Cardiff School of Sport

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Student name:	TOM IVORY	***Student ID:***	ST20004859
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Dissertation title:	THE EFFECT OF DIFFERENT CONDITIONED CONTRACTION TYPES ON POST ACVTIVATION POTENTIATION IN MALE RUGBY UNION PLAYERS.		
Supervisor:	RHODRI LLOYD		

Comments	Section
	Title and Abstract (5%) Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
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CARDIFF METROPOLITAN UNIVERSITY
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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

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THE EFFECT OF CONDITIONED CONTRACTION TYPE ON POST ACTIVATION POTENTIATION IN MALE RUGBY UNION PLAYERS.

(Dissertation submitted under the discipline of PHYSIOLOGY AND HEALTH)

TOM IVORY

ST20004859

THE EFFECTS OF DIFFERENT CONDITIONED CONTRACTIONS ON POST ACTIVATION POTENTIATION IN MALE RUGBY UNION PLAYERS.

Prifysgol Fetropolitan Caerdydd

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I would like to thank my dissertation supervisor, Rhodri Lloyd, for all of his help whilst undergoing this study. Secondly, I would like to thank both the physiology laboratory and the National Indoor Athletics Centre for allowing me to use their equipment and facilities. I would also like to thank the physiology technicians, in particular Jane Busch, for helping with the availability of the force platform. Finally to all of the participants that took part in the study.

ABSTRACT

The current study was conducted to examine the effects that different conditioned contraction types had post activation potentiation. Previous research has shown that a multitude of different conditioned activities can elicit a PAP response under the right conditions. Having said this, not much research has focused on which types of contractions are most effective. Seven male rugby union players (mean ± SD age, 21.1±0.7; body mass, 91.0kg± 15.2kg; height, 178cm± 0.1cm) performed a set of three drop jumps four minutes before and after a particular CC. These CC's consisted of a set of ten CMJ's, 5 dynamic squats at 80% 1RM and a ten second MVC at 120% 1RM. Averages for JH and PP were taken for each set of DJ's, results were then compared pre and post each intervention. DJ's were performed off of a 20 inch box onto an AMTI force plate. A repeated measures ANOVA was used to identify whether difference in each variable pre and post CC's varied between each CC used. A significance value of <0.05 was implemented, and one ANOVA was used for each intervention. Mauchly's test of sphericity showed that sphericity could be assumed among both ANOVA's, however, no significant differences could be found. It was delineated that although as a single sample no significant differences were found, some individuals did benefit from PAP. However, responses to particular CC's deviated between individuals. It was therefore concluded that when deciding what CC to use to elicit PAP, strength and conditioning coaches should examine individual affects, as oppose to team responses.

Key words: Jump height, peak power, post activation potentiation, conditioned contraction.

CHAPTER 1

INTRODUCTION

1.0 Introduction

The ability to produce a large amount of power is highly sort after within professional sports, and is often deemed necessary for success within many sporting situations. This has led to extensive research being conducted within the sports science community so that training programmes can be altered to maximise strength and power. Moreover, recent research has examined the phenomenon of post activation potentiation (PAP) due to its believed ability to increase the contractile properties of muscles for a short period.

PAP is defined as the increase in muscular performance following a conditioned contraction (CC) (Xenofondos et al., 2010), and refers to the phenomenon by which the contractibility of muscles are enhanced by their contractile history (Tillin and Bishop., 2009). Neuromuscular fatigue, is the most obvious effect of contractile history on the muscles. However, there is evidence to suggest that contractile history can actually enhance force production through the use of PAP.

Research suggests that three main mechanisms are responsible for PAP. Firstly, it is proposed that an increased phosphorylation of regulatory light chains (RLC'S) can increase calcium sensitivity (Tillin et al., 2009). This results in a faster cross bridge attachment within the muscle complex, causing an increase in muscular contractile force (Sale., 2002). Secondly, it is postulated that an increase in motor unit recruitment occurs. This allows for a faster and more synchronised recruitment of type II muscle fibres, allowing for a greater force produced by the muscles. Hodgeson et al. (2005) suggested that this may be due to an increased excitability of motor neurons and an increased quantity of neurotransmitters, resulting in a decreased neurotransmitter failure. Finally, it is purported that a change in pennation angle can occur as a result of a CC, which could increase muscular force. However, it is suggested that CC's can also cause an increase connective tissue and tendon compliance, which may counter the benefits of change in pennation angle. It has been theorised that PAP can increase short term power through the use of complex training. This is a method of training by which a CC is used to stimulate PAP within a muscle, followed by a plyometric exercise. By doing so, short term improvements can be made in the plyometric exercises, resulting in long term improvements in speed and power. Having said this, PAP is affected by a multitude of factors and may vary between individuals, which may be the reason behind contradictory research.

Research suggests that subject characteristics, such as fibre type and training status can affect the PAP response an individual may experience. It has been suggested that trained athletes have a greater resistance to fatigue as an adaptation of their training programmes (Chui et al., 2003). Similarly, is has been theorised that trained athletes can recruit larger motor units at a faster rate than untrained athletes (Judge et al., 2003; Duthie et al., 2002). Moreover, as type II muscle fibres undergo a greater phosphorylation of RLC's, subjects who possess greater amounts of type II fibres could benefit more from PAP. The conditioned activity used to elicit PAP can also have an effect on PAP. Research has shown that maximal voluntary contractions (MVC) are effective at enhancing a PAP response (Requena., 2008). It is suggested that this may be caused by the relatively light volume involved in a MVC, resulting in a lower amount of fatigue. In contrast, more recent research has shown that both dynamic squats (DS) and counter movement jumps (CMJ) are effective at producing PAP. Therefore at present, there is no unified agreement on an optimal CC.

In cohorts with research into CC's, many studies have examined the effect of recovery time on PAP. It is accepted that as immediately following a CC both PAP and fatigue are at high levels (Tillin et al., 2009), however as time elapses, both PAP and fatigue decrease. A multitude of literature has focused on PAP effects at different times of recovery, yet, no unified agreement can be found on an optimal recovery period. It is suggested that when conducting PAP research, the recovery period used should be adjusted to subject characteristics, type and volume of CC used. The aim of the current study was to examine which type of CC is most effective at exciting PAP, with specific focus on the CMJ, DS and MVC.

