The effect of ballistic potentiation protocols on elite sprint swimming: Optimizing performance.

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ABSTRACT

Warming up prior to an athletic event is important for performance, however in some competition scenarios there is a long wait between completing the warm up and the event. Thus potentiation protocols are becoming increasingly popular in a competition environment. The aim of the study was to determine the effects of practical potentiation protocols on 15m start performance in national level swimmers. Eleven national level swimmers participated in the study. Using a randomized cross over design participants completed a 15m swimming start following 4 different experimental conditions (swim specific control, resisted band squat, weighted counter movement jumps, drop jumps from a 45cm box) each separated by at least 48h. A repeated measures ANOVA showed a significant difference in 15-m swimming start performance following different warm-up protocols ($F_{(1.646, 14.810)} = 6.968$, p=0.01) A Post hoc Bonferroni test indicated that 15-m start time was significantly quicker with the band squat protocol compared to the swim specific protocol (6.65 ± 0.43 v 6.78 ± 0.43 s respectively, *p* = 0.04). The results conclude that practical potentiation protocols are able to enhance 15-m swim start performance when combined with a swim specific warm-up and supports the use of post activation potentiation (PAP) during competitive swimming environments.

KEY WORDS – Post-activation Potentiation, Swimming, PUSH^{TM} Band.

INTRODUCTION

Warming up prior to an athletic event is considered important for optimal performance (3). Warm-up protocols are generally classified as either active or passive. Passive strategies focus on increasing core temperature with the use of external means such as a hot shower or sauna, whilst active protocols focus on the use of exercise (3). Active warm-ups have been considered the norm to enhance physiological mechanisms prior to competition. These mechanisms include an increase in oxygen delivery to the muscles, anaerobic metabolism and nerve conduction rate all of which have been attributed to an increase in body temperature (3). The use of active warm-ups has been used extensively in the sport of swimming and has demonstrated performance benefits over several distances (11).

The competitive swimming environment poses many issues which may cause disruptions to the use of active warm-ups. These issues include delays in competition schedule, lack of pool warm-up facilities, time required for clothing changes and long marshaling periods. Disruptions can result in longer periods between warm-up and competition which can negatively affect performance (37). Therefore additional preconditioning / warm-up strategies may be required to maximize performance. Kilduff et al. (23) identified several alternative preconditioning strategies which may offset the negative effects of the time between warm-up and performance. These strategies include passive heat maintenance (8) hormonal priming (9), and post-activation potentiation (PAP).

PAP has been defined as an acute enhancement of muscle function following an intense muscle activity occurring as a result of the contractile history of the muscle (19). Performance increases have been shown in jumping (15), sprinting (27) and throwing (2). Increased performance following a potentiation stimulus has been attributed to increases in force production in subsequent muscle contractions which occur due to a higher rate of cross bridge formation resulting from influx of calcium into the muscle following muscle contractions (3,13,16,30). Other mechanisms proposed include an increase in neuromuscular activation and motor unit recruitment contributing to greater force production (19).

PAP protocols commonly utilise heavy resistance training (HRT), yet despite the depth of research supporting the positive effects HRT has on subsequent explosive movements (6, 15, 21, 22, 27) it has limited practicality in a competition environment. As such alternative protocols within competitions may need to be considered. Recent research has focused on varying potentiation protocols including ballistic exercise (30) utilising a variety of bench throws (36), loaded jumps (27), and plyometric exercises (25). Protocols involving jumps have been used within various research studies (26, 32) showing mixed results yet heavier loads in the form of bar loaded squat jumps (27) or weighted vests (12) have increased their effectiveness. Plyometric exercises have also been used during potentiation protocols but with no substantial conclusions made (25). However, there is a significant amount of research which supports the use of drop jumps inducing a performance increase (18, 25, 33) suggesting that the increased eccentric pre-loading may facilitate greater neural excitation (33). It also appears that multiple sets of plyometric activities have a greater effect on subsequent performance (33). Finally, the use of resisted band squats has predominately been used within complex training methods (1) but a single study has shown its use as a potentiation stimulus with similar performance enhancements to HRT (4).

PAP appears to have very little benefit on increasing maximum force production but has been shown to enhance the rate at which force is produced at a given velocity (30). The dive start in swimming is a time restraint activity which requires rapid force production in as little as 0.79

s (24). Alongside this, the start (time to 15-m) has been shown to be an important factor in overall sprint performance contributing to 30% of 50-m swim time and also been significantly correlated to jump height and peak power output (38). PAP therefore would be a plausible preconditioning strategy to enhance power production in swimmers (10).

