ACUTE EFFECT OF DIFFERENT TYPES OF UPPER BODY MAXIMAL CONDITIONING CONTRACTIONS ON POSTACTIVATION POTENTIATION
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ACKNOWLEDGEMENTS

I would firstly like to thank my supervisor; Joseph Esformes, who’s time, personal interest and practical guidelines could not have been more appreciated. I would also like to thank Danny Newcombe for giving his valuable time to help during data collection, as well as Jon Oliver for the guidance he gave me on the use of the EMG equipment. Finally, and arguably most significantly, I would like to thank all of the participants who gave up several hours of their time to take part in the present study.
ABSTRACT

The purpose of the current study was to validate the use of prior high resistance exercise (HRE) on subsequent muscular power exercises improvement. The study aims to examine the postactivation potentiation (PAP) effect produced by isometric (ISO), concentric (CON), eccentric (ECC) or concentric-eccentric dynamic (DYN) conditioning contractions in the bench press exercise upon subsequent neuromuscular activation, force, and power performance of the upper limbs during a ballistic bench throw exercise (BBT). Test variables measured were peak power output (PPO), peak force (F), peak distance (D), maximum rate of force development (max. RFD), maximum electromyography values (MEMG) and integrated average electromyography (AEMG). PAP is an increase in muscle isometric twitch and low frequency titanic force following a ‘conditioning’ activity which has been shown to improve muscular performance in speed and power activities. The theory of PAP suggests that prior high resistance exercise (HRE) induces a high degree of neural stimulation that results in an increased number of motor unit recruitment and a higher-frequency rate coding for several minutes following HRE. If this principle is correct, the test interventions will provide maximal stimulus for neuromuscular adaptations, thus increasing power output, providing support for the theory of complex training. Complex training is a recently advanced power training method characterized by a dynamic heavy-load exercise proceeded by a biomechanically similar plyometric exercise. 10 male amateur rugby league players of age; 20.4 (±0.8) years, weight; 90.2 (±13.8) kg and stature; 176.95 (±8.1) cm, and with at least one year’s resistance training history (2.19 ± 0.9 years), performed a BBT; pre (P1), and post (P2) a set of CON, ECC, ISO or DYN 3RM bench press’ on each testing day. P1 and P2 were performed on a smith machine, using a ballistic measurement system (BMS) to determine to determine the test variables, and neuromuscular activation characteristics were measured in the pectoralis major (PM) and triceps brachii (TB) using electromyography (EMG). The EMG data was analysed for maximum EMG (MEMG) and average EMG (AEMG). A change in either measure was determined as a change in motor unit recruitment and/or firing rate. Results found a significant increase (p<0.05) in PPO during P2, following ISO preconditioning. No significance was found in PPO following CON, ECC or DYN interventions, F, D or max RFD for either of the preconditioning interventions. Moreover, no significance in MEMG or AEMG was found between P1 and P2 following any of the
preconditioning contractions. However, a positive trend (p=0.052) was found in AEMG following ISO preconditioning. In conclusion; a 7 second ISO preconditioning contraction may offer a simple exercise that induces a potentiated neuromuscular environment conductive to enhanced performance during explosive dynamic powerful movements. The complex treatment did not enhance performance in BBT following CON, ECC and DYN interventions. However, neither was it found to have a detrimental effect on performance, and therefore may have organisational benefits in an athletes’ high volume training programme. For reliable results regarding the effectiveness of complex training a longitudinal training study needs to be investigated against other power training methods.
CHAPTER I

Introduction
1.0 INTRODUCTION

Postactivation potentiation (PAP) is recognised as an improvement in muscle-twitch force following a conditioning contractile activity such as a maximal voluntary contraction, resulting from increased neural excitation (Sale, 2002). It has been suggested that PAP has a positive effect on subsequent muscle actions, with the magnitude of the effect dependent upon the intensity and duration of the conditioning contractions (Shea, 1991). Due to the prolonged nature of the PAP effect, this phenomenon offers a theoretical strategy for optimizing force and power production beyond performance standards achieved without prior conditioning activity (French et al., 2003).

Power, alternatively termed as ‘Speed-Strength’ in the sport science literature (Stone, 1993), can be defined as the product of force and velocity at which that force is applied (Knuttgen and Kraemer, 1987), or as the rate at which work is performed (Sandler, 2005). Therefore, in order to maximise power, the greatest amount of force possible must be applied by the working muscle, or muscle group, as rapidly as possible.

As with all components of physical performance, in order to develop power a periodized training programme needs to be applied. This often involves the progression through mesocycles of muscular conditioning, including weight training, development of maximum strength and then conversion into power (Bompa, 1999). A number of training strategies and techniques are used to convert maximum strength into power, each developing different neural characteristics within the working muscles responsible for producing optimal levels of power.

Many studies (Adams et al., 1992; Allerheiligen, 1994; Armstrong, 1994) have indicated the advantages of combining weight training and plyometric training to develop power and improve performance. This is a time-efficient method for developing power without increasing the demands of an athlete’s training programme. This is of significant benefit to coaches at a time when it is already difficult to include all components of fitness
required for the sport, as well as technical and tactical training, without violating the principles of recovery (Ebben and Watts, 1998).

Complex training is a method that combines weight training and plyometric training. Complex training involves performing a high resistance exercise (HRE) followed by a kinematically similar plyometric exercise, which is suggested to initiate an acute ergogenic effect on the specific muscles working, producing an enhanced power performance (Ebben, 2002). Most studies examining the acute effects of HRE on subsequent explosive movements have been conducted with the intent to support or refute the efficacy of complex training protocols (Hodgson et al., 2005).

The main aim of the current study was to examine the PAP effect produced by isometric (ISO), concentric (CON), eccentric (ECC) or concentric-eccentric dynamic (DYN) conditioning contractions in the bench press exercise upon subsequent neuromuscular activation, force, and power performance of the upper limbs during a ballistic bench throw exercise (BBT).
CHAPTER III

Methodology
3.0 METHODOLOGY

3.1 Experimental Approach to the Problem

During this study all subjects were pre and post-tested during ballistic bench throw exercises with intervention strategies utilizing different muscular contractions to complete the preload stimulus of heavy bench pressing. This testing strategy was devised to gather data regarding the effect of using different muscular contractions, during the preload stimulus, on PAP effect. Each subject was required to attend a minimal of 5 laboratory sessions. In each experimental session each subject performed one of the following types of muscular contractions to complete a preload stimulus of the bench press: concentric, eccentric, coupled concentric and eccentric, and maximal isometric. Testing was performed in a randomised order to ensure that the subjects did not undergo the same sequence of muscular contractions.