CHAPTER 2

LITERATURE REVIEW

2.0 Post activation potentiation

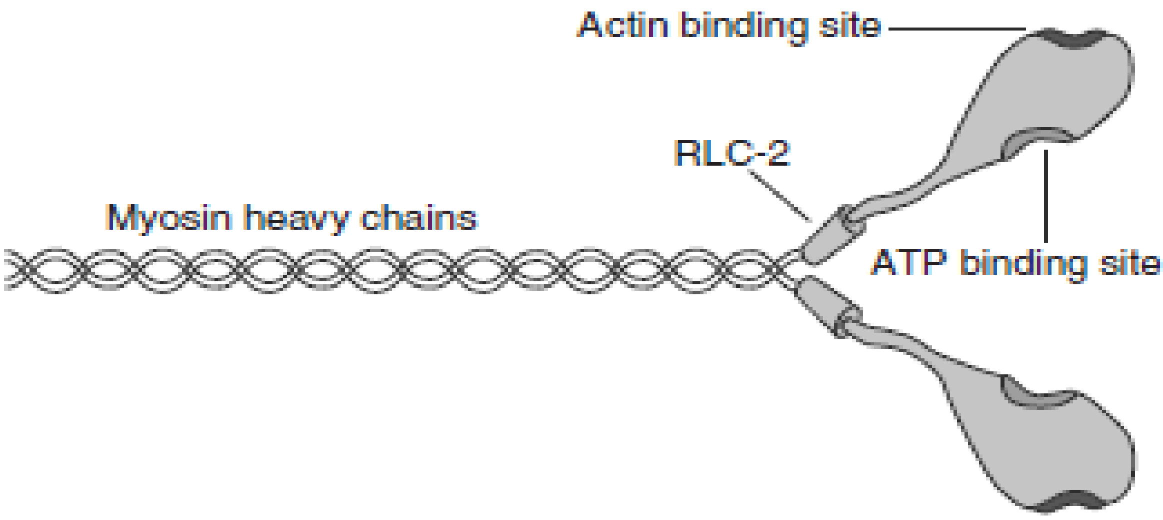
PAP is the mechanism by which an increase in muscular activation is enable through the use of a conditioned activity, usually a maximal or near maximal bout of resistance exercise (Baudry and Duchateau., 2007). Although similar to post tetanic potentiation (PTP), the difference between the two techniques is defined through the way in which the CC is provided. During PTP a CC is provided through the use of a percutaneous electrical stimulus (PES). Requena et al. (2008) stated that PES of the whole muscle at a high frequency for ~5-10 seconds produces the greatest immediate PTP response. Although effective, PTP requires the athlete to be connected to electro-stimulation electrodes to the required muscles. As a result PTP is not ideal to implement into sports training programmes as it is not very practical, especially with regards to sports teams. Oliver and Smith, (2010) also stated that such techniques can negate the need for a feed forward mechanism and can bypass some of the reflex feedback mechanisms that are present in stretch reflex. In contrast, to elicit PAP a conditioned stimulus is used. This involves the use of a conditioned contraction CC and is most effective if it involves the same muscle groups used for the plyometric exercise it aims to improve (Tillin et al., 2009). This study will focus on the use of PAP because the results are more applicable to training programmes within sports teams. There has been extensive research into the area of PAP involving both animal and human studies, and research suggests that if utilised correctly PAP could be implemented into a power training routine to enhance the stimulus of plyometric exercises. During recent studies the types of contraction used for the conditioned activity has differed between both isometric and dynamic contractions. Hamada et al, (2000) found that whilst investigating the effects of a conditioned stimulus on jump performance a 10 second maximal MVC evoked the highest PAP response. In contrast to this Rixon et al. (2007) proposed that a load greater than 80% of 1RM is sufficient to increase power output, and in turn increase PAP. Contradictory results found within PAP data has provoked research into the understanding of PAP mechanisms, and if proved efficient, could replace conventional warm up exercises and be used to as a training stimulus to enhance explosive exercises such as jumping and sprinting.

2.1 Physiological mechanisms of PAP

Research has shown that there are two main mechanisms behind PAP. Firstly PAP is thought to increase the phosphorylation of myosin regulatory light chains; this causes the actin-myosin interaction to become more sensitive to the release of Calcium ions (Ca^{2+}) in a subsequent twitch (Grange et al., 1993, Hodgson et al., 2005). It has also been proposed that PAP can increase the recruitment of higher order motor units (Chui et al., 2003) which can increase neural activity (Aagaard., 2002). There is further evidence which suggests that a conditioning stimulus can cause a change in the pennation angle of skeletal muscle which may contribute to PAP (Tillin et al., 2009), however more research is needed to support the results from these findings. The increase of PAP is thought to enhance performance of ballistic exercises such as jumping and sprinting through an increase of isometric rate of force development (Baudry and Duchateau., 2007a), increased torque of moderately high velocity isokinetic concentric contractions and an increased shortening velocity attained with various loads (Baudry and Duchateau., 2007b).

2.1.1 phosphorylation of regulatory light chains

A myosin molecule is composed of two heavy chains, forming the myosin head (Tillin et al., 2009). Two regulatory light chains (RLC) are contained within the myosin head (Grange et al., 1993), each of which encompasses a specific binding site which



. **Figure 1**. One myosin molecule.

accommodates for a phosphate molecule, altering the structure of the myosin head. Phosphorylation of RLC's is catalysed by the enzyme Myosin light chain kinase (MLCK), which renders actin-myosin interaction more sensitive to Ca^{2+} release from the sarcoplasmic reticulum (Hodgeson et al., 2005) and is responsible for ATP production. As the sarcoplasmic reticulum releases Ca^{2+} more readily, MLCK is activated, this results in more readily available ATP at the actin-myosin complex, increasing the rate at which cross bridges are formed and consequently allowing for an increase in twitch force and rate of force development (Metzger, Greaser and Moss, 1989)

2.1.2 Recruitment of higher order motor units

It is also evidenced that PAP can be caused through an increase in the recruitment of higher order motor units. It is indicated that a conditioned activity can increase activation of the group Ia neural fibres, as a result of an increase muscle spindle firing. This enhances the afferent neural volley, allowing for a decreased transmitter failure (Crum et al., 2012). The afferent neural volley is a term used to describe the process in which neural fibres activate the alpha neurons, causing muscular contraction. An action potential is created at the neural fibres and travels to the spinal cord. From here it is carried through to the adjacent α motor neuron in the agonist muscle causing it to contract (Tillin et al., 2009). Activation of α-motor neurons works on an all-or-none basis and transmitter failure at various synaptic junctions is prevalent during normal reflex or voluntary responses (Tillin et al., 2009). It has been suggested following a CC alteration in excitability of motor neurons, increase in quantity of neurotransmitters released from afferent terminals, increased efficiency of the neurotransmitters and a reduction in axonal branch point failure along afferent neural fibres occurs (Hodgeson et al., 2005, Tillin et al., 2009). Although the evidenced research is based upon animal studies, if a conditioned activity could induce an increase in higher order motor neuron recruitment in humans, the effect would result in an enhanced performance of the subsequent activity.

