMJ performance (12). Bogdanis et al. (2) investigated the optimal time when aiming to potentiate vertical jump performance following 3 x 3-second maximal isometric half-squats, and concluded that 4-6 minutes was an optimal recovery period for producing PAP. Additionally, peak individual responses following each of the CA identified significant enhancements in vertical jump performance following solely the isometric protocol (3.0 ± 1.2%; $p = 0.045$), with no significant increases identified following contractions of a dynamic nature.

As well as being used for gym-based power exercises such as a CMJ or bench press throws, it has been shown that PAP can be applied to speed and acceleration performance (1, 3, 29, 32). To the authors' knowledge, only two studies have investigated the effects of preceding sprints with maximal isometric contractions. Lim and Kong (12) examined the effects of preceding a 30m sprint with three different contraction types, namely; maximal isometric knee extensions, maximal isometric half-squats, and dynamic back squats. No significant improvements were seen within the sample as a whole group, but between-subject variations were observed, predominantly in response to the isometric squat CA. It was concluded however, that any improvements made were within the error of the test and thus no true change was noted. Similarly, Till and Cooke (28) used maximal deadlifts, tuck jumps, or isometric knee extensions in an attempt to potentiate 10m sprints and vertical jumps in elite academy footballers. In line with the findings of Lim and Kong (12), no significant differences were observed in any of the conditions, with large between-subject variations in 10m sprints again reported in response to the isometric protocol. Key inclusion criteria in Lim and Kong's (12) study however, was the requirement to be able to back squat 1.5 times body mass. It could be argued therefore, that the sole recording of data 4 minutes post-CA may have proven insufficient to bring to light any true change, given how both recovery time and strength level have previously been shown to be important factors influencing potentiation (11, 16, 22). Furthermore, isometric knee extensions negate any posterior chain recruitment; this a widely known factor influential within the acceleration phase of sprinting (32), and as such, may not have been the most apt method for potentiating sprint speed.

The amount of literature investigating the effects of PAP on change of direction speed (CODS) ability is limited, with only two studies identified (14, 33). Maloney et al. (14) involved a sample of elite badminton players (n = 8) undergoing three standardised dynamic warm-up conditions while wearing either a 5% bodyweight vest, a 10% bodyweight vest or a control condition. Following the warm-up, subjects completed CMJ and CODS tests at set time intervals (15 seconds, 2, 4 and 6 minutes). It was found that COD performance was significantly faster when compared to the control condition for both the 5% ($P = 0.02$) and the 10% ($P < 0.001$) conditions. In the second study by Zois et al. (35) 10 amateur football players completed a battery of tests relating to team sport physical performance including CMJ and reactive agility. The players preceded these tests with 1 of 3 interventions including, a normal football warm-up, small-sided games (SSG) or a 5RM on a leg press machine. It was found that compared to baseline measures, agility performance improved by 3.8 - 4.7% following the SSG and 5RM leg press respectively.

CODS has been reported as a major determinant of success in rugby players (8, 23, 31). When changing direction at a high intensity, an athlete must possess high levels of eccentric, isometric and concentric strength (25, 26). Spiteri et al. (25) identified a significant negative correlation between isometric strength and the pro-agility test ($r = -0.792$), as well as identifying that isometric strength was notably higher in faster subjects when performing both the pro-agility and t-tests (25), perhaps suggesting a notable relationship between isometric strength and CODS.

With this in mind, the purpose of this study was to determine whether performing maximal isometric half squats will improve subsequent CODS performance. A secondary aim was to discover the optimal post-CA recovery time for the CODS drill, assuming that an effect exists. It was hypothesised that preceding a CODS test with maximal isometric squats would enhance CODS performance.

METHODS

Experimental approach to the problem

This study was designed to investigate whether PAP could be applied to CODS training to enhance performance in elite academy rugby union players. The effect of PAP on direction change was evaluated by performing a baseline CODS test followed by 3 x 3-second maximal isometric squats, whilst standing on a force plate which measured maximal peak force (PF) and mean rate of force development over the first 300 milliseconds (RFD). The CODS test was then repeated at 1, 3, 5 and 7 minutes post-CA, with the intention of identifying the optimal recovery time for this protocol.

