Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

Empirical [1]

Student name: Joel Knight	***Student ID:*** St10001831
Programme: SCRAM	
Dissertation title: **The effect of squat depth on the post activation potentiation response during 40m sprint performance**	
Supervisor: Rob Meyers	

Comments	**Section**
	Title and Abstract Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
	Methods and Research Design

[1] This form should be used for both quantitative and qualitative dissertations. The descriptors associated with both quantitative and qualitative dissertations should be referred to by both students and markers.

	To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
	Results and Analysis [2] To include: description and justification of data treatment/ data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.
	Discussion and Conclusions [2] To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.
	Presentation To include: academic writing style; depth, scope and accuracy of referencing in the text and final reference list; clarity in organisation, formatting and visual presentation

[2] There is scope within qualitative dissertations for the RESULTS and DISCUSSION sections to be presented as a combined section followed by an appropriate CONCLUSION. The mark distribution and criteria across these two sections should be aggregated in those circumstances.

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CARDIFF SCHOOL OF SPORT

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TITLE

THE EFFECT OF DIFFERENT SQUAT DEPTH ON THE POST ACTIVATION POTENTIATION RESPONSE DURING 40M SPRINT PERFORMANCE

(Dissertation submitted under the discipline of Strength and Conditioning)

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Acknowledgements

Thanks to Rob Meyers for his continued support throughout the writing of this dissertation.

Abstract

Knight, JW. The effect of different squat depth on the Post Activation Potentiation response during 40m sprint performance. Previous studies have suggested that post-activation potentiation can have a positive effect in improving the performance of explosive strength and power activities. Also there is previous evidence to suggest that squat depth can influence muscle activation and performance. This study was designed to see whether squat depth had an influence on creating a PAP response and whether this response could affect sprinting performance over 40m. Fifteen male competitive, rugby players all whom train and participate in strength and conditioning sessions regularly (Height 186.30±4.678 cm; Weight 95.25±5.488 kg; 90 degree of knee flexion 1RM 190.67±29.93 kg; Parallel1RM 159.33±23.37 kg) performed a baseline sprint of 40m measured at 5, 10, 20 and 40m intervals. They also performed 3 reps at 90% of 1RM of both parallel and 90 degree squat variations followed by sprint tests at 5, 10, 20 and 40m intervals. Significant differences ($p<0.05$) were observed at 20m between baseline and parallel scores ($p=0.000$) and 40m between parallel and baseline ($p=0.016$) and parallel and 90 degree ($p=0.018$).There was also a significant difference between baseline and 90 degree score ($p=0.039$).However no significant differences ($p<0.05$) were observed at 5 or 10m. Whether the results in sprint performance came as a result of a PAP response cannot be completely assumed as there were a number of extrinsic variables that may have influenced performance results. However the study does provide sufficient evidence to suggest inducing a PAP response can influence sprinting performance and therefore warrants increased development of research into the subject area.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

In many sports the ability to accelerate to, and reach a high level of maximal speed can be highly beneficial. Studies have found that by increasing the available force of muscular contractions in appropriate muscles through specially designed resistance training programmes may result in an increase in acceleration and speed within an athlete (Bangsbo et al, 1991). There have been many resistance training programmes used to improve lower limb strength and power. These training programmes generally include a barbell back squat or squat variations exercise (Clark et al, 2012). There is also research into the effects of squatting to different depths and whether this can help to improve sprint and lower limb power performance (Clark et al, 2012). More recently studies into post-activation potentiation (PAP) and the potenial benefits provide to increasing power (McBride et al, 2005). However there has been little research into squat depth and its effect on producing a PAP response. Also there is a lack of research using explosive and powerful sport specific skills in order to test for a PAP response, for example sprinting performance. This is an area that needs to be further researched in order to establish whether there is an optimal squat depth when aiming to improve lower limb power and speed. This research would benefit strength and conditioning coaches, not only in their own understanding but in how the develop training programmes. Furthermore it will benefit athletes being coached as if they are able to develop greater muscular power and cause an increase in speed it is likely this will in turn lead to improved performance. This research combined with already well researched and understood training techniques and practices could lead to significant improves im athletic performance. In order to further understand this research area a study will be carried out designed to discover whether squatting to different depths can influence PAP response and whether this can lead to improved sprint performance. In order to this data will be collected from the testing of the study and analyse this data in order to discover whether the findings are significant. From the previous research that has been conducted into similar areas of study it can be hypothesised that the parallel squat variation will produce faster sprint times as it has been found that increased squat depth causes increased muscle activation (Catersiano, 2002) therefore there is likely to be a higher recruitment of motor units, which is a theory of how a PAP response is initiated (Chiu, 2003). However there may be some limitations of the study that need to be assessed. For example there will be some intrinsic variables that will be uncontrolled such as diet and the use of sports supplements. Whilst advice and guidelines will be given to participants regarding rest and recovery pre, during and post testing whether this advice is acted upon or not is not able to be controlled. Therefore some elements of extrinsic factors may have an affect on the results of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Squat and its Use in Training

The squat exercise is one of the most widely used exercises in nearly all training programmes. This is because the prime movers of sprinting and jumping are the knee and hip extensor muscles, which are the prime movers involved in squatting. Developing strength in these muscle groups in a biomechanically similar pattern has been shown to improve running speed and jumping ability over time in a number of populations, not the least of which are trained athletes (Roundtable, 1984). Due to the squats ability to develop both absolute strength and increase physical growth of the muscles it is favoured amongst conditioning coaches as an exercise to improve lower limb size and strength (Beachle, 1994). However there has been lots of research to determine which type of squat is most beneficial to improving athletic performance and also to what depth athletes should squat in order to achieve maximal advantage from the exercise. For example it is said to develop maximum hip or knee joint strength, the joint must be worked through a full range of movement (O'Shea, 1985). Furthermore by executing a full squat the knee joints are near maximal flexion and this greater range of motion promotes greater motor recruitment (Roundtable, 1984). This is why it is said that the deeper the squat the greater the training benefit due to the increased neuromuscular response (Roundtable, 1984). In a further study it was discovered that heavy back squats caused a significant increase in speed over a 10-20 metre interval compared to the control treatment (Yetter, 2008). More important however was the discovery that heavy back squats produced significantly greater speeds compared to the heavy front squat condition (Yetter, 2008). The different effects may be due to differing levels of muscular activation or also relate to the different mechanical aspects of the squat exercises used in the study. This research shows how heavily loaded back squat exercises could be incorporated into training and warm up programmes by coaching looking to improve sprint performance.