2.1.3 Changes in Pennation Angle

As of recent, research has suggested that the pennation angle of the muscles could be involved in PAP. This refers to the angle formed by the fascicles and the inner aponeurosis. It has been theorised that smaller pennation angles have a greater mechanical advantage with respect to applying force. Possible reasoning behind this could be explained by Fukunaga, Ichinose and Ito. (1997) who suggested that the sum of all of the individual fibres being applied to the relevant tendon during a muscular contraction are reduced by a factor of Cosϴ, where ϴ is equal to the pennation angle. If correct, then the smaller the pennation angle, the greater the force applied to the muscle tendon would be. However, more research is needed before conclusive assumptions can be made about this theory (Tillin et al., 2009).

2.2 Subject characteristics

2.2.1 Training ability

One of the factors affecting the presence and amount of PAP an individual may gain is training ability. It has been proposed that athletes participating in high level sports activities respond more to PAP than those who participate in recreational resistance training. Research has suggested that this may be due to the athlete's ability to recruit motor units both faster and at a higher firing rate. Furthermore, trained athletes may have more synchronised motor unit recruitment meaning that they can contract a greater number of muscle fibres quicker than untrained athletes. This is supported by Judge et al. (2003), who found that within 14 highly skilled field athletes a positive correlation was evident between increases in MVC torque and EMG stimulation following a sport specific training programme. This indicates that sport specific training can cause an increase in neural drive as an adaptation. Similarly, Duthie et al. (2002) found that following 3RM back squat peak power and peak force was decreased in weaker individuals, but increased for stronger individuals. Therefore it could be argued that athletes that take part in a sport that requires strength and power may be more subjective to the effects of PAP than recreational athletes.

Finally, it has been theorised that trained athletes have built up a resistance to fatigue as an adaptation of their training programmes, and are therefore more likely to maximise the PAP response (Chui et al., 2003). If true, this would result in a change in the fatigue-PAP relationship within trained athletes, with fatigue subsiding at a faster rate. Consequently, PAP could be utilised with shorter recovery periods than those used for untrained athletes. These findings highlight the importance of noting the athletic status of subjects when conducting PAP focused research, as sample consisting of both mix of trained and untrained athletes could cause conflicting results.

2.2.2 Muscle fibres

Increases in PAP are evident in high intensity activities that require a high amount of force production, speed and power. These movements therefore require a large amount of type II muscle fibres due to their ability to produce a large amount of force over a short period of time. Consequently, both individuals and muscle groups with large concentrations of type II fibres will exhibit a larger amount of PAP than those with a low amount of type II fibres (Hamada., 2000). Research suggests that this is due to the fact that type II fibres undergo a greater amount of phosphorylation of myosin RLC's in response to a CC (Moore and Stull., 1984). Hamada et al. (2000) studied the effect of fibre type on PAP, with muscle biopsies being taken from the vastus lateralis of both high and low PAP response individuals. Results showed that participants with a high PAP response to a MVC had a larger percentage of type II muscle fibres. Although studies rarely take muscle biopsies when examining PAP, it could be said that individuals with a larger percentage of type II fibres will respond better to PAP. Subsequently, when conducting research into PAP muscles containing higher percentages of type II fibres should be used to maximise results

2.3 Conditioning activity

Another factor that can affect the amount of PAP is both the type and the duration of contraction. Having said this fluctuations' within volume, intensity and types of contractions have caused conflicting data among previous research. Requena. (2008) found that when comparing voluntary contractions to percutaneous electrical stimulations (PEC) twitch potentiation was greater during the voluntary contraction up to 1 min of recovery, however by 3 minutes this difference dissipated. Furthermore when assessing which duration of contraction was best for PAP Hamada et al. (2000) found that twitch potentiation was greatest immediately after a conditioning brief (5-10 seconds) isometric MVC. The aforementioned studies suggest that a heavy load used for a MVC is most effective at increasing phosphorylation of RLC's and motor unit recruitment. However, Mitchell et al, (2011) examined the difference between an MVC and a 5RM squat at inducing PAP and found that performing one 5RM squat followed by a four minute break increased both jump height and twitch torque, indicating an effective PAP response. In agreement to this Kilduff et al. (2008) found that 3 sets of 3RM squats followed by an 8 minute break was most effective at increasing jump height. This could have been caused by the larger range of motion needed to perform the squat, as it is suggested to require a larger amount of motor units to complete the exercise (Caterisano et al., 2002). Conversely, recent research has looked into the effect of performing ballistic movements as a VC on jump performance. Chen et al. (2013) found that jump height increased through the use of bodyweight drop jumps (DJ). Counter movement jumps (CMJ's) were performed prior to the set of DJ's and at two, six and twelve minute intervals after performing a set of DJ's, with CMJ being significantly higher at all intervals after a set of DJ's was performed. Henceforward, contrasting research from the aforementioned articles illustrates the lack of knowledge within this area of PAP and future research is needed to fully understand this phenomenon.

2.4 Plyometric activity

Nonetheless, when conducting research into PAP it is important to consider what the most effective exercise is to measure the effects. As previously explained PAP maximises the effect of explosive movements. Consequently two main exercises have been repeatedly used among research within the field of PAP, these consist of sprinting and jumping. Both exercises are ballistic movements that may benefit from PAP and both are affected by an increase in rate of force development and power output, which is increased through PAP. Moreover, research in both tests has shown that PAP can improve the performance of these skills. McBride et al, (2005) found that sprint performance improved by 0.87% over 40 metres after performing a 3 RM back squat. Similarly Gourgoulis et al. (2003) found that vertical jumping performance increased by 2.39% following five sets of 2 squats at 20, 40, 60, 80 and 90% of the participants 1 RM. Henceforward the type of exercise used to measure the effect of PAP is often individualised among research and it could be said that this is determined by the training ability of participants involved.

However, it is of note that sprinting has many more variables that can affect performance. The main variable affecting sprint performance is technique, which consists of multiple factors; step frequency, step length, trunk lean, vertical oscillation and lateral movement. Such mechanics of running take years of practice to master effectively and if performed wrong can decrease performance. Hunter et al. (2004) highlighted that as a consequence of a negative interaction between step length and step rate an increase in one factor can result in a decrease in another. As a consequence trained sprinters have a greater mechanical efficiency due to greater technique. As a result of this a mixed sample between sprinters and non-sprinters could disrupt any correlations made between participants. On the other hand both CMJ's and DJ's are less technical, and carry similarities to various sporting movements. Therefore it could be argued that jump performance is a better predictor of the effects of PAP. Consequently, when conducting research into PAP the type of plyometric exercise used is dependent on the individual. However it could be said that when examining subjects that have little sprinting experience, the benefits of PAP may be more accurate using a jump test.