3.2 Subjects

Ten male amateur rugby league players participating in the B.U.C.S. Rugby League Championships were used in this study, all of which had volunteered to participate, undergone during mid-season (January - February). Written informed consent had been obtained from each of the participants pre-ceding any testing taking place, along with approval from the University of Wales Institute Cardiff ethics committee, and the completion of a Physical Activity Readiness Questionnaire (PAR-Q). An example of the informed consent form and PAR-Q are given in the Appendix. Subjects were recruited using the criteria that they had at least 1 year’s experience of a structured weight-training program, ensuring that they could perform the bench press technique correctly. The average weight training experience of the group was 2.19 (±0.9) years.

3.3 Experimental Procedure

Prior to undergoing the main experimental trials the subjects visited the laboratory to determine their 3RM, to familiarise themselves with the experimental procedure and to
practice the correct technique for the ballistic bench throw. Measurements of stature and mass were also recorded in this session. Following this familiarisation session, the subjects underwent 4 test protocols (concentric, eccentric, coupled concentric and eccentric, and maximal isometric contractions comparison). The first test was completed 48 hours after the first session, whereby each subject had refrained from alcohol, caffeine or strenuous exercise for at least 24 hours. Each session was at least 48 hours apart from each other and from heavy training sessions or competitive games. As each session commenced, the subjects were required to complete a standardised warm-up of 5 minutes of light-intensity cycling, proceeded by a number of dynamic stretches that incorporated the stretching of the musculature involved in the bench press and ballistic bench throw.

On test day 1 the subjects completed the standardised warm-up, followed by a baseline ballistic bench throw. Following a 10 minute recovery period, the subjects completed the preload stimulus of 3RM on the bench press, performing only the concentric phase of the repetitions, therefore only utilizing concentric contractions. Spotters were used to bear the weight during the eccentric phase to ensure that the subject is not required to control the eccentric phase of the bench press and therefore does not perform any eccentric contraction. Following a further 12 minute recovery period, the subjects completed a ballistic bench throw.

On test day 2 the subjects carried out the testing in the same manner, with the exception that only the eccentric phase of the 3RM preload stimulus was performed on the bench press. Again, spotters were used to bear the weight during the concentric phase to ensure that the subject is not required to perform the concentric phase of the bench press and therefore does not perform any concentric contraction.

On test day 3 the subjects carried out the same test again, but performed both the concentric and eccentric phases of the 3RM preload stimulus on the bench press.

On test day 4 the subjects underwent the same testing protocol, with the exception that a maximal isometric contraction was used as the preload stimulus, whereby the subject
was required to push maximally against a stationary bar at an angle of 110˚ for a period of 7 seconds.

In order to standardise the duration of each of the types of muscular contractions, subjects were instructed to perform each of the concentric only contractions and eccentric only contractions for 2 seconds per repetition. During the coupled eccentric and concentric contractions, it was necessary for the subjects to consciously monitor the pace of their repetitions to ensure that the total duration of all three repetitions did not exceed 7 seconds.

Verbal encouragement was given throughout to maximise performance and consumption was water was permitted during each test.

3.4 Measurements

**Strength Testing:** This was undergone in the first, familiarisation session. Following the completion of the standardised warm-up explained, a further 3 warm-up sets of 10 repetitions of 50% of estimated 1RM were performed. Following 2 minutes rest, subjects attempted 3 repetitions of a set load. If successful, this load was increased until the 3 repetitions could not be adequately performed through the full range of motion. A recovery period of 5 minutes between each attempt was imposed to ensure that all energy stores had been restored. The bench press was carried in accordance to the International Powerlifting Federation rules (International Powerlifting Federation, 2005).

**Ballistic Measurement System:** Peak power output (PPO), peak force (F), peak distance (D) and maximum rate of force development (RFD) was measured using a Ballistic Measurement System (BMS), during a ballistic bench throw performed on a Smith machine (Nova Fitness LTD, Radstock, UK) with a load of 40% of the subjects’ 3RM. The subjects were instructed to lift the bar from the starting position and to propel it as high as possible. Using IPF rules, it was necessary for subjects to keep their head, shoulders and the majority of the trunk in contact with the bench, and their feet in contact with the floor. These ballistic bench throws
were performed prior to the preload stimulus, as a baseline, and 12 minutes after, during each of the test sessions.

The BMS calculated each test variable by collecting bar displacement data during the ballistic bench throws. It was able to do this due to a cable-extension potentiometer (distance transducer) that produces a variable-voltage output in relation to the extension of a 3 metre cable. With the use of customized software, an analog-to-digital card was able to capture this voltage data, converting the voltage data into displacement data. The BMS system was calibrated against a known distance of one metre at the beginning of each test session.

Alemany et al. (2005) conducted a study assessing the reliability of the BMS for measurement of PPO and reported intraclass correlation coefficients of 0.93 for PPO obtained during the bench throw.

Electromyography: Electromyography (EMG) was used to record the muscle activity in both the pectoralis major and triceps brachii during the ballistic bench throws. Surface electrodes were applied to the subjects during the recovery period between the standardised warm-up and completion of the baseline bench throw. To prepare the subjects skin for surface electrodes the hair was shaved, dead skin removed with sandpaper and an alcohol wipe used to cleanse the surface. This preparation method, first proposed by Okamoto et al. (1987), aims to reduce the skins resistive effects on the signal (Carys and Cabri, 1993). Three surface electrodes were applied to each of the muscles, using a design model similar to that of Ebben et al. (2000). For the pectoralis major, one electrode was placed one-third of the distance from the centre of the sternum to the greater tubercle of the humerus; the second 1cm parallel to and in the same longitudinal axis as the first electrode. The third electrode was required to be positioned on an unrelated anatomical position to act as the earth electrode (Zipp, 1982). In this case the medial epicondylo of the humerus (elbow) was used. For the triceps brachii, the first electrode was placed one-third of the distance from the olecranon of the ulna to the infraglenoid tubercle of the scapula. The second was placed 1cm parallel to, and in the same longitudinal axis, as the first. The earth electrode was positioned on the styloid process of the radius.
The MEGAWIN MP6000 Professional recording system was used to collect EMG data, placed in a leather case strapped onto a belt around the subject’s waist. Loose wires were taped to the subjects’ torso using electrical tape. This was to firstly minimise the corruption of the readings due to noise, and secondly to prevent the loose wires from hampering with the bench throw technique. The EMG signal was sampled at 1000 Hz. Carys and Cabri (1993) have shown this to be large enough to detect the most rapid changes occurring in neuromuscular activity.

