NAME: ROBERT DAVEY

UNIVERSITY NUMBER: ST05003426

DEPARTMENT: PHYSIOLOGY

INSTITUTION: UNIVERSITY OF WALES INSTITUTE CARDIFF
EFFECT OF POSTACTIVATION POTENTIATION UPON AN AGILITY TEST
ACKNOWLEDGMENTS

The author would like to express his appreciation to the following people:

To my principle supervisor Dr. Joseph Esphormes, thank you for your support and time throughout these past few months. Special thanks to my good friend Tom Hargroves, who assisted main data collection, without you, collecting subjects’ second agility score would not have been possible.

To my eleven subjects, who turned up to each testing session on time, even when facilities and equipment constraints meant rearrangements at the last minute, I owe a great deal of gratitude. For giving 100%, and never asking for anything in return, I thank you for doing so.

To the technical staff Mike and Danny, at the School of Sport, University of Wales Institute Cardiff, without your knowledge and time I would not have had the equipment required to collect my data.
ABSTRACT

The ability change direction while sprinting is a determinant of sport performance in many field and court sports. Performance has theorised to be enhanced following a maximal or near maximal contraction for a subsequent explosive sports activity; this may be possible by inducing acute Postactivation Potentiation (PAP). PAP refers to the phenomenon by which the muscle elicits a heightened state of skeletal muscle, facilitating the volitional production of force. The potentiated state has been attributed to phosphorylation of myosin regulatory light chains, which makes actin and myosin more sensitive to Ca\(^{2+}\), also to an increase in neural activation. Recent studies have applied the principles of PAP to short-term motor performance as well as using it as a method for producing long-term neuromuscular changes through complex training. Complex training couples a dynamic maximal strength training exercise, with a biomechanically similar plyometric exercise. Optimal performance occurs when fatigue has subsided but the potentiated effect still exists. No investigations have implemented the phenomenon of PAP to a subsequent agility performance. Sports involving explosive actions, at present, cannot assume that sprint training methods will enhance agility. The aim of this study therefore, was to assess whether the performance of 5 RM voluntary pre-conditioning contraction, would elicit a response on a subsequent agility test (n=11). Findings produced no significant evidence (0.05 alpha level) to support the hypothesis that performance and muscle activation increases after a pre-conditioning contraction, agility times were not significantly different pre and post-stimulus. However, no detrimental effects were observed. Before any conclusions can be made as to the efficacy of exploiting PAP as a warm up for explosive agility activities, or as part of a complex training protocol, further scientific research is required.
TABLE OF CONTENTS

Acknowledgements i
Abstract ii

CHAPTER I - INTRODUCTION
1.1 Rationale 1
1.2 Hypotheses 3

CHAPTER II - LITERATURE REVIEW
2.1 Postactivation Potentiation 4
2.2 Applying Postactivation Potentiation to Explosive Sports Activities 5
2.3 Acute Effects of Postactivation Potentiation as a Warm Up 7
2.4 Relationship between Postactivation Potentiation & Fatigue 9
2.5 Pre-conditioning Exercise 12
2.6 Subject Characteristics 14
  2.6.1 Muscular Strength and Fibre-Type Distribution 14
  2.6.2 Training Status 15
  2.6.3 Gender 16
2.7 Type of Subsequent Activity 16
2.8 Summary 17

CHAPTER III - METHOD
3.1 Study Design 19
3.2 Sample 19
3.3 Pilot Study 20
3.4 Experimental Procedure 21
  3.4.1 Familiarisation & 1RM determination 21
  3.4.2 Agility Trials Pre-Stimulus 23
  3.4.3 Main Testing 25
3.5 Reliability 25
3.6 Statistical Analysis 26
3.7 Ethical Guidelines 27

CHAPTER IV - RESULTS
4.1 One-Sample Kolmogorov-Smirnov Test 28
4.2 Paired Samples Statistics 29
4.3 Paired Samples Correlations 29
4.4 Paired Sample Test 30
4.5 Means & Standard Deviation for Pre and Post-Stimulus Agility Scores 31
4.6 Individuals’ Percentage Potentiation 32
4.7 Relationship between Power-to-Weight Ratio and Agility Post-Stimulus 33

CHAPTER V - DISCUSSION
5.1 Relationship between PAP & Fatigue 34
5.2 Power-to-Weight Ratio 35
5.3 Effect of the Pre-conditioning Exercise 36
5.4 Subject Characteristics 36
5.5 Subsequent Agility Performance 37
5.6 Technical Error of Measurement (TEM) 38

CHAPTER VI - CONCLUSION
6.1 Limitations 40
6.2 Practical Implications and Future Research 42

REFERENCES
References 43
APPENDICES

A Table of Subjects’ Characteristics
B Table Showing Subjects’ Agility Scores Pre and Post-Stimulus
C Power-to-Weight Ratio & Agility Post-Stimulus Score
D PAR-Q and Consent Form
LIST OF FIGURES

**Fig. 2.2** Sale (2002), hypothesised relationship between force and velocity. The dotted line represents an upward and rightward shift of the force-velocity curve, due to an increase in RFD. PAP cannot increase maximum isometric force or maximum shortening velocity because they determined with high frequency stimulation. In contrast, PAP can increase RFD at high frequencies, an effect that may increase the acceleration and therefore with loads intermediate between the extremes of maximum force and velocity. If this were to occur, the load-velocity relation would become less concave; therefore shift upward and to the right.