2.5 Recovery time

Although it is well established that PAP is an effective mechanism for increasing ballistic performance, the recovery time allowed between the CC and the performance activity is vital to maximise performance. It is accepted that the longer the recovery period the greater the recovery from fatigue, however as time elapses the PAP stimulus slowly reduces (Sale., 2002). Kilduff et al. (2008) stated that 'following a bout of heavy resistance training, the muscle is in both a fatigued and potentiated state with subsequent muscle performance depending on the balance between these two factors'. Therefore an optimal balance between these two variables is imperative (Paasuke et al., 2007). Many studies have specifically looked at optimal recovery time to maximise PAP (Kilduff et al., 2008; Jensen and Ebben., 2003), however there has been no unified agreement on an optimal recovery period.

Tillin. (2009) suggested that after a conditioned activity both PAP and fatigue are increased. However as fatigue subsides quicker than PAP, it can be utilised at a later point during recovery. Additionally, immediately following a conditioned activity PAP is low, however so is that of fatigue. Therefore Sale. (2002) suggested that there may be two windows that could be utilised for an effective PAP response, one immediately after the CC and one at a later point in the recovery period when fatigue had subsided (figure 2).

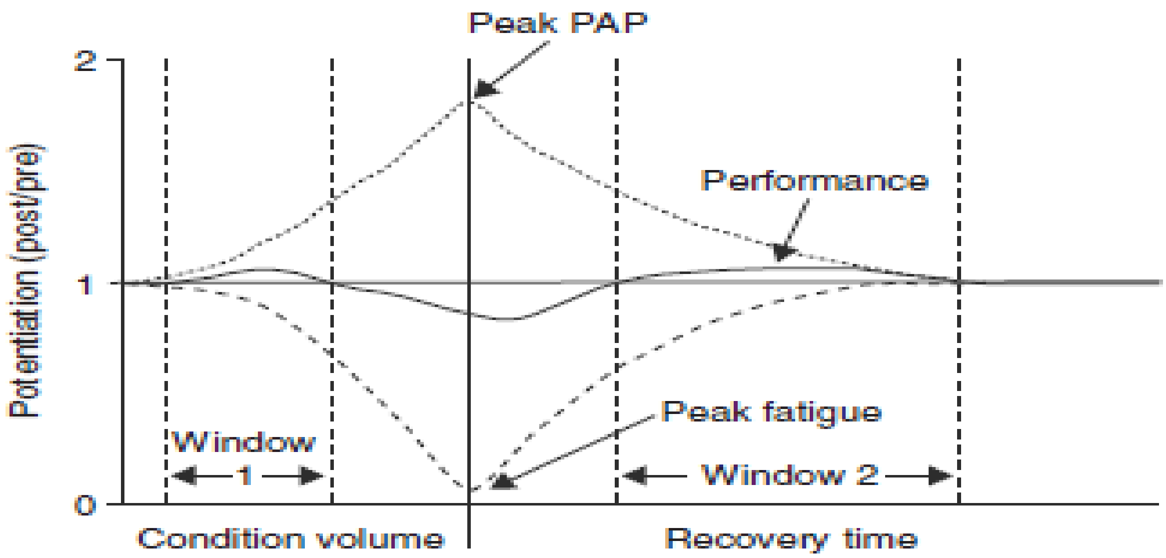


Figure 2. Model of the relationship between PAP and fatigue following a conditioned activity (Sale., 2002)

This is in agreement with Linder et al. (2010) who found that following 4 repetitions at subjects 4RM a 9 minute recovery was most effective at increasing sprint speed. Similarly Kilduff et al. (2008) tested the effect of recovery time on PAP in rugby union players at ~15 seconds, 4, 8, 12, 16, 20 and 24 minute intervals and found that jump height increased greatest (4.9%) at 8 minutes recovery. However, in more recent years Mitchell et al. (2011) found that a 4 minute rest after 5RM squat exercise was most effective at inducing PAP and increasing counter movement jump height. Subsequently, it is difficult to enforce an optimal recovery period due to conflicting results of previous studies. Having said this has suggested that recovery time differs between trained and untrained athletes (Hamada et al., 2000; Tillin et al., 2009; Chui et al., 2003). In light of this statement it could be said that optimal recovery time for PAP in individualised, therefore before conducting research into PAP recovery time should be adjusted to the CC used and the subject training status.

2.6 Rational

The above evidence makes it clear that considerable research has been conducted into the topic of PAP. Despite this, there are many contradictions among previous research which may be explained by the fact that PAP is not yet fully understood. When examining the previous literature there is a wide variety of CC's used to a elicit PAP response, yet there is no conclusive evidence on which type of CC is most effective at producing PAP.

Therefore the current study aims to examine the effects of various loads when performing VC's on DJ performance. The various loads will consist of body weight, 80 and 120% of participants 1 RM squat. The 120% load will involve a MVC; the reasoning behind this being that previous research has shown maximal isometric contractions to be effective at increasing PAP. The bodyweight load will involve dynamic CMJ’s as recent research has shown that performing explosive movements can increase PAP. Finally the 80% load will consist of 5 repetitions of DS to a 90 degree angle. Therefore, the study will not only look at the effects of various loads on PAP but also which type of contraction is most efficient at inducing PAP. The study will examine the effect of PAP on jump performance as there are less technical factors that attribute to jump performance as oppose to sprinting.

2.7 Hypothesis

The primary hypothesis of the current study is that each CC will produce an increase in PAP response, which in turn will increase jump height. The second hypothesis is that PAP, and therefore jump height, will differ between the conditioned activities.

CHAPTER 3

METHODS

3.0 Experimental approach to the Study

In advance of any testing participants height and weight was measured. Height was measured using a Stadiometer (Holtain, fixed Stadiometer, Crosswell, United Kingdom) and weight was measured using digital scales (SECA, 770, Hamburg, Germany). A squat rack was used to perform the squat exercise with medicine balls and boxes' being used to ensure each participant performs their squat to a 90 degree angle. Finally, participants performed DJ's on a force plate (ATMI, Accupower, Boston, USA). This enabled jump height and peak power (PP) to be measured for each participant. Participants took part in 4 sessions. The first session consisted of 1 repetition max testing for the back squat exercise with the others being PAP testing sessions; 120% of 1 RM isometric maximal contraction for 10 seconds, 80% of 1 RM for 5 reps, and bodyweight counter movement jumps for 10 reps.