Previous research looking into the effect of PAP on swimming performance has focused on using dynamic resisted sprints in the water prior to performance (17). Even though positive improvements have been found over 50m swimming performance this method of inducing PAP may not be practical in a swimming competition due to poor availability of the training pool in the lead up to competition. If PAP was to be utilised to its full potential during swimming competitions, land based activities would be required. In addition to this the role of fatigue from the contractile history of the muscle has been well established with muscle fatigue and potentiation co-existing and the relationship dictating performance (31). Despite this, there has been limited research identifying optimal recovery time following a potentiation stimulus (20, 21) with previous research showing performance using recovery times from 15 seconds to 12 minutes (7 20, 21).

Therefore the aim of the current research study is to determine the optimal recovery time following three ballistic warm-up protocols to optimise performance in a CMJ and to explore how practical potential protocols effect 15m start performance.

METHODS

Experimental Approach to the Problem

The research protocol followed a randomised, crossover design where each participant was required to report for testing on 7 separate occasions. The first 3 sessions were used to determine optimal recovery time following each separate potentiation protocol. Recovery time was determined by counter movement jump (CMJ) height to determine the subject's peak power output. The following 4 sessions required participants completing four 15-m dive starts following a potentiation or control protocol separated by 48 hours.

P*articipants*

Eleven national level swimmers (8 men and 3 female) volunteered to participate in this study which was approved by St Mary's University Ethics Committee in accordance with the Declaration of Helsinki. All participants were informed of the risks and benefits of taking part in the study prior to completing a health screening questionnaire and giving written informed consent in order to participate. Participant characteristics can be found in Table 1. Throughout the study participants were asked to maintain their usual training regime and were asked not to consume alcohol or caffeine 24 hours prior to testing days. In order to participate in the current study, participants were required to have at least 2 years of resistance training experience.

Table 1 about here.

Procedures

Six weeks prior to the experimental trials, participants were familiarised with the potentiation protocols, which were added to their weekly programmes. The first 3 testing sessions were used to identify participants optimal recovery time following the potentiation protocols, and took place at the same time every day, separated by 24 hours. On arrival participants anthropometric measurements of mass (kg) and height (cm) were taken and a standardised warm-up consisting of a 5-minute ergometer row (Concept 2 Ltd, Wilford, Nottingham, UK) and a series of dynamic mobility exercises were conducted. Participants were given a 10 minute recovery period before a baseline CMJ was conducted to measure subject's peak power output using an inertia sensor (PUSH™, PUSH, Inc. Canada) validated to provide key metrics of jump performance (35). In order to measure peak power output the PUSH™ App (Apple, San Francisco, CA USA) was downloaded to a smartphone and 1 PUSH Band was positioned on the sacrum of the subject using a PUSH Waist Belt. Participants were instructed to place their hands on their hips, drop to a depth they felt comfortable with and jump vertically in an attempt to gain maximum jump height. Participants then completed a 20-minute recovery period before completing 1 of the 3 potentiation protocols. Following each potentiation protocol participants completed a single CMJ at 15 s and 3, 6, 9 and 12 min post. The optimal recovery times from these results were used to establish the recovery time during the experimental conditions.

Figure 1 about here.

During the experimental conditions (Figure 1), participants completed 4 additional testing sessions separated by 48 hours. Each testing session required participants to complete a dive 15-m start following a swim specific warm-up and a 20-min wait period used to simulate time spent in call room before a race (Table 2). During 3 of the testing sessions participants completed a potentiation protocol (Table 3) during the 20-minute wait. Recovery time between the potentiation protocol and the 15m dive start was set as the optimal recovery time observed for the group during the preliminary tests.

The 15 m freestyle starts were conducted under race conditionings and FINA rules and regulations. All 15 m starts were recorded using a Sony DCR-HC51E (Sony UK Headquarters, Surrey, UK) situated at the 15 m mark for video analysis through Dartfish Pro Analysis – version 7.0 (Dartfish, Fribourg 5, CH). Participants were instructed to swim as fast as they could to a distance further than 15 m. Reliability of 15 m sprint swim starts have previously been reported with an ICC of 0.987 (22)

Table 2 about here.