**Fig. 2.4** A model of the relationship between PAP and fatigue following an MVC protocol, adapted from Sale (2002). Potentiation is represented as a ratio of post MVC value to pre MVC value (post/pre). As a result of fatigue subsiding at a faster rate than PAP, a potentiation in performance of a subsequent explosive activity is realised at a specific point in time during recovery.

**Figure 3.4.2** Representation of the adapted Illinois Agility Run. Players sprinted 10 meters, went around the cone and returned to the centre cone level to the starting line. They then swerved in and out of the four markers, returning to the centre cone once again. Two 10 m sprints finished the agility course.

**Fig. 3.6** Percent Potentiation Equation (Chiu et al., 2003).

**Fig. 4.5** Means & Standard Deviation for Pre and Post-Stimulus Agility Scores.

**Fig. 4.6** Change in Individuals’ Percentage Potentiation.

**Fig. 4.7** The Relationship between Power-to-Weight Ratio and Agility Post-Stimulus.

**Fig. 5.6** Equation for measuring Technical Error of Measurement (d = difference between replicated measures, n = number of subjects).
LIST OF TABLES

4.1 One-Sample Kolmogorov-Smirnov Test
4.2 Paired Samples Statistics
4.3 Paired Samples Correlations
4.4 Paired Sample Test
CHAPTER I
INTRODUCTION
1.0 INTRODUCTION

1.1 Rationale

Some form of preparatory exercise or warm up prior to the commencement of any strenuous physical activity, is a well accepted practice by athletes, coaches and sports scientists. Various forms of warm up exist, however the traditional paradigm involves a short period of low intensity aerobic activity, followed by static stretching and activity specific movements (Schilling & Stone, 2000). The justification for including a period of static stretching during this preparation phase is however unclear. Although static stretching has been theorised to enhance performance (Holcomb, 2000; Martens, 2004), a number of researchers have reported that an acute bout of pre-exercise static stretching may actually reduce anaerobic performance in adults through decreases in force (Kokkonen et al., 1998; Fowles et al., 2000) and power (Young et al. 1998; Cornwell et al. 2001; Cornwell et al. 2002). Faigenbaum et al. (2005) reported that jumping and sprinting performance declined significantly in children after an acute bout of static stretching.

Attention has turned to warm up procedures that involve the performance of dynamic movements consequently elevating body temperature, improving kinaesthetic awareness, enhancing motor unit (MU) excitability and developing fundamental movement skills. A relatively new training technique, Complex Training (CT) couples a dynamic maximal strength training exercise, with a biomechanically similar plyometric exercise.

Optimising these variables during an explosive sports activity might be possible by inducing acute Postactivation Potentiation (PAP). PAP refers to the phenomenon by which skeletal muscle “facilitates the volitional production of force” (Hodgson et al., 2005, p 586). According to Hodgson et al. (2005), two theories or mechanisms have been proposed to explain the potentiated state of muscle after
maximal or near maximal stimulation. One is the phosphorylation of myosin regulatory light chains (RLC) (Gossen & Sale, 2000; Hamada et al., 2000; Sale, 2002; Chiu et al., 2003; Sale, 2004; and Hodgson et al., 2005), resulting in structural alterations of the myosin head, making it more accessible to actin (Szczesna, 2003; and Hodgson et al., 2005). Subsequently, there is an increase in both the strength of myosin-actin cross-bridges, and the rate at which myosin-actin cross-bridges move from a non-force producing state to a force-producing state (Szczesna, 2003; Hodgson et al., 2005). As a result, there is a potentiation of subsequent activity, with the effect lasting for up to 20 minutes after initial activation (Ebben et al., 2000).

The other theory is an increase in neural activation, which may occur through the recruitment of higher-order MU, better MU synchronisation, a decrease in pre-synaptic inhibition, or greater central input to the motor neuron (Gullich & Schmidtbleicher, 1996; Chiu et al., 2003; and Hodgson et al., 2005). It is possible that PAP is the result of interactions between neural and muscular mechanisms that are not well understood at this time. If PAP could be utilised effectively, it might prove to be an optimal warm up technique prior to competition, or could enhance the training stimulus of power exercises (Gullich & Schmidtbleicher, 1996).

The ability to sprint repeatedly and change direction while sprinting are determinants of sport performance in many field and court sports, as evidenced in sports such as soccer (Reilly et al., 2000; Mohr et al., 2002), rugby (Meir et al., 2001) and field hockey (Keogh et al., 2003). Motor skills common to these sports, for example sprinting, agility and jumping, have biomechanical, kinematic, and muscular similarities (Bobbert & van Zandwijk, 1999), but proving associations between these motor skills is inconclusive. Evidence shows a weak relationship between straight sprint performance and change of direction speed performance (Young et al., 1996; Baker, 1999; Tsitskarsis et al., 2003; Little & Williams, 2005). Little & Williams (2005) reported that acceleration (10-m sprint times), top speed (20-m sprint times), and agility were distinct motor characteristics in a group of
professional male soccer players. In comparing the relationship between
performance of the Illinois agility test and a 20-m sprint, Draper & Lancaster
(1985) reported a statistically significant low to moderate correlation (r =0.472).
This represents an emphasis on the specificity of training with specific movement
patterns, as straight sprint training appears to have little or no influence on the
improvement of sprinting that involves changes of direction (Young et al., 2001).