The signal recorded was immediately downloaded, via an optic nerve, onto Megawin software for later analysis. Data was rectified (all negative values made positive). MEMG was found using a 25 point moving average as this is more of a stable measure than the raw peak (which could give one instantaneous value that is not in accordance with the rest of the data). AEMG was found using data within a given time frame of 0.5 seconds before and 0.5 seconds after the point that MEMG was reached. This time frame was used as no subject took longer than one full second to complete a BBT. In addition, using this time frame to obtain AEMG ensures that data is only used when neuromuscular activation is taking place.

3.5 Statistical Analysis

The SPSS version 15 computer package was used for statistical analysis of the data. The dependent variables being analysed were MEMG and AEMG for the PM and TB, and PPO, F, D and max RFD for the ballistic bench throw. A repeated-measures T-test was used to identify differences in the test variables between the pre and post values for each of the test variables following HRE. Significance was accepted at a level of $p \leq 0.05$. 
CHAPTER IV

Results
4.0 RESULTS

Table 1. Descriptive statistics of the subjects (n = 10)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (±s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>20.4 ± 0.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>90.2 ± 13.8</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>177.0 ± 8.1</td>
</tr>
<tr>
<td>Weight Training Experience (yrs)</td>
<td>2.19 ± 0.9</td>
</tr>
<tr>
<td>3RM Bench Press (kg)</td>
<td>89.3 ± 12.5</td>
</tr>
</tbody>
</table>

4.1 EMG Results

A repeated Measures T-Test revealed that no significant differences (p < 0.05) exist for MEMG or AEMG of PM and TB between the pre (P1) and post (P2) HRE for either of the experimental interventions (Table 2).

Table 2. Statistical analysis of the difference in MEMG and AEMG scores between P1 and P2 for each experimental intervention

<table>
<thead>
<tr>
<th>Pair</th>
<th>MEMG</th>
<th>AEMG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-Value</td>
<td>P-Value</td>
</tr>
<tr>
<td>CON P1 + P2</td>
<td>1.362</td>
<td>.206</td>
</tr>
<tr>
<td></td>
<td>.193</td>
<td>.106</td>
</tr>
<tr>
<td>ISO P1 + P2</td>
<td>-1.450</td>
<td>.181</td>
</tr>
</tbody>
</table>

* = Significant at the 0.05 level of alpha.
The repeated measures T-test generated p-values for each intervention that shows no significance (p>0.05).

Post hoc analysis indicated a decrease in EMG activity proceeding the CON and DYN contractions (Tables 3 and 4, respectively), although no significant difference was found.

Table 3. Individual and mean (±s) MEMG and AEMG results during P1 and P2 for CON HRE, and the percentage differences between the two protocols for both dependent variables. Notice a decrease in MEMG of 18.91% (± 43.47).

<table>
<thead>
<tr>
<th>Subject</th>
<th>MEMG P1 (µV)</th>
<th>MEMG P2 (µV)</th>
<th>Difference between MEMG P1 and P2 (%)</th>
<th>AEMG P1 (µV/s)</th>
<th>AEMG P2 (µV/s)</th>
<th>Difference between AEMG P1 and P2 (%)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>1091.58</td>
<td>1593.61</td>
<td>45.99</td>
<td>397.92</td>
<td>434.08</td>
<td>9.09</td>
</tr>
<tr>
<td>2</td>
<td>837.15</td>
<td>1059.54</td>
<td>26.57</td>
<td>261.60</td>
<td>265.89</td>
<td>1.64</td>
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<tr>
<td>3</td>
<td>1330.54</td>
<td>1133.96</td>
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<td>341.30</td>
<td>274.02</td>
<td>-19.71</td>
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<td>4</td>
<td>741.07</td>
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<td>236.26</td>
<td>204.94</td>
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<tr>
<td>5</td>
<td>1170.84</td>
<td>927.96</td>
<td>-20.74</td>
<td>340.56</td>
<td>293.18</td>
<td>-13.91</td>
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<tr>
<td>6</td>
<td>553.19</td>
<td>487.84</td>
<td>-11.81</td>
<td>178.42</td>
<td>164.99</td>
<td>-7.53</td>
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<td>7</td>
<td>2708.63</td>
<td>963.32</td>
<td>-64.44</td>
<td>713.41</td>
<td>729.15</td>
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<td>8</td>
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<tr>
<td>Mean</td>
<td>1344.76</td>
<td>1090.51</td>
<td>-18.91</td>
<td>395.32</td>
<td>360.01</td>
<td>-8.93</td>
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<tr>
<td>(±s)</td>
<td>(±647.59)</td>
<td>(±366.09)</td>
<td>(±43.47)</td>
<td>(±163.42)</td>
<td>(±163.97)</td>
<td>(±0.34)</td>
</tr>
</tbody>
</table>
Table 4. Individual and mean (±s) MEMG and AEMG results during P1 and P2 for DYN HRE and the percentage differences between the two protocols for both dependent variables

The table shows a decrease in AEMG activity of 1.43% (±18.58). In addition, results for MEMG show a decrease of 9.48% (±9.76).

<table>
<thead>
<tr>
<th>Subject</th>
<th>MEMG P1 (µV)</th>
<th>MEMG P2 (µV)</th>
<th>MEMG P1 and P2 (%)</th>
<th>AEMG P1 (µV/s)</th>
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<td>13.02898</td>
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<tr>
<td>Mean</td>
<td>1236.74</td>
<td>1119.49</td>
<td>-9.48</td>
<td>351.35</td>
<td>346.32</td>
<td>-1.43</td>
</tr>
<tr>
<td>(±s)</td>
<td>(±657.40)</td>
<td>(±593.25)</td>
<td>(±-9.76)</td>
<td>(±177.59)</td>
<td>(±144.60)</td>
<td>(±18.58)</td>
</tr>
</tbody>
</table>
EMG results for ECC contraction HRE show a mean decrease in MEMG (9.14% ± 16.76) during P2. However, an increase in AEMG of 6.22% (± 23.04) during P2 was found (Table 5).

