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Manuscript Title: The Effects of Postactivation Potentiation on Sprint and Jump Performance of Male Academy Soccer Players

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The Effects of Postactivation Potentiation on Sprint and Jump Performance of Male Academy Soccer Players

ABSTRACT

The purpose of this investigation was to evaluate the postactivation potentiation (PAP) effects of both dynamic and isometric maximum voluntary contractions (MVCs) on sprint and jump performance and establish whether PAP methods could be used effectively in warm up protocols for soccer players. Twelve male soccer players performed 4 warm up protocols in a cross over, randomised and counterbalanced design. In addition to a control warm up, subjects performed dead lift (5 repetitions at 5RM), tuck jump (5 repetitions) and isometric MVC knee extensions (3 repetitions for 3 seconds) as PAP treatments in an otherwise identical warm up protocol. After each treatment the subjects underwent three 10m and 20m sprints 4, 5 and 6 minutes post warm up and three vertical jumps (VJ) at 7, 8 and 9 minutes post warm up. Repeated measures ANOVA showed no significant differences in the first 10m ($p=0.258$), 20m ($p=0.253$) sprint and VJ ($p=0.703$) performance and the average 10m ($p=0.215$), 20m ($p=0.388$) and VJ ($p=0.529$) performance between conditions. There were also no significant differences in performance responses between the strongest and weakest subjects but large variations in individual responses were found between the subjects. The findings suggest that there was no significant group PAP effect on sprint and jump performance following dynamic and isometric maximum voluntary contractions compared to a control warm up protocol. However the large variation in individual responses (-7.1% to +8.2%) suggests PAP should be considered on an individual basis. Factors such as method, volume, load, recovery and interindividual variability of PAP must be considered in the practical application of PAP and the rigorous research design of future studies to evaluate the potential for performance enhancement.

KEY WORDS: warm up, power. strength, individual responses

INTRODUCTION

Speed, strength and power are all determinants of athletic performance and their optimisation in training or competition can be enhanced through an appropriate warm up. A warm up is undertaken prior to any athletic event with the majority of effects being attributed to temperature related mechanisms (3). However a mechanism currently receiving increased research attention is postactivation potentiation (2). Postactivation potentiation (PAP) is defined as an increase in muscle twitch and low frequency tetanic force after a previous conditioning contractile activity (20). Evidence suggests that PAP may enhance the ability of muscle to produce more force at a faster rate following previous muscle contractions. Over the past decade research has focussed on the effects of PAP on athletic performance using dynamic movements (1, 8, 13, 16, 21, 24) and isometric maximum voluntary contractions (6, 7, 9).

Although both dynamic movements and isometric maximum voluntary contractions (MVCs) have been used to elicit a PAP response, a number of exercises and protocols have been utilised. The majority of research on dynamic exercise in the lower body has used the squat exercise (2, 13, 16, 24) with the number of repetitions, intensities and rest periods varying amongst studies. Plyometric exercises have been used by Hilfiker et al. (10) and Masamoto et al. (15) in the form of drop jumps and double-legged tuck jumps, with a number of studies using isometric MVC leg extensions (6, 7) to elicit a PAP effect. Therefore the wide variety of methods used to enhance PAP highlights the uncertainty of the most effective protocol to elicit a PAP response (16) and few studies have been undertaken that compare different methods of eliciting PAP.

The majority of research in the lower body has tested PAP using the vertical jump test (8, 12, 13, 21, 24) with other studies using the horizontal jump (21) and knee extension performance (7). To date, only two studies found (4, 16) have examined the effects of PAP on sprint performance. Significant improvements in sprint performance were found at 40m following 3 repetitions at 90% 1RM of heavy loaded squats (16) and at 10 and 30m following 10 single repetitions at 90% 1RM of the back squat (4). These studies provide evidence that PAP has a beneficial effect on sprint performance, however further research is required to support these findings.

Although research on sprint performance is limited, the results obtained from previous studies on jump performance are contradictory. Young, Jenner and Griffiths (24) and Gourgoulis et al. (8) showed significant improvement in vertical jump performance while Jensen and Ebben (12), Jones and Lees (13) and Scott and Docherty (21) found no improvement. Gourgoulis et al. (8) examined vertical jump performance following 5 sets of 2 repetitions at 20, 40, 60, 80 and 90% 1RM of the half squat exercise and found a 2.39% increase in jump height. An increase of 2.8% in loaded countermovement jump performance also occurred in the study of Young, Jenner and Griffiths (24) following a set of 5 half squats at 5RM. Jensen and Ebben (12) found a decrease in ground reaction force for countermovement jumps after a set of squats at 5RM with the jump at 10 seconds being significantly lower than the pre jump score. A decrease in countermovement and drop jump height also occurred in 8 males following a set of squats at 5RM at different rest periods (13). Scott and Docherty (21) showed no significant difference in mean and maximal vertical and horizontal jumps following a 5RM back squat. These studies therefore show a large variability in jump performance following a previous muscle contraction to induce PAP. A number of factors such as rest period, number of repetitions and intensity of lift are methodological reasons why contradictory results possibly occurred with factors such as strength, gender, age and genetics contributing to interindividual variability in response to PAP protocols (19).