To the author’s knowledge, no investigations have implemented the phenomenon of
PAP to a subsequent agility performance. Sports involving explosive actions, at
present, cannot assume that sprint training methods will enhance agility. The aim
of this study therefore, is to assess whether the performance of 5 RM voluntary pre-
conditioning contraction, would elicit a response on a subsequent agility test.
Furthermore, the overall purpose is to help establish guidelines for utilising PAP as
a warm-up technique to enhance the performance and/or training stimulus of an
explosive sports activity.

1.2 Hypotheses

**H¹:** A pre-conditioning contraction will induce a significant increase in the
performance of a subsequent agility test.

**H null:** There will be no significant difference between the observed agility scores
of the two test conditions; pre and post conditioning contraction.

**H²:** Individuals with a high power-to-weight ratio will observe a greater response
to potentiation, evident in a faster agility time post stimulus.
CHAPTER III

METHOD
3.0 METHOD

3.1 Study Design

A quantitative approach to the assessment of whether the performance of 5 RM voluntary pre-conditioning contraction, would elicit a response on a subsequent agility test, was administered. Quantitative research involves the measuring of events using numerical data, and assumes that there is an objective truth which can be measured and explained scientifically. Subjectivity is minimised using this method (Thomas & Nelson, 2001).

3.2 Sample

Eleven healthy, physically active male students (mean, ± standard deviation (SD)) (age: 20.9 ± 0.9 years; stature: 176.3 ± 5.7 cm; mass: 73.8 ± 7.2 kg), were recruited from the University of Wales Institute Cardiff (UWIC). The criteria for selection included a history of competitive participation in an explosive sport (i.e., sprinting, rugby, soccer, tennis), previous resistance training experience, an ability to squat at least 1.5 times their body mass, and the passing of a physical activity readiness questionnaire (PAR-Q) examination (appendix D). Participants were instructed to abstain from any strenuous exercise including strength, power, aerobic training, forty eight hours prior to each testing session, the reason being, previous studies have reported that fatigue negatively affects neural activation responses, and highly trained subjects are more able to experiment PAP (Gullich & Schmidtbleicher, 1996; Chiu et al., 2003; Gourgoulis et al., 2003). Gullich & Schmidtbleicher (1996) commented that high anaerobic loads on the previous day lead to a reduction of the MVC effect on speed-strength performance. Recruits were also requested before each testing session to avoid alcohol, caffeine and the consumption of large meals for at least two hours prior to testing. Declaration that they did not ingest any performance enhancing ergogenic aids, in the form of illegal food supplements or medication related to performance, was sort.
3.3 Pilot Testing

Two of the eleven subjects completed several pilot testing sessions, two weeks prior to the main trials. The protocol for data collection was adapted from a combination of several studies (Radcliffe & Radcliffe, 1996; Young et al., 1998; Jensen et al., 1999; Ebben et al., 2000; Jensen & Ebben, 2003; Jones & Lees, 2003) for obtaining an individual’s 5 RM half-squat. Using methods described in section 3.3, the Smith machine bar, loaded with the athletes perceived 5 RM, was lowered to the desired position. From these prior studies, three or four trials were expected to be required for the subject to complete 5 repetitions with correct form. The subject decided if they could manage a higher weight, load was increased by 5 - 10 kg and the subject attempted another 5 repetitions. This process continued until the subject achieved their true 5 RM. A recovery period of 5 min between each set was implemented. The two participants in the present study however, obtained their 5 RM after the fifth trial; underestimation of their perceived 5 RM was to blame. Consequently the observed load at which the individual maxed out, was subject to criticism. After 3 or 4 sets subjecting one muscle group to isometric contractions, fatigue will become a major factor and the intensity at which the athlete can perform will decrease (Kraemer, 1997). Therefore, the observed 5 RM values for both participants were inaccurate. To account for possible fatigue due to underestimation, main testing involved the individuals’ 5 RM half-squat value being calculated from 1 RM trials. At 1 RM load, the athlete can perform more trials before fatigue negatively affects performance.

Orientating the goniometer at the correct locations (see section 3.3.1) on one participant proved difficult as he wore loose fitting tracksuit bottoms. For main testing, it was decided that participants should wear the correct attire of t-shirt, sport shorts and comfortable trainers.
The other pilot testing day, separated by three days to avoid fatigue, aimed to trial the Illinois agility run (described in section 3.4). The sample of males followed the warm up routine identical to that in section 3.4, and were demonstrated the correct running path. One problem arose from following the original protocol and using the timing gates in place of a standard stop watch. The Illinois Agility run traditionally requires the athlete to begin from lying face down behind the start line, and on command jumps to their feet and negotiates the course. From several time trials, it was observed that a break in the timing gate beam unintentionally occurred. On one occasion a subject bending down to get in the ready position, initiated recording by breaking the beam with his head. Secondly, the larger of the two individuals knocked the tripod holding the reflective plate out of synch, whilst jumping to his feet. Later testing trialled the commencement of the run from a standing position one metre behind the start gate. This eradicated any measuring error due to unintentional beam breaks, and was standardised for the main testing sessions using a clearly defined mark.