Subjects

Sixteen elite academy rugby players (age: 16 ± 0.41yrs; body mass: 88.7 ± 12.1kg; height; 1.83 ± 0.07m) from an Aviva Premiership club volunteered to take part in the study. All subjects took part in regular resistance and speed training, had at least two years of structured resistance training experience prior to the start of the study and were able to back squat at least 1.5 times their bodyweight. Furthermore, all subjects were familiar with the isometric squat and the pro-agility tests. All subjects were also free from any lower limb or back injuries for at least six months and no strenuous physical activity was undertaken in the 24 hours before the testing session. Ethical consent was gained from the ethical review board at the London Sport Institute, Middlesex University and written consent for subjects was obtained from parents or guardians as all of the participants were under the age of 18.

Procedures

Familiarisation session: Subjects began by having their anthropometric measurements recorded for body mass and height on a measuring station (Seca 764; Seca Ltd, UK). They were then re-familiarized with the pro-agility test, which they already frequently used to measure their CODS (15), and were allowed as many trials as they felt were needed to fully comprehend its requirements. The test involved placing two cones in a line 10 yards apart from each other. The subject started by straddling a pair of electronic timing gates (Brower Timing, Draper, UT, USA) placed halfway between the two cones, facing a direction 90 degrees away from each end. They then quickly accelerated to the right cone; touched it with their right hand, accelerated to the far cone and touched it with their left hand, and accelerated back past the middle cone recording a time to the nearest 0.01s (see Figure 1). This test was selected because of its capacity to challenge COD mechanics off of both sides and has previously reported 'very high reliability' (r = 0.90) (27). Finally, of all of the CODS tests examined by Stewart et al. (27) that required the athlete to change direction off both sides, the pro-agility test took the lowest amount of time to complete, and was therefore hypothesized to create the lowest amount of fatigue when subjects re-performed the test at 1, 3, 5 and 7 minutes post-CA.

*** INSERT FIGURE 1 ABOUT HERE ***

Subjects then undertook the maximal isometric squat protocol. This was completed standing on a force plate sampling at 1000Hz. (Kistler 9286AA force platform) that recorded peak force (PF) and mean rate of force development (RFD) over the first 300ms of the contraction. Force traces were used to calculate each of these variables, with PF measured as the highest value achieved on the trace during maximal isometric contraction, and RFD calculated as the mean force that occurred over the first 300 milliseconds of the force-time curve. Subjects then adopted a squat position underneath a secured barbell (Eleiko Sport, USA) in a squat rack with their knees at an angle of 140^0 (4, 17), using a goniometer to measure. Subjects were then instructed to push the bar as forcefully and fast as possible for three seconds. This was completed twice, with two minutes rest between measurements. The barbell was secured with sufficient weight, as well as straps, so as to prevent any movement.

Testing session: The testing procedures took place five days after the familiarisation session. Participants began by completing a standardised 10-minute CODS warm-up (see table 1) using the RAMP method (10). Two minutes later, two baseline measurements of the pro-agility test were completed. After 10 minutes of passive recovery, subjects began an isometric squat warm-up, which consisted of submaximal isometric contractions at approximately 50, 75, and 90% of the subjects' maximum exertion. Post warm-up completion, subjects performed 3 x 3-second maximal isometric squat contractions each separated by two minutes, in the same format as that used by Lim and Kong (12). Once completed, subjects were reassessed for the pro-agility test at 1, 3, 5, and 7 minutes post-CA.

*** INSERT TABLE 1 ABOUT HERE ***

Statistical Analysis

All statistical analysis was completed using IBM SPSS Statistics v21 software, with data being presented as mean ± SD. Normality was determined using the Shapiro-Wilk test and reliability of testing procedures was calculated using the intraclass correlation coefficient (ICC). A one-way repeated measures ANOVA test was used to compare the best baseline pro-agility test and each of the post-CA measurements (1, 3, 5, and 7 minutes) with statistical significance set at $p < 0.05$. Effect sizes (ES) were also calculated for the group and compared to baseline measurements. The magnitude of the ES was interpreted using the parameters outlined by Rhea (19) (trivial = < 0.25; small = 0.25 – 0.50; moderate = 0.50 – 1.0; large = > 1.0). Pearson's correlation analysis were carried out to discover whether there was a relationship between isometric strength:weight ratio and difference between subjects' baseline pro-agility test and best post-isometric agility test results.