**Table 5.** Individual and mean (±s) MEMG and AEMG results during P1 and P2 for ECC HRE and the percentage differences between the two protocols for both dependent variables

<table>
<thead>
<tr>
<th>Subject</th>
<th>MEMG P1 (µV)</th>
<th>MEMG P2 (µV)</th>
<th>MEMG Difference between P1 and P2 (%)</th>
<th>AEMG P1 (µV/s)</th>
<th>AEMG P2 (µV/s)</th>
<th>AEMG Difference between P1 and P2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1102.92</td>
<td>744.5597</td>
<td>-32.492</td>
<td>386.5895</td>
<td>759.5311</td>
<td>96.46965</td>
</tr>
<tr>
<td>2</td>
<td>689.66</td>
<td>848.92</td>
<td>23.09254</td>
<td>212.79</td>
<td>248.3835</td>
<td>16.72707</td>
</tr>
<tr>
<td>3</td>
<td>881.04</td>
<td>1117</td>
<td>26.78198</td>
<td>242.4816</td>
<td>254.3257</td>
<td>4.884526</td>
</tr>
<tr>
<td>4</td>
<td>821.04</td>
<td>736.6</td>
<td>-10.2845</td>
<td>215.1968</td>
<td>219.6012</td>
<td>2.046677</td>
</tr>
<tr>
<td>5</td>
<td>1125.77</td>
<td>998.11</td>
<td>-11.3398</td>
<td>302.4721</td>
<td>278.658</td>
<td>-7.87317</td>
</tr>
<tr>
<td>6</td>
<td>470.96</td>
<td>450.85</td>
<td>-4.27</td>
<td>172.3147</td>
<td>161.9276</td>
<td>-6.02797</td>
</tr>
<tr>
<td>7</td>
<td>2394.12</td>
<td>2219.46</td>
<td>-7.29537</td>
<td>718.8549</td>
<td>720.698</td>
<td>0.256392</td>
</tr>
<tr>
<td>8</td>
<td>1896.73</td>
<td>1279.66</td>
<td>-32.5334</td>
<td>531.0687</td>
<td>411.588</td>
<td>-22.4982</td>
</tr>
<tr>
<td>9</td>
<td>1069.04</td>
<td>1031.04</td>
<td>-3.55459</td>
<td>357.4417</td>
<td>302.7646</td>
<td>-15.2968</td>
</tr>
<tr>
<td>10</td>
<td>1371.89</td>
<td>1315.81</td>
<td>-4.08779</td>
<td>374.6628</td>
<td>374.8968</td>
<td>0.062466</td>
</tr>
<tr>
<td>Mean</td>
<td>1182.32</td>
<td>1074.20</td>
<td>-9.14</td>
<td>351.39</td>
<td>373.24</td>
<td>6.22</td>
</tr>
<tr>
<td>(±s)</td>
<td>(±578.04)</td>
<td>(±481.16)</td>
<td>(±16.76)</td>
<td>(±167.73)</td>
<td>(±206.38)</td>
<td>(±23.04)</td>
</tr>
</tbody>
</table>
A mean increase of 7.79% (±22.69) in MEMG and 4.86% (± 3.34) in AEMG was observed after ISO HRE (Table 6). Although not significant (p>0.05) this increase in AEMG can be considered as a positive trend as the repeated measures T-test demonstrates a P value approaching significance (p = 0.052).

**Table 6.** Individual and mean (±s) MEMG and AEMG results during P1 and P2 for ISO HRE and the percentage differences between the two protocols for both dependent variables

The majority of subjects experienced an increase in neuromuscular activity for both MEMG and AEMG but only the AEMG increase is considered a trend as the MEMG p-value was not approaching significance (P = 0.181).

<table>
<thead>
<tr>
<th>Subject</th>
<th>MEMG P1 (µV)</th>
<th>MEMG P2 (µV)</th>
<th>Difference between MEMG P1 and P2 (%)</th>
<th>AEMG P1 (µV/s)</th>
<th>AEMG P2 (µV/s)</th>
<th>Difference between AEMG P1 and P2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1025.77</td>
<td>1058.73</td>
<td>3.213196</td>
<td>363.5833</td>
<td>366.4613</td>
<td>0.791555</td>
</tr>
<tr>
<td>2</td>
<td>977.93</td>
<td>904.08</td>
<td>-7.55167</td>
<td>280.1713</td>
<td>329.1577</td>
<td>17.48441</td>
</tr>
<tr>
<td>3</td>
<td>648.12</td>
<td>646.23</td>
<td>-0.29161</td>
<td>188.0218</td>
<td>184.2683</td>
<td>-1.99631</td>
</tr>
<tr>
<td>4</td>
<td>710.46</td>
<td>735.58</td>
<td>3.535737</td>
<td>222.3019</td>
<td>235.7728</td>
<td>6.05976</td>
</tr>
<tr>
<td>5</td>
<td>608.62</td>
<td>769.5</td>
<td>26.43357</td>
<td>232.2688</td>
<td>265.5477</td>
<td>14.32773</td>
</tr>
<tr>
<td>6</td>
<td>662.15</td>
<td>747.77</td>
<td>12.9306</td>
<td>196.3227</td>
<td>200.4793</td>
<td>2.117276</td>
</tr>
<tr>
<td>7</td>
<td>2687.3</td>
<td>3286.66</td>
<td>22.30343</td>
<td>798.4464</td>
<td>782.2779</td>
<td>-2.025</td>
</tr>
<tr>
<td>8</td>
<td>1883.96</td>
<td>1974.19</td>
<td>4.78938</td>
<td>512.1936</td>
<td>539.1047</td>
<td>5.254075</td>
</tr>
<tr>
<td>9</td>
<td>1345.74</td>
<td>1196.89</td>
<td>-11.0608</td>
<td>328.4399</td>
<td>385.9827</td>
<td>17.52004</td>
</tr>
<tr>
<td>10</td>
<td>1365.21</td>
<td>1524.16</td>
<td>11.6429</td>
<td>360.68</td>
<td>362.57</td>
<td>0.52401</td>
</tr>
</tbody>
</table>

Mean 1191.53 (±s) 1284.38 (±s) 7.79 (±22.69) 348.24 (±186.50) 365.16 (±180.27) 4.86 (±3.34)
Figure 1 illustrates typical data of MEMG for the pectoralis major and triceps brachii.

**Figure 1.**

Pectoralis major

![Graph of Pectoralis major](image)

Triceps brachii

![Graph of Triceps brachii](image)
4.2 BMS Results

Following a 7 second ISO contraction on the bench press, PPO increased significantly (p = 0.038) by 3.0% (±3.7%). No significant effects were found between P1 and P2 protocols for any other test variables after the ISO intervention (Table 7).