3.4 Experimental Procedure

3.4.1 Familiarisation & 1RM determination

Subjects reported to the laboratory on three different occasions over a one week period, with each experimental session held three days apart to avoid fatigue. All trials were performed at the same time of day, to minimise diurnal variations. Consumption of water was permitted during each test. Room temperature was maintained between 20 and 24 °C (Oregan Scientific BAA913HG). Session one was completed the week before main testing, familiarising the eleven males with experimental apparatus, and to determine the load to be used during the potentiation protocols by obtaining individuals’ one repetition maximum (1RM) half-squat.

During familiarisation, subjects’ stature and mass were determined, using a fixed stadiometer (SECA, UK) and calibrated electronic weighing scales (SECA, UK),
measured to the nearest 0.1 kg and 0.1 cm, respectively. They first performed a warm-up routine identical to the one performed during the subsequent main trial. This consisted of 3 minutes low intensity work (60 rpm at a resistance of 1 kg) on a Monark 874 E weighted cycle ergonometer (Monark, Varberg, Sweden). One dynamic stretch for each muscle group, designed to activate functional movement in the legs and trunk, preceded an activity specific warm up. This included 12 repetitions of the back-squat without load, in order for the investigator to assess technique and evaluate knee angle with a goniometer. To measure knee angle precisely, the goniometer was centered at the lateral femoral condyle, and pointed one end towards the greater trochanter at the hip and the lateral malleolus at the ankle (Chiu et al., 2003). Brackets were subsequently positioned below the bar to prevent any knee flexion above 90 degrees. This was followed by two sets of 5 repetitions using a resistance that was 40 and 60 % of subjects’ perceived maximum. Five minutes after the warm-up subjects began their first test condition.

The 1RM half-squat test was performed using methods previously described by Hoffman (2006). A 5 minute rest period was imposed between all attempts to allow subjects adequate time to replenish phosphocreatine (PC) and adenosine triphosphate stores (ATP). All trials remained standardised by using the same Smith machine in the physiology laboratory. The benefit of performing the half squat on the Smith machine is that the bar is forced to travel over a predefined path and has the safety aspect of adjustable brackets. The squat exercise required the athlete to set under the bar, in an upright position, looking forward, grasping firmly the bar with both hands and placing it across the posterior Deltoid, resting on the Trapezius muscle at a self selected location. Foot position was kept constant for all half-squats, by marking the position of the heel that suited each subject. In their own time, the athlete descended to the parallel position which was attained when the greater Trochanter of the femur reached the same level as the knee (Chiu et al., 2003). The correct depth of each dynamic half-squat was kept constant by making a specific mark for each subject on the frame of the Smith machine. The athlete then ascended until full knee extension, trials not meeting the range of motion
criteria were discarded. Once satisfied with participants’ technique, subject one’s perceived maximum was loaded onto the Smith machine. Two spotters assisted in lifting the bar from the support rack and followed the bar in case intervention was required. If this attempt was successful the weight was increased by 5-10 kg and the subject attempted another repetition. This procedure continued until the subject failed to complete 1 repetition with good technique. One repetition maximum values were obtained within 5 attempts. These values were used to calculate individuals’ 5 RM (to the nearest 2.5 kg), using guidelines for developing power in multiple effort power events (rugby, soccer, tennis), based on 5 reps at 85% of 1 RM (Baechle & Earle, 2000). The 5 RM back-squat was chosen for the dynamic condition as it represented a typical lower body maximal resistance exercise (Jenson and Ebben, 2003), and a training intensity that had previously been reported to enhance performance of a subsequent explosive sports activity (Young et al., 1998).

### 3.4.2 Agility Trials Pre-Stimulus

Experimental session two required subjects to report to an indoor athletics centre (Mondo Sportflex Super X Classic surface), to determine agility performance, and having followed guidelines regarding preparation, previously mentioned in section 3.3.1. Recruits were requested to complete 3 minutes low intensity jogging, and a range of dynamic stretches (as in section 3.3.1), as a warm up. Agility was assessed using the Illinois agility run previously described in Davis et al. (2005). Figure (3.4.2) indicates the correct running pattern, which was demonstrated by the researcher and each athlete was allowed to jog through the cones once before the test trials began. Smart Speed Timing gates (Fusion Sport, Brisbane, Australia) were placed at the start and finish lines at a height of 1.0 m, and synchronised by the researcher. Protocol for agility data collection were kept standardised, participants commenced from a standing start 1 m behind the timing gates, on a clearly visible mark. Subjects were then free to begin testing when ready; Smart Speed’s remote timing unit automatically recorded the time when the athlete crossed the start and finish lines.
**Figure 3.4.2** Representation of the adapted Illinois Agility Run. Players sprinted 10 meters, went around the cone and returned to the centre cone level to the starting line. They then swerved in and out of the four markers, returning to the centre cone once again. Two 10 m sprints finished the agility course.