3.1 Participants

Approval for the current study was sought and accepted by the School of Sport Ethics Committee at Cardiff Metropolitan University. An email was sent out to all Cardiff Metropolitan School of Sport students inviting them to take part in the current study. Participants were accepted on the condition that they were part of a rugby team and took part in a strength training programme. All volunteers were presented with a participant information sheet (see appendix) stating that the current study was part of a level 6 dissertation project, and that aim of the study was to provide an insight into how different types of VC's can affect PAP. Additionally the information sheet explained the experimental procedure and that the squat exercises, CMJ and DJ possess potential injury risks. With this in mind participants were told that they can exit the study at any time without any need for explanation. Upon reading the participant information sheet participants were required to sign an informed consent form (see appendix) stating that the terms of their participation in the current study were explained and understood, and that they are willing to participate in the study.

8 male rugby players from Cardiff Metropolitan University (mean ± SD age, 21.1±0.7; body mass, 91.0kg± 15.2kg; height, 178cm± 0.1cm) took part in the study. All participants were physically fit, with no lower body injuries at the time of testing. They all had at least 2 years lifting experience; more specifically at performing the squat exercise. Testing sessions were organised so that each participant had not performed any lower body resistance

training at least 48 hours prior to testing to maintain the validity of the results. This was achieved by asking the participants to refrain from lower body training 48 hours prior to testing. Similarly, participants were instructed to refrain from drinking any alcohol 24 hours before any testing procedures took place. At the start of the first session the testing protocol was explained to participants, along with possible risks. Informed consent was obtained from each participant in accordance with the guidelines established by the Cardiff Metropolitan University Ethics Committee.

3.2 Warm up

Participants were instructed to undergo a general warm, up which involved pedalling at 60 Watts on a cycle ergometer for 5 minutes before any testing procedures took place (Pagaduan et al., 2012). Following this, participants were asked to perform dynamic stretching of the lower body and core muscles. (McCaulley et al., 2007).

3.3 Determining 1 repetition maximum

Each subject's 1 RM back squat was determined before any testing procedures commenced to calculate the correct loads for the following sessions. This followed a standardised procedure as outlined by Baechle et al. (2008). It involved instructing participants to warm up with a light resistance that will allow for between 5-10 repetitions. Following this there was a one minute recovery period, followed by an increase in load by between 10-20%. This weight was then lifted for between 3-5 repetitions. Another rest period of two minutes was then implemented, followed by an increase in weight by between 10-20%. Participants then lifted the weight for 2-3 repetitions. This was followed by a 2-4 minute recovery period, before an increase in weight by a further 10-20%. Participants were then asked to perform a 1 repetition maximum. If successful then participants had another rest period of 2-4 minutes. The previous step was then repeated. If the participant was unsuccessful, a reduction in weight was made by 5-10% before a one repetition maximum was attempted again. The load was continually increased or decreased until a 1 repetition maximum was found with proper technique.

Free weights were chosen in preference to smith machines as Schwanbeck et al., (2009) found a 43% higher muscle activation during the free weight squat in comparison to the smith machine, evidencing that free weights could elicit a greater PAP response. Further, the participants current training programme involved the use of free weights; therefore using a smith machine may not be the most accurate indicator of 1 RM performance due to a change in stimulus.

To maintain reliability among results, participants were instructed to squat at a 90% angle, this was ascertained through the use of both boxes and medicine balls. The lift was deemed successful if the bar continued to move in an upward direction without any assistance.

3.4 Post activation potentiation testing

Following 1RM testing session, the subsequent sessions involved testing of PAP. In each session the protocol was identical, however the load and type of conditioned contractions used varied.

Following the warm up each participant was instructed to perform 3 DJ’s on the force plate so that individual values for jump height and PP could be measured. When performing the DJ’s a 20 inch box was used. Participants were instructed to step off the box onto a force plate. On the descent they were instructed to keep their arms in Akimbo position (Kilduff et al., 2008) to isolate the lower limbs. This was used to stop the interference of the upper body contributing to jump height. Following this there was a 4 minute break to allow for recovery before the participants were asked to perform their conditioned contraction exercise.

The conditioned contractions consisted of one of the following, either 10 repetitions of CMJ’s, 5 repetitions of DS at 80% of their 1-RM or performing an isometric MVC for 10 seconds at 120% of their 1-RM. When performing the isometric contraction a load equal to 120% of the participants 1RM was utilised so that the bar could not be moved. The isometric contraction was performed with the legs at a 45 degree angle, and with the bar racked so that injury risk was minimal. Participants were instructed to get into position as if they were going to perform the squat exercise, then they were told to exert maximal force against the bar for 10 seconds. When performing the CMJ’s participants were again instructed to keep their arms in Akimbo position (Kilduff et al., 2008) so that arm swing did not contribute to the movement and PAP within the lower extremities was maximised. On the completion of a single jump they were told to reset themselves in the starting position and then jump again. This procedure was carried out until 10 successive jumps were performed.

Following the conditioned contraction there was another recovery period of four minutes before the second set of DJ's was performed (Mitchell et al, 2011), which was used so that fatigue within the skeletal muscles was lowered but with sufficient PAP present to allow for the significant results. In addition, since only one set of a conditioned activity is being performed fatigue will not be excessive due to a low volume of weight being lifted; therefore a recovery time of 4 minutes was most appropriate in these circumstances

3.5 Data analysis

A repeated measures one way analyses of variance (ANOVA) test will also be used to identify whether difference in jump height pre and post each CC varied between each CC used. A significance value will be set at >0.05 and all testing will be carried out using IBM SPSS statistics 20.

CHAPTER 4

RESULTS

4.0 Results

Mean results were shown with figures to establish any differences found when looking at a single sample. Figure 3 shows participants mean jump height results for the DJ with pre and post each intervention; DS, MVC and CMJ. Figure 4 displays participants mean PP results for each intervention; DS, CMJ, MVC.