Table 7. Individual and mean (±s) peak distance, peak force and maximum rate of force development values during P1 and P2 for ISO HRE and the percentage differences between the two protocols for each dependent variable

<table>
<thead>
<tr>
<th>Subject</th>
<th>Peak Distance P1</th>
<th>Peak Distance P2</th>
<th>Difference between P1 and P2 (%)</th>
<th>Peak Force P1</th>
<th>Peak Force P2</th>
<th>Difference between P1 and P2 (%)</th>
<th>Max. RFD P1</th>
<th>Max. RFD P2</th>
<th>Difference between P1 and P2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.653</td>
<td>0.664</td>
<td>1.68</td>
<td>592.7</td>
<td>592</td>
<td>-0.12</td>
<td>13050</td>
<td>13078</td>
<td>0.21</td>
</tr>
<tr>
<td>2</td>
<td>0.588</td>
<td>0.581</td>
<td>-1.19</td>
<td>609.4</td>
<td>529.8</td>
<td>-13.06</td>
<td>13070</td>
<td>13284</td>
<td>1.64</td>
</tr>
<tr>
<td>3</td>
<td>0.656</td>
<td>0.644</td>
<td>-1.83</td>
<td>640.3</td>
<td>662.1</td>
<td>3.40</td>
<td>13471</td>
<td>13438</td>
<td>-0.24</td>
</tr>
<tr>
<td>4</td>
<td>0.69</td>
<td>0.711</td>
<td>3.04</td>
<td>526.8</td>
<td>612</td>
<td>16.17</td>
<td>13050</td>
<td>13080</td>
<td>0.23</td>
</tr>
<tr>
<td>5</td>
<td>0.648</td>
<td>0.639</td>
<td>-1.39</td>
<td>583.5</td>
<td>619.3</td>
<td>6.14</td>
<td>13003</td>
<td>12812</td>
<td>-1.47</td>
</tr>
<tr>
<td>6</td>
<td>0.734</td>
<td>0.714</td>
<td>-2.72</td>
<td>698.2</td>
<td>795.6</td>
<td>13.95</td>
<td>12543</td>
<td>14403</td>
<td>14.83</td>
</tr>
<tr>
<td>7</td>
<td>0.731</td>
<td>0.746</td>
<td>2.05</td>
<td>728.2</td>
<td>741.3</td>
<td>1.80</td>
<td>13903</td>
<td>13958</td>
<td>0.40</td>
</tr>
<tr>
<td>8</td>
<td>0.622</td>
<td>0.657</td>
<td>5.63</td>
<td>642.4</td>
<td>655.7</td>
<td>2.07</td>
<td>13080</td>
<td>13252</td>
<td>1.31</td>
</tr>
<tr>
<td>9</td>
<td>0.651</td>
<td>0.658</td>
<td>1.08</td>
<td>636.3</td>
<td>591.9</td>
<td>-6.98</td>
<td>13890</td>
<td>13882</td>
<td>-0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.598</td>
<td>0.575</td>
<td>-3.85</td>
<td>452.3</td>
<td>473.4</td>
<td>4.67</td>
<td>10698</td>
<td>10635</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

Mean: 0.66 (±0.05)  0.66 (±0.05)  0.27 (±2.93)  611.01 (±79.72)  627.31 (±93.88)  2.67 (±8.66)  12975.80 (±903.56)  13182.20 (±1017.03)  1.59 (±4.72)
PPO was also found to increase following the concentric (3.95%) intervention, although these changes were shown to be insignificant (p = 0.223), along with all other variables tested for each of the HRE interventions (Table 8).

**Table 8.** Mean (±s) percentage differences in PPO, peak force, peak distance and maximum rate of force production between P1 and P2 for each HRE intervention*

Table 8 presents the results for the test variables after each of the HRE interventions. However, analysis using repeated-measures T-test revealed no significance to be present. No trends can be interpreted as p-values were not approaching significance (p<0.05).

<table>
<thead>
<tr>
<th>Intervention</th>
<th>PPO (%)</th>
<th>Peak Force (%)</th>
<th>Peak Distance (%)</th>
<th>Max. RFD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentric</td>
<td>3.95 ± 9.87</td>
<td>1.63 ± 15.80</td>
<td>-6.16 ± 48.12</td>
<td>-1.27 ± 9.48</td>
</tr>
<tr>
<td>Eccentric</td>
<td>-0.44 ± 12.09</td>
<td>-3.45 ± 6.12</td>
<td>6.57 ± 39.95</td>
<td>-1.12 ± 2.25</td>
</tr>
<tr>
<td>Con/Ecc</td>
<td>1.09 ± 9.09</td>
<td>-2.54 ± 6.73</td>
<td>-5.86 ± 16.94</td>
<td>2.42 ± 10.41</td>
</tr>
<tr>
<td>Isometric</td>
<td>3.00 ± 3.70</td>
<td>2.67 ± 8.66</td>
<td>0.27 ± 2.93</td>
<td>1.59 ± 4.72</td>
</tr>
</tbody>
</table>

*Values = mean ± standard deviation
CHAPTER V

Discussion
5.0 DISCUSSION

The object of the current study was to provide sports scientists and strength and conditioning coaches with an increased understanding of PAP in the upper body and to offer suggestions for new training methods for improving performance through complex training. In contrast with previous findings (Baker, 2001b; Gulich and Schmidtbleicher, 1996; Radcliffe et al., 1996) but similar to previous upper-body studies (Ebben et al., 2000; Hrysomallis and Kidgell, 2001), CON, ECC and DYN conditioning contractions in the bench press had no significant effect upon subsequent neuromuscular activation, force, and power performance of the upper limbs during a ballistic bench throw exercise (BBT). A significant effect, however, was found on PPO following an ISO conditioning contraction, along with a positive trend in AEMG. This discussion will now focus on mechanisms via augmentation to power output may occur as a result of the intervention of an ISO HRE set, more notably the reasons for no apparent effect following CON, ECC and DYN conditioning contractions along with possible explanations for the findings from EMG data. The discussion includes limitations of the study, possible avenues for future research and conclusions that can be drawn from the findings of the study and the practical applications of these findings.

5.1 BMS

At present, it can only be postulated as to how previous HRE may increase power output (Baker, 2003). Previous authors have deduced, however, that this acute augmentation in power may be the result of neural adaptations such as increased descending activity from the higher motor centres, direct myoelectrical potentiation, increased synchronisation of motor unit firing, reduced peripheral inhibition from the Golgi tendon organ, reduced central inhibition from the Renshaw cell, and enhanced reciprocal inhibition of the antagonist musculature (Fleck and Kontor, 1986; Gulich and Schmidtbleicher, 1996; Ebben and Watts, 1998; Young et al. 1998; Ebben et al., 2000; Baker, 2001a). Baker (2003) suggests that
neither of these possible mechanisms are necessarily exclusive of each other and that a number of them could function together simultaneously.