Throughout all trials subjects were verbally encouraged to perform at maximal effort, and were given continual feedback on technique. Andreacci et al. (2001) demonstrated that frequent verbal encouragement at the beginning, leads to significantly greater maximum effort in a treadmill test than when no encouragement is given or when the encouragement is infrequent.
3.4.3 Main Testing Session

Exactly one week after the familiarisation session subjects returned to the laboratory for the main trial. This commenced with the same three-stage warm up programme as in familiarisation. Participants were tested one after the other, each following identical protocol. Five minutes post warm up, subject one set themselves under the Smith machine, and indicated when the spotters should lift the load from the brackets. 5 repetitions at the individuals’ calculated load were carried out, repetitions not meeting the range of motion, were repeated. From the completion of the fifth repetition, each subject started an individual stopwatch and had exactly 4 minutes before the commencement of the agility run. This intra-complex rest interval was administered on the basis of previous research who found a positive effect on the potentiation of the lower body (Young et al., 1998). The rest interval also allowed for the short walk to the indoor athletics centre, where the agility course was laid out identical to the previous session.

3.5 Reliability

Reliability concerns the degree to which replicated measures provide both consistent and accurate scores, and are influenced by measurement error and undependability. Reliability will be high due to the nature of the study design, having fewer testing errors occur in a laboratory setting. However being a false environment, more errors in terms of performance are expected (Bland, 2000).

Maximal testing raises issues regarding reliability of repeating trials, especially several days between sessions, as in the case of the present study. Only the subject will know if they are exerting maximal effort, however some untrained participants will not know how far to push themselves. To attempt to minimise this, verbal encouragement was implemented throughout. All measurements involve some error; some were due to performance inconsistency by the tester and the athlete. Reliability was kept consistent in terms of ‘stability’ by measuring variables with
the same equipment (i.e. Smith machine, goniometer, timing gates) on different occasions (Bland, 2000).

Furthermore the timing gates minimised investigator error by a system called error correction processing (ECP), which examined all events (such as the leading hand, torso, and trailing hand) passing through the single beam gate, and used the start of the longest break i.e. the torso (Fusion Sport, Brisbane, Australia).

3.6 Statistical Analysis

Conformation that all dependant variables were normally distributed was assessed via a Kolmogorov-Smirnov test (see section 5.1). Normal distribution was accepted at a significant level greater than p>0.05. Data were expressed as the mean and ± SD. Statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS for Windows version 12.0, SPSS, Inc., Chicago, IL). For all statistical comparisons, the Alpha level of significance was set at p > 0.05 (95 % confidence level). A paired-samples T-test was administered to assess the acute positive effects of a pre conditioning half-squat on a subsequent agility test. A paired-samples T-test was used because there were two related observations and the aim is to observe if the means on these two normally distributed interval variables differ from one another.

Additional comparisons to determine if an individual’s power to weight ratio might influence agility score. A Pearson’s correlation for each subject’s power-to-weight ratio and the potentiated agility test score were administered. The relationship between power-to-weight ratio and the participants’ agility score post-stimulus were the analysed variables (section 5.3).

Each agility score, pre and post-stimulus, were also assessed in terms of the percent potentiation, a commonly used measure to assess the relative change in
performance following postactivation potentiation. Percent potentiation greater than 100% indicates PAP, equal to 100% indicates no potentiation, and less than 100% indicates postactivation depression (Chiu et al., 2003) (fig.3.6). Appendix C, shows subjects’ percent potentiation in tabulated form.

\[
\text{% Potentiation} = \frac{\text{Potentiated Variable}}{\text{Un-potentiated Variable}} \times 100
\]

**Fig. 3.6** Percent Potentiation Equation (Chiu et al., 2003)

### 3.7 Ethical Guidelines

As a researcher it is our responsibility to ensure the investigation does not detrimentally affect the physical, psychological and social well being of the participants. As stated in the consent form (Appendix D), participation is entirely voluntary and withdrawal at any time will not incur retribution. Before providing written informed consent, subjects completed a PAR-Q and received a clear explanation of the protocol, including a demonstration of the correct half-squat technique, and the risks and benefits of participation. In compliance with the provisions of the Data Protection Act (1984), all data sheets were identified via subject number, kept separately from consent forms and stored in locked cabinets within locked office facilities within the Cardiff School of Sport. Participants were assured that only the researcher and supervisor, would be the only people to have access to personal information and results.
CHAPTER IV
RESULTS
4.0 RESULTS

4.1 One-Sample Kolmogorov-Smirnov Test

<table>
<thead>
<tr>
<th></th>
<th>Agility Pre-Stimulus</th>
<th>Agility Post-Stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Normal Parameters(a,b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>15.6718</td>
<td>15.5055</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>.38654</td>
<td>.44523</td>
</tr>
<tr>
<td>Most Extreme</td>
<td>Absolute</td>
<td></td>
</tr>
<tr>
<td>Differences</td>
<td>Positive</td>
<td>.133</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>-.223</td>
</tr>
<tr>
<td>Most Extreme</td>
<td>Absolute</td>
<td>.223</td>
</tr>
<tr>
<td>Differences</td>
<td>Positive</td>
<td>.164</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>-.164</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov Z</td>
<td></td>
<td>.740</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td></td>
<td>.644</td>
</tr>
</tbody>
</table>

a  Test distribution is Normal.
b  Calculated from data.