This study was designed to assess the uncertainty regarding the most effective method to induce PAP, support the limited evidence on the effects on sprint performance and provide individual responses to PAP protocols similar to that of Hilfiker et al. (10). The purposes of this study were to: (a) determine the PAP effects on group sprint and jump performance; (b) compare the PAP effects of a weight exercise, plyometric exercise and isometric MVC on sprint and jump performance; (c) determine the effects of PAP on average performance; (d) evaluate the effects of strength levels on PAP response; (e) examine the variation in individual responses following PAP protocols. It was hypothesised that sprint and jump performance would significantly improve following the PAP treatments compared to the control warm up.

METHODS

Approach to the Problem

A repeated measures, cross over, randomised design involving 4 treatments (control, weight exercise, plyometric exercise and isometric MVCs) was used to evaluate the effects of PAP on sprint and jump performance and compare different methods of eliciting a PAP response. Sprint times were measured at

10 and 20m and jump performance was assessed using a standard countermovement vertical jump test (22). The effect of strength on response to PAP treatment was also evaluated alongside the individual responses of each participant.

Subjects

Twelve full time professional male academy soccer players (age, 18.3±0.72 years; stature, 176.72±5.03 cm; body mass 72.1±8.0 kg) participated in the study. All subjects had at least 12 months weight training experience (mean 25.7±6.9 months) with all players introduced to weight training at the club. Players were in the soccer season when the testing was conducted and competed once a week with resistance training undertaken twice a week. All participants were familiar with the exercises used as they were part of their training programme and were also familiar with the 20m sprint and vertical jump tests as these were part of their regular fitness testing battery. Institutional ethics approval was obtained and all subjects gave written informed consent before participating in any of the testing.

Procedures

Subjects performed 4 testing sessions over a 4 week period in a cross over, randomised and counterbalanced order involving the three potentiation protocols (weight exercise, plyometric exercise, MVCs) and the control protocol. The participants performed the testing at the same time of day in an indoor environment with participants instructed not to perform any training the day prior to testing. Players consumed their normal diet throughout the study but did not drink any caffeinated beverages in the 3 hours prior to testing. This was controlled through the academy, where players are fed at regular times throughout the day. Prior to any testing participants underwent both a strength test to determine their 5RM for the weight exercise and a familiarisation session on the isokinetic dynamometer. Figure 1. illustrates the study design.

Insert Figure 1 here

PAP Protocol: The subjects warmed up by performing 5 minutes jogging followed by dynamic exercises, followed by one of the 4 treatments. Following the PAP treatment and prior to assessment subjects undertook a 4 minute walking recovery period as performance enhancement following PAP exercise has been reported following a 4 minute recovery period (1, 6, 16, 24). The 4 treatment protocols were:

Control: No PAP treatment and participants had 4 minutes recovery following the dynamic exercises and were then assessed.

Weight exercise: Participants performed 5 repetitions of the deadlift exercise at an intensity of 5RM. The deadlift exercise was used as all participants were familiar with the exercise as it was part of their training program and it had not been previously used in the research. 5 repetitions at 5RM was utilised as Young, Jenner and Griifiths (24) found performance improvements using this volume and intensity of the squat exercise.

Plyometric exercise: Subjects performed 5 maximal repetitions of the double legged tuck jump exercise. This exercise was used as it is an exercise the subjects used as part of their training programmes, uses similar muscles to the deadlift and was chosen ahead of a high intensity plyometric exercise (e.g. drop jump) as the subjects had not previously performed this intensity of plyometric exercise. 5 repetitions were performed to try to match the volume of the deadlift exercise.

Isometric MVCs: MVCs of the knee extensors were performed on a Cybex 6000 isokinetic dynamometer. The leg was positioned at 90° of knee flexion and participants were instructed to perform maximal effort leg extensions against the lever arm of the dynamometer. The maximal effort leg extensions were performed for 3 repetitions of 3 seconds per leg with 15 seconds rest in between repetitions. This protocol was utilised as French, Kraemer and Cooke (5) found an increase in drop jump and knee extension maximal torque performance following this protocol.

Testing Protocol: Following the warm up protocol three 20m sprints at 4, 5 and 6 minutes post PAP were performed. Sprint times were measured at 10m and 20m using Newtest Powertimer 1.0 Testing System timing gates. Subjects began the test 0.5m behind the initial timing gate in a standing start (17) and were instructed to set off in their own time. Following the sprint tests the subjects performed 3 countermovement jumps on a Newtest Powertimer 1.0 Testing System jump mat at 7, 8 and 9 minutes post PAP treatment. A countermovement jump with no arm movement was performed, which involved subjects starting from an upright position with hands positioned on hips, then flexing the hips and knees and immediately jumping vertically as high as possible (22).

Statistical Analyses

For statistical calculations, the mean of the 3 sprints and jumps was used. Intraclass correlation coefficients were calculated for the 3 repetitions of sprints and jumps for the control condition using an excel spreadsheet by Hopkins (11). Intraclass coefficient correlation values were 0.812-0.83 for the 10m sprint, 0.787-0.801 for the 20m sprint and 0.946-0.948 for the vertical jump. Analysis of results was conducted using a factorial repeated measures analysis of variance (ANOVA) test with bonferroni adjustment on SPSS version 13.0 software (SPSS Inc., Chicago, IL). The alpha level was set at $P<0.05$ and the Huynh-Feldt adjustment was used where required based on a test of sphericty. Figures show the results as a percentage of the control protocol performance, with each control performance considered to be 100% of the individual's maximal performance (i.e., a sprint time of less than 100% and a vertical jump score greater than 100% represent an improved performance). Additional comparisons were also made between the strongest and weakest subjects based on their 5RM deadlift in relation to their body weight. The strongest subjects were those above the average 5RM dead lift in relation to body weight with the weakest group being those whose value was below the average.