Gullich and Schmidtbleicher (1996) and Young et al. (1998) suggest that in order to increase motor unit activation (and therefore muscular power) the intervention strategy must be a very heavy resistance of maximal or near-maximal intensity (≥85-90% 1RM). This could offer an explanation for an increase in PPO following ISO contractions, as the present study entailed a HRE of the subjects 3RM which is in the 85-90% 1RM range. However, this does not explain the lack of significant effects following CON, ECC and DYM interventions. In addition, previous research, such as that of Baker (2003), have entailed a much lower resistance of 65% 1RM but have still reported a significant positive effect on power output. This would suggest that other test procedures are responsible for the increase in power following ISO HRE.

French et al., (2003) reported significant improvements in selected explosive dynamic muscle actions (drop jump, knee extension) following a sequence of 3 sets of 3-second isometric knee extensions. In comparison, 3 sets of 5-second contractions had no benefit on the same exercises, and in some cases, countermovement jump for example, exercise performances were significantly reduced. This, as French et al. (2003) suggest, shows that total preconditioning time adapts physiological responses, and that 9 seconds, or 3 sets of 3 seconds, facilitates a heightened neural environment, for instance PAP, that can coexist with fatigue. A total time of 15 seconds, or 3 sets of 5 seconds, on the other hand seems to induce muscular fatigue that eradicates the beneficial effects of PAP. This could offer a reason for significant results for ISO conditioning contractions as this was the only intervention whereby the contraction phase was timed at 7 seconds. Although attempts were made to ensure each HRE set took 7 seconds to complete, it is possible that the CON, ECC and DYN interventions took longer than this, and so the heightened neural environment had diminished. Vandervoort et al. (1983) also observed that the extent of potentiation was depressed if preceded by HRE that exceeded 10 seconds.
At this stage it is not known exactly via which avenues an increase in power output may occur, but it is conceivable that some acute neural adaptations are responsible for the effect (Baker, 2003).

Previous literature has also suggested a number of reasons for the lack of significant effect found following CON, ECC and DYN interventions in the present study.

Gullich and Schmidtbleicher (1996) state that PAP is a phenomenon that gives an athlete the potential to improve their performance of explosive dynamic muscle actions. Haff et al. (1997) describe explosive muscle actions as contractions with an activation period of ≤0.25 seconds, where initial and max. RFD are the primary factors affecting performance. This was the rationale behind the collection of data of max. RFD in the present study, although no significant effects were found on this test variable. Taking into consideration a time period of 1 second was used to calculate AEMG, it is apparent that the BBT performed by the subjects took longer than 0.25 seconds to complete. In light of this, the BBT does not adhere to the defining characteristics of explosive activity described by Haff et al. (1997), and therefore it may not be surprising that the effects of PAP were absent from these measures. Hamada et al. (2000b) have also indicated that the effects of PAP are best observed during high velocity muscle actions (<0.25 seconds). Additionally, Newton et al. (1996) have suggested that performing very heavy resistance at slow lifting speeds may explain the lack of power enhancement observed for the majority of the interventions in this study. According to the speed-control theory (Enoka, 1983), the neural output may have been attuned to the slower speed of the heavy bench pressing, reducing the possibility of positive neural adaptations occurring during the subsequent power exercise. Consequently, it is possible that HRE of >85-90% 1RM, performed at inherently slower lifting speeds, may not provide an optimal stimulus for upper body power development (Baker, 2003). This is a very plausible explanation for the lack of power augmentation following CON, ECC and DYN interventions, but a significant increase of 3.00% (±3.7) for ISO intervention as this
intervention did not entail a lifting speed, in contrast with the CON, ECC and DYN contractions.

Komi (1986) and Wilson et al. (1991; 1992; 1996) offer another possible avenue of power augmentation as the stiffness of the musculo-tendinous unit and specifically the series elastic component (SEC). Depending on the resistance to be overcome, increased SEC stiffness may be useful in regulating force output during stretch-shorten cycle movements (Komi, 1986; Wilson et al., 1992). A HRE set of 65% 1RM may temporarily result in a favourable increase in SEC stiffness, proving favourable for power production in proceeding power training exercises (Baker, 2003). However, Wilson et al. (1992) suggests that a HRE set of 85-90% 1RM may temporarily result in a SEC that is stiffer than would be optimal considering the lighter resistance to be overcome in the power movement. This may explain the lack of significant results for the CON, ECC and DYN interventions in the present study, although it would be assumed that the same effect should have occurred proceeding ISO contractions. Thus, this explanation cannot fully explain the results of this study.

It has been suggested that the discrepancy in previous literature regarding the effect of performing a high load exercise prior to a high power exercise may be explained by differences in training level among subjects used (Chiu et al., 2003). Duthie et al. (2002) found that stronger subjects improved peak force and peak power during jump squats following 3 sets of 3RM half squats, whereas weaker subjects showed a small decline in peak force and peak power. Young et al. (1998) also found similar results using a vertical jump as the test measure. The neural excitation achieved following heavy loading is greatest within type II muscle fibres (Hamada et al., 2000b; Sale, 2002), suggesting that stronger individuals are better able to benefit from PAP as they may possess a higher proportion of type II muscle fibres compared to their less strong peers (Hodgson et al., 2005). Hamada et al. (2000b) found that individuals identified as the highest PAP responders had a higher percentage of type II muscle fibres, as well as a greatest type II area.
However, these studies have been retrospective, therefore the relationship between fibre type and the ability to utilise potentiation for subsequent explosive movement has not yet been established. The effect of strength on PAP needs to be established through longitudinal studies that increase strength and then determine its effect on subsequent PAP (Hodgson et al., 2005). It may be that, even though only those with at least 1 year’s weight training experience were used, and the mean 3RM bench press of the subjects was 89.3 ± 12.5 kg’s, the subjects may not have been strong enough to experience the full benefits of PAP.

Hamada et al. (2000a) has also shown potentiation to be greatest in muscles involved in the subjects sport. Although the upper limbs are involved in the sport of rugby league, it can only be speculated whether there is enough involvement for the PAP effect to be maximised. In addition, Chiu (2003) states that explosively trained subjects would have greater activation of the musculature involved, causing increased phosphorylation of the myosin regulatory light chain, resulting in faster contraction rates and rate of tension development (Rassier and MacIntosh, 2000). Although all subjects had at least 1 year’s weight training experience, the type of weight training undergone was not taken into account. Therefore, the lack of significant difference for CON, ECC and DYN interventions may be a result of a lack of previous explosive training.