The Kolmogorov-Smirnov significant values displayed in table 4.1 are; 0.74 for Agility Pre-Stimulus and 0.545 for Agility Post-Stimulus. If the p-value is less than 0.05, there is insufficient evidence to suggest the distribution is not normal, therefore this data can be described as normally distributed (p>0.05), and no violations of the test assumptions have been made. As a consequence the researcher can proceed with the assumption of normality, and continue with the T-test.
4.2 Paired Samples Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>Agility Pre-Stimulus</td>
<td>15.6718</td>
<td>11</td>
<td>.38654</td>
</tr>
<tr>
<td></td>
<td>Agility Post-Stimulus</td>
<td>15.5055</td>
<td>11</td>
<td>.44523</td>
</tr>
</tbody>
</table>

The dependant variables being compared are identified in table 4. The Mean, N, Standard Deviation, and Standard Error of the Mean for each variable are given.

4.3 Paired Samples Correlations

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>Agility Pre-Stimulus &amp; Agility Post-Stimulus</td>
<td>11</td>
<td>.967</td>
</tr>
</tbody>
</table>

Here the correlation between each of the pairs of variables is given in table 4. This is a repeated-measures analysis using the same sample twice. The correlation value of .967, as expected has a high degree of correlation between the two sets of scores. This being greater than 0.05 effectively means that there is no significant differences in the test re-test scores was observed. Therefore the H¹ can be rejected and the null hypothesis can be accepted.
4.4 Paired Sample Test

<table>
<thead>
<tr>
<th></th>
<th>Paired Differences</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Std. Error Mean</td>
<td>95% Confidence Interval of the Difference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Pair 1</td>
<td>Agility Pre-Stimulus - Agility Post-Stimulus</td>
<td>.16636</td>
<td>.12118</td>
<td>.03654</td>
</tr>
</tbody>
</table>

Here the descriptive statistics for the difference between each pair of variables is given. The T-test results displayed in table 4.4. The output shows an n of 11 and a mean of .16636. This statistical analysis produced a t-value of 4.553, and an asymp. Sig. (2-tailed) value of (p-value) of 0.001. Consequently there is no significant difference in agility scores pre and post stimulus (p<0.05).

The t-statistic for the coefficient is the ratio of the coefficient to its standard error. It can be tested against a t distribution to determine how probable it is that the true value of the coefficient is really zero. Df represents the degrees of freedom (4.553). The mean difference (.16636) is what is actually being tested against zero. The result is insignificant t(11) = , p = .001. We reject hypothesis 1 in favour of the alternative null Hypothesis.
Figure 4.5 Means & Standard Deviation for Pre and Post-Stimulus Agility Scores

Graphical representation of the 11 recruits’ mean, Pre and Post-Stimulus Agility test scores, with standard deviation. The graph shows a decrease in mean time post-stimulus, however a larger standard deviation.
Figure 4.6 Change in Individuals’ Percentage Potentiation

Each variable was also assessed in terms of the percent potentiation, a commonly used measure to assess the relative change in performance following postactivation potentiation. Percent potentiation equal to 100% indicates no potentiation, greater than 100% indicates PAP, and less than 100% indicates postactivation depression. 10 out of the 11 subjects observed a positive percentage potentiation, the anomaly to the results produced a negative potentiation, by performing the post-stimulus agility run, slower.
Figure 4.7 The Relationship between Power-to-Weight Ratio and Agility Post-Stimulus

Relationship indicates a general trend between the two sets of data, with the exception of two anomalies. Data points on the regression model appear to be in strong correlation with the line of best fit. The results agreed with previous research and this study's hypothesis, the subjects with a lower power-to-weight ratio recorded slower agility times. Therefore the relatively stronger individuals recorded faster agility times (Appendix C).
CHAPTER VII
CONCLUSION
6.0 CONCLUSION

It has been proposed that a MVC will induce PAP, resulting in an enhancement of various movement mechanics, consequently improving performance, or the training stimulus, of a subsequent ESA. However, although research investigating the effect of an MVC on a subsequent twitch contraction has consistently recorded PAP, evidence verifying the same effect during an ESA is equivocal. The reason for this is primarily due to the differences in experimental protocol implemented by the various studies.

Factors such as MVC type, volume, recovery period following the MVC, subject characteristics, and type of ESA executed after the MVC have a large influence on the interaction between PAP and fatigue, ultimately determining the effect of an MVC on subsequent performance. Due to the contrasting results of past research, to date there are no empirically established guidelines for the utilisation of PAP in training or performance. Furthermore, the effects of an MVC on the activation of higher-order MU, a variable associated with one of the proposed mechanisms of PAP, are unclear.

To conclude, the present findings produced no significant evidence to support the hypothesis that performance and muscle activation increases after a pre-conditioning contraction, however a treatment effect cannot be ruled out.

6.1 Limitations

Conclusions from the current study however, are only representative of how the analysed sample responded to the treatment. The more heterogeneous the sample, the higher the correlation in terms of reliability. The present study was homogenous in design, whereby the sample was not representative of the whole population; the recruits were limited to 20-23 year old male sports students at UWIC, and further limited to only those with previous explosive sport participation,
resistance training experience, and availability on testing days. This meant that only a small sample size (n = 11) were analysed, and undermined the statistical power of the results. Generalising to other populations therefore did not apply. Subjects were unpaid volunteers, so motivation during performance would have been mostly intrinsic. However, subjects will be encouraged to give maximal effort at all times. Therefore coaches should be aware of how the individual athlete may react to the complex method.