Finally, each subject had their minimum difference (MD) calculated to determine whether real changes in CODS performance were noted, or whether any minor improvements in time were by pure chance. This was calculated as the standard deviation of the differences in test times multiplied by the critical z-score of 1.96 (30).

RESULTS

Statistical analysis revealed all data as normally distributed (p > 0.05). Analysis using the ICC calculation revealed that the baseline pro-agility tests (0.78), PF (0.88) and RFD (0.81) were all at an acceptable level of reliability (see Table 4), (26, 30). Mean PF and RFD were recorded at 3139.9 ± 679.7N and 4965.7 ± 1211.9 N.s^{-1}. A repeated measures one-way analysis of variance (ANOVA) test revealed a significantly slower pro-agility test time at 1 minute post-CA compared to the baseline score (4.82 ± 0.16 vs. 4.67 ± 0.16, ES = 0.98; p = 0.018). No other significant differences were found at any other time points (see Table 2). No significant correlations were found between isometric strength:weight ratio and difference between subjects' baseline and best post-iso agility test results. When investigating individual results, 3 out of the 16 subjects within the study achieved a MD improvement during one or more post-CA pro-agility tests (see Table 3).

*** INSERT TABLES 2–4 ABOUT HERE ***

DISCUSSION

The primary aim of this study was to investigate whether performing maximal isometric contractions had an effect on an athlete's ability to change direction, using the pro-agility test as an outcome measure. The results of the present study indicate that the concept of postactivation potentiation cannot be applied to enhance CODS ability when isometric squats are used as the CA, in elite academy rugby players. However, it is important to note that individual responders did exist within the sample.

To date, there is very little literature that has looked into the idea of applying PAP to CODS performance (14, 35). Instead of isometric squats, the CA used in the study by Maloney et al. (14) was more ballistic and similar in nature to the following CODS drill, and involved wearing a weighted vest. The results of the present study may suggest that CODS cannot be enhanced through use of maximal isometric squats in all athletes. Bogdanis et al. (2) investigated differences in muscle action type on PAP for vertical jump performance, and used the same isometric CA protocol of 3 x 3-second maximal contractions as used in the present study. Isometric contractions were shown to be the most effective type for producing PAP, within a sample of 14 elite athletes, with the highest vertical jump improvement of approximately 3% shown between 4-6 minutes following the CA. The reason why a PAP effect may have been observed in Bogdanis' study was because vertical jumps, like the isometric CA, involve the application of force in the sagittal plane only. When quickly accelerating during the pro-agility test, previous literature has shown that horizontal force production is more important than vertical force (18), and this may explain the equivocal findings seen in the present study. Additionally, vertical jumps completed immediately after the CA were significantly reduced compared to the baseline performance, which again demonstrates the balance between potentiation and fatigue in terms of recovery time, and is in agreement with the results of the present study.

The improvements observed at 3, 5 and 7 minutes post-CA were not statistically significant overall, but when looking more closely at the results, it was apparent that some individuals did respond to the CA stimulus, and improved their pro-agility test times. This was shown by the fact that 3 out of 16 subjects within the sample achieved the necessary MD compared to their best baseline pro-agility test score after undergoing the CA. These improvements were observed at 5 and 7 minutes, with most responders achieving their best test time at 5 minutes post-CA. This finding has been previously reported in the literature (12, 16, 29), and reinforces the idea that testing should be used within sports training environments to identify individuals that respond to a PAP stimulus. It should also be noted that performing maximum isometric squats did not have a detrimental effect on COD ability, provided that adequate recovery was given to subjects. With this in mind, further investigation is warranted to overcome the limitations of the present study.