Another possible explanation for the appeared failure of HRE to induce PAP in CON, ECC and DYN interventions is the amount of recovery time between P1 and P2. Kilduff et al. (2007) reported that the optimal recovery time to maximise the PAP effect on peak power output (PPO) is 12 minutes. However, Ebben et al. (1999) state that the optimal recovery time appears to be variable among individuals. Consequently, the recovery time of 12 minutes may have masked any potentiated effect in the group of subjects used in the current study. Previous research (Young et al., 1998; French et al., 2003) has also suggested that a time period of 3-4 minutes may be more beneficial to induce PAP.
5.2 EMG

The positive trend found in AEMG following ISO intervention is in agreement with previous literature by Gullich and Schmidtbleicher (1996) and French et al. (2003). Gullich and Schmidtbleicher (1996) found increased EMG activity of human motor units following isometric muscle actions, and strength training studies have further demonstrated increased EMG activation of reflex potentiation after performing HRE (Sale et al., 1983). Although findings were found to be insignificant, French et al. (2000) also suggested that EMG responses showed a trend of increased neural activity following 3 sets of 3-second isometric contractions on the lower body. Although it is not possible to make definitive judgements using present data, the pattern of increased AEMG following ISO HRE, along with supporting evidence from other research, is most likely an indication that ISO HRE resulted in a greater number of activated motor units.

Ebben et al. (2000) have conducted a study that has assessed neural output levels during upper-body complex training methods. Results found no change in EMG activity during the power exercise performance, which may not be surprising given that no performance augmentation was reported either. These findings support those of this study, suggesting that performing HRE prior to an explosive power exercise does not induce a significant positive effect on neuromuscular activity.

Cabrera et al. (2009) found similar results after conducting a study involving twelve men (age = 22.9 ± 2.7 years) performing a bench press throw (using a load of 55% 1RM) 4 minutes after completing five isotonic conditioning presses at either 50, 70 or 86% 1RM. No significant effects or interactions were observed in EMG data. This supports the view of the current study that preconditioning HRE does not induce increased power performance in proceeding explosive power exercises.
It can only be speculated as to the reasons for this lack of effect on EMG data. Fatigue commonly manifests itself by an increase in EMG amplitude and/or decreased AEMG (Housh et al., 2006). The absence of significant change in AEMG for all of the test interventions in the present study suggests that the 12 minute recovery period was sufficient to avoid neuromuscular fatigue from confounding any underlying potentiation (Cabrera et al., 2009). Therefore, the lack of significant effect on EMG data cannot be attributed to fatigue. It may be that, given Young et al. (1998) and French et al. (2003) suggestions that a time period of 3-4 minutes of recovery is more beneficial to induce PAP, the period of 12 minutes used in the current study is too prolonged and PAP may have dissipated.

Furthermore, this study did not measure the direct indices of PAP, for example, twitch potentiation and therefore it cannot be concluded that PAP was not present as such.

**5.3 Limitations of the Study and Recommendations for Future Research**

A small sample size (n = 10) were tested and analysed. This small sample size may undermine the statistical power of the results (Moher et al., 1994).

Electromyography (EMG) equipment was used to measure the neuromuscular activity of the pectoralis major and triceps brachii during the tests. Despite the use of electrical tape to secure the wires to the subject’s torso, cross talk may still have occurred in the signal (Koh and Grabiner, 1992). This cross talk can be caused by impedance from the skin as well as moving wires.

All subjects were male sports science students with the investigation taking place during the subject’s mid-season, making it difficult to control their activity levels to ensure that they had refrained from strenuous exercise for at least 24 hours prior to testing.
Findings of the present study are also limited to the muscle groups studied and type of HRE and explosive movement used. Additional limitations include the inability to isolate the concentric and eccentric phases of the BBT for PM and TB.

It may be suggested that any further research using EMG equipment should use a collection frequency of greater than 1,000Hz in order to quantify any significant change in response to neural adaptation (French et al., 2003). Inclusion of triggered and integrated cinematography to delineate between eccentric and concentric EMG activity may also be beneficial (Ebben et al., 2000).

Further research should investigate the manipulation of other training variables including; rest intervals between HRE and proceeding explosive exercise and number of HRE sets per training session.

In addition, future research could focus on elite athletes as subjects as the extent of performance adaptation from complex training are small and so would mainly benefit this population.

For reliable results regarding the effectiveness of complex training a longitudinal training study needs to be investigated against other power training methods.

5.4 Conclusions and Practical Applications

In conclusion, the present study has made an initial attempt to indicate that a 7 second ISO preconditioning contraction may offer a simple exercise that induces a potentiated neuromuscular environment conductive to enhanced performance during explosive dynamic powerful movements. However, CON, ECC and DYN preconditioning contractions were shown to have no significant effect on any of the test variables measured during an explosive dynamic powerful movement. Results also indicate that the test interventions had no
detrimental effects on performance, thus at the very least following ISO preconditioning contractions with explosive powerful movements is beneficial in terms of time management.

It would appear that an increase in power output can occur when a set of an ISO HRE is followed by an explosive power exercise. It is advised that 12 minutes recovery be applied between the HRE and P2, however, strength and conditioning coaches should be aware that individual responses exist in terms of the optimal time for PPO and therefore, in order to effectively develop an athletes’ power-generating capabilities, their optimal recovery time needs to be individually determined (Kilduff et al., 2007). Determination of the optimal recovery period for the upper-body also requires further validation.

The findings of the present research suggest that the PAP effect can be applied to training for increased power development in the form of complex training incorporating only ISO HRE followed by dynamic power exercises. Examples could include an ISO contraction on the bench press followed by lighter BBT in a smith machine, explosive push-ups or medicine ball throwing exercises. If access to a gym or bench press is restricted, pushing against an immovable object, for example a wall with assistance from a partner, can be a practical means of inducing PAP (French et al., 2003). The unequivocal advantage of the complex training concept is that strength and conditioning coaches could easily integrate speed and strength training into the same session.

Though the extent of performance adaptation using this method is small and may not be commonly considered for training of amateur athletes, the potential benefits that such acute improvements in performance hold to a highly conditioned elite athlete should not be underestimated (French et al., 2003). French et al. (2003) go on to suggest that, using the PAP effects of short-term ISO contractions, improved performances may be obtained by integrating complex training sequences into a functional warm-up program for training or competition. Examples for the upper body could be the use of heavier than normal balls, or throwing implements in the latter stages of the warm-up.
It has also been suggested by Fees (1997) that complex training can be beneficial among athletes for injury rehabilitation and athletic reconditioning. This premise warrants further investigation.

Although findings of the present study suggest that complex training may be an effective method of power development, the efficacy of using isometric contractions as a pre-conditioning stimulus in complex training upon long-term improvements in power performance is unknown (Hodgson et al., 2005). Thus, its functional application to motor performance and training can only be determined through continued research.