2.2 Maximal Squat Strength and Sprint Performance

There is evidence to support the claim that maximal squat strength causes an increase sprint performance. Wisloff (2004) found a significant correlation between 10 metre sprinting times and 1 repetition maximum during a free weight squat. Also

McBride et al (2009) found there was a significant correlation (r= -0.940) between maximal squat strength and 10 and 40 yard sprint times. They also found a negative significant correlation at 5 yard sprint times (McBride et al, 2009). There have also been studies into whether an improvement in maximal squat strength can cause an increase in sprint performance. It was found after an 8 week pre-season training period both absolute and relative squat strength values showed significant increases which was reflected in the significantly faster sprint performances over 5 m (Comfort et al, 2012). Similarly Chelly et al (2009) found a significant improvement in squat strength, leg power, and jump height and sprint performances in young male soccer players. This suggests that by improving maximal squat strength sprint performance can be improved. This information would be useful to conditioning coaches as they can use it within specific training programmes. They can also be incorporated into phases of training in order to ensure athletes peak at the time of competition. In a further study concentric knee extension torque was found to be significantly correlated to 15 and 35 metre sprint times (r=-0.518 and 0.688, respectively) (Dowson, 1998). In McBride et al's (2009) study they were able to conclude the idea that the strength of the lower-body musculature appears to play a role in maximal sprinting velocity. Although Harris et al reported a statistically non-significant correlation between a machine squat 1RM and 10 meter and 40 meter sprint times (r = 0.200, -0.140, respectively)(Harris et al, 2008).Thus, it appears that a free weight multiple-joint structural measure of strength might have a more significant predictive capability in terms of sprinting ability (McBride et al, 2009). This evidence can be used in determining exercise selection when testing for a relationship between lower limb strength and sprinting performance.

2.3 Squat Depth and Muscle Activation

There is also the suggestion that there is different muscle activation throughout different squat depths. Many different squat depths are used in training and all are practical, however it is believed that a squat depth to parallel is the most effective in improving athletic performance (Clark et al, 2012). However the study was limited as the selection of the test load as this would have represented very different relative loads for the squat at each depth (Clark et al, 2012). To improve the study different loads relative to the participant's one repetition maximum in each of the three squats performed could be used, rather than one standardised load for all three lifts. These findings are supported by a study where the activation of muscles of the quadriceps, hamstrings, and buttocks for squats to 3 depths, partial, parallel, and full with knee angles of 135, 90 and 45 degrees, respectively, was measured. Caterisano (2002) found increased muscle activation with squat depth was only found in the gluteus maximus in the full squat (35% mean integrated EMG) compared with 17% in the partial squat. In a pilot study data indicated that the clearest EMG signal was attained in subjects who possessed a relatively low percentage of body fat (<10%). These findings were used effectively, as all participants had a body fat percentage of less than 10%. However only 10 participants were used in the testing procedure, a larger group of participants would be able to increase the reliability of the study's findings. In a further study it was found Rectus femoris and erector spinae activity were significantly higher during the parallel squat condition ($p < 0.05$). Biceps femoris and gastrocnemius activation was similar between the partial and parallel squats (Gorsuch et al, 2010). However in another study Wretenberg (1996) found contrasting evidence. They measured the activation of the vastus lateralis, rectus femoris and the long head of biceps femoris in power lifters and strength trainees. They completed a squat combined average of 200kg for one repetition for the full squat. All participants performed both parallel and full squats. The found no difference in muscle activation across the two depths of squat (Wretenberg, 1996). However the same load was being used when performing both the partial and parallel squats. The reason that no difference in muscle activation was found may be due to the fact that the loading of the partial squats was not great enough. To increase the studies validity different loads suitable of causing near maximal contractions in both the partial and parallel squat exercise. The use of the quarter squat exercise as a training element can be called into question due to the study performed by Hartmann et al (2012). They found that quarter squat training did not produce any significant changes in vertical jump performance and did not develop any increases in maximal rate of force development and maximal voluntary contraction in the trained joint angle. Instead quarter squat training elicited significant declines in both isometric force-time parameters (Hartmann et al, 2012). These findings are supported by Weiss et al (2000) who found the training group who performed quarter back squats did not show significant transfer effects of 1RM to parallel back squats after training and demonstrated significant lower dynamic maximal strength values ($p =< 0.05$) than the training group that carried out parallel back squats. The information gathered from the results of these studies can be used in many different areas of sport. They can be especially useful for biomechanists and conditioning coaches in determining the best depth to squat to in order to produce the most forceful lower limb contractions. Also it highlights the need for further research to be carried out on the different effects training at different squat depths can cause. The findings in these studies present the need for further research to be done in order to better understand optimal squatting depths for athletes in different training situations.

2.4 Power and Muscular Strength

Power and muscular strength have always been considered essential attributes for athletes to possess in order to perform successfully in different team or individual sports. Due to this there have been many studies designed to test different training strategies effectiveness at improving an athlete's power. Different strategies have been developed for the improvement of power. These include an athlete working against their own body mass for example plyometric training (Kilduff et al, 2007). Also types of resistance training of varying intensities have been experimented with to find the optimal load for power development. Recently studies concerning the maximal loading of muscles in order to create an increase in muscular performance within a short period afterwards (Sale, 2002). This training method may have additional benefits for rugby players because of the multifaceted nature of the game and the fact that players are required to produce large amounts of force quickly against contrasting external loads during a game (e.g. side-stepping or scrummaging) (Kilduff et al, 2007). The study of post activation potentiation is therefore important as it can be used in a practical aspect in order to improve performance. For example by training with a maximal or near maximal load before a sprint event could help to improve an athlete's performance. Therefore further study into the area of post-activation potentiation is needed in order to develop greater understanding of how it can be used to improve performance in athletes.

2.5 Post-Activation Potentiation

Post-Activation Potentiation (PAP) is defined as an increase in muscle performance after a conditioning contraction. The conditioning contraction could be a maximal voluntary contraction (Hamada et al, 2000) it could also be an evoked tetanic contraction (post tetanic potentiation) or a series of evoked twitches (Xenofondos et al, 2010).It has been reliably found that by using such conditioning stimuli there can be an increase in explosive movement patterns, rate of force development and twitch contractions (Xenofondos et al, 2010).

2.6 Post –Activation Potentiation Mechanisms

Two Primary mechanisms have been used to explain the occurrence of PAP. The first elucidation for the muscles potentiated state after they have been maximally or near maximally stimulated is the phosphorylation of myosin light chains (Rassier & MacIntosh, 2000). The actin-myosin interaction via the calcium released from the sacrcoplasmic reticulum is the main attributant to this mechanism (Sale, 2002). Also, the myosin light chain kinase, which is responsible for making more ATP available at the actin-myosin complex that, in turn, increases the rate of actin-myosin cross-bridging (Xenofondos et al, 2010). Hence, the maximum conditioning stimulus increases the power output of the cross bridges and this in turn improves the performance of explosive movements (Hodgson, 2005). The second theory proposed is that the stimulus causes the recruitment of higher order motor units (Chiu et al, 2003). Also increased neural activity may occur through recruitment of more motor units and a better synchronization of motor units (Aagaard, 2003). Therefore the PAP may result from neural and muscular mechanism interactions that are still not fully understood at this time (Xenofondos et al, 2010).