RESULTS

First Sprint and Jump Performance Post PAP

Figure 2 shows each PAP protocol result relative to the control results for the 10 and 20m sprint at 4 minutes and vertical jump at 7 minutes post PAP. 10m and 20m sprint performance improved to 99.43±2.93% and 99.79±2.64% of the control result following the deadlift protocol, with vertical jump also improving to 101.01±4.70% and 100.61±5.92% of the control following the deadlift and tuck jump warm up protocols, however no significant improvements were found for any protocol.

Insert Figure 2 here

Average Sprint and Jump Performance

Figure 3 shows the average performance changes for 10m and 20m sprint performance at 4, 5 and 6 minutes and vertical jump performance at 7, 8 and 9 minutes. Sprint and vertical jump performance improved compared to the control following both the deadlift (10m=98.88±1.87%, 20m=99.38±1.67%, VJ=101.42±3.18%) and tuck jump (10m=99.74±2.01%, 20m=99.96±1.84%, VJ=100.37±3.24%) warm up protocols but decreased following the isometric MVCs (10m=100.25±2.99%, 20m=100.31±2.47%, VJ=99.85±4.63%). However, there were no significant differences between any of the PAP conditions each assessment.

Insert Figure 3 here

Effect of Strength Levels

Table 3 shows the results for each test when comparing the 6 strongest (72.5±8.22kg) and 6 weakest subjects (62.5±8.80kg) based on their 5RM deadlift. The table illustrates that the strongest group performed better in all tests except for the 10m sprint and vertical jump following the MVC protocol. However, there were no significant differences between the strongest and weakest groups in response to the PAP protocols each assessment

Insert Table 1 here

Individual Responses

Figure 4 shows the mean change in performance of the responders and non responders for each PAP protocol and assessment. Figure 4 illustrates the individual changes of each subject for each test and PAP protocol (where no bar appears for a subject this represents a 0% change). The graph illustrates that the range of responses by each individual varies between participant, test and PAP method used.

Insert Figure 4 here

There is a great consistency between the results for the 10 and 20m sprint with patterns emerging on the responders and non responders to the PAP protocols. For sprint performance participant numbers 1 and 3 had large positive responses following all PAP protocols, especially the deadlift and MVC protocols, with improvements up to 4.6%. However there were also participants who responded negatively to the PAP protocols with participants 2, 9 and 10 sprint performance decreasing. A 6.4% decrease in 10m sprint performance was found for participant 9 following the MVC protocol.

Large individual responses were also evident for vertical jump performance. Participants 9 and 10 responded negatively to all PAP protocols with only participants 1, 7 and 11 responding positively to all methods. However large individual gains were made in vertical jump performance by a number of participants with participant 1 having the greatest improvement of 8.2%, following the MVC protocol.

Insert Figure 5 here

DISCUSSION

The present study was undertaken to evaluate if there were any PAP effects of two forms of dynamic exercise and isometric MVCs on sprint and jump performance and it was hypothesised that sprint and vertical jump performance would both improve following each PAP warm up protocol compared to the control warm up. The main findings of this study however, showed no significant group effects of any PAP treatment on sprint and jump performance and that there were no significant differences between any of the

PAP methods.

Although no significant changes were evident, 10 and 20m sprint at 4 minutes post PAP and vertical jump performance at 7 minutes post PAP were improved following the dead lift warm up protocol. Average sprint and vertical jump performance across the three tests were also improved following the deadlift and tuck jump warm ups, showing a positive effect on subsequent performance. However, as no tests at the level of neuromuscular activation (e.g. EMG or twitch) were undertaken the mechanism responsible for this trend towards an improved performance could not be assessed. Given the strength of the cross over, randomised and counterbalanced research design that was used, the slightly improved performance following the dead lift and tuck jump protocols is attributable to PAP methods utilised in the warm up protocols, even though the group responses were not statistically significant.

Only two studies (4, 16) have assessed the effects of PAP on sprint performance. Mcbride et al. (16) found a significant 0.87% improvement at 40m (p=0.018) following a set of heavy loaded squats (3 repetitions at 90% 1RM) whilst Chatzopolous et al. (4) found a 2.6% improvement at 10m and 1.77% improvement at 30m 5 minutes post 10 single back squat repetitions. Both studies showed sprint performance could be enhanced following PAP protocols; however, it is difficult to compare these investigations with the present study due to the different protocols utilised. A high degree of variability exists in the repeated ballistic action of sprinting (22, 23) with participants being unable to perform identical starts and body position changing at the end of a sprint (16) being possible reasons why no significant improvement occurred especially at short distances such as 10m and 20m.

A number of studies have analysed the effect of PAP response on vertical jump performance. Studies by Radclife and Radcliffe (18), Young, Jenner and Griffiths (24) and Gourgoulis et al. (8) found contradictory results to the current study, with jump performance significantly improving by 1.5%, 2.8% and 2.39% respectively. A number of studies (12, 13, 14, 21) all found similar results to this study with no significant improvement found in jump performance, however these studies did use a variety of vertical, broad and drop jumps to measure PAP following a set of squats with different rest periods, volumes and intensities of weight exercise and experience of subjects used compared to the current study. A possible reason why no significant improvement in vertical jump occurred in this study is that the test was performed 7 minutes after the PAP treatment. Sale (20) stated that the longer the recovery between the end of the conditioning activity and beginning of performance, the greater the recovery from fatigue but also the greater decay of the PAP mechanism. The 7 minutes recovery may be too long for PAP to still be evident, with the sprints also causing a greater fatigue than passive or low intensity exercise. However, as performance was slightly improved following the dead lift and tuck jump protocols it may be that some PAP was still induced. To find a significant enhancement in vertical jump it may have been more appropriate to use a separate testing session from the sprints with a 4 minute recovery period.