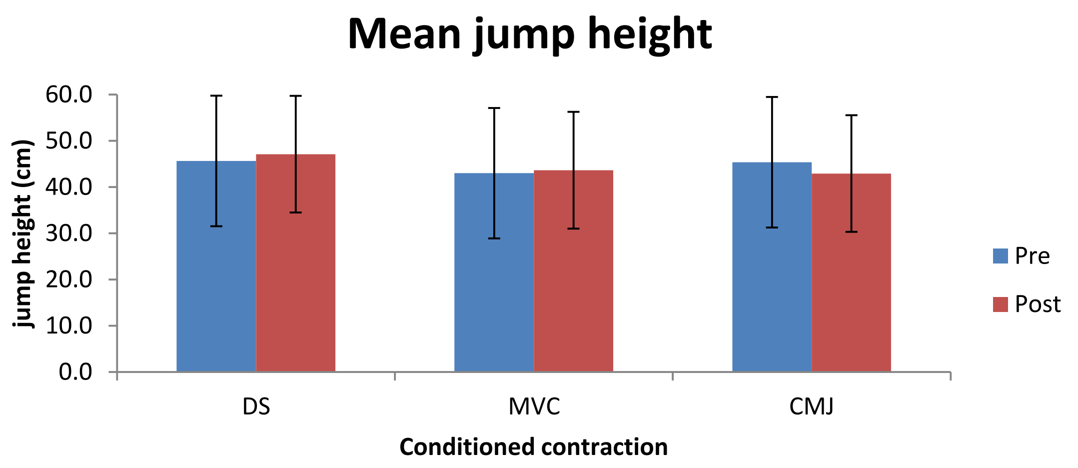


Figure 3. Mean and SD results for participants JH pre and post each intervention.

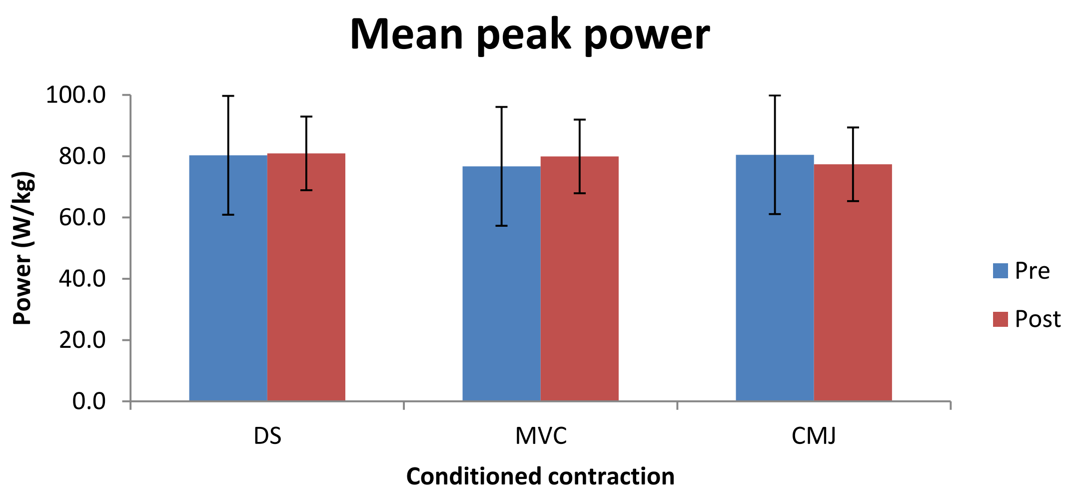


Figure 4. Mean and SD results for participants PP pre and post each intervention.

Participant's individual results for jump height and PP were compared against one another to try to identify which CC was most effective for each participant, with a minus number resulting in a decrease in the specific variable, and a positive number resulting in an increase. Tables 1 and 2 show each individuals response following each CC, with table 1 focusing on jump height and table 2 on PP.

Table 1. Individual differences in jump height among the three CC's.

JH(cm)			
Subject	*DS*	*MVC*	*CMJ*
1	18.1	13.2	-11.6
2	3.1	-0.1	-2.4
3	6.3	-8.8	-4.9
4	-14.1	-5.1	-6.2
5	0.5	-3.4	1.3
6	-8.2	1.9	5.7
7	4.6	6.8	1.1

Table 2. Individual differences in PP among the three CC's.

PP (W/KG)			
Subject	*DS*	*MVC*	*CMJ*
1	30.18	16.4	-17.5
2	-4.3	-2.2	-10.8
3	-2.1	-7.2	10.3
4	-21	-9.9	-7.1
5	-1.7	1.1	1.1
6	-1.3	6	1
7	4.7	18.5	1.1

4.1 One way repeated measures ANOVA

A repeated measures ANOVA was used to identify any significant differences in jump height and PP pre and post each CC. Two one way repeated measure ANOVA's were used, one for each variable, with a significance value set at <0.05. Mauchly's test of sphericity showed that for both PP and jump height ANOVA's sphericity could be assumed, however no significant differences were found.

CHAPTER 5

DISCUSSION

5.0 Discussion

The aim of the present study was to investigate the effects of various contraction types on PAP and subsequent DJ height, which was achieved through measurements of DJ height and PP. The single sample results support the null hypothesis in which there were no significant differences between each of the three contractions and jump height. A repeated measure ANOVA demonstrated that there were no significant differences between jump height pre and post each CC as the pairwise comparison value was greater than 0.05. However results did support the second hypothesis, being that each CC produced a different PAP response.

When examining figures 3-5 it is clear to see that although responses to each CC differed, the CMJ contraction was the only intervention to consistently cause a decrease across all of the measured variables. Tables 1 and 2 display the individual responses of jump height and PP to each CC. All participants, excluding subject 4, found an increase in jump height after a CC suggesting that a PAP response did occur. The tables help to demonstrate how the responses to PAP are individual, with 3 of the participants responding better to the DS intervention, 1 participant responded best to the MVC intervention and 2 responding best to the CMJ intervention. Therefore, to say that there was no PAP response because no significant differences were found is unwise. When looking at the sample as a whole either no significant differences or a decrease in performance was found, yet, individuals did witness a PAP response.

Similar studies have found corresponding results to the current findings in the present study. Duthie et al., (2002) found that when using a heavy load squats (3 reps of 3RM) no significant differences were found when examining both power output and jump height. Similar findings were apparent in Chaouachi et al’s study., (2011) who found that after performing a variety of squat loads no significant differences between load and rest interval were found. However, the two samples used in these studies consisted of women and volleyball players. This is important to consider as it has not only been found that women are less subjective to the effects of fatigue (Rixon et al., 2007), but also that athletes that are able to squat 1.5 times their body weight are more sensitive to PAP. Since Volleyball players have no need to undergo a strength program due to the nature of their sport, they may therefore be less sensitive to the effects of PAP. In contrast, the current study used competitive rugby union players currently going through a strength and conditioning program. The differentiation in subject characteristics between the aforementioned studies and the current study therefore makes it difficult to justify a comparison.