2.7 Post-Activation Potentiation Effect on Performance/Rest Times

Post activation potentiation has been primarily studied in order to assess whether it can cause an increase in power from athletes. Many of the studied carried out look at lower limb power and use counter movement jump or sprint tests, in order to determine whether there is a significant correlation between the conditioning contraction and test performance. There have been several tests looking at the effect of loaded back squats on counter movement jump performance. It has been found that after a maximal voluntary contraction in the back squat exercise, jump power improvement was significantly greater than maximal dynamic squats (Rixon et al, 2007). This suggests the need for a maximal or near maximal contraction to occur for the post-activation potentiation effect to take place. This information would be useful to strength and conditioning coaches when determing training loads of athletes and could also be used effectively in warm-ups for certain sports. Similarly Heavy-load squats performed at near-maximum workloads, as well as shorter rest periods, when used as part of a warm-up have previously been shown to increase vertical jump performance (Hansen et al, 2007). Furthermore another study found countermovement jump heights to be significantly higher than baseline scores although only after significant recovery time was allowed. When performed directly after the heavy resistance training jump height became significantly reduced (Kilduff et al, 2007). This suggests that recovery time is a key element in utilising the post-activation potentiation effect. Another study found similar results with countermovement jumps 4-13% decreased 10 seconds after performing heavy resistance training. It also found no increase in jump height after 4 minutes of recovery, again suggesting the importance of allowing sufficient rest intervals (Jensen, 2003). The significance of rest timings are very important when linking the findings into practical application as the studies have shown if significant recovery time is not allowed the post-activation potentiation effect will not be able to be fully applied to increasing an athlete's performance in certain situations. Other studies however seem to contradict previous findings. It was found that after performing near maximal muscular contraction there was a 3% improvement in 40 metre sprint times after 4 minutes recovery time (Rahimi, 2007). This contradicts Jensen's findings that showed no increase in countermovement jump after 4 minutes of recovery time. This suggests there may be different optimal recovery periods for different testing scenarios such as countermovement jumps and sprint tests. Another study has been found to support the theory of differing recovery intervals for sprint and countermovement jump tests. It was found after maximally loaded back squats after a 5 minute rest interval there was a 3% decrease over 10 metre sprint time and 2% decrease over 30 metre sprint time (Chatzopoulos et al, 2007). These studies emphasise the importance of giving athletes optimal recovery time in order to ensure that they are best conditioned to produce a post-activation potentiation response. Whilst there is still are debate of what is an optimal rest period in order to maximise the PAP response Kilduff et al's (2007) results suggest that the optimal rest period is largely down to the individual. "Results showed that 14 participants (70%) attained their highest power output, peak rate of force development, and jump height after 8 min of recovery, while three attained their peaks after 12 min. The remaining three participants produced their best results after only 4 min of recovery .The studies also suggest that a recovery period of minimum of 5 minutes is needed in order for post-activation potentiation to influence sprinting performance. (Kilduff et al, 2007)". This shows how the PAP response is mainly down to individual differences. To generalise findings however it can be suggested that a recovery period of minimum of 5 minutes is needed in order for post-activation potentiation to influence sprinting performance.

2.8 Effective Loads to Induce Post-Activation Potentiation Response

Whilst it appears that all studies use either maximal or near maximal loads to try and induce the post-activation potentiation response in the muscle fibres. However most studies are slightly different in the percentage of maximal loading they use. Although, most studies do use a barbell back squat as the pre conditioning contraction in order to try and produce a post-activation potentiation response. The studies also seem to vary depending upon the testing procedure. For example, when using a 30m sprint test Chatzopoulos et al (2007) found used 10 sets of 1 rep at 90% of 1RM lift, this was followed by a 3 minute rest interval between sets. Whilst another study by Rahimi (2007) with a 40m sprint test used 2x4 reps of 80% of 1RM and gave 2 minute rest intervals between sets. In a study involving collegiate football players a heavy squat protocol of 3 reps at 90% of 1RM was used (McBride et al, 2005). This found a significant difference was the 40-m sprint time between heavy squat and the control of no pre-conditioning exercise (McBride et al, 2005). In a further study a significant increase in performances with elite sprinters occurred when performing a heavy resistance warm-up consisted of 90% of their 1RM for 5 sets of 1 repetition in the back-squat exercise (Pfaff, 1997). Again in a further study elite rugby players had significantly improved 20-m sprint times after a preload back-squat warm-up that consisted of 1 set of 5RM (Matthews et al, 2004). The studies all suggest that optimal loading is between 80-100% of 1RM. This means that the minimal loading that can be used top initiate a PAP response is 80% of the participants 1RM. However this information needs to be applied to different squat depths as an 80% 1RM squat to parallel is likely to be different to 80% 1RM squat to 90 degrees of knee flexion. This draws attention to the lack of research into PAP responses at different squat depths and the need for further research if this area is to be developed and better understood. What can be generalised from the findings is that there needs to be a minimal loading of at least 80% of participants 1RM in order for there to be a significant PAP response. Also there is a large variance in the number of repetitions performed when inducing a PAP response, although it would seem that 3 repetitions at 90% of 1RM is the minimal number of reps that caused a significant response.These findings provide useful information to be used by coaches in designing training programmes and warm up routines in order to try and provide an improvement in sprinting performance.

2.9 Factors Effecting Post-Activation Potentiation

There are also other factors that may have an effect upon the PAP response, for example training status. Evidence has been found that show that athletes with more than three years of resistance training experience appeared to respond optimally to conditioning activities. (Wilson et al, 2004). These findings are supported by Chiu et al (2003) who found 1-3% increases in countermovement and drop jumps in trainied participants compared to a 1-4% decrease in performance in recreationally trained individuals. However these results have been linked with the notion that the fatigue-potentiation balance is more favourable in trained individuals (Wilson et al, 2004). “It should also be noted that trained individuals demonstrate elevated regulatory myosin light chain phosphorylation activity relative to those untrained, suggesting that increased power output may be bi-directionally mediated with increased training experience (greater PAP and lower fatigue) (Sale, 2002)”.

2.10 Need for Further Research

Many studies researched into what the optimal rest intervals for initiating the post-activation Potentiation response is. Further studies have discovered the optimal loading to produce a PAP response and it is widely regarded that the free weight barbell back squat is the best exercise when looking to instigate a PAP response in the lower limbs. Although whilst there has been lots of information discovered, there is still need for further research in order to determine the effect of different squat depth on the Post Activation Potentiation response during 40m sprint performance. Furthermore the combination of squat depth and PAP is an area that has not been combined much in research. There is not much peer reviewed literature into this area and there is need for more studies in order to better understand this area of research. If an optimal squatting depth for creating a PAP response in the lower limb muscles can be established this information could be used by coaches and conditioners alike when designing training and warm up programmes designed to improve sprint performance in athletes.

CHAPTER THREE

METHOD

3.1 Participants

The participants will be 15 male competitive, rugby players all whom train and participate in strength and conditioning sessions Height 186.30±4.678 cm; Weight 95.25±5.488 kg; 90 degree of knee flexion 1RM 190.67±29.93 kg; Parallel1RM 159.33±23.37 kg). All athletes will be familiar with resistance training as well as the free weight barbell back squat exercise. This is because Ritti-Dias et al (2011) concluded that novice trainees required 2-3 1RM testing sessions for each exercise to accurately assess muscular strength. All participants will have the protocol explained to them and informed consent will be given to each participant before testing.