A wide variety of methods have previously been used to elicit a PAP response, which highlights the uncertainty of the most effective method to induce a PAP effect (16). This study improved on previous research by comparing three different methods to elicit PAP in a cross-over, randomised and counterbalanced design against a control protocol. Although there was no significant group difference in performance changes following each method the results did vary with average performance tending to improve following the deadlift method, improving only slightly following the set of tuck jumps and decreasing following the isometric MVC protocol. Performance changes may have differed between the three methods due to the volume and intensity utilised for each method. The 5 repetitions at 5RM used for the deadlift was similar to the volume and intensity used by Young, Jenner and Griffiths (24), Jensen and Ebben (12), Jones and Lees (13) and Scott and Docherty (21) and provided a performance improvement of 1.12%, 0.62% and 1.42% for 10m, 20m and vertical jump performance. The use of the tuck jump as a plyometric exercise to induce PAP only improved performance slightly by 0.26%, 0.04% and 0.37% respectively and has only been researched once before by Masamoto et al. (15) who found improved 1RM squat by 0.6% following 3 tuck jumps. However when Masamoto et al. (16) and Hilfiker et al. (10) used a drop jump a 3.5% ($p<0.05$) increase in squat occurred (15) and a 2.2% ($p<0.05$) improvement in countermovement power occurred (10). It is likely that the trend towards improved performance is due to similar mechanisms as for the weight exercise, with the explosive type loading of the plyometric exercise enhancing the excitability of the fast twitch motor units and therefore priming these units to play a more significant role in performance (15). However, 5 repetitions of a relatively low-force intensity plyometric exercise such as the double legged tuck jump may not have been great enough to create a PAP effect (16). It may have been more appropriate to use a greater number of repetitions or use a higher intensity plyometric exercise e.g. the drop jump to induce a greater PAP response. The isometric MVCs protocol decreased sprint and jump performance possibly due to fatigue being caused by the high intensity contractions separated by short rest periods. The 15 seconds rest used in this study between the MVC contractions may be the reason performance decreased due to the fatigue of the muscles in between MVCs. Although French, Kraemer and Cooke (6) found improved drop jump and knee extension performance following 3 repetitions of 3 seconds they used a 3 minute rest periods between contractions. Therefore the selection of intensity and volume for all exercise types is important in eliciting a PAP response.

An important consideration in the literature is the experience of the athletes used to induce a PAP, with Ebben (5) stating that there is a relationship between strength and PAP. This study demonstrated that stronger subjects generally had faster sprint times and greater vertical jump performance than the weaker group. However, there was no significant difference in response to PAP between the strongest and weakest groups, although vertical jump performance did improve in the strongest group following the dead lift by 2.6% and tuck jumps by 1.35% compared to a 0% change and a decrease of 0.6% in the weaker group. These results are similar to those of Gourgoulis et al. (8) who found the strongest group improved vertical jump by 4.01% compared to only 0.42% in the weakest group. These results support the suggestion that strength levels influence the magnitude of PAP effects, but in the present study the magnitude of difference in response was not significantly different between the strongest and weakest participants. The differences in speed between the strongest and weakest subjects were also not significant in the study of McBride, Nimphius and Erickson (16), which may have been due to there being little difference in strength between the two groups.

Other individual factors alongside strength may influence the response to a previous contractile activity and Gullich and Schmidtbleicher (9) concluded that PAP response varied greatly between individuals, which was apparent in the current study. Performance changes varied between participants, PAP protocol and assessment with performance changes ranging from -7.1% to 8.2% compared to the control protocol. These results suggest that an interindividual variability does exist in response to PAP with a number of variables including training age, training status, chronological age, genetics (muscle fibre type), gender and strength levels effecting response to PAP (19). The individual variability, with some participants responding positively and some not responding has implications for the use of PAP with individual athletes. Coaches and athletes are advised to establish if they are responders or non responders in a training environment, prior to recommending or rejecting PAP protocols as part of a standardised warm up.

The results from this study found that sprint and jump performance did not significantly improve following a weight exercise, plyometric exercise or isometric MVCs warm up protocol when compared to a control warm up involving no PAP method. There was no group difference between any of the responses in initial or average performance to the PAP methods and there was also no significant difference in response based on the strength levels of the participants. However a number of factors need to be considered when evaluating the effects of PAP, including method, volume, load used, recovery time and as well as interinvidual variability including training age, training status, chronological age, genetics (muscle fibre type), gender and strength levels. Therefore further research is required to clarify the variation in reported effects of different PAP protocols on a number of performance variables, using a strong research design such as that used in the present study.