The results of the current study may be applicable to sports with brief, discrete maximal efforts, such as sports involving sprinting, jumping or throwing actions.
REFERENCES


Appendices
Appendix A: Informed Consent Form

UWIC

Informed Consent Form

Subject: Name ____________________________ Sex: M
Date of birth ____________________________

Investigators: Matt Keenan (Student) Joseph Esformes (Member of Staff)

Ethical Approval Gained? Yes / ☒

Title of the Study:

The Acute Effects of Different Types of Upper Body Maximal Conditioning Contractions on Postactivation Potentiation

Objective and Procedures to be Employed

Before you read and consider the information presented below it is important that you are aware that all of the proposed exercise tests and measurement techniques have been examined by an ethics committee, which has accepted that the proposed study is suitable for use with consenting, human subjects.
Objective

The major aim of the present study is;

1). Discover the effects of different types of upper body maximal conditioning contractions on PAP in amateur rugby league players.

Exercise protocol

You will be required to attend the laboratory on five occasions. Before commencing the main experimental trials, you will be required to visit the laboratory in order to determine your 3RM for CON, ECC, ISO and a combination of CON and ECC contractions, to have descriptive measurements taken of you and to become accustomed with the testing methods.

To determine each subjects 3RM a standardised warm-up will need to be undergone, involving light intensity cycling for 5 minutes, followed by dynamic stretching of the upper body. Subjects then performed 3 warm-up sets of 50% of their 1RM. Proceeding this warm-up set, subjects are required to attempt 3 repetitions of a set load, only executing the CON phase of the lift, with 2 spotters taking the weight on the ECC phase. If successful, the lifting weight will be increased until you would not be able to lift the weight through the whole range of motion. A 5 minute rest period between each attempt will be enforced to allow the subjects energy stores to be replenished. This same protocol would then need to be replicated to determine the 3RM for both the ECC, ISO and combination of both contractions. Clearly, ECC contraction involves only performing the downward phase and ISO will involve holding the bench press at an angle of 110° to the floor for a period of 7 seconds.

The first experimental test will be conducted 48 hours after the strength trial. You will be required to abstain from alcohol, caffeine and strenuous exercise the day before the test. After undergoing a standardised warm-up of 5 minutes of light intensity cycling, you will be required to complete a base line ballistic bench press, on a Smith machine, of 40% of your
1RM. During the bench press throw you will be instructed how to perform the movement correctly. A ballistic measurement system will be used to collect bar displacement data and the software provided with this equipment will calculate the power output produced. An EMG recorder will also be strapped to the participant, connected to six surface electrodes, which will record the neuromuscular activity of the pectoralis major and tricep brachii.

Following a 10 minute recovery period, you will complete one set of your 3RM bench press for CON contractions. A ballistic bench press would then be performed 12 minutes after.

The second experimental test would be conducted 48 hours after the first test, at the same time of day and in the same manner as in test day one with the exception that ECC contractions will replace CON contractions in the 3RM preload stimulus.

The third experimental test would be conducted 48 hours after the second test, at the same time of day and in the same manner as in test day one and two, with the exception that ISO contractions will replace CON and ECC contractions in the 3RM preload stimulus.

The fourth experimental test would be conducted 48 hours after the third test, at the same time of day and in the same manner as in test day one and two, with the exception that a combination of CON and ECC contractions will replace individual CON and ECC contractions in the 3RM preload stimulus.

Test sessions will be performed in a randomised order.

Potential Risks

The risks outlined below will only apply to a small number of subjects. However, it is important you are made aware of possible outcomes in order to provide written, informed consent to participate in this study.
During Exercise

In any test requiring physical exertion the possibility of injury is always present, no matter how small. While these risks are very unlikely to be encountered – these must be mentioned for Health and Safety reasons. Two spotters will be present at all times when performing the bench press, and to capture the bar following the bench throw. Although these measures are being taken, the bench press is being performed on a Smith machine and so safety hooks will be in place.

Following Exercise

There may be some light muscular fatigue and discomfort following the resistance exercises, but this should be minimal as only a small number of repetitions are being carried out and all subjects will be accustomed to weight training.

Benefits

In becoming involved in this study you will enable us to collect data which forms part of a research programme. Subjects will also get experience in being involved in a study. Subjects will also receive information regarding their strength and power performance and the findings of this study may provide subjects with alternative methods of training to improve their performance.

The Data

All data collected during the testing will remain anonymous and will be treated with the strictest confidence, although it could form the basis of eventual scientific publications and/or presentations.

NB - The University and its staff accept no liability for any matters arising, either directly or indirectly, from the information and recommendations given to you as a result of the outcomes of your test. It is the responsibility of the athlete to ensure that the Sport Scientist
is aware of any medical conditions or other information that might affect either the test itself or the interpretation of the results and subsequent recommendations.

**Statement by the Subject**

I have been made fully aware of the risks and benefits involved from partaking in the present study. I understand that I am free to withdraw from the study at any time and that the results of the study will be treated anonymously and with total confidentiality.

I have had my attention drawn to the document produced by the American College of Sports Medicine (1997) entitled “Policy Statement Regarding the use of Human Subjects and Informed Consent”. It has been made clear to me that if I feel my rights are being infringed and / or my interests are being ignored, neglected or denied, I should inform the chairman of the Cardiff School of Sport Research Ethics Committee who will undertake to investigate my complaint.

Signed: ______________________  Date: __________________

(Subject’s signature)

I certify that the details of the study have been fully explained and described in writing to ____________________, and this information has been fully understood by him.

(Subject’s name, printed)

Signed: ______________________  Date: __________________

(Independent witness’ signature)

Participant’s contact details:
Address (including postal code):

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Home telephone number: __________________________
Mobile telephone number: __________________________
E-mail address: __________________________
Appendix B: Physical Activity Readiness Questionnaire (PAR-Q)

Yes  No

□  □ Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

□  □ Do you feel pain in your chest when you do physical activity?

□  □ In the past month, have you had chest pain when you were not doing physical activity?

□  □ Do you lose your balance because of dizziness or do you ever lose consciousness?

□  □ Do you have a bone or joint problem that could be made worse by a change in your physical activity?

□  □ Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

□  □ Do you know of any other reason why you should not do physical activity?

If you have answered yes to any of these questions, please add details below.
Similarly, if there are any situations which will prevent you from exercising, please write them below:

____________________________________________________________________

____________________________________________________________________

Print name.................................................................

Signed.................................................................

Date.................................................................