3.2 Testing Instruments

A squat rack, Olympic barbell and weight plates will be used to carry out both of the squat movements (half and full squats). A goniometer will also be used to ensure correct angle of knee flexion is achieved during the squat exercises. This will ensure that all participants reach the same degree of squat depth as all knee flexion angles are the same. The time of each sprint will be measured using electronic smart speed timing gates. This will ensure accuracy of results and lessen the risk of human error. There will be 5 pairs of smart speed gates used. This is so times can be taken at 5, 10, 20 and 40 metre intervals. The participants will carry out the sprints on the same standardised indoor running track in the National Indoor Athletics Centre located on Cyncoed Campus at Cardiff Metropolitan University.

3.3 Procedure

Testing Day 1: Participants will need to complete participant information and consent forms. After this the participants will need to have their height and weight recorded along with basic information such as their weight training history. After this has been done participants will complete a standardised warm up consisting of 10 minutes cycling followed by dynamic stretching the emphasis on stretching the musculature associated with the squat. After the warm up has been completed each individual attempted one repetition of a set load (1- RM) and, if successful, the lifting weight will be increased until the weight could not be lifted through the full range of motion for the 90 degree of knee flexion squat (Kilduff et al, 2007). This protocol will be followed by all participants when establishing their one repetition maximum for the squat exercise.

Testing Day 2: After a period of at least 48 hours has passed participants will start testing day 2 with the same warm up that was used on day 1. They will then carry out the same one repetition maximum testing procedure that was used to determine one repetition maximum in the 90 degree of knee angle flexion squat. This protocol will be applied to the parallel barbell back squat movement so that a one repetition maximum can be determined for that exercise.

Testing Day 3: On testing Day 3 the same standardised warm up that has been used throughout the testing procedure shall be used again prior to participants recording a baseline time for their 40 metre sprint. This will be measured using the smart speed timing gates in order to achieve maximum result accuracy.

Testing Day 4: On testing day 4 participants will again perform the standardised warm up. They will then proceed to perform 3 sets at 90% of their one repetition maximum of either the 90 degree of knee angle flexion squats or the parallel squats. The load is 90% of one rep max because many studies have found for the post activation potentiation effect to take place muscular contractions needs to be maximal or near maximal and 3 sets of 90% of 1RM was found to be a good potentiating load (McBride et al, 2005). Also as the energy system being used is mainly the adenosine tri-phosphate and phosphocreatine system. This means there will be a rest period of 3 minutes passive recovery to allow the ATP-PC system sufficient time to fully replenish (Bendahan et al, 2003). Between the performance of the squat and the sprint there will be a rest period of 5 minutes (Chiu, 2003). This should allow the participant sufficient recovery without removing the post-activation potentiation effect caused by performing the squat. These results will enable findings to be drawn to see whether the squat has had an effect upon sprinting performance. After the rest period the participants will then carry out a sprint over 40 metres with smart speed gates at the 5, 10 and 20 and 40 metre distances. The results will be collected ready to be analysed.

Testing Day 5: On testing day 5, the participants will perform whichever squat movement they did not perform on testing day 4. The same protocols as used on day 4 will be observed when carrying out the testing procedures. The results will again be collected for analysis.

3.4 Data Collection

Participants were required to complete an informed consent form and PAR-Q form prior to testing. These were on printed sheets that were handed out upon arrival for testing and then were collected back in and placed in a secure folder. Once testing began, data was collected and input to a Microsoft Excel spreadsheet. Participant's heights, weights and 1RM for parallel and 90 degree of knee flexion squats were input into a Microsoft Excel spreadsheet. From this data 90% of participants 1RM were calculated using a simple formula taking the 1RM value, dividing it by 100 and multiplying it by 90. This was repeated for both parallel and 90 degree of knee flexion values. The participant's times were then recorded using the Smart Speed timing gates at 5, 10, 20 and 40m intervals for all three different variations (baseline, parallel and 90 degree) and input into another Excel spreadsheet. The data from this Excel spreadsheet was then exported into IBM's SPSS data analysis programme for statistical analysis.

3.5 Data Analysis

The data was analysed in IBM's SPSS programme using a one-way repeated measures ANOVA. From this analysis the mean and standard deviation for 5, 10, 20 and 40m sprint intervals for baseline sprint scores and the parallel and 90 degree of knee flexion squat variations was used to see what the differences between the different conditioning contractions were. As sphericity was not assumed for any of the different sprint intervals the Greenhouse-Geisser test score was used to determine whether there was any significant difference ($P<0.05$) within-subjects effects. Using the mean and standard deviation scores produced in the one-way repeated measures ANOVA, graphs were created for baseline, parallel and 90 degree of knee flexion sprint times at 5, 10, 20 and 40m. These graphs were created using the 2-Dimensional clustered column tool in Excel and error bars for each graph were created, by inputting the standard deviation scores created in the one-way repeated measures ANOVA in SPSS, into the custom error bar tool. Also using a post-hoc Bonferroni pairwise comparisons test it could be observed where the significant differences between the different test variations occurred.

CHAPTER FOUR

RESULTS

4.1 Participants

Table 1: Table showing the mean and standard deviation in height, weight, parallel squat 1RM and 90 degree of knee flexion 1 RM from participants.

	Height (CM)	Weight (KG)	90 Degree 1RM (KG)	Parallel 1RM (KG)
Mean (+SD)	186.30±4.67	95.25±5.48	190.66±29.932	159.33±23.36

Table 1 shows that there was a large variation in height, weight and squat strength between participants.

4.2 5m Data

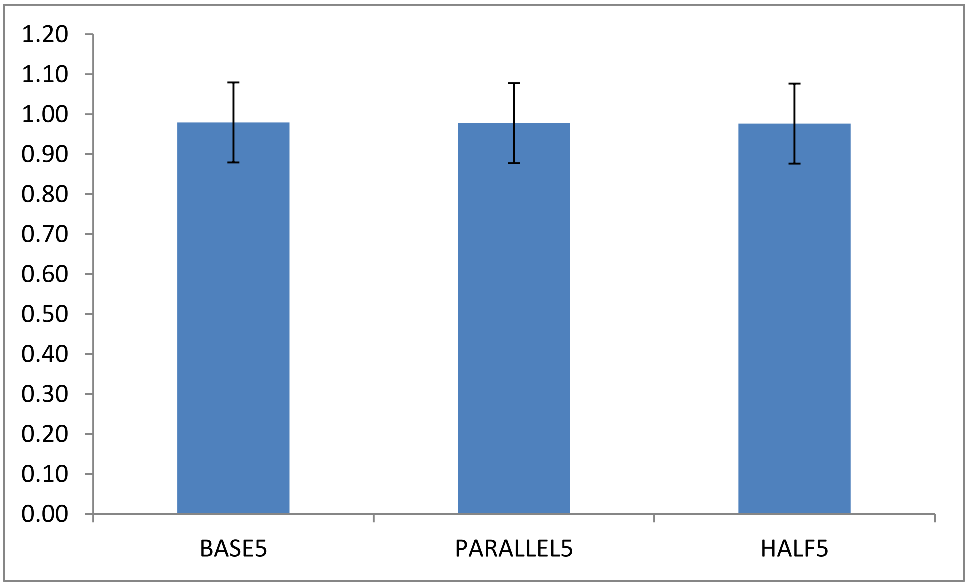

Figure 1: Graph showing mean participant 5m sprint times for both parallel and 90 degree squat pre-conditioning contractions and the baseline score (No pre-conditioning contraction.