Seeing as this is one of the first studies looking at PAP for COD performance using isometric testing procedures, comparable information is sparse. However, it is feasible that the lack of significant improvements in performance was down to the age of the players. According to Lloyd et al. (13) at the age of 16, males may be coming to the end of an "adolescent spurt" in the maturation process with hormone balance likely being affected. It is plausible that should any relationship between strength and CODS exist, the age of the players could have interrupted any potentiation effect, although this explanation is purely anecdotal as no procedures were undertaken to corroborate this claim. Additionally, the performance of the pro-agility test at multiple time points after the CA may have resulted in some minor fatigue that may have diminished the potential PAP effect for some of the later COD test trials.

The size of the sample in the present study may have had an effect on the results obtained, as a higher number of participants would have allowed the possibility to split the group by position. Additionally, not all sports teams have access to weight training facilities, and so it may be useful to identify another way of eliciting potentiation that is more field-based and both kinematically and kinetically similar to the movement aiming to be enhanced, such as a weighted warm-up protocol, a plyometric preconditioning activity or sled drags at various loads, which are all dynamic in nature (14, 29, 32).

In conclusion, this study suggests that performing multiple sets of maximal isometric squats will not significantly enhance change of direction ability in the short-term in elite academy rugby players, although individual responders did exist within the sample.

PRACTICAL APPLICATIONS

The findings from this study suggest that performing 3 x 3-second maximal isometric squats will not cause a PAP effect when aiming to enhance CODS within the pro-agility test in elite academy rugby players. However, with the exception of 1 minute post-CA, isometric squats did not negatively affect performance, showing that isometric and CODS training using the pro agility test can be completed in a set-for-set format. However, it is suggested that practitioners find alternative methods when aiming to potentiate CODS within the pro-agility test, thus further research surrounding this component of performance would appear to be needed.

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Figure 1: Pro-agility test diagram