PRACTICAL APPLICATIONS

Although this study failed to show any significant PAP effect on group sprint and jump performance from previous research and the small but non-significant improvements that occurred in this study, it may be possible to enhance individual performance using PAP methods in a warm up protocol. The greatest gains of using PAP appear to be on an individual basis with a large variability in the individual responses to PAP protocols found in this study. The individual changes in performance varied between a decrease in performance of 7.1% to an improvement in performance of 8.2%. Therefore coaches, fitness specialists and players themselves need to examine individual responses to PAP methods during training to establish if performers are either responders or non responders prior to either implementing or rejecting PAP procedures into individual warm up and performance preparation routines. Given the variability in both individual response and research evidence, practitioners need to consider a number of factors including method, exercises, intensities, volumes and recovery time to fully benefit from the application of the underpinning theory of PAP. Although it may seem a considerable task to determine individual responses for different athletes possible improvements of up to 8% would suggest it is worthwhile undertaking to establish individuals that do respond positively and consistently to PAP procedures.

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FIGURE LEGENDS

Figure 1. Full Study Design

Figure 2. The effect of PAP on performance in 10 and 20m sprints and vertical jump

Figure 3. The average effects of PAP on performance in 10 and 20m sprints and vertical jump over a number of subsequent tests.

Figure 4. The average of responders and non responders to each PAP protocol for each test.

Figure 5. Individual performance changes compared to the control for each PAP method for the (a) 10m, (b) 20m and (c) vertical jump assessments.

Figure 1. Full study design

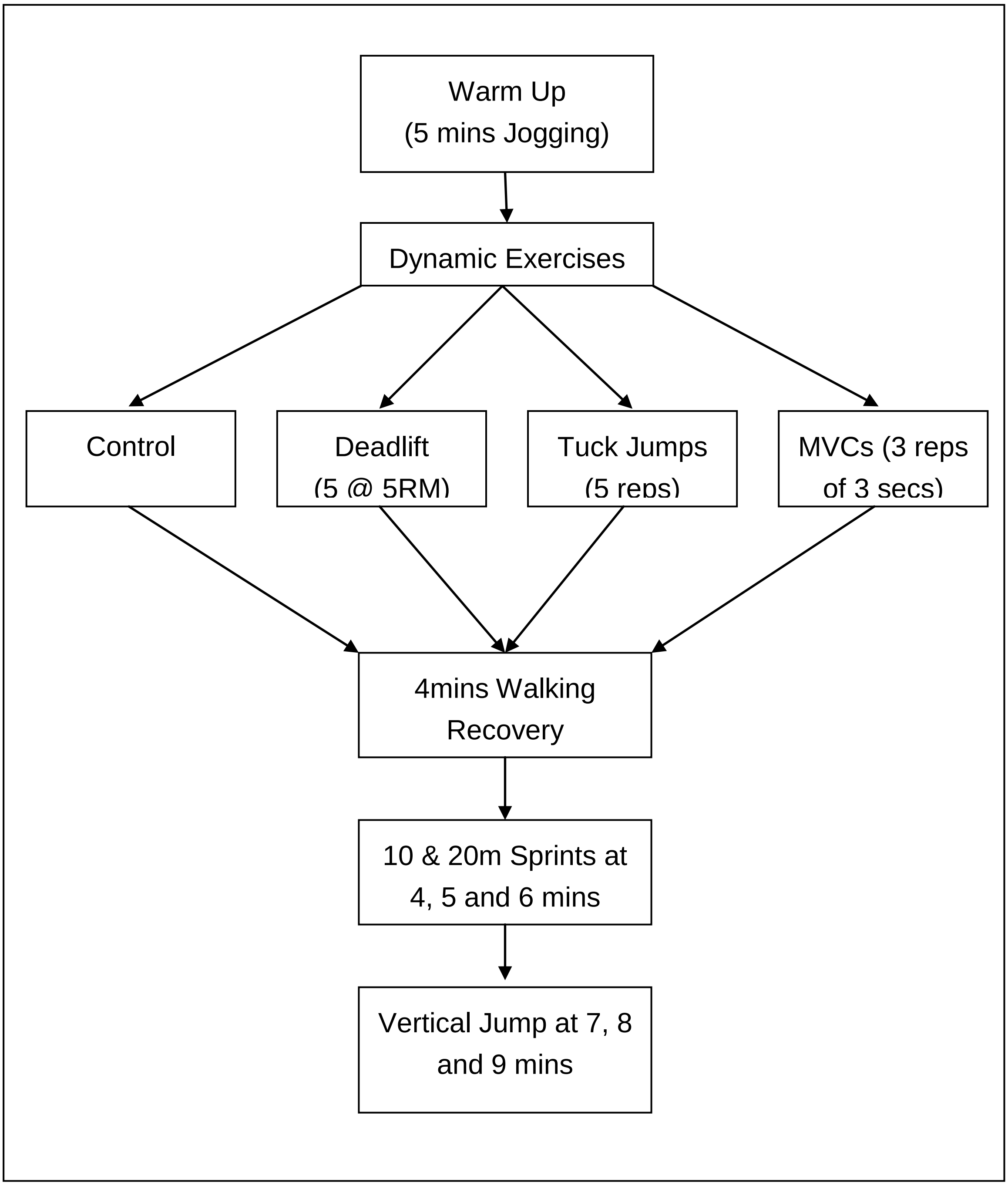


Figure 2. The effect of PAP on performance in the first 10 and 20m sprints and the first vertical jump tests.