In figure 1 the mean 5m sprint time for baseline, parallel and 90 degree squat variations can be observed. Whilst the parallel squat variation appeared to produce slightly faster 5m sprint times than the baseline and 90 degree squat conditions sprint times, statistical testing revealed the difference was not significant ($p>0.05$).

4.3 10m Data

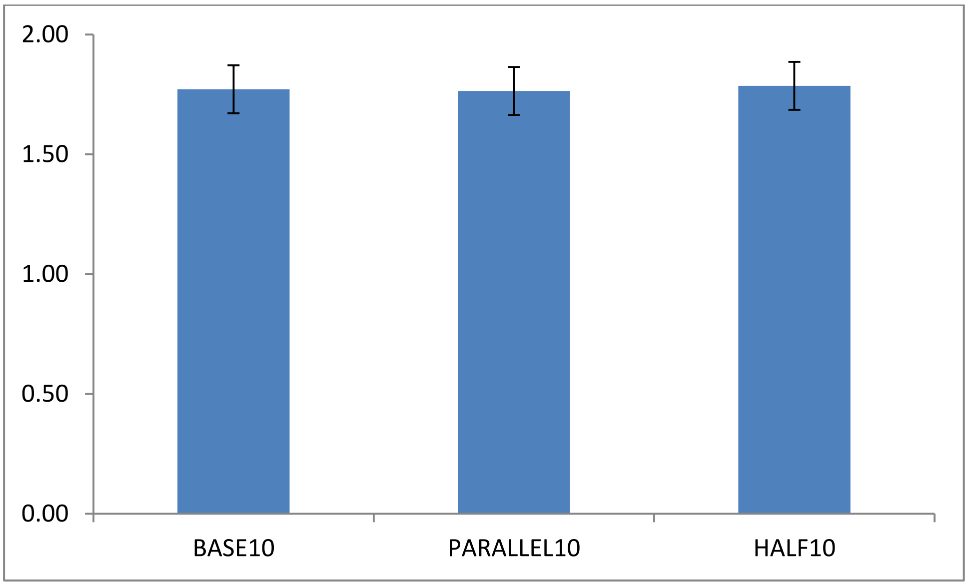

Figure 2: Graph showing the mean participant 10m sprint times for both parallel and 90 degree squat pre-conditioning contractions and the baseline score (No pre-conditioning contraction.

Figure 2 shows the mean of participant's 10m sprint time after performing both the parallel and 90 degree squat variations. It shows that overall the parallel squat variation produced a faster 10m sprint time and this was found to be statistically significant ($p<0.05$) however there were no significant differences in the Bonferroni pairwise comparisons test. The error bars of the graph show the standard deviation for the different test variables.

Table 2: Table showing the significance of the different test variables at 10m in a post-hoc Bonferroni pairwise comparisons test.

10m Sprint		
Squat		Significance
Baseline	Parallel Squat	0.085
	90 Degree Squat	0.171
Parallel Squat	Baseline	0.085
	90 Degree Squat	0.063

90 Degree Squat	Baseline	0.171
	Parallel Squat	0.063

Table 2 shows that there was no significant differences ($p<0.05$) between the parallel squat variation, 90 degree of knee flexion squat variation and the baseline sprint scores.

4.4 20m Data

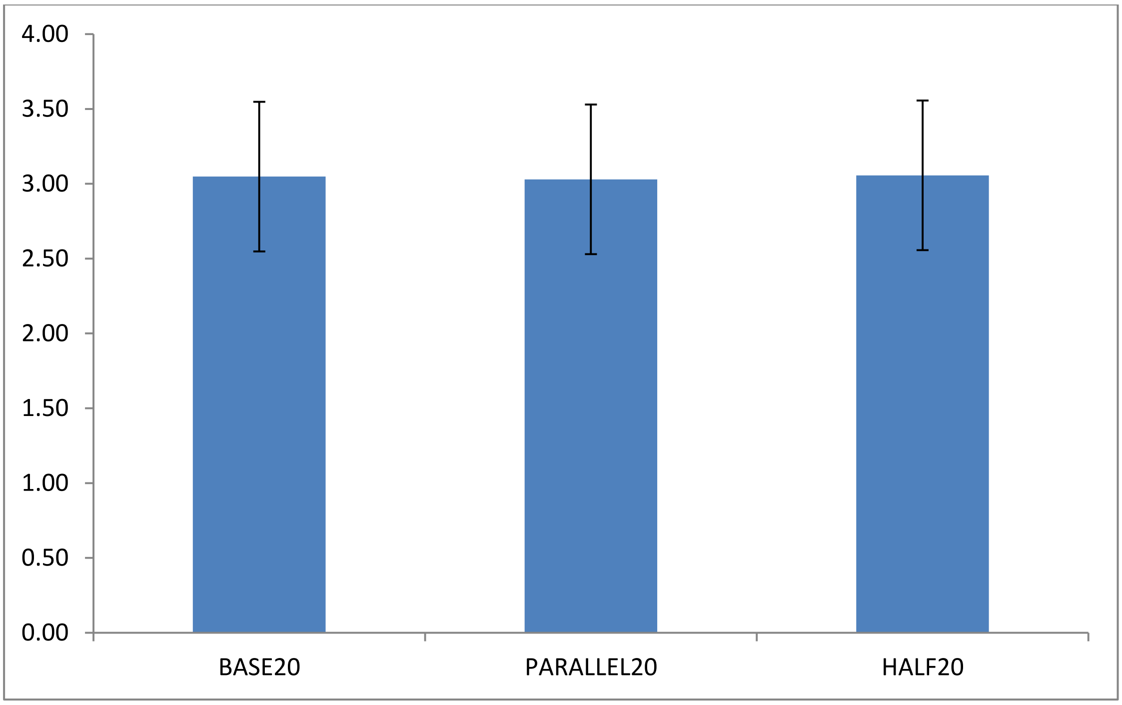

Figure 3: Graph showing the mean participant 20m sprint times for both parallel and 90 degree squat pre-conditioning contractions.

Figure 3 shows the mean participant's 20m sprint time after performing both the parallel and 90 degree squat variations. It shows that overall the parallel squat variation produced a faster 20m sprint time and this was found to be statistically significant compared to the baseline sprint score but not to the 90 degree of knee flexion squat variation. The error bars of the graph show the standard deviation for the different test variables.

Table 3: Table showing the significance of the different test variables at 20m in a post-hoc Bonferroni pairwise comparisons test.

20m Sprint		
Squat		Significance
Baseline	Parallel Squat	0.000
	90 Degree Squat	1.000
Parallel Squat	Baseline	0.000
	90 Degree Squat	0.062
90 Degree Squat	Baseline	1.000
	Parallel Squat	0.062

Table 3 shows there was a significant difference ($p<0.05$) between baseline 20m sprint scores and 20m sprint scores after the parallel squat variation. It also shows there was a difference between parallel squat and 90 degree squat at 20m however it was not statistically significant.