Potentiation protocols

The resisted band squat protocol was performed using 2 resistance bands (My Protein, UK). Participants completed 3 sets of 3 repetitions of band resisted squats with a 2-minute recovery period between sets. Each resistance band provided 60 to 150lbs of resistance (4). The resistance bands were placed over each subject shoulders and anchored to the opposite foot. The weighted jump protocol consisted of 3 sets of 3 repetitions of CMJs with an additional load of 15% of bodyweight using a weighted vest (4). Participants set themselves in comfortable jumping positions then lowered themselves to a predetermined height and rapidly accelerated themselves vertically to reach maximum jumping height. During the drop jump protocol participants completed 2 sets of 5 repetitions of drop jumps from a height of 45cm. Ten seconds rest was given to participants between repetitions to set themselves up on the box and 3 minutes rest between sets (25).

During the potentiation protocols, participants completed the protocols wearing athletic footwear and gym clothing. During the band squats and weighted jump protocol, participants lowered themselves to the same depth as a swimming start with their knee angle at between

135° to 145°. This was measured prior to completion of the protocol and observed by a member of the research team to ensure the correct depth was met. All participants were given verbal encouragement throughout the protocols.

Table 3 about here.

Statistical Analysis

Statistical analysis was performed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). Data is presented as mean ± SD and significance level was selected at $p \leq 0.05$ A repeated measures 1-way ANOVA with a Bonferroni post hoc test was carried out to determine if peak power output changed following the potentiation protocols and to assess the differences between 15-m start time between the swim specific warm-up and potentiation protocols. Effect sizes (ES) were calculated using Cohens D.

RESULTS

Ten out of the 11 participants completed all experimental trials fully. One female participant was unable to complete one of the 15-m trials as video analysis showed that the participant slowed down prior to the timing mark. For this reason this participant has been excluded from the results.

Figure 2 about here.

A repeated measures ANOVA indicated no significant differences between baseline CMJ and subsequent time points following the band squats, ($F_{(2.06, 18.56)} = 2.515$, $p = 0.107$), weighted jump, ($F_{(2.12, 19.079)}$ = 1.363, p = 0.281), and drop jump ($F_{(3.36, 30.25)}$ = 0.636, p = 0.615) (Figure 2). However notable increases in peak power output of 6.9%, 7.8% and 2.9% were observed during the band squats, weighted jump and drop jump protocols respectively following 6min, 3min and 15s.

The group mean for peak power in the band squat protocol was 6 minutes with 5 participants achieving their highest peak power at that time (3min N=2, 6min N=5, 9min, N=2, 12min N=2). The group mean for the weighted jump protocol was 3 minutes with 5 participants observing their highest peak power at that time (15s N=2, 3min N=5, 6min N=4). The mean for the drop jump protocol was 15 seconds with 5 participants observing their highest peak power at that time (15s N=5, 3min N=2, 6min N=2, 9min, N=1, 12min N=1).

Table 4 about here.

A significant difference was observed between 15-m start performance and different warm-up potentiation protocols ($F_{(1.646, 14.810)}$ =6.968, p = 0.01). Post hoc tests using the Bonferroni correction revealed that 15-m start times were significantly quicker in the band squats protocol (6.70 ± 0.45s) compared with the sport specific warm up condition (6.81 ± 0.42 s) (p = 0.04, ES = 0.30). A significant difference was also observed between the band squats protocol and the weighted jump protocol (6.86 ± 0.42 s) (p = 0.003, ES = 0.40). There was no significant difference between the weighted jump and drop jump protocol (6.84 ± 0.44 s) (p = 0.857, ES = 0.09), nor was there a significant difference between the swim specific warm up and the drop jump protocol (p = 1.000, ES = 0.04).

DISCUSSION

The results of the present study indicate that PAP can be utilised alongside traditional warm-ups, by including 3 sets of 3 repetitions of resisted band squats in a race timeline, to enhance swim start performance following 6 minutes recovery. Previous research has been inconstent with studies supporting the use of PAP (17) and others finding that potentiation protocols produce similar performance times compared to standard warm-up protocols (22).

Although the current study is unable to identify the cause of the increase in start performance it is most likely due to an increase in peak power output produced during the block phase of the start, possibly arising from myosin light chain phosphorylation (14). The use of resistance bands has been well documented in research surrounding power development (1) and more specifically the use of contrast training methods. Modifying traditional strength exercises, such as the back squat, with resistance bands alters the kinetics of the movement to allow the user to produce higher power output at the start of the movement and continue to apply high levels of force throughout (1). During low-volume and high-velocity movements, a greater force and power output have been observed (28), allowing for greater muscle activation during the concentric phase of the movement which is also believed to enhance PAP protocols.