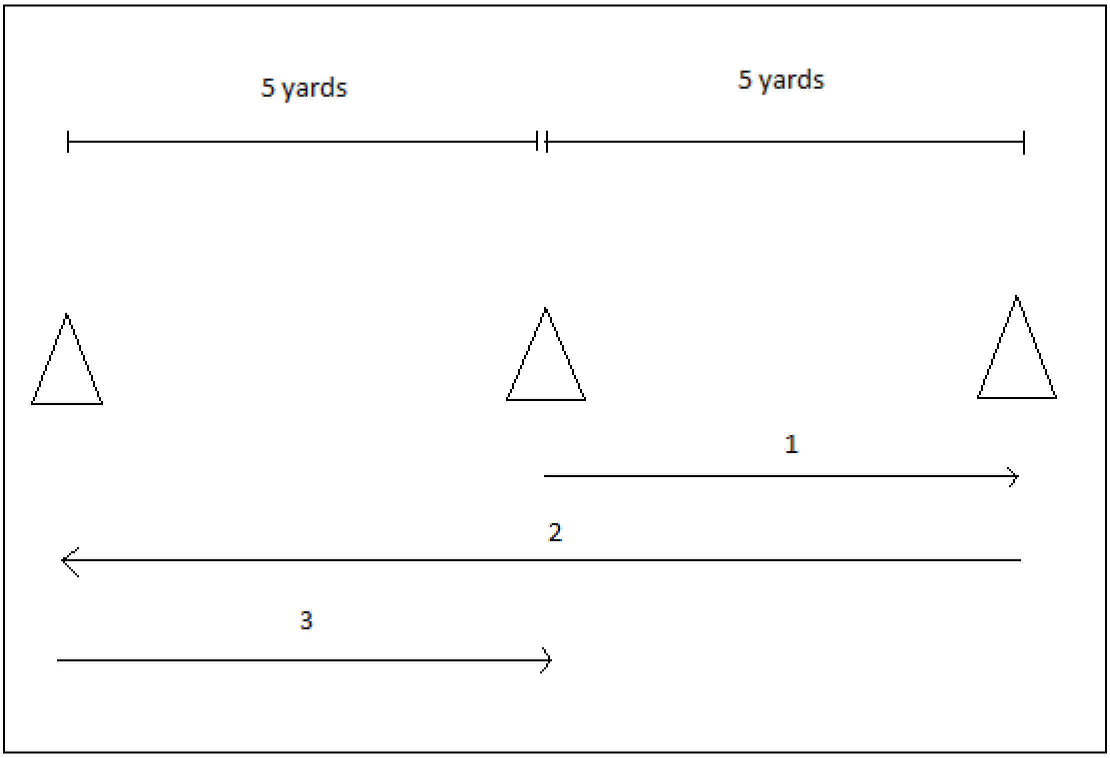

Table 1: Standardised CODS warm-up

Exercise/Drill	Sets	Repetitions
Bodyweight Squats	1	10
Forward/Lateral Lunges	1	10 each direction
Leg Swings	1	10 each side
10m acceleration drill	1	3 x 10m
Partner Mirror drill	1	2 x 10 seconds
Pro-agility test practice	1	1 at 60%, 1 at 80%

Table 2: Results for the pro-agility test at baseline and at 1, 3, 5 and 7 minutes post-isometric squat protocol, including confidence intervals (CI) and standard error of mean (SEM)

	Mean time (sec)	**95% CI (lower bound)**	**95% CI (upper bound)**	**SEM**	**Effect sizes from baseline**
Pro-Agility (baseline)	4.67 ± 0.16	4.58	4.73	0.040	n/a
Pro-Agility (1 min)	4.82 ± 0.16 *	4.76	4.92	0.038	0.98
Pro-Agility (3 min)	4.58 ± 0.17	4.48	4.68	0.046	0.55
Pro-Agility (5 min)	4.51 ± 0.22	4.38	4.63	0.057	0.81
Pro-Agility (7 min)	4.58 ± 0.24	4.44	4.72	0.064	0.41

* Indicates significantly slower than baseline ($P < 0.05$)

Table 3: Individual results for the pro-agility test at baseline and at 1, 3, 5 and 7 minutes post-isometric squat protocol, with individual minimum difference and Isometric strength:weight ratios (N/kg).

Subjects	**Pro-Agility (baseline)**	**Pro-Agility (Post 1 min)**	**Pro-Agility (Post 3 min)**	**Pro-Agility (Post 5 min)**	**Pro-Agility (Post 7 min)**	**Individual Minimum Difference**	**Isometric Strength: Weight ratio (N/kg)**
1	4.58	5.03	4.77	5.01	4.97	0.47	37.1
2	4.81	5.08	4.62	4.71	5.12	0.64	33.2
3	4.71	4.80	4.70	4.37	4.45	0.37	42.2
4	4.75	5.05	4.76	4.44	4.50	0.54	31.8
5	4.81	4.94	4.64	4.67	4.79	0.33	21.1
6	4.39	4.79	4.44	4.48	4.47	0.46	38.6
7	4.80	4.92	4.72	4.54	4.60	0.31	25.6
8	4.65	4.72	4.34	4.28	4.33	0.40	45.2
9	4.69	4.68	4.65	4.51*	4.54*	0.15	37.3
10	4.55	4.86	4.39	4.26	4.33	0.55	33.4
11	4.72	4.80	4.49*	4.63	4.80	0.38	38.3
12	4.63	4.87	4.51	4.36	4.46	0.45	37.8
13	4.40	4.55	4.23	4.12	4.19	0.37	43.3
14	4.65	4.67	4.53	4.47*	4.55	0.18	33.7
15	5.02	4.83	4.87	4.72*	4.61*	0.24	41.0
16	4.53	4.59	4.56	4.61	4.64	0.09	28.6

* indicates that a subject has achieved a meaningful improvement in pro-agility performance greater than their respective error of the test (individual minimum difference) when compared to baseline

Table 4: Intraclass Correlation Coefficient (ICC) results for pro-agility test and force plate readings, including confidence intervals (CI) and coefficient of variation (CV).

Test	**Intraclass Correlation Coefficient (ICC)**	**95% CI (lower bound)**	**95% CI (upper bound)**	**Coefficient of Variation (%)**
Pro-agility test baseline	0.78	0.606	0.909	1
Peak Force	0.88	0.752	0.952	7
Rate of Force Development	0.81	0.624	0.921	13