4.5 40m Data

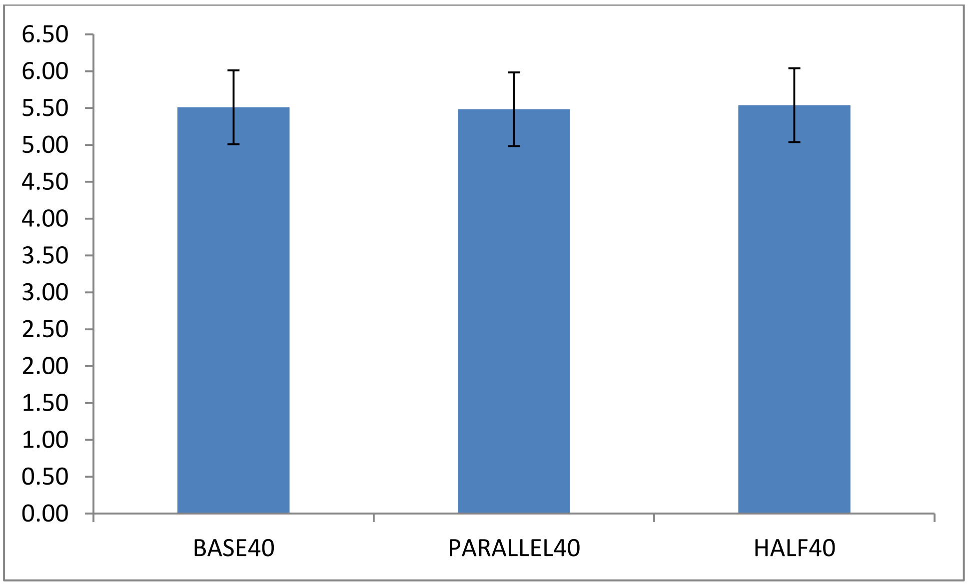

Figure 4: Graph showing the mean participant 40m sprint times for both parallel and 90 degree squat pre-conditioning contractions.

Figure 4 shows the mean participant's 40m sprint time after performing both the parallel and 90 degree squat variations. It shows that overall the parallel squat variation produced a faster 40m sprint time and this was found to be statistically significant compared to the baseline and 90 degree squat variations. The error bars of the graph show the standard deviation for the different test variables.

Table 4: Table showing the significance of the different test variables at 40m in a post-hoc Bonferroni pairwise comparisons test.

40m Sprint		
Squat		Significance
Baseline	Parallel Squat	0.016
	90 Degree Squat	0.039
Parallel Squat	Baseline	0.016
	90 Degree Squat	0.018
90 Degree Squat	Baseline	0.039
	Parallel Squat	0.018

Table 4 shows that there is a significant difference ($p<0.05$) between the parallel squat variation and the 90 degree squat variation. Also there is a significant difference between the baseline and the parallel squat variation. Furthermore there is a significant difference ($p<0.05$) between the baseline score and the 90 degree squat variation.

4.6 Means and Standard Deviations for Sprint Intervals

Table 5: Table showing the mean and standard deviation for baseline, parallel and 90 degree of knee flexion sprint times at 5, 10, 20 and 40m.

	Baseline Sprint	Parallel Sprint	90Degree Sprint
5m Time	0.98 (±0.086)	0.98 (±0.085)	0.98 (±0.086)
10m Time	1.77 (±0.110)	1.77 (±0.110)	1.79 (±0.116)
20m Time	3.05 (±0.168)	3.03 (±0.168)	3.06 (±0.165)
40m Time	5.51 (±0.303)	5.49 (±0.309)	5.54 (±0.293)

Table 5 gives an overview of the mean sprint time for the different testing variables at 5, 10, 20 and 40m intervals. Table 5 also shows the standard deviation for each of the variables at the different timing intervals.

4.7 Height, Weight and Squat Strength Correlations

Table 6: Table showing correlations between height, weight, parallel squat 1RM and 90 degree squat 1RM. *. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

		Height	Weight	Parallel 1RM	90 Degree 1RM
Height	Significance		0.025*	0.248	0.112
Weight	Significance	0.025*		0.009**	0.001**

Table 6 shows there are significant correlations between height and weight. It also shows there are significant correlations between weight and both of the squat variation 1RM's. Furthermore it shows there is a significant correlation between parallel squat 1RM and 90 degree of knee flexion squat 1RM.

4.8 Squat Strength and Sprint Time Correlations Table 7:

Table 7: Table showing correlations between parallel and 90 Degree squat variations 1RM. **. Correlation is significant at the 0.01 level (2-tailed).

		Baseline 5	Baseline 10	Baseline 20	Baseline 40
Parallel 1RM	Significance	0.149	0.267	0.409	0.420
90 Degree 1RM	Significance	0.085	0.310	0.477	0.471

Table 7 shows that there is no significant correlation between parallel or 90 degree of knee flexion 1RM and baseline sprint times at 5, 10, 20 or 40m.

CHAPTER FIVE

DISCUSSION

5.1 Results

Initially the results gained from the study suggest there is a significant difference ($p<0.05$) between parallel squat sprint times at 40m when compared to the 90 degree of knee flexion squat condition. This shows a score of significance and that the PAP response causes the most improvement in performance between 20 and 40m. This suggests that performing a back squat to parallel can induce a greater and more powerful PAP response than the performance of a back squat to 90 degrees of knee flexion. Also it was found that at 10, 20 and 40m intervals the mean baseline times were lower than the parallel squat variation.

This is similar to findings in Hartmann et al’s (2012) study as the quarter back squat training group had a significantly lower 1RM in deep back squats compared to the control group (no training). This is suggested by Hartmann et al (2012) to be a result of not being “able to transfer the accentuated maximal strength potential into the deep knee positions of the demanding coordination sequence of back squats”. This may suggest that any PAP response gained by performing the 90 degree of knee flexion squats may not have been able to be effectively utilised as the muscular activation during this squat may be un-related to the muscle activation in sprinting activities.

Correspondingly the reason that the parallel back squat appears to produce a greater PAP response could be attributed to the fact that studies have found greater muscular activation when performing parallel squats compared to partial squats (Catersiano, 2002; Gorsuch et al, 2010). The greater level of muscular contraction in the parallel squat may have caused the PAP response, as by performing a near maximal contraction to a greater depth may have resulted in a greater increase in recruitment of motor units (Hodgson, 2005). Evidence suggests that using conditioning stimuli can increase in explosive movement patterns, rate of force development and twitch contractions (Xenofondos et al, 2010). Previous research has suggested that to develop the maximum strength capable of the hip or knee joints the joint needs to be stressed through maximal range of motion (O’Shea, 1985). This links with findings that increased squat depth leads to an increased range of motion which in turn promotes greater motor recruitment from the working muscles (Roundtable, 1985). This is supporting evidence as to why the parallel squat was found to be more beneficial in promoting a PAP response, as it is likely the greater range of knee movement caused an increase in the number of motor units recruited. Therefore because the parallel squat is deeper than the 90 degree squat, an increase in sprint performance may be observed due to increased explosive movement and rate of force development as a result of a higher number of motor units being recruited by squatting to a lower depth. This theory is supported by evidence from Roundtable (1984) who stated that the deeper the squat the greater the training benefit due to the increased as a full squat the knee joints are near maximal flexion and this greater range of motion promotes greater motor recruitment neuromuscular response. Therefore according to Hodgson (2005) the PAP response observed comes directly as a result of increased recruitment of the motor units within the muscles. However whilst the different squat conditioning contraction may be responsible for the improved sprint performance observed there were no tests on the level of neuromuscular activation and therefore the mechanism responsible cannot be assessed fully.