No significant differences were seen on 15-m start performance during the weighted jump and drop jump protocol which are contradictory to previous research (18, 25, 32) which have shown to be the most effective ballistic methods in enhancing short duration athletic performance (26). Differences in protocols between studies may be one reason why differences in performance outcomes have been found. Previous research using drop jumps have implemented similar protocols (5) but with the current study using a much lower drop height. The height at which drop jumps are performed change parameters such as power and velocity (34) which may alter the effect it has on subsequent movements. As volume of the potentiating exercise is a known factor to influence subsequent performance, differences between studies volume of potentiation protocols need to be considered. The current study used a total volume of 10 CMJs whereas Tahayori (32) used a total volume of 15 CMJs. Individual differences can play large role in the effect PAP has on performance and as a result, protocols need to be highly specific. In the aforementioned studies, both sets of participants took part in sports with a high reliance of plyometric capabilities. Both sets of participant's may have a far greater training age compared to swimmers who rarely utilise the stretch shortening cycle (SSC) to its full capacity. Therefore, the utilisation of PAP through the use of plyometric activity may be dependent on the participant's ability to utilise their SSC. It is also interesting to note, previous research into plyometrics and PAP has shown only increases in performance where sprinting or CMJs have been used as the performance test, which relies greatly on plyometric capability (18, 25).

The secondary aim of the study was to find the optimal recovery time required from a potentiating stimulus to increase CMJ performance and despite the coexistence of potentiation and fatigue being the prominent reason for varied recovery time. This is the first study to show the effects recovery has on CMJs following ballistic potentiation protocols. Preliminary tests showed no significant time effect was found within any of the potentiation protocols however notable increases of peak power output were seen. Major championships are not won by significant differences. Thus, small improvements in performance measures, such as peak power, may be sufficient to enhance performance. However a limitation of the current study was that recovery times set for each condition were based upon the group average, not for each individual.

The current findings support the growing volume of evidence to support the view that shorter recovery times are necessary between ballistic potentiation protocols and subsequent performance in comparison to HRT (26). Optimal recovery times following HRT have been recommended between 8 to 12 minutes when using loads up to 87% of 1RM (21) whereas the longest recovery time shown in the current study was 6 minutes supporting previous findings (5). Intensity of potentiation protocols will directly impact recovery times as higher loads during HRT will produce both greater potentiation within the skeletal muscle but also a greater amount of fatigue which will require longer recovery periods. The reduced external loading placed on individuals during ballistic exercises may be a credible reason to why optimal recovery times are far less than HRT and also between the potentiation protocols in the current study. Resisted band squats provide greater external loading than 15% of BW used during a CMJ. However, there is contradicting research which suggests recovery periods following ballistic exercises are similar to those of HRT (4, 28).

The magnitude at which the potentiating protocols increased participants power values were lower in the current study compared with earlier studies which found 12% increase in mean power output following a 5-minute recovery using the same three recovery protocols used within this study (4). The present study measured peak rather than mean power output which may be one reason for the differences in results. It is also well established that individual differences have a contributing factor into the effects of PAP and resistance-training backgrounds may affect the result. Shorter recovery times have shown to be more beneficial in trained individuals. It is thought that this is because trained athletes are more sensitive to PAP protocols (6), which may explain why larger increases in performance have been previously seen. However, with both studies showing increases in performance, it suggests the use of resisted band squats may be a practical alternative to HRT when attempting to enhance explosive power. With these two studies being the only studies to have used resistance band to elicit a PAP response, further research is required to understand its use.

With the current research supporting the use of potentiation protocols on start performance more research is required to assess the effects PAP has on 50-m swimming performance. It would be reasonable to assume that faster times to 15-m would produce faster 50-m as 30% of the swim is attributed to the start (10). However, due to the body being buoyant in the water, no ground reaction forces are applied, therefore land based protocols arguably will have limited effect on swimming speed. There is limited research investigating the use of PAP over 50m performance. Tahayori (32) observed no significant difference between a traditional race-specific warm-up and a lower body PAP protocol over 50m. Adding to this research, Hancock (17) investigated the use of a PAP protocol compared to a swim specific warm up on 100m performance. While there was no significant difference observed between groups, there was a trend towards a significant improvement in performance over the first (p=0.51) and second (p=0.058) 50m split times in the PAP trial. This equated to an improvement of 0.26 and 0.27 seconds in the first and second 50m, respectively. Given that sprint swimming races are often won by narrow margins, this is a considerable improvement.