Equipment restrictions and time constraints meant that testing times were limited, and the experimental procedure had to adhere to these factors. Muscle biopsies were not taken so subject muscle fibre type distribution was not known. As a result, the differences in agility times, pre and post-stimulus were an observed response.

The Illinois Agility Run may be heavily influenced by the ability to sprint quickly over short distances instead of measuring the ability to change directions. In addition, the duration of the original test is approximately 16 – 18 s; therefore performance may have metabolic limitations (Vescovi & Mcguigan, 2007). The length of time between test and re-test of the agility runs, may also have had an affect on the reliability, the longer the time to re-test, the weaker the correlation.

Findings of the study are limited to the lower body muscle groups observed, type of pre-conditioning stimulus and subsequent power exercise, intra-complex rest interval incurred, and the sample population recruited. In addition the use of a Smith machine may not provide as much muscular tension as compared to free weight squats using an Olympic bar.

Within the limitations of this study, complex training implemented acutely in the form of a warm up, may not offer ergogenic advantages. The results however offer no detrimental effects associated with resistance exercise.
6.0 Practical Applications and Future Research

Before any conclusions can be made as to the efficacy of exploiting PAP as a warm up for explosive agility activities, further scientific research is required. Future research should aim to investigate the manipulation of these inter-dependent variables, while taking into account the additional effects of factors such as subject characteristics and type of subsequent activity. Furthermore, considering that field and court sports generally include these changes of direction in response to a stimulus, for example another player’s movement, or the ball, it would seem vital to provide testing and training that mimics this demand to increase specificity.

The overall purpose should be to establish specific guidelines explaining how to optimise the effects of contractile history and utilisation of PAP, for the benefit of both acute performance and training. Investigations should assess the specific mechanisms of PAP and fatigue following a pre-conditioning contraction, and analysis of their combined effects on subsequent ESA’s in subjects of different physiological states.
REFERENCES
REFERENCES


Fusion Sport, Brisbane, Australia. *Error correction processing (ECP)*. No Date. (online) http://fusionsport.com/portal/content/view/16/79/. Accessed on 12.02.08


APPENDIX A
## Table A. Subjects’ Characteristics

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Stature (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>181.5</td>
<td>76</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>178.6</td>
<td>92.3</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>175.6</td>
<td>77.9</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>175.8</td>
<td>73.1</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>187.1</td>
<td>66.3</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
<td>176.1</td>
<td>67.8</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>169</td>
<td>73</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>181.6</td>
<td>74.4</td>
</tr>
<tr>
<td>9</td>
<td>21</td>
<td>171.2</td>
<td>66.3</td>
</tr>
<tr>
<td>10</td>
<td>21</td>
<td>168.6</td>
<td>73.2</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>174.5</td>
<td>71.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Means</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.9</td>
<td>176.3</td>
<td>73.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.9</td>
<td>5.7</td>
<td>7.2</td>
</tr>
</tbody>
</table>
APPENDIX B
Table B. Table Showing Subjects’ Agility Scores Pre and Post-Stimulus

<table>
<thead>
<tr>
<th>Subject</th>
<th>Agility Pre-Stimulus (secs)</th>
<th>Agility Post-Stimulus (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.96</td>
<td>14.77</td>
</tr>
<tr>
<td>2</td>
<td>15.92</td>
<td>15.72</td>
</tr>
<tr>
<td>3</td>
<td>15.72</td>
<td>15.39</td>
</tr>
<tr>
<td>4</td>
<td>15.89</td>
<td>15.64</td>
</tr>
<tr>
<td>5</td>
<td>15.03</td>
<td>14.69</td>
</tr>
<tr>
<td>6</td>
<td>15.88</td>
<td>15.84</td>
</tr>
<tr>
<td>7</td>
<td>15.85</td>
<td>15.88</td>
</tr>
<tr>
<td>8</td>
<td>16.12</td>
<td>16.08</td>
</tr>
<tr>
<td>9</td>
<td>15.41</td>
<td>15.29</td>
</tr>
<tr>
<td>10</td>
<td>16.01</td>
<td>15.77</td>
</tr>
<tr>
<td>11</td>
<td>15.6</td>
<td>15.49</td>
</tr>
</tbody>
</table>

| Means   | 15.67                       | 15.51                        |
| StDev   | 0.39                        | 0.45                         |
APPENDIX C
**Table C. Power-to-Weight Ratio & Agility Post-Stimulus Score**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Weight (kg)</th>
<th>1 RM (kg)</th>
<th>Power-to-Weight Ratio</th>
<th>Agility Post-Stimulus Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76</td>
<td>170</td>
<td>2.24</td>
<td>14.77</td>
</tr>
<tr>
<td>2</td>
<td>92.3</td>
<td>160</td>
<td>1.73</td>
<td>15.72</td>
</tr>
<tr>
<td>3</td>
<td>77.9</td>
<td>180</td>
<td>2.31</td>
<td>15.39</td>
</tr>
<tr>
<td>4</td>
<td>73.1</td>
<td>160</td>
<td>2.19</td>
<td>15.64</td>
</tr>
<tr>
<td>5</td>
<td>66.3</td>
<td>140</td>
<td>2.11</td>
<td>14.69</td>
</tr>
<tr>
<td>6</td>
<td>67.8</td>
<td>140</td>
<td>2.06</td>
<td>15.84</td>
</tr>
<tr>
<td>7</td>
<td>73</td>
<td>150</td>
<td>2.05</td>
<td>15.88</td>
</tr>
<tr>
<td>8</td>
<td>74.4</td>
<td>120</td>
<td>1.61</td>
<td>16.08</td>
</tr>
<tr>
<td>9</td>
<td>66.3</td>
<td>140</td>
<td>2.11</td>
<td>15.29</td>
</tr>
<tr>
<td>10</td>
<td>73.2</td>
<td>150</td>
<td>2.05</td>
<td>15.77</td>
</tr>
<tr>
<td>11</td>
<td>71.6</td>
<td>180</td>
<td>2.51</td>
<td>15.49</td>
</tr>
</tbody>
</table>