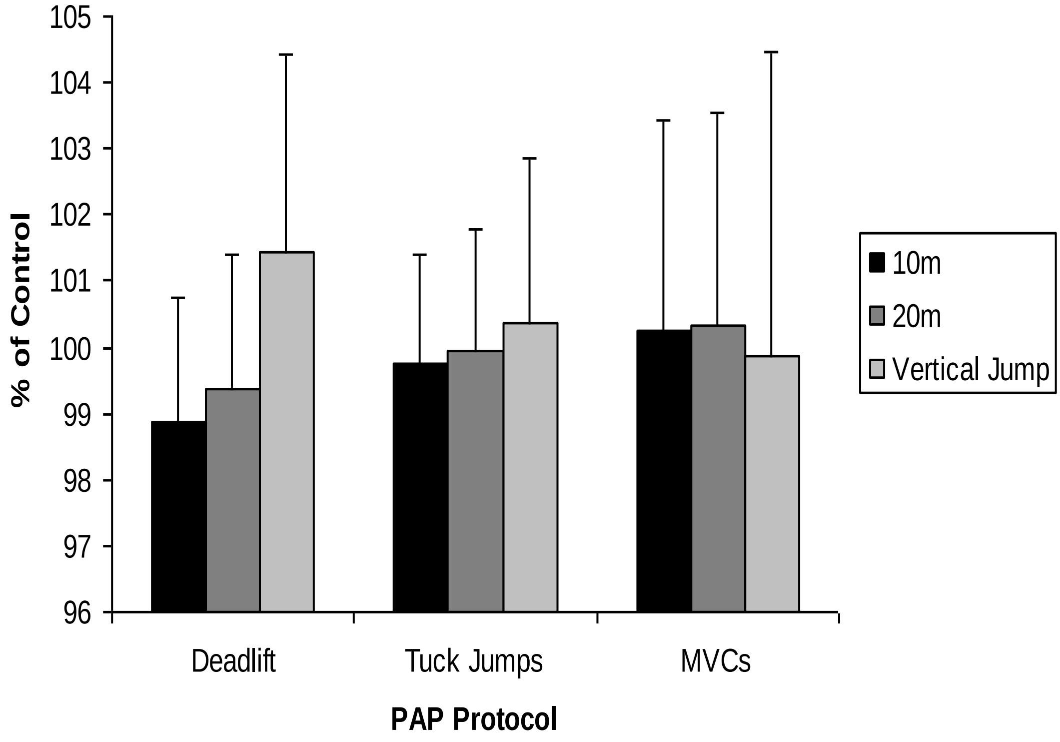


Figure 3. The average effects of PAP on performance in 10 and 20m sprints and vertical jump over a number of subsequent tests.

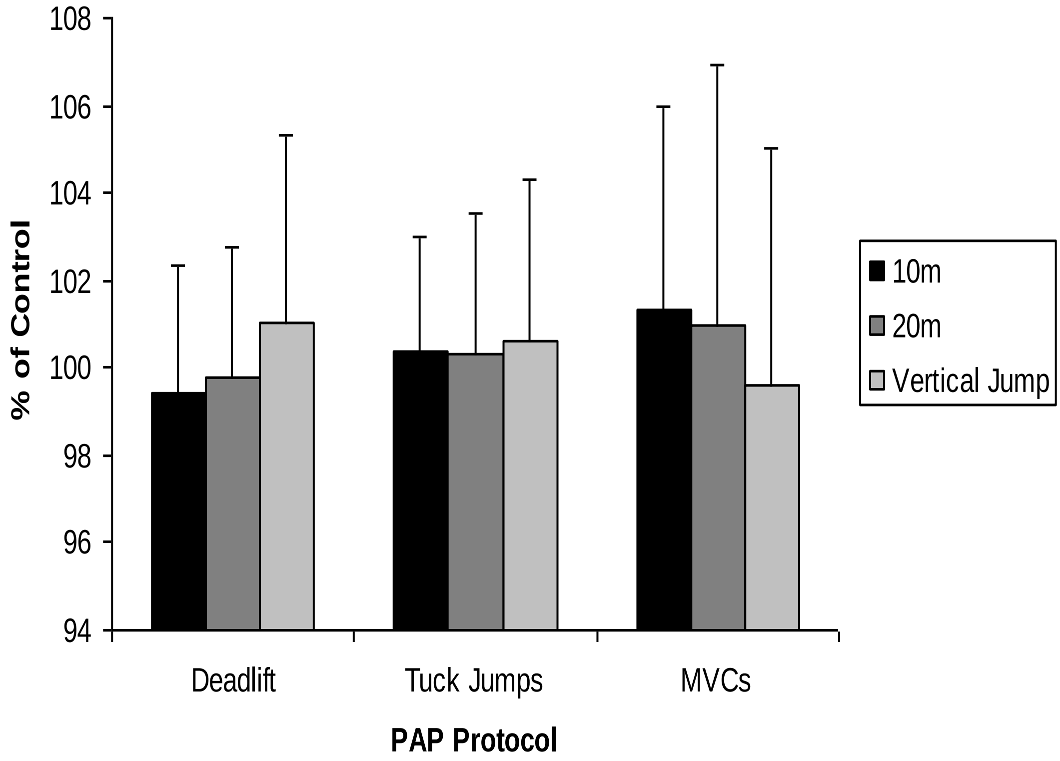


Figure 4. The average of responders and non responders to each PAP protocol for each test.