The current research has only investigated a potentiation protocol with the use of a single exercise and as it is common in many warm-up protocols to include a combination of exercises. It may be plausible that including band resisted squats within a prolonged warm-up protocol could enhance performance further. Further research in implementing race times which incorporate a number of preconditioning strategies is required. With any PAP protocol, there is always a recovery period following the potentiating stimulus and research should look into what can be done during this period to either maintain muscle potentiation without the onset of fatigue or even increase muscle potentiation. In addition future research could also consider using individualized recovery durations rather than using times based upon the group average.

In summary the current study clearly supports the use of practical potentiation protocols to enhance start performance, specifically implementing 3 sets of 3 repetitions of resisted band squats following a traditional warm-up.

PRACTICAL APPLICATIONS

The findings will benefit strength and conditioning practitioners who are implementing preconditioning strategies on a pre-race timeline. The current findings suggest that practical protocols are likely to enhance 15m swim start performance when used with a traditional swimming warm-up in comparison to the use of a traditional swimming warm up alone. Due to its use of simple equipment, the band squats would be the most practical method to be used within a competition environment.

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FIGURES

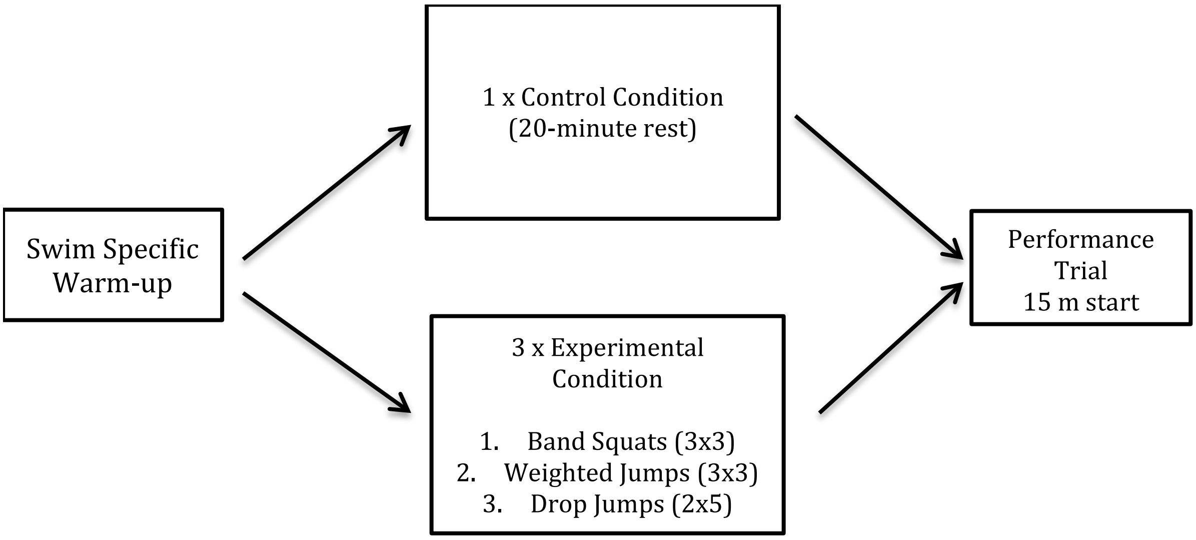

Figure 1. Experimental design of the main trials

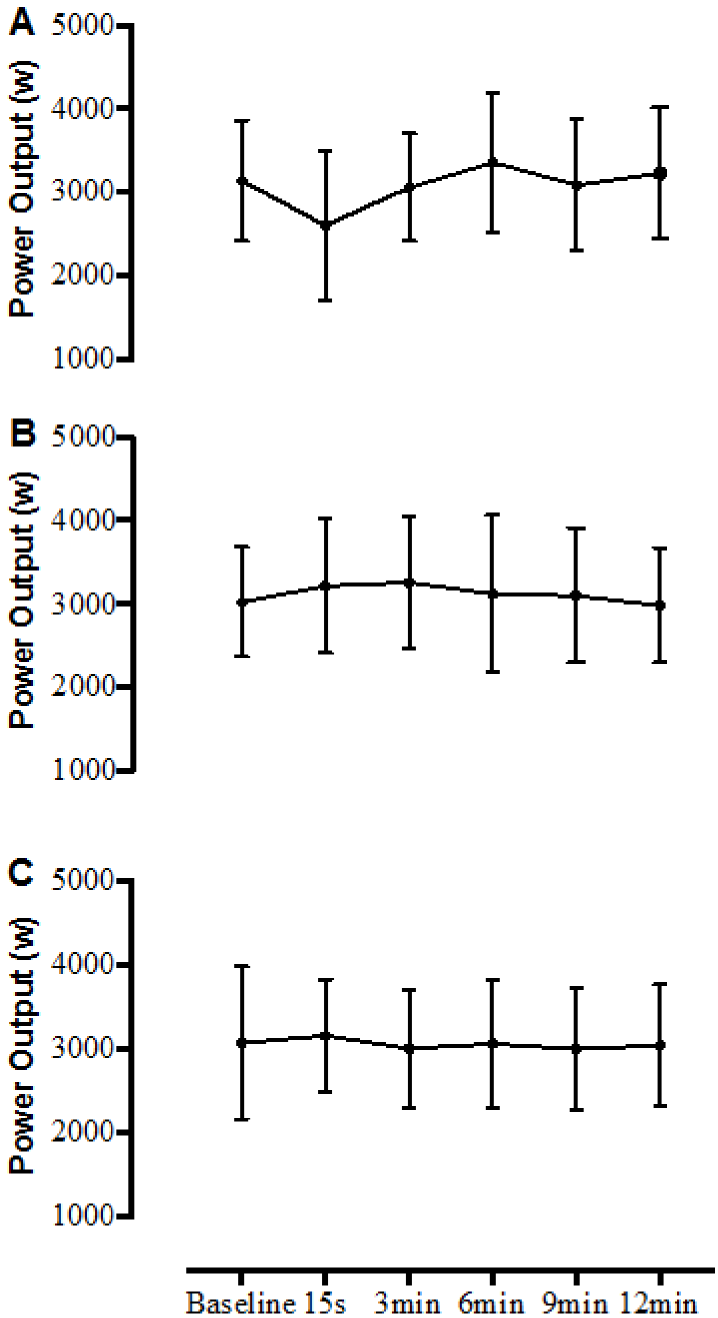

Figure 2. Absolute Peak power output from countermovement jumps at baseline and 15s, 3 min, 6 min, 9 min and 12 min following the A – Band Squat, B - Weighted Jump, C - Drop Jump potentiation protocols. Values are reported as mean ± SD.

TABLES

Table 1. Participant's baseline characteristics during the first testing session (n=11)

Characteristics	Mean ± SD
Mass (kg)	78.97 ± 12.80
Height (cm)	182.13 ±10.27
Age (yrs)	19.00 ± 1.25
15m swim (s)	6.81 ± 0.42

Table 2. Standardized swimming warm-up

Warm-Up	**Exercises**
Dynamic Mobility	1. 5 mins Myofasical release
	2. Spideram x10
	3. Inchworms x10
	4. Glute Bridge x10
	5. OH Lunges x 6ea
	6. Arabesques x6
	7. Dynamic Squats x6
Swim specific warm-up	1. 400 swim
	2. 4x50 as kick/drill
	3. 4x50 Freestyle, Rest 15s (*1- build, 2-25 fast/25 easy, 3-easy, 4-pace)*
	4. 2x15m Starts (*At race speed)*

Table 3. Sets and repetitions for exercises within each protocol.

Protocol	Exercise	Sets	Reps	Optimal Recovery
Band Squat	Band Resisted Squat	3	3	6 minutes
Weighted Jump	Weighted Jump Squat	3	3	3 minutes
Drop Jump	Drop Jump (45cm)	2	5	15 seconds

Table 4. Percentage change of peak power output (PPO) in countermovement jumps from baseline to peak during each potentiation protocol including coefficient of variation (CV).

Potentiation Protocol	PPO at baseline (w)	PPO change to peak (%)	CV %
Band Squat	3142 ± 724	6.9	13.4
Weighted Jump	3024 ± 662	7.8	10.2
Drop Jump	3071 ± 912	2.7	19.0