It is well documented that trained subjects are more liable to the effects of PAP (Chui et al., 2003; Judge et al., 2003; Hamada et al., 2000) yet the current study found no significant PAP response. The lack of any significant differences among the current study and the aforementioned studies suggests that the criterion needed to participate in the current study was not rigid enough. Although it was a requirement that subjects were physically fit rugby players undergoing a strength and conditioning training program, it was not clear what stage in their training cycle they were in (hypertrophy, strength, power). Tillin et al. (2009) suggested that a negative correlation can be found between strength to power ratio and potentiation of peak power following 6RM back squats. The study also found that when separating the groups into different strength to power ratios, the group with the lowest strength to power ratio received the greatest effect from PAP. Therefore it could be said that subjects that are less able to convert strength into power are more susceptible to the effects of PAP (Tillin et al., 2009). In the current study, subjects may have had differing strength to power ratios depending on what stage of their training program they were in. Consequently, subjects that had a greater response to PAP may have been in the hypertrophy block of training, during which power becomes less of a focus in order to allow for the appropriate volume of training to be completed for muscular hypertrophy, resulting in a lower power to strength ratio. In contrast, subjects that were in the power phase of their training program would be more able to convert strength into power efficiently and would therefore be less subjective to a PAP response caused by a CC.

It could be said that the lack of any significant results from the current study was caused by fatigue. Similar findings can be reported from Behm et al., (2004) who found that following a MVC subsequent activation was decreased. It could be argued that with a longer recovery fatigue would have dissipated, allowing for a greater utilization of PAP. Linder et al, (2010) found that following a 4RM squat the most significant increase in sprint speed was found at 9 minutes. This suggests that the mechanisms behind PAP are negatively affected by fatigue, yet by allowing a longer recovery period fatigue will lower below that of PAP, allowing for an increase in performance. However, contrasting data has been found when looking at the relationship between PAP and recovery time. Chen et al, (2013) found that following a set of DJ's CMJ height was increased significantly at all rest intervals, (2,6 and 12 minutes) with CMJ after 2 minutes recovery being significantly higher than the following rest periods. It is of note that shortly after a CC PAP is present, but so is fatigue, causing a decrement in performance (Tillin., 2009).

However, although fatigue dissipates as recovery time increases, so does PAP (Sale., 2002). This makes finding an optimal balance between the fatigue-PAP relationship difficult. It has been proposed that there are two optimal windows for PAP utilization (see figure 2), one being present immediately after the CC, and the other window being further into recovery once fatigue has had a chance to dissipate but with PAP still at moderate levels. It could be said that the recovery time used in Linder and Chen's studies fell in each of these PAP 'windows'. The difference between the two previous studies being that the volume of conditioned contraction differs, with Chen et al using a low volume CC, and Linder et al using a higher volume CC. Therefore it may be that with a lower volume CC, recovery time should be kept short to utilize the initial PAP window. Conversely, when using a larger volume CC a greater rest period should be used to take advantage of the second PAP window. The current study used a rest period of 4 minutes, which may have fallen between these two windows, meaning that fatigue had not dissipated enough for PAP to be utilized (Sale., 2002). Similarly, in the present study a mix of sub maximal, maximal and supra maximal loads were used. This could have meant that the recovery time of 4 minutes was too long for the sub maximal load resulting in a drop in PAP, however it may have been too short for the maximal and supra maximal load resulting in fatigue being too high to obtain optimal results. Although the intent was to keep all conditions the same to increase reliability of the results, it may have been more accurate if varied recovery times were used depending on CC type.

Alternatively, fatigue from prior training sessions may have caused negative effects within the results. Although it was stated that all subjects must not have trained 48 hours prior to testing, due to their busy training programs the subjects were involved in, it was difficult to avoid this. The fitness fatigue model states that different training stressors result in differed physiological adaptations. These consist of either fitness or fatigue after effects, the fitness after effect being a positive response, and the fatigue after effect being a negative response. Chui et al. (2003) suggested that for strength and power athletes such as the ones who undertook this study, fitness affecting factors include muscle cross sectional area, muscle contractile protein composition and muscle metabolic enzyme contractions. The interaction of the fitness and fatigue after affects can cause a change in performance following the conditioned stimulus (figure 6).

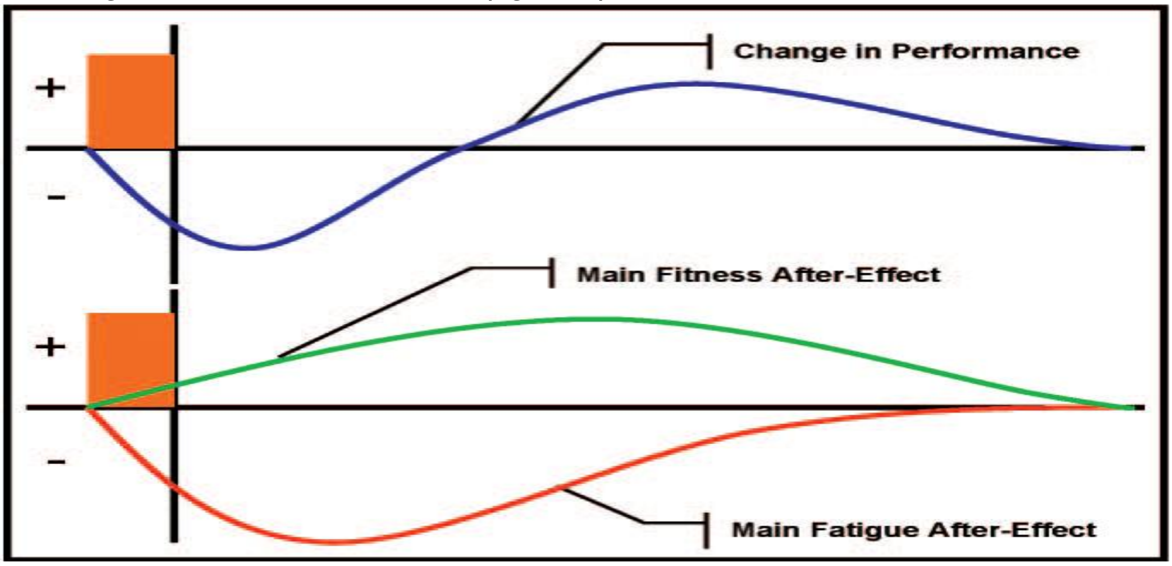


Figure 6. The relationship between fitness and fatigue post exercise.

The fitness fatigue model suggests that post exercise, both fatiguing and fitness effects occur. Therefore it could be said that the subjects that participated in the study were experiencing fatigue effects due to previous training sessions, and required a greater rest period before fitness effects could be witnessed. It is of note that, while participants may have been in different stages of their training program, a brief decrement in performance can occur regardless whether the program focused on volume or intensity (Chui et al., 2003).