Whilst a significant difference was observed at 20m between baseline and parallel variations and 40m sprint intervals between all of the different squat variations, there was no significant difference between variations found at the 5 or 10m intervals. There may be some extrinsic factors that account for this. One may be that 5 and 10m are such short distances to be covered it is unlikely that there would be any significant differences observed as most participants sprint time is unlikely to change between 0-10 metres. Although there is contradictory evidence as it was found after an 8 week pre-season training period both absolute and relative squat strength values showed significant increases which was reflected in the significantly faster sprint performances over 5 m (Comfort et al, 2012). This shows that significant differences can be observed in the short distance sprint. Therefore, it may be that the proposed benefits of PAP are not fully utilised in sprints over short distances and rather they become significant over longer sprint performances.

5.2 Supporting Studies

The findings of this study are similar to other studies that have measured PAP by testing vertical jump performance and rate of force development. Hartmann et al (2012) found that deep back squat training produced significantly higher explosive strength scores in the maximal rate of force development in both the left and right legs in comparison to the quarter back squat group. This supports the research's findings as the deeper squat movement produced significantly faster sprint times than the baseline score at 20 and 40m. This also supports research that states the parallel back squat is the optimal exercise to use because peak functional augmentation is elicited better when using similar contraction types as the target movement (Morrissey et al, 1995).

5.3 Approach to Study

The approach to carrying out this study can be deemed effective as the research question that was set out at the start of the study has been answered. As there was very little previous research into the area of study it was difficult to find many similar protocols or methods that has been carried out. However the methodology was thoroughly and effectively researched and the method that was produced was designed in order to elicit the greatest PAP response that would be possible. Optimal recovery time for producing a PAP response was extensively examined and was determined based on Chiu (2003), Kilduff et al (2007) and Bendahan et al's (2003) previous research. This area of the study was difficult as there is so much contradictory evidence to suggest what optimal rest timings are. For example within a single study of Kilduff et al (2007) Results showed that 14 participants (70%) attained their highest power output, peak rate of force development, and jump height after 8 min of recovery, while three attained their peaks after 12 min. The remaining three participants produced their best results after only 4 min of recovery .The studies also suggest that a recovery period of minimum of 5 minutes is needed in order for post-activation potentiation to influence sprinting performance. This part of the study can be justified as it was designed to give the participant sufficient recovery without removing the post-activation potentiation effect caused by performing the squat and within the previous evidence referenced the 5 minute recovery period was the most effective in producing a PAP response. Furthermore the pre-conditioning contraction designed to produce a PAP response was considered and in-depth research was carried out to ensure the correct loading and repetition was used. Evidence from previous studies suggested that muscular contractions need to be maximal or near maximal in order for a PAP response to be produced (Chatzopoulous et al, 2007; Rahimi, 2007; McBride et al, 2005). Throughout the majority of the studies referenced in order to obtain an effective PAP inducing load, the 90% of 1RM is the most commonly used load that was found in producing a significant PAP response. Whilst there is many differing numbers of repetitions used a lifting a 90% of 1RM load, McBride et al's (2005) protocol was used as it produced an effective PAP response in the participants 40m sprint performance, which is a similar testing procedure to the one that was carried out in this study. Additionally there has been some research into other factors that have been found to effect PAP response. Evidence found suggested that athletes with more than three years of resistance training experience had optimal response to conditioning activities (Wilson et al, 2004). Therefore, most of the participants who took part in the study had three or more years of resistance training experience in order to optimise chances of a significant PAP response. This was important as Sale (2002) also found evidence to suggest trained individuals have elicit a greater PAP response and lower fatigue, this was supported by Wilson et al (2004) who found the fatigue-potentiation balance is balance is more favourable in trained individuals more favourable in trained individuals. By ensuring participants were experienced in resistance training it reduced the chance that the results would be affect by participant fatigue.

5.4 Participant Differences

The results show that there were large variations in height, weight and squat strength between the participants who were tested. This may have an effect on the results as there is previous evidence to suggest that maximal squat strength causes an increase in sprinting performance (Wilsoff, 2004; McBride et al, 2009). Due to the large differences in the squat strength within participants it could be argued that some participants would be pre-disposed to perform faster sprints due to the greater lower limb strength that they possessed. In order to improve this aspect of the study, participants of similar heights, weights and squat strengths could have been used. However it was found that there was no significant correlation between parallel and 90 degree squat 1RM's and baseline sprint performance, which suggests that this factor would have had little influence on the outcome of the test results.

5.5 Critical Evaluation of the study

The study has shown that there is a significant difference in sprint performance at 20 and 40m sprint intervals. There are a number of critical points that need to be mentioned. One of the main criticisms of the study is that testing was not carried out at the same time of day for all participants which could have had an effect as studies suggest "performances of high-intensity short duration exercise (i.e., less than 1 min) present the common characteristic of being higher in the afternoon (between 16:00 and 20:00 h) than in the morning (between 06:00 and 10:00 h). For instance, maximal power output achieved during cycling sprints is higher in the evening than the morning" (Zarrouk, 2012). This means that some participants performance increases may be as a result of performing the testing at different times of the day. A further critism of the study is that the diet of the participants was not monitored or controlled. Neither was the use of any sports supplements the participants may have used. If one participant had a poor diet between testing days its is likely that their recovery would be hindered and would likely be slower to recover than a participant eating high protein and good quality carbohydrates as part of their everyday diet. "Most recreation ally active individuals can maintain their glycogen stores by consuming approximately 55-60% of total daily energy from carbohydrate" (Gibala, 2005). Therefore if the participant's diet is poor they may have depleted glycogen stores which would have a negative impact on performance. Another element of the study that could crticised is that there was no control of participants outside of the study. Although participants were advised to rest and avoid alcohol between testing days and prior to testintg being carried out because there was no control over this it is unclear whether they acted as they were advised to do so. If they had consumed alcohol the day before testing it may have had a netgative effect on their performance and recovery. It was found that alcohol increases blood flow to any areas of damaged tissue which slows down recovery, thus having a negative impact on performance (Calder, 2009).Overall the main critisim of the study would be that it has too many uncontrollable extrinsic factors that may have influenced the data that was collected for results.