**Means**  
73.8  
153.6  
2.38  
15.51  

**StDev**  
7.2  
18.6  
0.19  
0.45
Physical Activity Readiness Questionnaire (PAR-Q)

Please Circle the answers to the following questions:

1. Has your Doctor ever said you have heart condition and that you should only do physical activity recommended by a Doctor?  
   
   Yes / No

2. Do you feel pain in the chest when you perform physical activity?  
   
   Yes / No

3. In the past month have you had chest pain when you were not doing physical activity?  
   
   Yes / No

4. Have you recently been absent from lectures due to illness?  
   
   Yes / No

5. Do you lose your balance because of dizziness or do you ever lose consciousness?  
   
   Yes / No

6. Do you have a bone or joint problem that could be aggravated by physical activity?  
   
   Yes / No

7. Have you any muscle injury condition that may require further rest between exercise?  
   
   Yes / No

8. Is your Doctor currently prescribing drugs for blood pressure or a heart condition?  
   
   Yes / No

9. Do you know of any other reason why you should not partake in physical activity on medical grounds?  
   
   Yes / No

If you have answered yes to any of the above, please add details below:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Signed ________________________  Date ________________________
As part of my undergraduate dissertation experimental procedure, titled ‘Effect of postactivation potentiation upon agility performance’, I require between 10-15 subjects and wondered if you would be kind enough to help me with my research. The study aims to test the physiological phenomenon that explosive strength of a muscle or group of muscles is enhanced following maximal or near maximal contractions; this is termed Postactivation Potentiation.

Participation is entirely voluntary, and at any stage of the process, you are free to withdraw without retribution. If you do withdraw the researcher may wish to retain the data that has been recorded from you but only if you agree, otherwise your records will be destroyed.

The criterion for selection requires a history of competitive participation in an explosive sport (i.e., sprinting, rugby, soccer, tennis), previous resistance training experience and an ability to squat at least 1.5 times your body mass. Participation entails attending three testing sessions, over a one week period:

- First test session familiarises subjects with testing procedures and will obtain individuals 1 repetition maximum (RM) half-squat, in order to calculate 5 repetition maximum.

- Second session will measure the participant’s fastest Illinois agility run from two trials.
Third session combines the two protocols; participants will carry out 5 half-squat repetitions, followed 4 minutes later by the same agility run.

This research will provide the participants with the latest scientific strategy for optimising their muscular power to improve both acute performance and training. Furthermore, subjects will have their lower body strength and agility scientifically tested.

This study requires subjects to perform at maximal effort during the back squats, and agility test. Consequently, subjects will experience feelings of discomfort due to fatigue. There is also a possible risk of delayed onset muscle soreness, or muscle injury. Every effort will be made to minimise any risk associated with these tests, by having all participants perform familiarisation sessions and a thorough warm-up and cool-down during each testing session. Subjects will also be continually coached on correct postures and techniques for all test exercises.

In compliance with the provisions of the Data Protection Act (1984), data sheets will be identified via subject number will be kept separately from consent forms, and stored in locked cabinets within locked office facilities within the Cardiff School of Sport. Myself and dissertation tutor Dr. Joseph Esphormes, will be the only people to have access to personal information and results.

Your participation in this study does not prejudice any right to compensation that you may have under statute of common law. The Ethics Committee at the University of Wales Institute Cardiff requires that all participants are informed that, if they have any complaint regarding the manner, in which a research project is conducted, it may be given to the researcher or, alternatively to the Dissertation Supervisor Dr. Joseph Esphormes. All study participants will be provided with a copy of the Consent Form for their personal records.
I confirm that I have read, and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactory.

I fulfil the criteria for participation.

I understand that my participation is voluntary and that I reserve the right to withdraw at any time without reason, or retribution.

(Tick where appropriate)

_____________________________________________      ________________________
(Signature of Participant)       Date

_____________________________________________      ________________________
(Signature of Experimenter)      Date

If you have any questions concerning the research, please feel free to ask the researcher at any time. Further information regarding this study may be obtained from:

Robert Davey Tel: 07825393181
Sport & Exercise Science Undergraduate, UWIC

Dr. Joseph I. Esformes, PhD., CSCS.
Lecturer in Physiology
University of Wales Institute, Cardiff
Cardiff School of Sport
Cyncoed Road
Cardiff, CF23 6XD, UK
Tel: +44 (0) 29 2041 7060