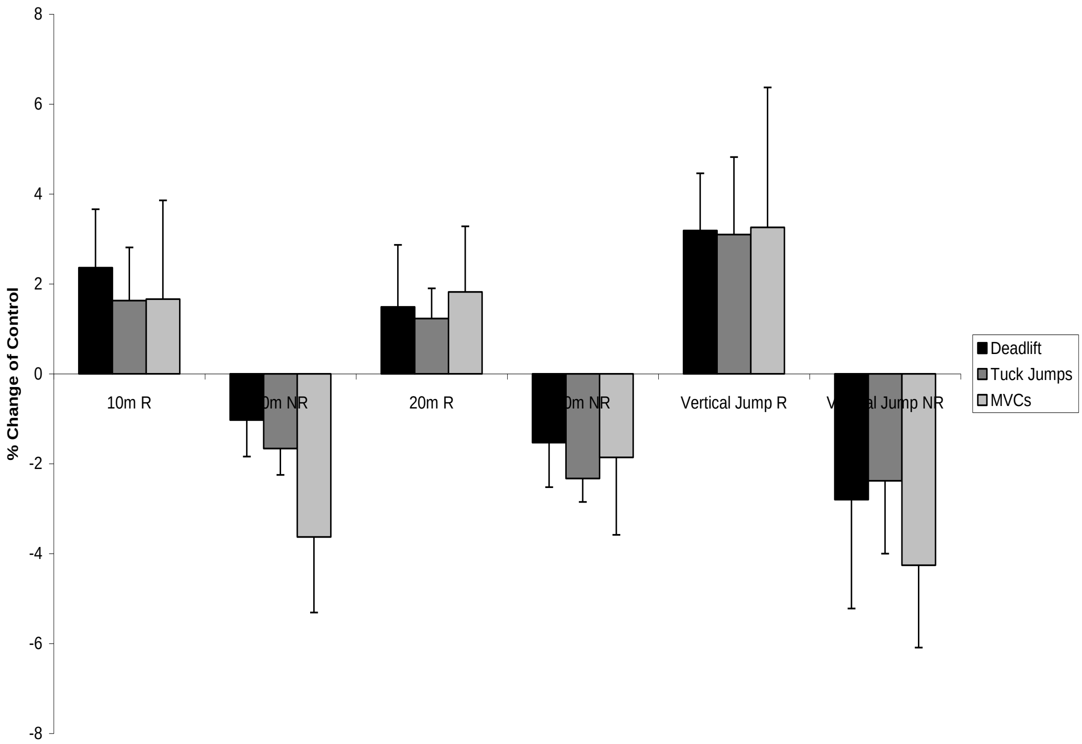
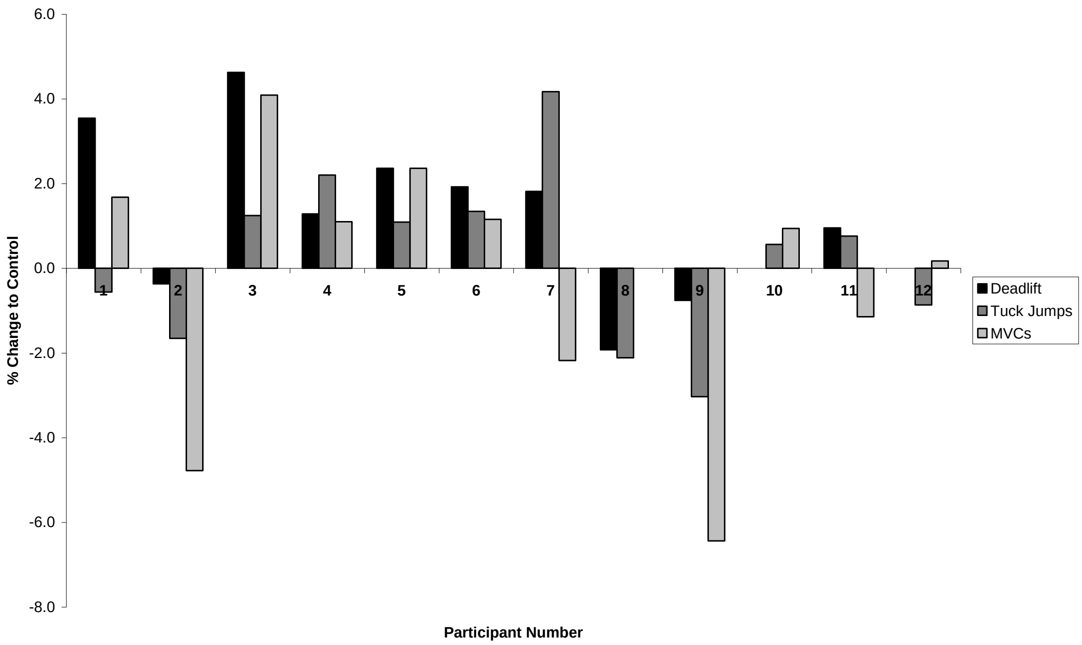
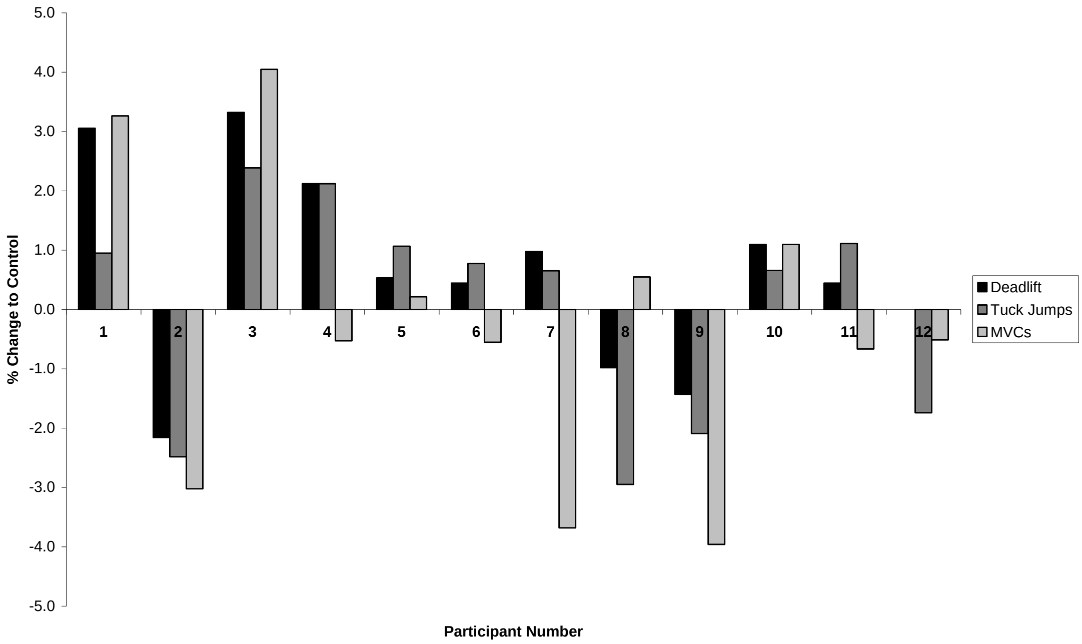