5.6 Answering Research Question

In answer to the research question the effect of different squat depth on the post-activation potentiation response during 40m sprint performance it was found that different squat depths do have an effect on PAP response. As hypothesised it was found that the parallel squat variation did cause significantly faster sprint times at 20 and 40m than the 90 degree of knee flexion squat and the baseline sprint scores. This evidence has useful practical applications as the use of parallel squat can now be used within training programmes and warm-up activities in order to initiate a PAP response within athletes. If used correctly this evidence may lead to improvement in athletic performance and produce significantly faster sprint times. However whilst the most significant differences were observed in the longer sprints it may be effective to conduct similar testing over longer distance sprints (e.g. 100m) to further determine how effective inducing a PAP response could be.

CHAPTER SIX

CONCLUSION

6.1 Conclusion

In conclusion the investigation carried out has found evidence that by performing near-maximally loaded squats to a parallel squat depth causes a post-activation potentiation response that leads to an increase in sprint performance over a 40 metre distance, with statistically significant differences ($p<0.05$) at the 20 and 40m intervals when compared to a baseline sprint test (no pre-conditioning contraction) and at 40m compared to the 90 degree of knee flexion squat variation. The study also found that a 90 degree of knee flexion squat actually produced slower average speed at 10, 20 and 40m when compared to the baseline sprint score although this was not a significant difference except at 40m. Therefore it can be observed that it is likely that the PAP response caused by performing the 90 degree of knee flexion squats was not significant enough to enhance performance rather cause performance to suffer as a result of fatigue. This is supported by the idea that the parallel squat produces an effective PAP response as the greater range of knee movement causes an increase in the number of motor units recruited. Therefore because the parallel squat is deeper than the 90 degree squat, an increase in sprint performance may be observed due to increased explosive movement and rate of force development as a result of a higher number of motor units being recruited by squatting to a lower depth (Roundtable, 1985).

6.2 Critical Evaluation

Whilst the study has found useful evidence related to PAP response and its practical applications, there are still a number of areas that need to be critically evaluted. Although it appears that a PAP response is the cause of the different sprint times observed it cannot be directly established as the only cause due to a number of uncontrolled variables that may have affected the study's results. For example it could be improved by using participants who have similar height, weight and maximal strength scores as Wilsoff (2004) and McBride et al (2009) found that maximal squat strength causes an increase in sprint performance, and therefore some participants would be pre-disposed to perform faster sprints due to the greater lower limb strength that they possessed. Although in this study it was found that there was no significant correlation between parallel and 90 degree squat 1RM's and baseline sprint performance, which suggests that this factor would have had little influence on the outcome of the test results. Also diet and rest periods of participants were not controlled consequently it cannot be stated that these variables did not have some impact on the results of the study. Furthermore the study was not carried out at the same times of the day for all participants due to their other daily commitments, evidence suggests "performances of high-intensity short duration exercise (i.e., less than 1 min) present the common characteristic of being higher in the afternoon (between 16:00 and 20:00 h) than in the morning (between 06:00 and 10:00 h)" (Zarrouk, 2012). This means that the time of day performance was monitored also cannot be said to have not had some influence upon the results. Hence whilst there is significant evidence to suggest that a PAP reponse caused the improved sprinting performance observed it cannot be directly linked to this without the extrinsic variables mentioned being more carefully monitored and controlled.

6.3 Practical Impliactions of Research

The evidence found during the conduction of this study has useful real-world practical applications to sport. For example the results show that sprint performance can be improved after a near maximal parallel back squat is utilised as part of a warm-up. Therefore the use of this exercise cannot be underestimated in the formation of warm-up and training programmes. The information could be extremely useful for strength & conditioning specialists, athletes and coaches alike when trying to improve explosive strength activities such as sprinting, particularly in a performance environment (e.g. rugby match/athletics competition). The evidence found from the study give grounds for further investigation into the subject area in order to better understand the proposed benefits PAP can give to improving athletic performance.

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APPENDICES

PARTICIPANT INFORMATION

APPENDIX A

Participant	Height (CM)	Weight (KG)	1RM Parallel Squat (KG)	1RM 90 Degree Squat (KG)	90% 1RM Parallel	Weight Used	90% 1RM 90 Degree Squat	Weight used
1	188.20	90.40	140	160	126	125	144	145
2	190.50	104.50	180	220	162	160	198	200
3	194.50	108.60	180	245	162	160	220.5	220
4	180.60	92.30	175	210	157.5	157.5	189	190
5	188.50	98.00	155	180	139.5	140	162	160
6	183.00	88.80	130	160	117	115	144	145
7	183.50	97.40	170	195	153	155	175.5	175
8	185.50	90.30	100	125	90	90	112.5	112
9	175.60	93.60	150	175	135	135	157.5	157.5
10	183.60	95.40	170	200	153	150	180	180
11	190.20	98.40	190	220	171	170	198	200
12	188.20	91.60	150	175	135	135	157.5	157.5
13	188.00	92.30	160	190	144	145	171	170
14	190.10	95.50	180	215	162	160	193.5	195
15	184.50	91.70	160	190	144	1.45	171	170

APPENDICES

PARTICIPANT SPRINT TIMES

APPENDIX B

Participant	5m Baseline	10m Baseline	20m Baseline	40m Baseline	5m Parallel Time	10m Parallel Time	20m Parallel Time	40m Parallel Time	5m 90 degree Time	10m 90 degree Time	20m 90 degree Time	40m 90 degree Time
1	0.93	1.67	2.88	5.27	0.92	1.67	2.87	5.18	0.93	1.69	2.93	5.35
2	0.98	1.73	3.03	5.45	0.95	1.73	3.01	5.45	0.98	1.73	3.01	5.45
3	0.86	1.75	3.01	5.51	0.86	1.73	3.00	5.43	0.88	1.78	3.04	5.55
4	0.98	1.78	3.15	5.56	1.01	1.78	3.12	5.54	0.95	1.79	3.16	5.61
5	1.02	1.83	3.13	5.62	1.03	1.81	3.11	5.61	1.02	1.83	3.18	5.67
6	1.05	1.85	3.19	5.67	1.05	1.84	3.17	5.65	1.06	1.85	3.21	5.69
7	1.12	1.98	3.28	6.11	1.11	1.98	3.25	6.09	1.12	1.98	3.22	6.11
8	1.07	1.91	3.22	5.83	1.07	1.88	3.21	5.81	1.08	1.98	3.24	5.84
9	1.10	1.90	3.25	5.93	1.09	1.91	3.24	5.91	1.08	1.93	3.26	5.92
10	1.07	1.82	3.19	5.64	1.06	1.82	3.16	5.63	1.07	1.83	3.18	5.66
11	0.90	1.64	2.85	5.21	0.90	1.63	2.83	5.13	0.91	1.71	2.95	5.34
12	0.89	1.60	2.76	5.10	0.88	1.59	2.73	5.09	0.89	1.59	2.74	5.11
13	0.93	1.69	2.90	5.18	0.94	1.70	2.88	5.20	0.91	1.68	2.85	5.16
14	0.90	1.77	3.04	5.49	0.90	1.76	3.04	5.47	0.88	1.77	3.02	5.51
15	0.89	1.66	2.84	5.10	0.89	1.64	2.82	5.08	0.89	1.65	2.85	5.12