With regards to the varied PAP responses within tables 1 and 2, individuality may have affected the results. Previous research has postulated that the variables that affect individuality include muscle fiber type, gender and training experience of the subjects (Rixon et al., 2007; Chui et al., 2003; Hamada et al., 2000). It is stated that athletes with a higher percentage of type II muscle fibers will have a greater benefit from PAP (Hamada., 2000) due to a greater phosphorylation of RLC's (Moore et al., 1984). Similarly, Rixon et al. (2007) studied the difference in PAP response in both men and women and identified that men with no lifting experience still produced a larger peak power than the experienced women lifters. It was suggested that this may be due to a larger amount of fat free mass in the male athletes, resulting in a higher amount of type II fibers. Although the current study used rugby union players involved in a strength and conditioning program, body fat percentage was not recorded. As a result of this, the amount of fat free mass may have differed between subjects meaning that the amount of type II fibers may have varied between participants. Similarly specific roles within rugby union vary depending on positions, for example, a front row forward requires a large amount of strength to perform their role on the field but doesn't have much use for speed. Conversely, whilst strength is important, a rugby union winger requires a large amount of speed and power. As a result, subject characteristics may have differed, depending on what position each participant played. As position specific data was not recorded in this study, individuality within results could have been affected.

5.1 Limitations

During the present study a number of limitations surfaced and should be addressed. Firstly, a relatively small sample size of 8 subjects was used, which would have meant that the results were more vulnerable to anomalies in data. Coupled with the fact that a small sample size can have little statistical power when compared to an athletic population, means that only speculative assumptions cannot be made from the present data.

Further, recovery periods between the conditioned contraction and the second set of DJ's was not adjusted for the different types of conditioned contractions used. Although the aim of a set recovery period for all conditions was to maintain reliability among results, the different load of the contractions could have produced a varied response on PAP. It could be said that the CMJ's could have made use of a shorter recovery time, whilst the 80% and 120% load could have made use of a longer recovery period.

Training status of the individuals may have been a cause of the variation within the results. As subjects with a lower strength to power ratio can receive a larger benefit from PAP (Tillin et al., 2009), subjects who were in the power block of training could have received less PAP response from the CC and vice versa.

Finally, individuality among the participants may have negatively affected the results. As body fat percentage and position specific data was not recorded, differences in body fat percentage and type II fibers may have caused a difference in the results.

CHAPTER 6

CONCLUSION

6.0 Conclusion

The current study sought to highlight an understanding between the effects of a complex training method on PAP response, with a specific focus on how CMJ's, dynamic squats' and MVC's affects jump height and PP within rugby union players. The aim of the study was to try and establish which CC was most effective at eliciting a PAP response. Therefore, difference in variables pre and post each intervention was examined between the differing CC used to see if there were any significant differences.

Despite a lack of any significant differences being found in the current study, particular trends were identified, namely that on average all measured variables were increased following the DS intervention, and PP was increased following the MVC intervention. In spite of this, certain limitations were also identified in the present study making it hard to draw any conclusive findings. First and foremost, the recovery time used in the present study did not adhere to each intervention, meaning that a fatigue response could have caused a drop in performance among individuals. Similarly, individual subject characteristics such as fat free mass, training cycles and position specific data were not recorded. This could have resulted in varied amounts of type II muscle fibers and strength to power ratios between individuals, causing the high variability between individual results. Therefore a more rigid participant recruitment protocol was needed to obtain reliable results.

As a result of this study, it could be said that the effects of PAP are individual, and therefore an optimal CC for one subject may not be optimal for another. As a result, coaches should seek to find an optimal CC for each individual, as oppose to a group of athletes.

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APPENDICES

APPENDIX A

ETHICS APPROVAL STATUS

Date: 14/02/2014

To: Tom Ivory

Project reference number: 14/3/37U

Your project was recommended for approval by myself as supervisor and formally approved at the Cardiff School of Sport Research Ethics Committee meeting of [include the one that applies 29th May 2013, 26th June 2013, 24th July 2013, 16th October 2013, 27th November 2013].

Yours sincerely

RSL

Supervisor

APPENDIX B

PARTICIPANT INFORMATION SHEET

Participant information

Title of project: The effect of conditioned contraction type on post activation potential in rugby union players.

Background

There has been a lot of research into the area of post activation (PAP), the main theory behind it being that PAP can increase the performance of ballistic skills such as jumping and sprinting through the use of conditioned contractions (VC). However despite an abundance of previous research it is still not fully understood which load is best when performing a VC to maximise PAP.

What you will be asked to do

If you agree to take part in the project you will be asked to attend 5 sessions ranging from between 20-30 minutes each. The first session will consist of 1 repetition max testing for the squat exercise. The following sessions will consist of post activation potentiation testing where participants will be asked to perform 2 sets of drop jumps on a force plate with a set of either body weight counter movement jumps, 5 dynamic squats at 80% of participants 1 repetition maximum, or a maximal isometric contraction of the squat exercise held for 10 seconds.

Are there any risks?

There is a risk of injury when performing the conditioned contractions and jumping exercises if a proper warm up is not used. This will be addressed by making sure that all participants have had a proper warm up before any resistance training takes place.

Your rights

Participants have the right to stop taking part in this study at any time without reason.

What happens to the results of the study?

The results from this research will be included in a dissertation project and published by Cardiff Metropolitan University. However subject’s names will remain anonymous.

Are there any benefits from taking part?

Participants will be presented with the information collected from the study if asked to further their knowledge into the subject. They will also gain valuable experience in partaking in a dissertation study which will help when performing theirs in the future.

What happens next?

Enclosed in this letter you will find a consent form. You will need to complete this and upon doing so we will get in touch about performing your first session.

How we protect your privacy

No names will be taken during the study, instead subject numbers will be used instead to ensure that you cannot be identified within the study.

Further information

If you have any further queries do not hesitate to contact me.

Mr Tom Ivory
07930503920
Tom-ivory@hotmail.co.uk

APPENDIX C

INFORMED CONSENT SHEET

Informed consent

Title of project: The effect of conditioned contraction load on post activation potential

Name of researcher: Mr Tom Ivory

Participants to complete this section: Please tick the box

1. I confirm that I have read and understand the information sheet. I have had chance to ask any questions and have had them answered satisfactorily. ☐

2. I understand that the study is voluntary I am free to stop taking part at any time without reason. ☐

3. I understand that the data of the study may be used for reporting purposes but I will remain anonymous. ☐

4. I agree to take part in the study. ☐

Your name

____

Your signature _________________________ Date _________________________

Name of person taking consent _________________________ Date _________________________

Signature of person taking consent

____