Figure 5. Individual performance changes compared to the control for each PAP method for the (a) 10m, (b) 20m and (c) vertical jump assessments.

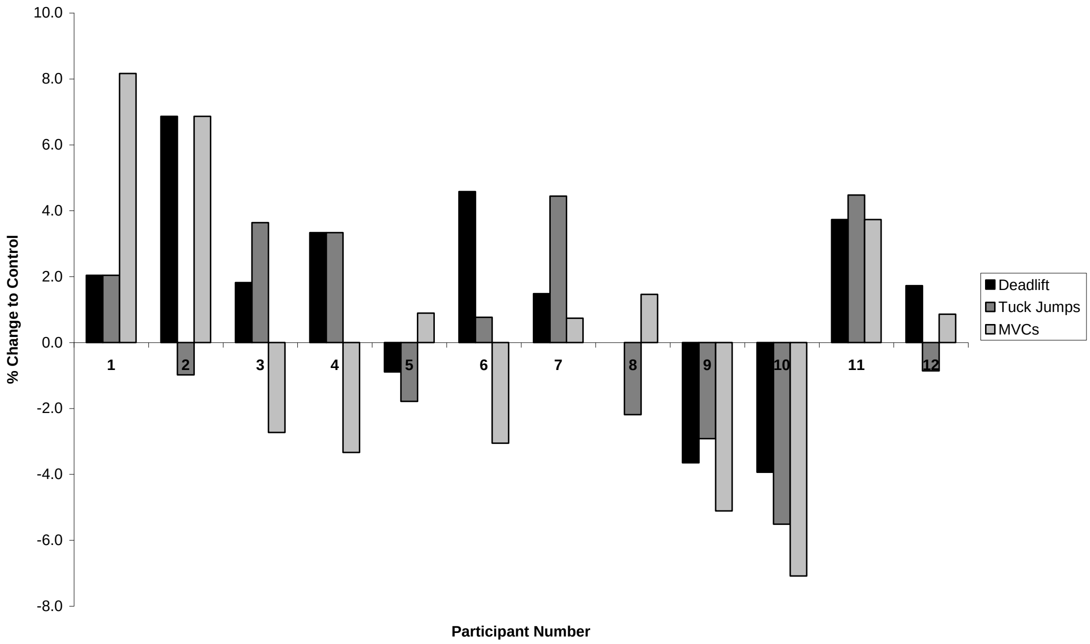
(a)



(b)



(c)


10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
% Change to Control
1
2
3
4
5
6
7
8
9
10
11
12
Participant Number
Deadlift
Tuck Jumps
MVCs

TABLES

Table 1. Comparison of Strongest vs Weakest Participants

		Strongest (n = 6)	**Weakest (n = 6)**
	5RM Dead lift (kg)	72.5 ± 8.22	62.5 ± 8.80
	Relative values (kg)	1.001 ± 0.04	0.874 ± 0.08
10m	Control	1.791 ± 0.05	1.815 ± 0.07
	Dead lift	1.768 ± 0.04	1.797 ± 0.07
	Tuck Jumps	1.788 ± 0.06	1.808 ± 0.07
	MVCs	1.808 ± 0.07	1.806 ± 0.06
20m	Control	3.082 ± 0.08	3.121 ± 0.08
	Dead lift	3.067 ± 0.06	3.096 ± 0.08
	Tuck Jumps	3.072 ± 0.08	3.128 ± 0.10
	MVCs	3.104 ± 0.07	3.116 ± 0.10
Vertical Jump	Control	40.78 ± 4.71	40.28 ± 5.00
	Deadlift	41.83 ± 4.25	40.28 ± 4.86
	Tuck Jumps	41.33 ± 4.78	40.0 ± 5.08
	MVCs	40.44 ± 4.23	40.50 ± 4.38